Tackling complexity using interlinked thinking: well-being as a case study

A dissertation presented in partial fulfilment of

the requirements for the degree of

Doctor of Philosophy

in **Ecological Economics**

at Massey University, Palmerston North

New Zealand

Vicky Elizabeth Forgie

August 2016

Abstract

The world today is made up of a series of highly interconnected complex systems characterised by uncertainty. Human minds struggle with complexity, and the tools available to help us are limited. This often leads to reductionism, focusing on the parts rather than the whole. Working with individual parts ignores the dynamics that result from interdependencies between components. It is these interactions that determine the behaviour we experience in real world situations. This dissertation presents 'interlinked thinking' as a communication and analytical approach to help people work with, rather than ignore, complexity. It aims to build understanding of feedbacks loops and systems in a way that does not require expert modelling skills. It is a participatory process that allows people not familiar with systems thinking to have a structured dialogue on how components interrelate, and share their mental models. Links between components are debated and decided on in a workshop session. The resultant causal loop diagrams are transcribed to a matrix and an algorithm run to analyse the links in the system.

The interlinked thinking method was tested using three case studies to answer the principal research question: *Does understanding the relationships between indicators add value and progress sustainable well-being?* Well-being is multi-dimensional, and the complex behaviour of the well-being system does not come from individual indicators but from the interrelationships between indicators and resultant feedback loops. Participants who applied interlinked thinking confirmed value was gained from: (1) increased understanding of the indicators in the system; (2) more visible relationships; (3) expanding the toolkit to work with complexity; (4) an increased ability to bring important issues to the attention of decision-makers; (5) consideration of intervention impacts; and (6) encouraging integrated thinking.

Interlinked thinking can be replicated and used in any situation where having a better understanding of interconnectedness is important but time, resources, and modelling skills are limited.

Key words: interlinked thinking; systems thinking; sustainable well-being; causal loop diagrams; complexity; interconnected; feedback loops; mental model

Acknowledgements

My first tribute is to my father Bruce Reaburn who had a deep love of knowledge and was steadfast in ensuring his seven children had the educational opportunities he missed out on.

Foremost thanks go to my supervisor Associate Professor Marjan van den Belt for providing the opportunity to undertake this research, as well as encouragement and direction over the last five years. Sincere thanks also to Dr Garry McDonald (co-supervisor) for his input and always sound advice.

This research was undertaken as part of the Ministry for Business, Innovation and Employment funded Sustainable Pathways 2 (MAUX0906) research project. I would like to formally express my appreciation to the Ministry for funding this research. Sustainable Pathways 2 research team members Dr Beat Huser, Melanie Thornton, and Regan Solomon have contributed in many ways to the outcome of this research for which I am most grateful.

I would especially like to thank Richie Singleton at Greater Wellington Regional Council, Philip Walker at Statistics New Zealand, and Peter Salter at the Ministry for Social Development for their input and assistance organising the case study workshops.

Thanks to the staff and students of the System Dynamics course at Bergen University, Norway for the opportunities, challenges and knowledge they shared. My appreciation also to Dr Anthony Cole for introducing me to Frederic Vester – the source of inspiration for the route I took with this study.

Special thanks to Janet Lowe for the great work on formatting, Anne Austin and Pippa Grierson for proof reading, and Tomas Burleigh Behrens for writing the algorithm code.

Richard, Rhiannon, Samuel and Lucy (Forgie) deserve the credit for sustaining my well-being throughout the PhD candidature. Thank you for your love, encouragement and support.

To my caring friends, Heike Schiele and Virginia Cook my sincerest gratitude: ‘No road is long with good company.’[1]

[1] Turkish proverb

Table of Contents

Figures

Tables

Glossary

Abbreviation	In Full
ANS	Adjusted Net Savings
BRAINPOoL	Bringing Alternative Indicators into Policy
DGPI	Dynamic Genuine Progress Indicator
FEEM SI	Fondazione Eni Enrico Mattei Sustainability Index
GDP	Gross Domestic Product
GHG	Greenhouse gases
GNH	Gross National Happiness
GNP	Gross National Product
HDI	Human Development Index
HPI	Happy Planet Index
Hshld	Household
MSD	Ministry of Social Development
OECD	Organisation for Economic Co-operation and Development
PCA	Principal component analysis
PSM	Participatory Systems Mapping
QoL	Quality of Life
SNZ	Statistics New Zealand
SP2	Sustainable Pathways 2
SR	Social Report
SUPERU	Social Policy Evaluation and Research Unit
TNS	The Natural Step
UNDP	United Nations Development Program
WCED	World Commission on Environment and Development
WR	Wellington region
WR-GPI	Wellington Region Genuine Progress Index
WRS	Wellington Regional Strategy

1 INTRODUCTION

Both citizens and policy makers are generally aware of the high degree of connectedness, and the resultant complexity of the world we live in. There is a need for integrative tools to navigate complex interconnected systems when decisions are made. As more and more detailed information becomes available, the trend is to delegate the integration of knowledge to specialists with technical expertise and tools. A key reason for this delegation is time and cost. Decision-makers and policy people when dealing with uncertainty are after the best information they can acquire within a set time period and budget.

As a consequence integration skills become a specialist activity sub-contracted to experts. Non-specialists (the majority of decision-makers and policy people) lack the tools to consider how factors interrelate in their day-to-day work situation. The focus of their decision-making thereby narrows to their own area of knowledge increasing the risk that insufficient weight is placed on critical relationships with other domains of influence. In an interconnected world decisions have significant cause-and-effect, so not taking interrelationships between factors into account (for example, how an increase in inequality can increase racism) will result in silo conversations, which are not addressing root causes.

This dissertation develops a method for policy-makers to consider the interconnectedness between their area of expertise and other areas in an accessible way. The method does not require a large investment of time, or the skills of an expert modeller; such as those belonging to the system dynamics fraternity. The new approach laid out in this dissertation can be replicated and used in any area where having a better understanding of interconnectedness is important. It has been tested in three cases studies related to well-being. The reason, given the wealth of possibilities, that these three case studies have been selected is that case study one directly links to the research carried out as part of the Sustainable Pathways 2 project (discussed in the next section). The second case study was requested by participants involved in the first case study. The third case study was chosen by the researcher to test the method developed in a non-participatory context and with international rather than New Zealand indicators.

This introductory chapter maps the research undertaken. It first introduces the Sustainable Pathways 2 project to provide the context in which this research was positioned. The rationale and importance of the study is then discussed. This is followed by the principal research question, and the intermediate questions addressed in answering the principal question. Subsequent chapters address each of the intermediate questions. Last a précis of each chapter is provided.

1.1 RESEARCH CONTEXT – SUSTAINABLE PATHWAYS 2

This research is part of the wider research project 'Sustainable Pathways 2' or 'SP2' which was funded by the Ministry of Business Innovation and Employment from 2009 to 2015 (MAUX0906).

The goal of the SP2 research project is to provide a range of tools and processes to support integrated, dynamic, and strategic decision-making, specifically at the local government level in New Zealand (van den Belt, Forgie, et al., 2010). Central to SP2 are the many challenges associated with the sustainable well-being of the increasing number of people living in cities. Typically, bigger populations result in pressure to provide transport infrastructure, education, health, employment, housing, etc., at the same time as protecting heritage, biodiversity, landscapes, water, and other environmental and social qualities. Managing the trade-offs related to well-being through time is a key concern of the SP2 project. For instance: will the result of exploiting the environment today be restricted and poorer quality outcomes in the future?

The toolkit (see Figure 1-1) that has been assembled as part of the SP2 project provides practical and implementable tools to assist the integrated decision-making processes of local government planning in 21st century New Zealand. The complexity associated with achieving quality urban living puts severe strain on segmented planning frameworks. The SP2 toolkit increases the options for dealing with this complexity, providing both technological and non-technical platforms to support integrated decision-making and governance.

The SP2 research project addressed three objectives:

Objective 1: To work with stakeholders to build systems thinking skills and develop scoping models. To achieve this objective, a series of workshops involving stakeholders from the public, private, and non-government sectors were held in the Auckland Council and Greater Wellington regions. As part of these workshops stakeholders worked together and built qualitative and quantitative models. These models were created to provide an integrated picture, from the stakeholder's perspective, of how key variables (such as health, education, transport, the economy) relate to each other and interact over time (with time lags taken into account). The Objective 1 research team members were from Ecological Economics Research New Zealand, based at Massey University.

Objective 2: To bring together existing models covering population, land use, transport, economic activity, and environmental factors into a platform where they interlink. The resultant 'Integrated Scenario Explorer' models were constructed for both the Auckland Council and Greater Wellington regions. These models provide detailed spatial modelling capacity and simulate high-resolution scenarios. Their function is to facilitate ways to explore, in advance, alternative transition pathways and the long-term impacts of present day decisions. Research team members were from Market Economics (Auckland) and the Research Institute for Knowledge (The Netherlands).

Objective 3: To advance new ways to embed integrated planning into council actions and processes. This required the institutionalisation in councils of the tools developed by the SP2 project to support decision-making. The Objective 3 research team was solely comprised of researchers seconded from councils — Auckland Council, Greater Wellington Regional Council, and Waikato Regional Council. Three Council co-collaborators were paid to be part of the research team and were tasked with leading the social transition and institutional change required as a prerequisite to the adoption of the SP2 toolkit applications.

The decision-support tools implemented by the SP2 research team to facilitate integrated decision-making at local and central government levels in New Zealand are shown in Figure 1-1. The developed toolkit spans the non-technical (on the left) to the technical (on the right).

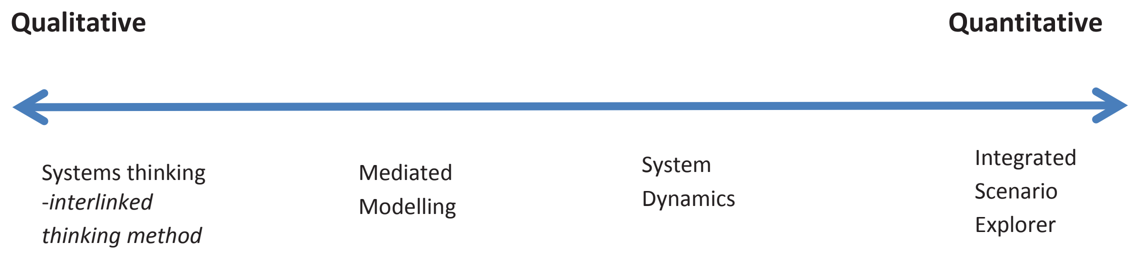


Figure 1-1: SP2 integrated decision support toolkit.
(Adapted from van den Belt & Forgie, 2015, Figure 1, p. 1).

'Systems thinking' was used in a series of workshops which focused on freshwater management in the Auckland Council region (van den Belt & Forgie, 2015). Systems thinking is a field of knowledge that emphasises the importance of feedback loops that result from the interaction between component parts over time. You get insight into how things work in the real world by looking at the whole and the patterns that exist (Senge, 2006; Maani and Cavana, 2007).

'***Mediated Modelling'*** is a process of model building '*with*' rather than '*for*' stakeholders, ideally over a series of 8-10 workshops held at monthly intervals (van den Belt, 2000, 2004). The Mediated Modelling workshops had ***'System dynamics'*** models[2] constructed as outputs (van den Belt, Forgie, Stouten, & Solomon, 2012; van den Belt, Forgie, Stouten, Thornton, & McDonald, 2012).

---

[2] For example, the Auckland region system dynamics model integrated: A) Population by four ethnic groups: Pasifika; Asians; Maori (indigenous people of New Zealand); and Europeans; and change due to i) births; ii) deaths; iii) immigration; and iv) emigration; B) The Economy under four themes: employment; 'attractiveness' of the region; GDP; and funding gaps; C) Education achievement measured by the National Certificate of Educational Achievement (NCEA) level 2 or higher qualifications; D) Health care demands for children and the elderly; E) Terrestrial natural capital depletion due to urbanisation and stressor pressure; F) Transport (active mode); G) Crowding (and quality) of housing; H) Governance and policy solutions; I) External factors such as Climate Change and unemployment outside the Auckland region.

At the right end of the continuum, the ***'Integrated Scenario Explorer'*** models were constructed for both the Auckland Council and Greater Wellington Regional Council regions, to provide high resolution spatial modelling capacity. The 'Integrated Scenario Explorer' models capitalise on the significant investments that the Councils have made in existing modelling infrastructure. The models were not built from scratch; rather they connect models in current use for decision-making purposes. The choice was made to connect existing models as these models have been subject to extensive review and debate, including court processes.

'Interlinked thinking'[3] is the tool described in this dissertation. The construction of the Mediated Models and Integrated Spatial Explorers required significant time commitments, from both end-users and modellers. In addition, specialist modelling skills are needed to build and operate these models. Underlying the development of interlinked thinking was a revealed need to provide systems insights and socialise the use of the specialised SP2 quantitative models to maximise their benefits.

The process of developing the Mediated Modelling and Integrated Scenario Explorer models made apparent the significant gap between people proficient in the use of systems modelling and those who had no previous experience or exposure. Interlinked thinking aims to bridge this gap, extend people's systems horizons, and provide a way to share mental models in a systems context. Moreover, the aspiration was to do this without requiring significant inputs of resources and time. Interlinked thinking therefore fills a need and complements the integrative toolkit.

The case study topic of 'well-being' came out of the 'Mediated Modelling' workshops, run for the Greater Wellington region. The stakeholders agreed that gaining a better understanding of the relationships between the indicators used to measure well-being in the region (the Wellington Region Genuine Progress Index or WR-GPI) would be a valuable contribution from the SP2 project.

Within the context of the SP2 research project there was the added requirement that any new tool developed should complement the other research streams. Therefore,

[3] I have used 'interlinked thinking' as the name for the method developed in this dissertation.

the method developed specifically worked towards understanding relationships between indicators in a way that:

- adds/demonstrates value to users over and above unconnected indicators
- is manageable and low cost
- facilitates policy-making by making mental models and relationships explicit
- is transparent
- enhances understanding of the impacts of intervention/change; and
- increases understanding of complexity

Interlinked thinking, developed as a complementary tool in the SP2 toolkit, aims to allow people to work with systems without being experts.

1.2 RATIONALE AND IMPORTANCE OF THE STUDY

The SP2 toolkit is concerned with providing practical and implementable tools to facilitate integrated decision-making processes in local government. The SP2 tools all focus on encouraging thinking systemically, exploring understanding of linkages, and help decision-makers approach challenges from a systems perspective. When the SP2 toolkit is utilised, users choose the appropriate tool by selecting the one that best adds value to their current context.

Understanding interconnectedness is important for people to make sense of the world in which they live. Complex behaviour does not come from the complexity of the components but from the interactions (feedback loops and time lags) among components (Hovmand, 2014; Sterman, 2000). To operate successfully decision-makers need to understand the emergent properties of the system well enough to make changes in the right direction. A connected system has general patterns that are not obvious from studying the individual parts of the system. The need for assistance in this respect is nothing new. As Simpson stated in 1944:

> Synthesis has become both more necessary and more difficult as evolutionary studies have become more diffuse and more specialized. Knowing more and more about less and less may mean that the

> relationships are lost and the grand pattern and great processes of life are overlooked (Simpson, 1944, p. xv).

The relationships in a system and the complex patterns of interconnections are revealed via feedback loops. Following these feedback loops allows us to gain understanding of how effects can be distanced in time and space, from their cause. According to Kim "How we describe our actions in the world affects the kinds of actions we take in the world" (1999, p. 6). Therefore, being able to show and understand the interrelationships in a complex system will facilitate managing that system. We are also better able to manage situations where mental models are aligned, so it is important that assumed relationships between factors are visible and explicit (Kim, 1999).

The specific research interest for this dissertation is well-being and how indicators chosen to measure well-being interconnect. For example, as material standards of living increase, greater pressure is put on scarce natural resources for the output of more goods. Both the production and disposal of these goods degrade the environment, which impacts well-being. There are also other unheeded influences on well-being, such as loss of leisure time to finance purchases, the negative health impacts from stress, and detachment from nature. All these factors interconnect and there are delays in the system between present-day actions and when the actual impacts are felt.

Understanding of the relationships between indicators gains importance with their more extensive use to cope with information overload. As the world becomes more complex indicators are used to help make sense of our lives and track outcomes from multiple paths of activity (Bossel, 1998, 1999). This greater dependence on indicators accentuates the importance of selecting the correct ones and understanding the context in which they function. Sayings such as "you are what you measure" or "what you don't measure you can't justify" or "if you measure the wrong thing you do the wrong thing" gain even more relevance when we are selective about the information we choose on which to base our decision-making. For these significant reasons, both indicators and indicator selection is researched as part of this dissertation in Chapter 5.

The most commonly used indicator for well-being is Gross Domestic Product (GDP). A strong link has been forged between economic growth and social well-being in people's minds due to the extensive use of GDP as a proxy for how well a country is performing. Increased economic growth, measured by domestically produced goods and services, has become such an important goal that politicians can get support from voters for promising policies based on economic objectives alone.[4] However, when environmental and social costs outweigh the benefits of economic production, a country or region can enter a period of 'uneconomic growth' (H. Daly, 1996). In this situation, GDP growth results from dealing with social and environmental problems, rather than from economic activity that contributes to citizens' well-being (Costanza, Hart, Talberth, & Posner, 2012; H. Daly, 1996, 2013; Forgie & McDonald, 2013).

There is increasing recognition of the need for indicators that provide more than just economic information as the basis for policy decisions. (H. Daly & Cobb, 1994; Hamilton, 1999; McGuire, Posner, & Haake, 2012; Stiglitz, Sen, & Fitoussi, 2009; Wellington Regional Strategy Office, 2011; Wilson, Anielski, & Seidel, 2007).

Alternative Indicators, like the WR-GPI, have been developed to track progress over a wider value set and thereby determine real progress towards achieving societal goals. Alternative well-being measures stress the importance of non-monetary aspects of life such as nature, friends, family life, quality neighbourhoods, education, and health. Indicators used in alternative well-being measures are generally reported in three ways: individually; as part of an indicator dash-board; or, aggregated into composite indicators (Hammond, Adriaanse, Rodenburg, Bryant, & Woodward, 1995; Jollands, 2003; OECD, 2008).

How indicators interlink is not usually taken into account in well-being measures. Instead, each of the indicators is treated as an independent variable – not impacted on by changes in the other variables measured. Future well-being trends are extrapolated from past data, implying trends will continue – an assumption likely to be inaccurate. This type of linear view provides a way of describing *what* happened *when*, but little insight into *how* things happened and *why*. A more interlinked approach that

[4] GDP was never intended to be used in this way. This is discussed in Chapter 3.

incorporates feedback loops (i.e. acknowledges interdependencies, time lags, non-linarites and so on) is a way to gain understanding of the forces that produce experienced behaviours (Kim, 1999) and the likely future implications. Typically, indicators report what has happened in the past, and are far removed from the event that causes them to change. Better understanding of the potential reason for this change and the role of slow and fast indicators, backward- and forward-looking indicators, and so on is critical to understanding the cause-and-effect relationships that determine the direction of change in an indicator.

Recognition that there is a lack of understanding as to how well-being indicators interrelate is widespread. The call for more research in this area has been made globally. The Office for National Statistics based in the United Kingdom has interactions between well-being measures listed as a key research requirement. The stated "next phase of the MNW [Measure of National Well-being] programme is to identify and explore areas which deviate from 'norms' and to investigate what, if any, relationships exist between the factors affecting well-being" (Self, Thomas, & Randall, 2012, p. 7).

The OECD has developed the 'Better Life Index', and is promoting an international research agenda on well-being measurement to better inform decision-making. Dynamics within the well-being system are a key interest (Durand, 2012).

The Canadian Index of Wellbeing researchers, working at the forefront in the well-being measurement field, identified "links in the form of causal interactions or mere correlations among the indicators housed in different silos" as one of the issues requiring further investigation in their study (Michalos et al., 2011, p. viii).

The research undertaken for this dissertation is a response to this identified gap in understanding in New Zealand. The WR-GPI study acknowledges the framework for measuring trends in well-being for the Greater Wellington region consists of a set of unconnected indicators. Effort to develop the WR-GPI framework focused on the individual indicators that mattered most to the region. Lack of understanding of how the WR-GPI well-being indicators interlink is admitted with Durling (2011, p. 6) saying: "little is known about the influences and relationships between the elements". Reference to lack of understanding as to how indicators interlink in the WR-GPI is also made in the Wellington Regional Strategy: “There is also interaction among all aspects of the framework, although we are far from knowing all the constituents and determinants of these interactions” (2011, p. 9).

This dissertation uses the methodology of systems analysis and systems thinking to understand the interrelationships between indicators. Systems analysis “is the multidisciplinary problem-solving activity that has evolved to deal with the complex problems that arise in public and private enterprises and organizations…systems analysis deals with diverse problems and different contexts, it assumes many forms adapted to the problems, the systems, and their contexts” (Miser & Quade, 1985, pp. 15-16). It uses the quantitative and structural tools of science and technology. Systems thinking – while similar to systems analysis – is a more qualitative approach. It is “based on the primacy of the ‘whole’ and of relationships. It deals with hidden complexity, ambiguity and mental models” (Maani & Cavana, 2007, p. 2). Systems approaches add value when working with issues characterised by complexity and uncertainty. They aim to clarify issues by presenting alternatives in a common framework and inform the decisions made via political processes.

Understanding links between different parts of a system and the emergent properties of a system is a prerequisite for insight into policy implications (Shmelev, 2011). Treating well-being indicators as unconnected neglects the systemic (and dynamic) nature of the real world processes. This also ignores the fact that indicators are embedded in a larger total system containing many feedback loops. Having a system of interlinked measures provides a way of exploring alternatives from a what-if framework and allows users to better take into account the uncertainty that more closely represents reality.

An additional motivation for this research is to investigate the potential for indicators to be used in a more proactive way. Better understanding of how indicators interrelate, from a systems perspective, provides a means for locating and understanding leverage points where interventions may lead to improved future outcomes. Tools are needed to assist anticipate impacts that interventions in one area may have on another (and at multiple scales e.g. time, space, hierarchy, etc.). Such tools increase understanding of the system, and the likelihood that beneficial actions will be taken in a complex system. The fact that these actions are often counterintuitive (Forrester, 1973) makes the tools potentially of even greater value. Advancing this understanding is at the core of this research.

1.3 RESEARCH QUESTION

This research aims to provide a procedure to analyse interlinkages in a way that complements the outputs of the SP2 project and adds to the SP2 toolkit in a new and novel way. An understanding of the interlinkages and integrated nature of the indicators selected to measure well-being should, hypothetically, provide new knowledge and insight for policy over and above reporting based on individual indicators or indicator aggregation. The principal research question this dissertation aims to answer is:

"Does understanding the relationships between indicators add value and progress sustainable well-being?"

This question is answered using the methodology of answering the following intermediate questions:

(1) What is meant by 'sustainable well-being'? (Ch 2)

(2) What measures are used to assess progress in well-being? (Ch 3)

(3) Can a systems approach be used to understand the relationships between well-being indicators? (Ch 4)

(4) Are there specific requirements that indicators need to comply with when part of a system? (Ch 5)

(5) What method can be used to determine the links between indicators, and better understand the resultant cause-and-effect relationships? (Ch 6)

(6) How do you select the appropriate indicators to measure well-being, and, what insights can be gained from applying the method developed to understand the relationships between these indicators? (Ch 7)

(7) Is the method developed to understand relationships between indicators able to be used with different indicator sets? (Ch 8)

(8) Is the method developed to understand relationships between indicators able to be used in a non-participatory context? (Ch 9)

How the intermediate questions relate to the primary research question is set out in Figure 1-2.

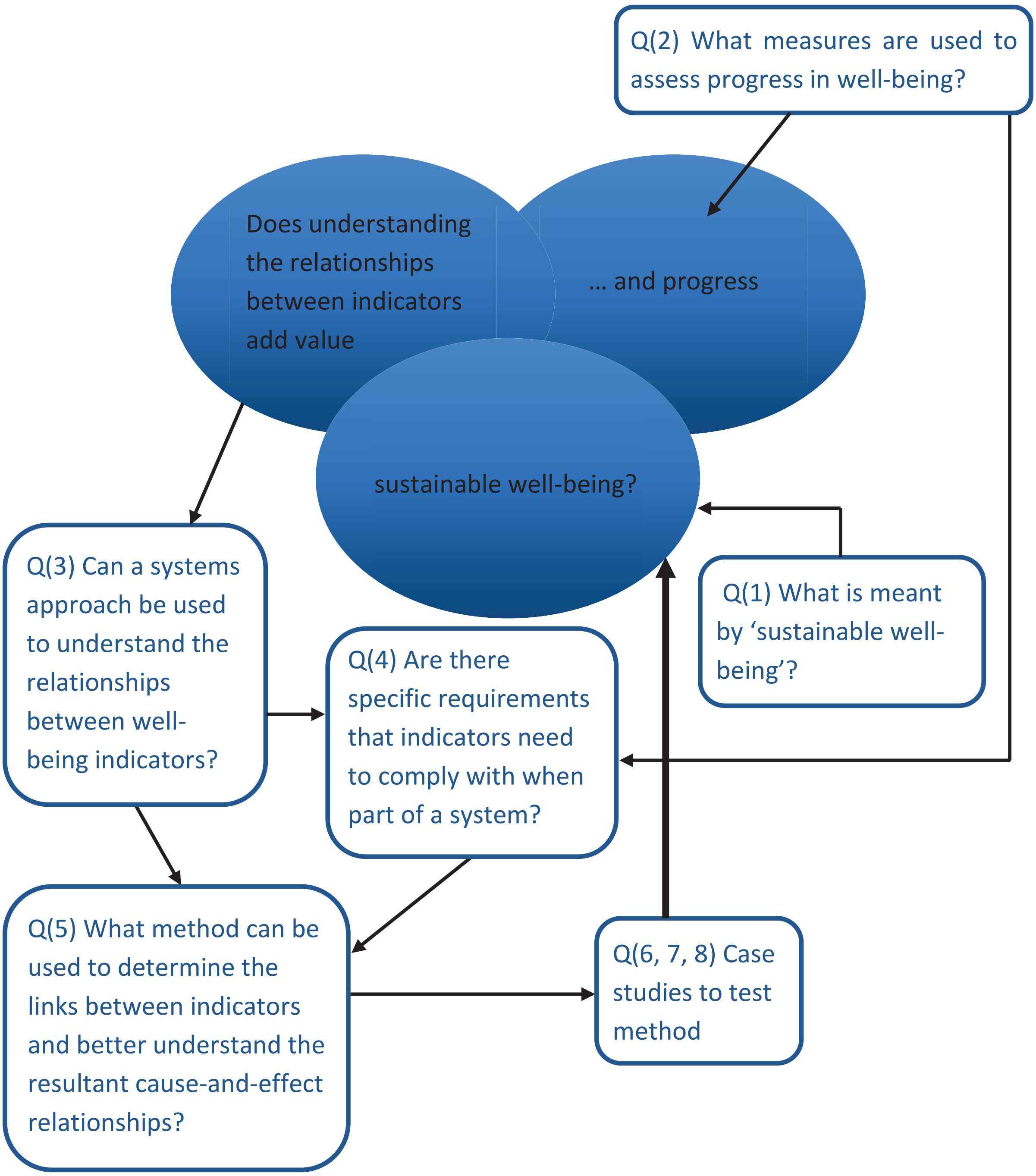


Figure 1-2: How research questions interlink.

The ultimate ambition of this research is to accelerate the progress towards sustainable well-being at multiple scales; i.e. local, regional, national and global. Each of the intermediate questions is explored to contribute to the answering of the principal research question.

The first intermediate question (Q1) defines ‘sustainable well-being’ as the aim of the SP2 project is to further this goal. The analysis and discussion of ‘sustainable well-being’ is a prerequisite for Q2. The goal of Q2 is to overview existing measures used to assess progress in well-being, and evaluate their ‘fit’ for this purpose.

A theoretical framework for linking indicators is required before assessing whether better understanding the relationships between indicators can add value. The third question (Q3) considers whether a systems approach provides the prerequisite theoretical basis and tools. The outcomes from this question inform Q4 and Q5.

The fourth question (Q4) seeks to identify whether indicators connected as a system have attributes that vary from individual indicators selected for well-being measures. The outcomes from Q2 provide a ‘control’ to compare against when answering Q4.

Q3 and Q4 provide the substantive background for Q5, which seeks to find a method for interlinking indicators. To test whether understanding the relationships between indicators adds value and progresses sustainable well-being requires the development and implementation of a method to: (1) connect indicators; (2) provide information on the connected indicators; and (3) evaluate its usefulness.

Q5 sets out the method for interlinking indicators. The three intermediate questions (Qs 6, 7, and 8) test in a real world context the usefulness of the method developed. Three case studies were used to determine the benefits derived from better understanding of relationships between indicators. Two of the case studies involved participants, and questionnaire responses were used to evaluate the usefulness of linking indicators and understanding relationships. The third case study tested whether new insights to achieve sustainable well-being could be gained from linking indicators as a desk-top activity. The answers to Qs 6, 7, and 8 are synthesised to answer the overall research question, discuss how effective the approach proposed is, and whether or not research criteria established at the outset are met.

1.4 DISSERTATION STRUCTURE

The position taken with this research is not to tackle complexity with complexity, but to provide a transparent process by which people interested in exploring and understanding the relationships in a system can do so. This is done following the logic set out in Figure 1-3 and the dissertation structure as described below.

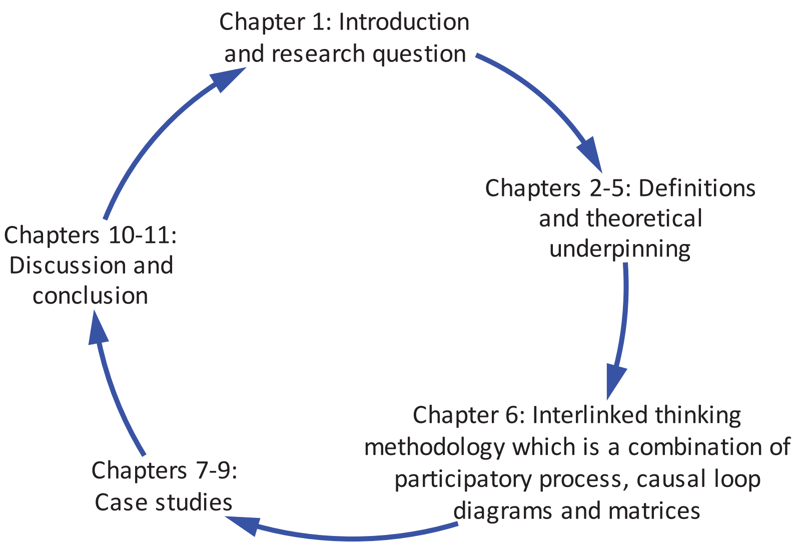


Figure 1-3: Dissertation chapter overview.

First, Chapter 2 addresses the question "What is meant by 'sustainable well-being'?" Terms such as 'progress', 'well-being', 'happiness', and 'life satisfaction' are all part of the broad lexicon used to describe the purpose of public policy. Just like GDP, these notions can take on a life of their own without clear distinctions. Therefore, these concepts are explored starting with 'progress.' Then well-being is considered as the indicators that are interconnected in this research all relate to alternative ways to measure changes that impact on the lives of citizens. For clarification purposes the similarities and differences between 'sustainability' and 'well-being' are explained. A framework for well-being as a system is presented. The components of the well-being system are then discussed and defined. These are: subjective well-being measures; basic human needs; sustainable development; and capital assets. The chapter concludes with the definition of sustainable well-being to be used going forward in this dissertation.

Chapter 3 considers "What measures are used to assess progress in well-being?" First, it provides an introduction to GDP, the widely accepted proxy used as a gauge for well-being, and discusses why this is not appropriate. This is followed by a brief overview of the international movement underway to replace GDP with broader well-being measures. It then reviews a subset of the many measures that have been proposed for this purpose. One such measure is the “Genuine Progress Index”, which is the measure used by the Wellington Region, and is central to this research. The well-being measures in the subset are evaluated for how well each one meets the requirements to assess progress in sustainable well-being when judged against the criteria established in Chapter 2. A critique of alternative measures and why there has been limited uptake of ‘Beyond GDP’ measures concludes this chapter.

Chapter 4 introduces systems theory and systems tools as this branch of knowledge focuses on connectivity between variables in a system and the repercussions. This introduction is required because the theoretical foundations for the approach taken to interlink indicators in this dissertation come from the systems thinking and system analysis schools of thought. The purpose of using a systems approach is to better understand sustainable well-being and also to provide new insights that are forward looking and able to inform policy. The question of interest is: “Can a systems approach be used to understand the relationships between well-being indicators?”

Chapter 5 contemplates “Are there specific requirements that indicators need to comply with when part of a system?” To answer this question the process followed is to compare the well-documented existing criteria for selecting indicators for composite or dash-board well-being measures, with approaches that select indicators from a systems perspective. This chapter starts by reflecting on “what is an indicator?” and “what are the attributes of a good indicator?” Drawing on the literature, some guidance is provided on how indicators should be selected when they are the component parts of an integrated system.

Chapter 6 sets the challenge: “What method can be used to determine the links between indicators, and better understand the resultant cause-and-effect relationships?” It then proceeds to explain the method referred to as ‘interlinked thinking’ devised as part of this research to link indicators. The interlinked thinking steps are first set out, then each step is worked through. The method uses a combination of participatory process, causal loop diagramming for determining links, and matrices for analysis. Participants make the links they consider important in the system. These links are then analysed using graph theory to provide participants with an insight into the system they have constructed. This chapter concludes by discussing the outputs from interlinked thinking and what differentiates this tool from other available tools.

Chapter 7 addresses the question “How do you select the appropriate indicators to measure well-being, and, what insights can be gained from applying the method developed to understand the relationships between these indicators?” Empirical research was undertaken to answer this question using the WR-GPI indicators. The Greater Wellington Regional Council hosted two workshops where the interlinked thinking method described in Chapter 6 was tested. Participants were members of the WR-GPI working group reviewing the WR-GPI framework and the indicators that comprise it. Participants were surveyed at the start of the first workshop and at the end of the second workshop to get their views on the interlinked thinking method and how useful they thought it was.

Chapter 8 evaluates, “Is the method developed to understand relationships between indicators able to be used with different indicator sets?” This case study uses the Ministry of Social Development ‘Social Report’ indicators. Two workshops were held with participants predominantly from central government agencies. The interlinked thinking method described in Chapter 6 was again applied and stakeholders were surveyed at the start of the first workshop and at the end of the second workshop to get their opinions.

Chapter 9 considers “Is the method developed to understand relationships between indicators able to be used in a non-participatory context?” The interlinked thinking method developed as part of this research was applied in a third case study using the OECD Better Life indicators. The OECD ‘Better Life Index: Measuring Well-being and Progress’ website (http://www.oecdbetterlifeindex.org/) uses 11 topics to measure well-being. The OECD consider these dimensions cover the material living and quality of life conditions essential for measuring whether or not life is getting better. Information on the OECD better life website and wider literature was used to determine links. This desktop study was undertaken to determine if the interlinked thinking method is useful when applied in a format other than that of a participatory workshop.

Chapter 10 brings together the results of the three case studies and presents the opinions of the participants involved in the WR-GPI and Social Report workshops. Specifically, it addresses, through the questions posed in the preceding chapters, the overall research question *"Does understanding the relationships between indicators add value and progress sustainable well-being?"* The extent to which interlinking indicators as a system added more value than using individual indicators or indexed and aggregated indicators is assessed. Next, the ways in which interlinked indicators can support decision-making are examined. A critique of the approach and the limitations of the interlinked thinking method follow. The scope for improving the interlinked thinking method and future workshop facilitation is also discussed. Last, an update on recent developments using a combination of causal loop diagrams and matrices is provided to acknowledge other work in this area.

Chapter 11 draws conclusions from the research undertaken and outlines the new contributions to knowledge that have been attained as a result of this dissertation. It assesses how well stakeholder requirements have been met, the research limitations, and reflects on the areas where future research will advance the use of interlinked thinking.

1.5 SUMMARY

This introduction provides the context for the research undertaken for this dissertation. It first explains the research area of interest: the relationships between well-being indicators and whether or not better understanding of these relationships adds value and progresses sustainable well-being. The SP2 project, of which this research and its objectives are part, was then outlined. Why this research is of value, and the importance of looking at well-being as an interconnected system, were explained.

To carry out this research a number of research questions have been set. Answering these questions generates the learning from this research and provides the topic question for each chapter. An outline of each of the chapters was provided to map the dissertation structure.

Chapter 2 considers the first research question, which seeks to establish what we mean when we talk about ‘progress’ and ‘well-being’. These value definitions are pivotal to this research.

2 SUSTAINABLE WELL-BEING

In this chapter the question of "what is meant by 'sustainable well-being'?" is addressed. First, the chapter explores the concepts of progress and well-being and how these change with time. Our current understanding of well-being has been molded by the debate on what defines progress for societies. Therefore, how progress is conceptualised modifies the definition of well-being and the prerequisites for better societies. Identifying and promoting better societies is a powerful motivator for people (Sen, 1999). Therefore well-being improvement should be a central goal for both policy makers and the public; and a proviso for policy decisions.

This chapter starts by discussing progress as an antecedent to well-being. It then moves to clarify what we mean when we refer to 'well-being'. A framework for well-being as a system is presented and the different components that together determine well-being are set out. Based on the well-being theory reviewed, these are: subjective well-being measures; basic human needs; sustainable development; and capital assets. The chapter concludes with a summary of the principles of sustainable well-being and the key areas extended by the research undertaken in this dissertation.

2.1 PROGRESS AS AN ANTECEDENT TO WELL-BEING

Historically, 'what is progress?' and 'how is it best measured?' has been a long-standing debate. Progress implies a goal and a direction, which necessitates a value judgement and agreed-on measure for assessment (Ginsberg, 1973). Therefore, progress takes many forms and directions.

2.1.1 How the concept of progress has evolved

Ginsberg (1973) traces the origins of progress to the era of the Enlightenment, or the Age of Reason, from the 1650s to the 1780s. The concept of progress and capacity of humans to continuously adapt and move towards a better future appears to have originated in this era. During this period the evident advances in science, social improvement, and material consumption reinforced confidence in man's ability to drive progress. Human progress was less defined by fatalistic, religious-based ideals, and instead "linked with the growth of science and its applications, with the spread of the rationalist and humanitarian outlook, and with the struggle for political and religious liberty" (Ginsberg, 1973, p. 636). The spread of these ideas and attitudes was accelerated by the Industrial Revolution, which took place from the 1760s onwards, and allowed the wider population to be privy to knowledge via the mass production of books, pamphlets, papers, and journals. The political ideals that resulted influenced important social legislation such as the United States *"Bill of Rights"* and the French *"Declaration of the Rights of Man and of the Citizen".*

Progress can be interpreted as a form of 'disjointed incrementalism', where we move forward in a disorderly way to some notionally better situation. Lovejoy and Boas (1935, p. 6) argue that progress is "a tendency inherent in nature or in man to pass through a regular sequence of stages of development in past, present and future, the later stages being – with perhaps occasional retardations or minor retrogressions – superior to the earlier". This definition recognises that progress is not linear. History tells us that progress is cyclical, and impacts on cultures differently. Inventions accelerate exploitation and progress until limits are hit and decline sets in (Bateson, 1972). The past has been full of wars, famines, disease, and struggles that have been significant set-backs. Some civilisations have spread and prospered, while others have been destroyed (Diamond, 2005; Flenley & Bahn, 2003).

Lee (1992) agrees that progress is not necessarily a smooth upward trajectory. However, for him setbacks are a catalyst for producing better and cheaper alternatives that in turn lead to further progress. "Resource scarcities have on occasion resulted in genuine crises. In the past, however, these crises were not only always overcome, but generated information and motivation for responses that fuelled continued economic progress" (Lee, 1992, p. 52). Progress for Lee can, therefore, be interpreted as a continued process of knowledge accumulation that allows exploitation of, and value to be added to, the natural capital resource base on which humans depend. Examples given by Lee include the move from wood to coal, whale oil to crude oil, and from bronze to iron.

Instead of linking progress to science and material goods, an alternative view is to consider progress as advances in moral achievements such as freedom, justice, and equality. For Robertson (1912) a viable test to determine progress is the extent by which pleasurable and intelligent life increases in quantity and quality.

Comte (cited by Mills, 1866), believed progress is not an aggregation of small changes but, more the outcome of a pulse through the entire system with the main agent of change 'intellectual advancement'. Mills (1866), in a similar vein, advocated that passion and interest influenced the moral, political, and religious realms, but the intellectual movement was responsible for everything else that contributed to progress.

Progress optimists cite the many past negative predictions that have not come to fruition as proof that progress can be maintained. These include well-recorded predictions, such as those by Malthus (1826) and Ehrlich (1968), that population growth would lead to starvation and pestilence, or that of Jevons (1909) that coal supplies would run-out and bring progress to a halt. More recent predictions, that oil supplies would run out and bring an end to our current energy intensive progress (Hubbert, 1962; Kunstler, 2005; Roberts, 2004), have also not yet come about.

Given that in recent history disasters have not wiped out cumulative gains in average living standards (Nasar, 2011), cornucopians see no reason to doubt that knowledge, technology, and the market place can indefinitely overcome obstacles to progress (J. Simon, 1996). Therefore, such futurists argue that continued progress, material provision and overcoming environmental problems can all be achieved with technology advancement.

2.1.2 Advances in technology and materialism as progress

The rise in a material standard of living, leisure time, education, and increased life expectancy are all proof to progress optimists that life in modern societies is better now than for previous generations (Veenhoven, 2010). Specialisation of skills, working for each other, the exchange of goods and services combine to increase our standard of living and allow a more populous world to achieve greater prosperity (Porter, 1998).

Also, factors such as reduced poverty, greater equality, and less discrimination, provide people with opportunities to improve their well-being (Jones, 2002). Societal development and the welfare state have broken the " …traditional religious view of earthly life as a phase of penance awaiting paradise in the afterlife" (Veenhoven, 2010, p. 106).

There is, however, skepticism that advances in technology and materialism are adequate to sustain societal progress (H. Daly, 1996, 2013; Jackson, 2009). Using growth in knowledge as a measure of social progress ignores the fact that science and technology can be used for both good and bad.

With technology there is an increased level of risks associated with progress that is not well understood or evenly spread. Major risks to modern-day progress potentially include: (1): cyber-attacks, given the inter-connectedness of computer systems controlling power, food supply, banking, etc.; (2) bioterrorism and the release of genetically engineered harmful microbes and viruses; (3) food shortages as a result of a failure in 'just-in-time' delivery systems; (4) pandemics due to increased mobility and globalisation; (5) malignant computers not performing as designed; and, critically, (6) climate change and the feedback effects caused by accelerated warming (Centre for the Study of Existential Risk, n.d.).

In particular, pressure on the environment is seen as a major constraint to sustained progress. The mass-scale exploitation of natural resources in conjunction with production of wastes and pollutants has been increasing since the Industrial Revolution. While the market place may force more efficient allocation of inputs as prices rise, environmental degradation and natural resource are exogenous to market prices. As a consequence, the free ecosystem services of assimilation provided by nutrient recycling, the hydrological cycle, and gas regulation are in many places being exceeded from a human anthropocentric life-sustaining point of view (Rockstrom et al., 2009). Overloading is resulting in a build-up of greenhouse gas in the atmosphere, water degradation, and toxic wastes. There are known negative impacts on the many provisioning, supporting, regulating, and cultural services provided by ecosystems that at many scales are beginning to fail due to anthropogenic disturbance (Millennium Ecosystem Assessment, 2003).

If natural capital and man-made capital are complementary (H. Daly, 1996), a shortage of either will be a limiting factor to progress. In the past, man-made capital has been in short supply but it can now be argued that natural capital is becoming the scarce factor (H. Daly, 1996, 2005). Growth in knowledge and technology allows natural capital to be transformed at ever increasing rates. A significantly greater population, demanding higher material standards of living has resulted in the accelerated loss and degradation of ecosystems and the services they provide. As these are the 'life-support' systems required for human survival, it is feared that progress in the future will be more hazardous due to the damage to these systems (IPCC, 2013).

Views differ on how progress will play out in the future. On one side, there are predictions such as those made in *"The Limits to Growth"* (Meadows, Meadows, Randers, & Behrens, 1972) that population growth, resource extraction, and pollution from industrialisation will eventually cause ecosystems to collapse. Technological progress may have mitigated resource scarcities for the limited period considered by the various studies undertaken this is not proof that technology will continue to do so indefinitely (McDonald, 2006) or that adverse outcomes will not result (Flannery, 2005). If the assumption that technology can overcome biophysical constraints is false there will be unsustainable problems (Costanza, 1999). Other predictions deem this as pessimistic (Barnett & Morse, 1963; Lee, 1992; J. Simon, 1996) and place faith in man's resourcefulness, adaptability, and technological prowess (Petersen, Frantz, & Shammin, 2014).

2.1.3 Time use as progress

The balance between work and leisure is another way to measure progress. Using this approach, progress can be measured by the extent to which human needs can be satisfied with minimal labour input.[5] Productivity changes from technology and capital investment thereby provide a way to gauge progress.

Keynes (1930) in his essay *‘Economic Possibilities for our Grandchildren’* saw progress as the way to move to a 15-hour work week, and a quality rather than quantity way of living. Capital accumulation would be the solution to the ‘economic problem’ of mankind. Keynes considered the economic problem of providing sufficiency in the absolute sense for all peoples as achievable – though he admitted the desire for superiority might be insatiable. Freedom from the need to provide the basics would allow people to devote energies to non-economic purposes and participate in the arts of life.

2.1.4 Equality as progress

Global upheavals such as the Depression (1929–1939) and the two world wars (1914–1918 and 1939–1945) saw the rise of the welfare state and more egalitarian societies. A more equal society with opportunities for all was considered as progress. Before these events wealth was concentrated in the hands of a relatively small number of rich families (Piketty & Zucman, 2014).

The advantages associated with greater equality are considered to be both societal and individual (Boyle & Simms, 2009; OECD, 2015; Piketty, 2014; Wilkinson & Pickett, 2009). For society, greater equality is a way to foster cohesion and democracy as it prevents political influence from getting into the hands of a wealthy few. Based on evidence across OECD countries, Wilkinson and Pickett (2009) argue that life expectancy, literacy, social mobility, and trust are all better in more equal societies. On the other hand, where there is inequality, infant mortality, obesity, homicide rates, and mental illness are worse.

---

[5] New Zealand was one of the first countries to formalise an 8-hour working day, and since 1899 the 8-hour work day has been commemorated by a public holiday on Labour Day. The concept promoted was 8 hours for work, 8 hours for sleep and 8 hours for leisure and the pursuit of personal activities. Additional hours worked over and above 40 per week resulted in overtime payments. If this is a measure of progress New Zealand can be considered as regressing. Labour reforms in the 1990s have resulted in many people working in excess of 8 hours a day; and others who would like to work 8 hours a day do not have the opportunity to do so.

When social and political instability result from inequality this negatively impacts all members of society (Stiglitz, 2002). From an economic perspective extreme inequality impedes growth. Economic activity is reduced as the wealthy save a higher proportion of their income than the middle and lower groups in society (OECD, 2015). It is also argued that human-capital based growth is less as inequality marginalises members of society with the potential to contribute (Hellier & Lambrecht, 2013; Jones, 2015; OECD, 2015).

Inequality is a relative measure that reflects time and technological change.[6] It can arise among individuals, groups, communities, ethnicities and nations. When equality is used as a measure of progress the question remains what should be equal given the diversity of human interests and needs. There is generally a trade-off between equality in one area (e.g. rights) and inequality in another area (e.g. income level). According to Sen, "Wanting equality in what is taken to be the 'central' social exercise goes with accepting inequality in the remoter 'peripheries'." (Sen, 1992, p. x).

The argument for equality as progress put forward by John Rawls (1999) in *"A Theory of Justice"* is that all individuals have an equal right to basic liberties and fair quality of opportunity. Furthermore, disadvantaged members of society should be looked after to compensate for naturally occurring inequalities (the Difference Principle).

Sen (1992) in his monograph *"Inequality Reexamined"* considers Rawl's 'concept of equality of opportunity' to be restrictive as it does not take into account the natural diversity of humans and the factors that underlie the capability to take up opportunities. In Sen's view, inequalities associated with class, gender, and community result in people having very different abilities to achieve outcomes from the same set of primary goods.

[6] For instance, access to consumer goods like sugar or mobile phones, which were at one time the prerogative of the rich, does not mean there is now less inequality.

Most economists use differences in the distribution of economic stocks (wealth), or flows (income), as the preferred measure of inequality.[7] As inequality is relative it is determined by comparison (A. Atkinson, 1970).

In liberal market economies (that typify most advanced countries) there has been a move away from progressive tax and welfare policies to foster more egalitarian societies since the 1970s. Instead, the direction is economic self-reliance and growth to provide opportunities and employment, thereby, addressing inequality via the so-called 'trickle-down effect'. The argument for this policy direction is that despite an increase in relative inequality, globally there has been an overall increase in living standards.

Data show that inequality is growing (Boyle & Simms, 2009; Gijsberts, 2002; OECD, 2015; Piketty, 2014; Wilkinson & Pickett, 2009), and is higher in liberalised market economies than coordinated market economies (Chusseau & Dumont, 2013; Jackson, 2009).

Factors contributing to greater inequality include the rise in knowledge-based economies (leading to more demand for skilled workers than for unskilled workers); the globalisation of trade (unskilled work has gone off-shore to countries with low labour costs); and the political and institutional power of those who accumulate wealth (Adamson, 2013; Chusseau & Dumont, 2013). Thomas Piketty, (2014) in his book *"Capital in the 21st Century"*, drew attention to growing wealth inequality and the reestablishment of earlier extreme wealth patterns.[8] His research shows wealth is becoming increasingly concentrated through the ability of affluent people to pass on wealth, provide offspring with better opportunities, and wield greater political influence.

---

[7] Inequality is represented by either the Lorenz curve, Gini coefficient, or using indicators as with the Atkinson index.

[8] From studying wealth distribution in eight countries, Piketty (2014) deducted the general rule that wealth will concentrate when the rate of return to wealth (r) grows faster than the rate of economic growth (g) (i.e. r>g). In a free market system there are no forces pushing against the steady concentration of wealth. Any factors that slow economic growth (e.g. ageing population, lower consumer demand, slower population growth) will further concentrate wealth. Even moderate savings rates lead to large wealth–income ratios.

2.1.5 Economic growth as progress

The concept of economic growth as progress is the dominant paradigm for most nations. Economic thought, as it is now known, can be traced back to the Physiocrats who flourished in France in the mid-1700s (Spiegel, 1991). Led by Francois Quesnay, the Physiocrats theorised that there was a 'natural order' that was followed by both nature and society and this was not to be interfered with. Quesnay's *Tableau économique* has been described as the "forerunner of Marx's schemes of reproduction, input-output analysis, modern national accounting systems, multiplier analysis, and general equilibrium analysis" (Sandelin, Trautwein, & Wundrak, 2008, p. 13).

2.1.5.1 Classical economists

Following the Physiocrats, economic thinking was advanced by the Classical economists[9] who developed the following economic theories in the 18th and 19th centuries:

Growth: For the early Classical economists, such as Adam Smith, growth was generated by producing physical goods that had added value over and above that of the labour and raw material inputs, and thereby created an economic surplus (Brue & Grant, 2013). Smith believed technical innovation could enhance specialisation in manufacturing and this would increase output – despite having a negative impact on the physical and mental health of the workers. Specialisation provided a way to increase the surplus available to trade and reinvest (Canterbery, 2011; Sandelin et al., 2008; Spiegel, 1991).

Classical economists later in the period were not as positive about the long-term prospects to generate growth via capital accumulation (E. K. Hunt & Lautzenheiser, 2011). A summary of their argument is: Any increase in capital would be accompanied by a greater demand for labour to operate the capital. This would have the effect of increasing wages above subsistence levels and population growth would result. A

[9] Karl Marx originally coined the term "classical economics". The list of classical economists includes, among others, Adam Smith (1723–1790), Jean-Baptiste Say (1767–1832), Thomas Malthus (1776–1834), David Ricardo (1772–1823), Nassau Senior (1790–1864), James Mill (1780–1864), John Stuart Mill (1806–1873), and Karl Marx (1818–1883).

bigger population requires more food, which brings into cultivation less productive land. The diminishing productivity of land means more labour input per unit of food produced is required, and therefore the price of food would increase. Higher prices for food would lower the prices of manufactured goods (under the classical assumption of constant average prices) and thereby reduce profits for manufacturers. The subsequent decline in profits leads to less capital accumulation, a decline in growth and eventually a stationary state economy. Ricardo's theory of wages acknowledged that wages might fluctuate according to short run supply and demand but they would always tend towards subsistence (Sandelin et al., 2008).

While unrestricted trade (both national and international) and increased specialisation might be able to offset diminishing returns and delay the on-set of the stationary state, it was generally considered population expansion would outweigh these gains. Malthus's theory that population increased geometrically as opposed to agricultural output, which increased arithmetically, reinforced this view.

The notion that energy and capital might overcome diminishing returns and generate growth was not conceived by Classical economists (Galbraith, 1987). Mills in *"Principles of Political Economy, with some of their Applications to Social Philosophy (1848)"* saw positives associated with reaching a stationary state where the economy would reproduce itself but not grow – man could be freed from the incessant drive for material progress and pursue loftier purposes (Sandelin et al., 2008).

Market: In 1776 Smith published his *"Inquiry into the Nature and Causes of the Wealth of Nations",* which conceptualised the 'invisible hand', an idea not dissimilar to the 'natural order' of the Physiocrats. This described how if each person in a free market conducts their economic affairs in their own best interest the economy works to the advantage of all and thereby maximises the welfare of everyone. The economy was a self-stabilising system of markets that worked efficiently when free from interference and government intervention (Mills, 1848/1909). A market that allowed wages and prices to adjust rapidly enough to maintain equilibrium would make people as well off as economically possible, given a country's resources and wealth distribution – although it would be unable to protect against disasters such as drought, political instability, famine, and war.

Value: Most early classical economists considered labour the only real measure of exchangeable value – a view echoed by Marx a century later. However, as goods were produced from the combined inputs of labour, land, and capital,[10] it was later accepted that all inputs, not just labour, were of value. Value was redefined as the cost of production measured by wages, profit and rent inputs.

Smith (1776) made the distinction between 'value in use' and 'value in exchange'. This was because he was puzzled that many of the essential things in life were free or virtually free; an issue not solved until the concept of marginal utility a century later (Galbraith, 1987). Smith used water as a good example of high use, but low exchange value, and diamonds as the opposite.

Distribution: Income was distributed between labour, land, and capital in the form of wages, rents, and profits. The explanation of value in classical economics, therefore, was simultaneously an explanation of distribution (Sandelin et al., 2008). Landlords received rents, workers received wages, and capitalists received profits on their investments.

Accounting system: Wealth was the stock of physical assets minus the national debt. National income was determined by what was spent now, and what remained to increase the national stock of assets (D. Coyle, 2014). For Smith, only those involved in making physical commodities, agriculture, and industry counted when estimating national income, whereas, the provision of services was a cost to the economy (Sandelin et al., 2008; Spiegel, 1991).

2.1.5.2 Neoclassical economics

Neoclassical economics, which is the dominant school of economic thought and practice in today's western world, overtook Classical economics in the 1870s. It is typified by the marginalist approach,[11] which places importance on both the demand and supply sides of economic activity. Alfred Marshall,[12] highly regarded as the

[10]The classical production function is $Y=f(L, K, R)$ where Y=output; L=labour; K= capital; R=rent.

[11] The margin revolution is usually dated from the Englishman, William Stanley Jevons's Theory of Political Economy (1871), the Austrian, Carl Menger's Principles of Economics (1871), and the Swiss economist Léon Walras's Elements of Pure Economics (1874–1877).

[12] Though he saw himself as a developer of classical doctrine (Staley, 1989).

foremost neoclassicist for his writings in *Principles of Economics* (1890), set out supply and demand schedules and the concepts of consumer and producer surplus (Sandelin et al., 2008). Neoclassical economists are associated with the following economic theories/doctrines:

Growth: Neoclassical growth theory is generally considered to begin with the work of Harrod, Domar and Solow[13] (E. K. Hunt & Lautzenheiser, 2011; McDonald, 2006). These theorists modelled economic growth as a stable process determined by exogenous factors such as consumer preferences and technology. In the late 1980s and early 1990s technological innovation was deemed to be endogenous and an economic activity that generated growth in itself.[14] The argument was that when investments are made in new capital or research and development innovative knowledge is generated that spills over to the rest of the economy. Such benefits are maximised in neo-liberal economies where institutions encourage investment and do not interfere in the market place.

Neoclassical growth models have been critiqued at multiple levels. First, they are subject to the theoretical problems associated with aggregating different forms of capital. Second, the conclusions that can be drawn from the models are limited, given the narrow set of assumptions. Third, they focus on achieving a balanced growth path that may be misguided (Piketty & Zucman, 2014). Fourth, much of the research effort conducted to date on growth theory has proceeded without consideration of possible

---

[13] Their work is often linked together as the Harrod-Domar-Solow model. The $\beta = s/g$ formula (β=the long-run capital-output ratio; s=net savings rate; g= income growth rate) was developed by Harrod (1939) and Domar (1947). According to Piketty & Zucman (2014) the neoclassical growth model developed by Solow in the 1950s had a long-run capital-output ratio (β) equal to the ratio between the saving rate and the growth rate of the economy. The flexible production function $Y=f(K,L)$ involving capital-labour substitution, makes balanced growth possible (Solow, 1956). The formula derived by Harrod (1939) and Domar (1947) used fixed coefficient production functions. With these models, stable growth only occurs when the 'actual rate of growth' is the 'warranted rate of growth' and inventories are not above or below the desired level.

[14] Different types include: 1) Research and development and human capital formation; 2) Spillovers, which occur when knowledge developed in one area/industry is transferred and allows technical improvement elsewhere; 3) Creative destruction as a result of the diffusion of innovation from as niche market to widespread use; 4) Technology learning as a result of refining a process through on-going use (McDonald, 2006).

biophysical or thermodynamic constraints. According to McDonald (2006), once these concerns are adjusted for, growth models exhibit diminishing returns to labour and capital, though technological progress can potentially offset these effects. A race therefore exists between the increasing returns of technological advancement and the diminishing returns of resource scarcity/environmental degradation (McDonald, 2006).

An additional criticism of the neoclassical approach to growth is the inherent inconsistency between micro- and macro-scales. At the microeconomic level there is an optimal growth point for a firm (assuming perfect competition) at which it will stop production. This is when the marginal revenue generated by an additional unit of production is less than the marginal cost of producing that unit. However, at the macro-level there are no limits, or recognition that economy is unable to grow indefinitely (Georgescu-Roegen, 1971; Daly, 1996).

Market: Neoclassical economists have generalised the use of marginal principles (marginal utility, marginal cost, and marginal revenue) to a universal principle of rational economic behaviour based on producers and consumers (referred to as households and firms) and the circular economy. Market supply and demand are aggregated across firms and households into general equilibrium models[15] where all prices are variable and all markets clear. Market interactions are optimised to determine an output and price where no individual would desire to change his or her actions (i.e. Paereto efficient allocation). The market allows economic development that both improves opportunities and capitalises on the increased skills of individuals (D. Coyle, 2014).

Value: Use value is determined by the perceived marginal utility or enjoyment a consumer derives from a good. Exchange value is determined by the opportunity costs of diverting inputs into one good as opposed to another. Rent from land/location is no longer considered a factor of production. The neoclassical production function is: Y=*f*(L, K).

[15]The market in neoclassical economics is represented as a giant system of simultaneous equations. Leon Walras is credited with developing the idea of general equilibrium of supply and demand captured in a system of equations price and quantities determined endogenously within the system.

Distribution: The distribution of goods and services by the market is determined by ability and willingness to pay. The interest rate paid to capital owners reflects relative risk. Wages paid are determined by the supply and demand of labour. Skills in short supply will derive a premium over those easily replaced.

Accounting system: The accounting system used is the System of National Accounts. The GDP indicator tracks, in monetary terms, the goods and services produced by the domestic economy in a given time period. Mainstream neoclassical economics sees GDP growth as progress.

2.1.5.3 Other schools of economic thought

There are a number of heterodox schools at variance with core neoclassical economics. Six of these are now briefly defined.[16] These definitions are followed by a more detailed discussion of Ecological Economics, as this dissertation is grounded in the Ecological Economics conceptual paradigm.

Evolutionary economics emphasises innovation and the diffusion of knowledge and technologies in the economic system. The economy is in a continual state of dynamic non-equilibrium as it adjusts to new forces coming into play, at the same time as existing technologies and means of production are replaced. Social constructs and governance systems also bring about changes in the economic system, so evolutionary economics integrates human behaviour, fairness, and justice.

Institutional economics is concerned with power relationships, and the control and organization of the economic system. Different institutions coordinate the economic and social activity of the market, especially the government and the legal system. The market mechanism is just one part of the organisational structure. With institutional economics (as with evolutionary economics) the dynamics of structural change are important and the neoclassical concepts of static equilibrium and associated optimality are rejected.

[16] Further discussion is beyond the scope of this dissertation. It is noted there are many cross-overs and similarities between each of these areas as well as with standard neoclassical economics.

Coevolutionary economics focuses on the adaptive relationship between the economy and the environment. It is defined by H. Daly & Farley (2004, p. 430) as: "The study of the mutual adaptations of economy and environment. Economic activity induces change in the environment, and changes in the environment in turn induce further changes in the economy in a continuing process of coevolution."

Development economics describes how the booms and busts in the economic cycle follow a pattern of "creative destruction" (Schumpeter, 1961). Growth occurs in spurts because innovation is haphazard. When innovation occurs it provides a stimulus for investment and innovation but that cannot be sustained indefinitely (Schumpeter, 1961). During economic downturns, obsolete firms and industries are forced to close. Innovative and efficient firms and industries survive, and foster the long-term increase of productivity and living standards.

Complexity economics operationalises computer simulations to better understand the functioning of the economic system and its dynamic nature. Simulation captures the fact that microeconomic events do not occur in isolation. Instead, there are macroeconomic impacts that continuously disrupt equilibrium and generate feedback effects at the microeconomic level.

Behavioural economics "in general, challenges orthodox economics theory and its foundational assumptions regarding human behaviour, its institutional underpinnings …its poor prediction power and its intrinsic non-falsifiability." (Kao & Velupillai, 2015, p. 239). Influential behavioural economists include Kahneman and Tversky, who opt for 'prospect theory' instead of 'expected utility theory', and incorporate concepts such as subjective probability and loss aversion into human decision-making.

2.1.5.4 Ecological economics

Ecological economics, a transdisciplinary field of inquiry, draws on many different disciplines and schools, including classical, neoclassical, and heterodox economics, as well as the biophysical sciences and social sciences. Defining characteristics of ecological economics are concern, primarily, with the scale of the economy in relation to natural systems, fair distribution of resources, and the efficient allocation and use of both market and non-market resources.

Growth: From an ecological economics perspective, physical economic growth is limited by environmental constraints. The economy is an open[17] subsystem functioning within a system that is materially closed, finite, and non-growing, although open to solar energy. The scale of the economy and human lifestyles impact the finite Earth system and its ability to sustain itself over time. The ecological economics paradigm is strongly influenced by the first and second laws of thermodynamics. The first law dictates that neither matter nor energy can be created or destroyed. The second law describes how the quality (measured in entropy) of matter and energy changes with use and moves from ordered (useful forms) to dispersed (not useful forms). A prime concern of ecological economics is that as we move from an 'empty world' where natural capital is plentiful, to a 'full world' where the size of the economy and the population are large, we are impinging on the ability of the Earth to sustain itself and continue to produce the free goods and services humans depend on for existence.

Whereas neoclassical economics are optimists and have confidence in the ability of new technology to compensate for the diminishing returns brought on from depleting any fixed or finite resources, ecological economists advocate for prosperity without material growth (Costanza, Alperovitz, et al., 2012; Costanza, Hart, et al., 2012; H. Daly, 2003; Jackson, 2009; Victor, 2008; Videira, Schneider, Sekulova, & Kallis, 2014). Growth when it occurs needs to be non-material and in areas that do not impact the life-support functions of the planet. Such areas include better social institutions and infrastructure, improved mental and physical health, and higher levels of education.

Because of its ecological foundation, ecological economics growth concepts are also derived from natural systems. One such concept is that growth is a stage in the adaptive cycle as described by Holling & Gunderson (2002) and shown in Figure 2–1. The degree of interconnectedness in the cycle is shown on the X axis. The rate of accumulation in the cycle is shown on the Y axis. In the growth phase, the system expands, becomes more connected, and increases in complexity. This makes the system less open to change and decreases resilience. A shock event can collapses the system, which then undergoes a process of reorganization before the slow process of

[17] Open systems take in and give out both matter and energy. With closed systems matter circulates within the system and only energy moves in and out.

regrowth. This cyclical pattern is observed in many systems (Bossel, 1998; Vester, 2007). It is even possible to interpret the rise and fall of civilisations as following a similar pattern (Diamond, 2005).

The following stages set out in Figure 2–1 can be applied to both ecological and economic systems (Holling & Gunderson, 2002):

'r' indicates the instantaneous rate of growth. This stage is characterised by extensive dispersal ability that enables rapid growth in an ecosystem. In an economy this is the entrepreneurial and exploitation phase.

K is the maximum expansion that is attainable. This stage is conservation focused. Resources use is specialised and there is a high level of interconnectedness. In an economy this would be the bureaucratic stage.

'Ω' is the release phase where the tightly over-connected and rigid ecological/economic system is subject to a shock event. This brings about sudden release.

'α' is the reorganisation phase where pioneer species can capture opportunities. This allows innovation and restructuring in an economy. In a society this would be when policies and processes are changed.

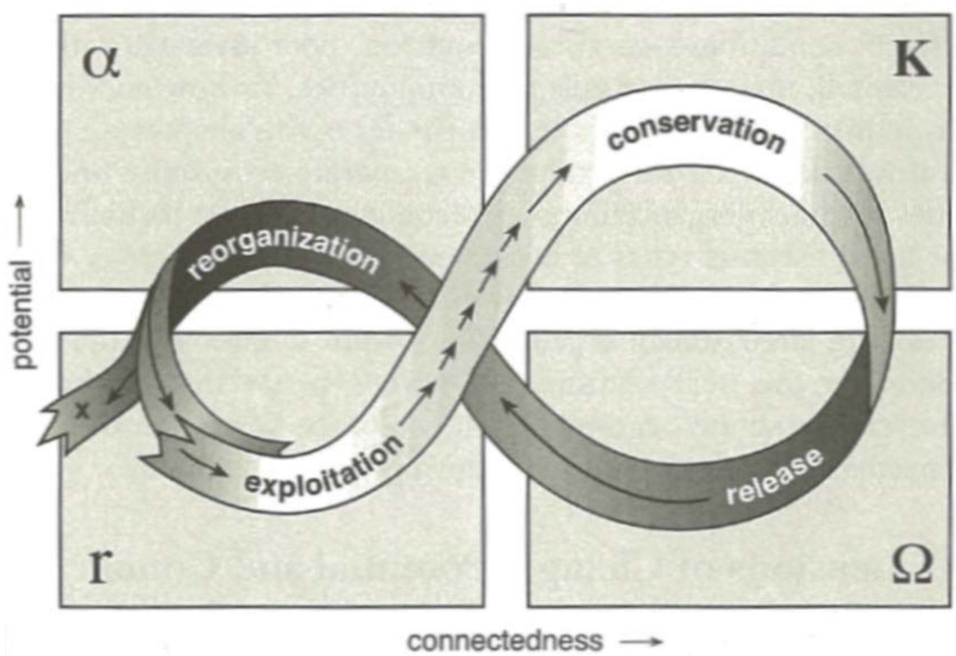


Figure 2-1: The adaptive cycle (Source: Holling & Gunderson, 2002, p. 34).

By understanding the adaptive cycle it "seems possible to identify points at which a system is capable of accepting positive change, and possible to use those leverage points to foster resilience and sustainability within a system" (Holling, 2000).

Market: Ecological economics does not consider the market to be the only means of achieving efficient allocation of resources among alternative uses. While the market place might[18] be capable of effectively allocating resources that have a price, it does not deal adequately with non-market goods. These include ecosystem goods and services. With ecological economics the market can only achieve a good outcome if what is being allocated efficiently represents a worthwhile goal for society (Bromley, 1990).

Value: The normative value system of ecological economics reflects sustainability and therefore the maintenance and integrity of social, built, human and natural capital. All species – not just humans – have intrinsic value, and the rights of future generations to enjoy a lifestyle that meets their requirements for well-being is recognised.

Distribution: Ecological economics advocates for interpersonal comparisons of utility so that distribution has efficiency and fairness associated with it. Rather than basing distribution decisions on Pareto criteria, the goal is to maximise overall social utility (H. Daly & Farley, 2004). This can be achieved through redistribution, as the marginal utility a poor person obtains from an additional unit of a good or service will be greater than that of a wealthy person whose desires are saturated.

Accounting system: Ecological economics promotes non-material ways to increase prosperity and alternative well-being measures to the GDP growth paradigm (Bina, 2013; Costanza et al., 2015; H. Daly & Cobb, 1994). For example, the use of Genuine Progress Indicators which more comprehensively take into account the real cost of producing GDP.

2.1.6 Summary of progress ideals

In summary, it can be said progress is different things to different people, and how it is judged changes with time, social norms, and technology. The widely accepted modern

[18] This is debatable, given the assumptions associated with the free market system.

day interpretation of progress is the degree of advancement in technology and material standards of living. The yardstick used to gauge this is growth in GDP.

In a democracy what is meant by progress should ideally be decided by societal consensus and shared values. The resultant vision then determines the hierarchy of policy priorities (Shmelev, 2011) and how resources are best allocated to achieve progress. Despite its significance, the progress debate rarely occurs in political forums and the vacuum is filled by the goal of growth in GDP. The goal of government and hence their policies therefore becomes to create a better life for all citizens by increasing GDP.

The next section provides an overview of some of the many ways well-being can be construed and how improved well-being can be considered a measure of progress.

2.2 THE CONCEPT OF WELL-BEING

Well-being is an ambiguous term with many usages, meanings, and conceptions (Gasper, 2007). Selecting the best ways to assess well-being is a challenge, as what determines 'well-being' varies from one individual to the next, from community to community, between cultures, by location, and across countries. In addition, well-being is so extensive in scope that it can be argued that everything we do, and is done to us, impacts on our well-being. As human well-being is multi-dimensional (Alkire, 2002; McGillivray, 2007; Sen, 1999, 2008) it is not able to be captured by any one measure (such as GDP).

While some researchers use the word 'well-being' as a distinct term, others (such as Easterlin, 2001, 2003; Easterlin & Angelescu, 2009) use well-being interchangeably with alternative terminology. The different descriptors used include: quality of life, happiness, living standards, human development, welfare,[19] social welfare, well-living,

[19] The word welfare has a long history of use in economic theory. For Smith (1776), economics was about how to increase human welfare, and based on this, determine policy to best promote human happiness. Smith calculated economic welfare as the annual output from labour divided by the number of people able to consume it (E. K. Hunt & Lautzenheiser, 2011).

utility and life satisfaction. The following provide examples of the many different ways that well-being is described:

- Walsh (2005) defines well-being as "living and faring well" or "flourishing". Well-being consists of both economic and non-economic factors and can be considered to be a necessary condition for human happiness and what a good life achieves.
- The UNDP definition is "expanding people's real freedoms–so that people can flourish" (UNDP, 2010, p. 22).
- Well-being is defined by McGillivray (2007) as a description of the state of an individual's life situation. An individual's well-being is considered to be aligned with satisfaction with life, pleasure, enjoyment, health, leisure, personal development opportunities to fulfil one's potential, and having a purpose so that life has personal meaning.
- Neumeyer (2004, 2007) uses the term well-being interchangeably with welfare and utility, and defines it as the satisfaction of human preferences. The more human preferences are satisfied (health, education, freedom, autonomy, recreation, experience of nature, plus others) the greater is well-being.
- The Millennium Ecosystem Assessment (Millennium Ecosystem Assessment, 2005) sees human well-being as made up of multiple constituents, including health and a healthy physical environment, good social relations, freedom of choice and action, security and the basic material needs for a good life.

'Welfare', as in 'welfare economics', refers to analysis of incomes, wealth and utilities. Welfare economics reduces human behaviour to maximising utility. People maximise their utility through market transactions and the buying and selling of goods. The extent to which utility and interpersonal comparison can actually be measured is an on-going debate (Spiegel, 1991). Maximising economic human welfare remains the objective of neoclassical economics with a change in welfare defined as the change resulting from different production/consumption bundles. Microeconomics is referred to as 'welfare economics' because it focuses on maximising utility at the margins. Pareto efficiency is considered the "first theorem of welfare economics" as it defines in economic terms the meaning of maximum utility. An ecological economics definition of 'welfare' is: "A psychic state of want satisfaction or enjoyment of life – an experience not a thing – the basic reason to be of economic activity" (H. Daly & Farley, 2004, p. 441). This definition encompasses more than utility change resulting from consumption.

- Prescott-Allen (2001, p. 5) defines human well-being as “a condition in which all members of society are able to determine and meet their needs and have a large range of choices”.
- Coleman (1998, p. 33) recognises the interdependencies of well-being, which he describes as a “highly uncertain and complex system where economic-social-environmental indicators interact in ways that are indirect, non-linear, cumulative and synergistic”.

2.2.1 Individual versus societal well-being

Human well-being is made up of both individual and societal factors. Individual well-being, while connected to societal well-being, differs from it. Individual well-being is concerned with how a person’s basic needs are met, and how satisfied they are with the opportunities presented to achieve their person-specific (e.g. health, education) needs. Social well-being relates to attributes shared with others such as belonging to a community, having an affirmative attitude towards others, and contributing to society and its positive development (McGillivray, 2007). It also encompasses factors such as whether a society is peaceful, resilient, open to diversity, and so on.

Individual and societal well-being is interconnected. As Giddens (1984, 1991) explains, the structure of society and the individual are a duality that cannot be considered apart – individuals structure society and society structures individuals.

Beaumont (2011) places well-being in a nested structure, as in Figure 2-2, to show this interdependency. An individual’s well-being is determined by their own assessment of how they feel. How they feel will be determined by attributes that directly affect their well-being such as health, relationships, finance, education, work, and dwelling location. An individual has some degree of immediate control over such things but their provision is also a function of the wider societal institutional structure.

Contextual factors such as governance, the economy, and the natural environment are higher scale influences on well-being that are beyond any one individual. Human well-being is supported by the economy, the governance structure, and the natural environment. Typically, these factors provide the enabling conditions to achieve human well-being (Hall, Giovannini, Morrone, & Ranuzzi, 2010). In Figure 2-2 equity/fairness (which is a distribution issue), and sustainability over time (which is an intergenerational issue) impact across all levels.

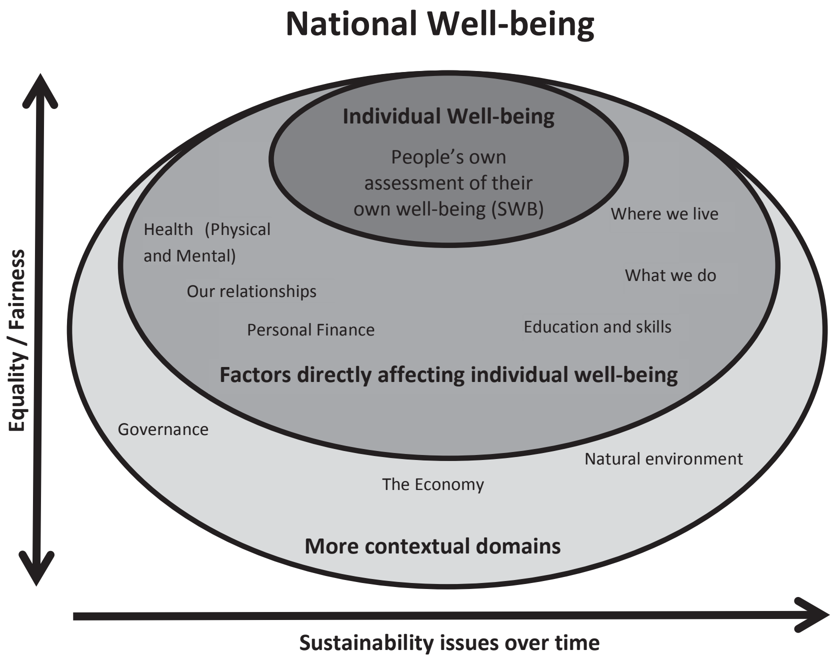


Figure 2-2: National well-being framework (Source: Beaumont, 2011). SWB=Subjective well-being.

Government policy creates opportunities for humans to meet their needs. Individuals place weighting/preferences on different things, raising important considerations for analysis and policy when looking beyond individual well-being to societal well-being (Costanza et al., 2007). In addition, the weights given to various factors evolve as social norms change, therefore government responses need to also change.

The research focus of this dissertation is not the personal choices individuals make that influence their well-being but rather the policy decisions that impact on both individual and societal opportunities to achieve well-being.

2.3 CONCEPTUALISING WELL-BEING AS A SYSTEM

This research situates well-being in an interlinked system made up of interdependencies. Well-being is not considered to be the sum of multiple factors aggregated together, or the dependent variable in a regression analysis. Instead, through relationships, well-being is part of a system that is impacted on by the components in the system; and in turn, impacts the rest of the system.

Well-being as a system of interlinked components requires a framework to set out the assumptions and values on which it is based. There are many different frameworks that have been developed to portray the conceptual base for achieving well-being. Despite, or because of this, assessing conceptual appropriateness still remains a key area for research (Harkness, 2007). Widely used frameworks include the Millennium Ecosystem Assessment (2005), the "Full World" Model of the Ecological Economic System (Costanza, Cumberland, Daly, Goodland, & Norgaard, 1997), and the OECD Framework of the Progress of Societies (Hall et al., 2010).

A sound framework provides a logical structure for evaluating the system and ensuring essential components and the relationships between those components are included (Millennium Ecosystem Assessment, 2005). Making the conceptual base of the framework explicit is important because it is influential in determining the robustness of outputs (McGillivray, 2007).

2.3.1 Well-being as a system

The conceptual framework of well-being used in this dissertation is set out in Figure 2-3. The framework from the Alliance for Sustainability and Prosperity (www.asap4all.org) brings together the key components of the sustainable well-being system.

Figure 2-3: Well-being framework (Source: www.asap4all.org).

The items in black are partially picked up by GDP. Arrows indicate inter-relationships and how factors are interconnected in both directions.

The overall goal of the system is sustainable well-being for both humans and other species, taking into account equity of distribution. To achieve well-being, basic human needs must be met. This has to be done in a way that satisfies people and meets their subjective well-being criteria.

Sustainable development reflects the different strategies that can be used to fulfil basic human needs and subjective well-being criteria. These strategies determine how the combined asset portfolio of a country or a region is managed. This includes the need to acknowledge that decisions made in the present have consequences for the well-being of both the current population and future generations.

The quality and quantity of the Capital Assets in Figure 2-3 are the foundation for sustainable well-being. These are the capital stocks on which nations rely to bring into fruition specific policy targets. The ethical base for sustainable well-being is the need to maintain the capital assets (stocks) that the well-being of all humans and the rest of nature depend on. As all sources of capital (built, natural, human or social) are subject to depreciation, their use needs to be allocated with care. Depletion needs to be compensated by new investment to ensure a flow of services into the future. The scale (relative to nature) at which the economy operates is critical. This is shown in Figure 2-3 by the system being enclosed by planetary boundaries, thus indicating limits are imposed in terms of ecological scale.

Sustainable well-being aims for developmental growth. The focus therefore is on the items in white in Figure 2-3. At present with GDP used as a proxy measure for well-being, what is captured is limited to transactions in the marketplace heavily biasing towards the items in black.

The aspects of (1) Subjective well-being; (2) Basic Human Needs; (3) Sustainable Development; and (4) Capital Assets shown in the Figure 2-3 framework are discussed in more depth in the following sub-sections. Then Section 2.4 sets out how the "Overall Goal: Sustainable, Prosperous and Equitable Well-being for humans and the rest of nature" is conceptualised in this dissertation.

2.3.2 Subjective well-being

Subjective well-being can be described as the way people make multi-dimensional evaluations of their lives, including mental assessments of life satisfaction and affective evaluations of moods and emotions (Argyle, 1987; Diener, 1984; Eid & Diener, 2003; McGillivray, 2007). Subjective measures capture an important well-being dimension that is missed if only objective[20] measures are used. 'Subjective' describes evaluations made by the individuals being assessed (Angner, 2010; Costanza et al., 2007). They provide vital information about how people perceive their well-being, which may not correspond with how it is assessed using more objective measures. Data for subjective measures are collected mainly via surveys and questionnaires. Assessments can be

[20] Objective measures still have a subjective element and biases are not erased by the use of statistical data (Myrdal, 1969). All human knowing is constrained by our perceptions and our beliefs (Pangaro, 1991) so there is always some degree of valuation involved (Bossel, 1998). Research design, in particular hypothesis setting, can only falsify and never prove a hypothesis is correct.

qualitative or quantitative, and, as they are often location-based, can provide important insights for policy at the local level.

The validity of subjective measures is debated. There is a risk that people are socialised into discounting personal well-being (Harkness, 2007), and judgement reflects relative rather than absolute conditions (Schwarz & Strack, 1999). For example, in a community where people live in poverty, an individual who has a slightly higher standard of living may be considered wealthy. Kahneman (2011) makes the distinction between experienced and remembered well-being and shows that how things are remembered differs from how they are experienced. Such framing effects can be influential in outcomes (Gasper, 2007). Despite this debate, the value of subjective measures is increasingly recognised and assessment methodologies are improving. Two subjective measures that are commonly used to assess well-being are happiness and life satisfaction.

2.3.2.1 Happiness

Happiness is just one of the emotional responses humans are capable of and is associated with feeling good or short-term pleasure; also referred to as hedonic well-being (Engelbrecht, 2009).

Surveys on happiness, regularly undertaken at the global scale by the Gallup World Poll, conclude happiness relates to how psychological and social needs are met. Day-to-day happiness is associated with things like being free from pain, rested, respected, and intellectually engaged.

The weightings put on the multiple factors that influence happiness differ with respect to different people, cultures, and circumstances. Both individual choices and public policy can make a long-term difference to happiness (Headey, Muffels, & Wagner, 2010). Happiness levels can be determined by factors such as genetics, family, activities, friends, and work satisfaction. Social structures and communities are also important (Gasper, 2007). Some studies (Frey & Stutzer, 2002a, 2002b) list demographic and personality factors (such as health, age, family, education), gender, political factors (such as freedom, participation, and democratisation), and also include economic factors (such as income and employment/unemployment).

There has been extensive research into the link between material wealth and happiness. The general theory is that income is important if you are poor but after a certain level further increases in income do not contribute to happiness (Easterlin, 2003; Hatfield-Dodds, 2005; Kahneman, Krueger, Schkade, Schwarz, & Stone, 2004; Schepelmann et al., 2010; UNDP, 2010). Longitudinal studies of the relationship between improvement in happiness and growth in GDP per capita across 37 countries reveal no significant long-term relationship (Easterlin & Angelescu, 2009). Though rich people are happier than poor people, the levels of overall happiness are not greater in rich countries (those with high GDP) than poor countries (those with lower levels of GDP). This association is known as the 'Easterlin paradox' (1974).

In affluent societies there is evidence that non-market sources such as family, health, and recreation make a greater contribution to happiness than market sources (Jackson, 2009; McGillivray, 2007). Helliwell (2003) shows that GDP and subjective well-being decouple at a relatively low GDP per capita level, and factors such as effective social and political institutions, high mutual trust, and low rates of corruption become more important.

Over the lifetime of an individual, income and age are positively associated up to retirement. Happiness does not advance in the same way. The reason is the level of satisfaction with material possessions is relative (Easterlin, 1974, 2001). Thus, as incomes rise people relate their happiness more to the material level of others in society than to their own personal level of material comfort.

2.3.2.2 Life satisfaction

Life satisfaction is widely understood to be a longer-term measure of how content people are with their life overall. Diener (1994) defines life satisfaction as the more global evaluation by people of their own life. It is more reflective in nature and responses are likely to vary depending on life stage. For Frisch et al., (2005) life satisfaction is a cognitive construct independent of any mood state, more a function of expectations and attitudes. Life satisfaction can be interpreted as more than just an emotional reaction; it can be taken as contentment from leading a meaningful or fulfilling life or living well (eudoamonic well-being), and as relating to intrinsic goals and cognitive judgement. Income is more closely related to life satisfaction. People with higher incomes tend to have higher levels of life satisfaction (Kahneman, 2011). According to Inglehart et al., (2008), at a societal level, life satisfaction is more sensitive to economic conditions than is happiness. At a national level, life satisfaction is considered to be a more effective measure of subjective well-being than affective measures such as happiness (Diener, Diener, & Diener, 1995; Vemuri & Costanza, 2006).

2.3.3 Basic human needs

Well-being is impacted by how human needs are satisfied. Fulfillment can be interpreted as meeting the subsistence needs all humans have for survival, or, the ability to meet needs at a much higher level.

Abraham Maslow (1943) made a seminal contribution to well-being theory by ranking needs in a hierarchy that humans have to work through in ascending order. Physiological needs such as food, water, and sex have to be met first, and only then can humans climb the ladder to achieve in ascending order: security; love and belonging; self-esteem; self-actualisation, knowledge, aesthetics, and beauty. Maslow (1968) later added intrinsic values, which involve helping others to reach their potential. An extensive array of literature exists covering how to define basic human needs and how they are best met. The following brief discussion covers: (1) Sen's basic capabilities approach; (2) The basic needs approach of Max-Neef et al.; and (3) Alkire's basic human values approach. These are well-recognised contemporary multi-dimensional conceptualisations of what well-being comprises. Following this, the Costanza et al.,(2007) Quality of Life approach is introduced to show how needs can be linked to the capital assets that can satisfy them.

2.3.3.1 Sen's capability approach

Sen (2008) sees well-being as consisting of informed, rational preferences applied to functions and capabilities. Functionings are the things a person can do, or be, when leading their life, and make up a person's being. Individuals apply different weights to functions depending on their preferred lifestyle. Capabilities are derived from functionings and represent the mix of opportunities a person has available to achieve his or her desired well-being. Capabilities depend on both individual characteristics and societal organisation. According to Sen (2008):

> The functionings relevant for well-being vary from such elementary ones as escaping morbidity and mortality, being adequately nourished, having mobility, etc., to complex ones such as being happy, achieving self-respect, taking part in the life of the community, appearing in public without shame… (p. 276).

Freedom allows people to expand their capabilities and lead the life they to which they aspire. Sen identifies five different freedoms: political freedoms; economic facilities; social opportunities; transparency guarantees; and protective security (Sen, 1999).

Sen (1999, 2008) focuses on individual capabilities, responsibilities, and opportunities. Increasing human capabilities is good because it improves choice, well-being, freedom, the ability to influence social change, and economic production. Sen sees well-being as consisting of both the ability to pursue goals or to not have goals at all. Individuals have different values and preferences, so the important measure is the freedom (or capabilities) available to achieve desired functionings.

The capability approach does not identify any specific functionings (or subset of functionings) as being of critical importance. Neither does it provide a list of the capabilities or a hierarchy for increased well-being. Sen (1999) argues that the capabilities to be nurtured are a value judgement and as such they need to be determined via a transparent process. A multi-dimensional approach to development such as Sen's, requires many value choices be made explicitly by: democratic institutions; participatory processes; and public debate.

2.3.3.2 Max-Neef et al.'s basic needs theory

The needs theory is a multi-dimensional taxonomy that distinguishes between 'needs' and 'satisfiers' (Max-Neef, Elizalde, & Hopenhayn, 1991). Nine human needs are considered the same for all cultures and time periods: subsistence, protection, affection, understanding, participation, idleness, creation, identity, and freedom. In setting this list Max-Neef et al., (1991) acknowledge that there are other ways by which needs can be classified, and any list is subject to modification.

While needs remain fixed, how they are met by satisfiers varies according to time, place and circumstances. Each economic, social and political system determines the choice of satisfiers, and the quality and quantity provided. Therefore, culture is the key determinant of how human needs are met, which in turn determines both human deprivation and human potential. For example, lack of subsistence can be equated to deprivation, whereas opportunity to participate enriches human potential. It is possible for one satisfier to contribute to meeting many different needs; and needs are able to be met by multiple satisfiers.

For psychological and physical health all needs must be met. A failure to do this leads to human poverty of some form. Economic goods can only meet some of the needs of individuals; other needs, such as affection and participation, require social interaction and therefore communal activities.

Max-Neef et al., (1991) make the point that human needs are interrelated and interactive, and can therefore be understood as a system. With the exception of subsistence, which covers the need to stay alive, there is no hierarchy in the system. Satisfying needs is a continuous process of synergies and trade-offs.

2.3.3.3 Alkire's basic human values approach

For Alkire (2002), meeting human needs is best expressed as the extent to which the 'dimensions of human development' are fulfilled. She defines human development as "[H]uman flourishing in its fullest sense – in matters public and private, economic and social and political and spiritual" (Alkire, 2002, p. 182). Human development is more than the achievement of well-being for a person at a particular time; it also considers what a person can do about the causes they follow, and about non-individualist aspects of social living. 'Dimensions' are described as components that coexist with other components. Alkire does not present these as being part of an integrated system.

The dimensions of human development are not the pre-requisites for 'what a good life is' but rather general and universal principles that are intrinsically valuable to all people. Satisfying these values is a way to conceptualise the achievement of well-being. For Alkire the dimensions provide the basic 'reasons for action' (human ends rather than means) that people from any culture and speaking any language would provide in answer to the question "why do I do what I do?" and where no additional reason would be required. The list Alkire selects as best fitted to meet the requirement of 'the dimensions of human development' is that described by Finnis (Grisez, Boyle, & Finnis, 1987) and set-out in Table 2-1.

Table 2-1: Reasons out of which people act in seeking 'wholeness' or 'well-being' in pursuing human development

Life itself – its maintenance and transmission – health, and safety
Knowledge and aesthetic experience. "Human persons can know reality and appreciate beauty and whatever intensely engages their capacities to know and to feel."
Some degree of excellence in *Work and Play.* "Human persons can transform the natural world by using realities, beginning with their own bodily selves, to express meaning and serve purposes. Such meaning-giving and value-creation can be realized and in diverse degrees."
Friendship. "Various forms of harmony between and among individuals and groups of persons—living at peace with others, neighbourliness, friendship."
Self-integration. "Within individuals and their personal lives, similar goods can be realized. For feelings can conflict among themselves and be at odds with one's judgements and choices. The harmony opposed to such inner disturbance is inner peace."
Self-expression or Practical Reasonableness. "One's choices can conflict with one's judgments and one's behaviour can fail to express one's inner self. The corresponding good is harmony among one's judgments, choices and performances – peace of conscience and consistency between one's self and its expression."
Religion. "Most persons experience tension with the wider reaches of reality. Attempts to gain or improve harmony with some more-than-human source of meaning and value take more forms, depending on people's world views. Thus, another category...is *Peace with God, or the gods, or some nontheistic but more-than-human source of meaning and value."*

Source: Grisez et al., (1987)

Additional conditions dimensions are required to meet include being defined clearly enough to not be ambiguous but broad enough to meet diverse needs. Dimensions should not cover the same quality multiple times; therefore they need to be *incommensurable*. They must be *irreducible*, in that the dimension list cannot be reduced any further, and last, they must be *nonhierarchical* to allow the order of importance to change with time (Alkire, 2002)[21]. The work of other researchers (e.g. Max-Neef, Cummins, Nussbaum, Doyle and Gough, and many others) is used by Alkire to provide an extensive overview of the various attributes that contribute to human well-being. These are presented as described by the original authors, and Alkire makes no attempt to integrate them into one list or see any reason to require general

[21] Italics as used by Alkire (2002).

agreement (the list is provided in Appendix 1). Instead, Alkire (2002, p. 193) recommends to anyone wanting to establish their own list to evaluate well-being that they select dimensions according to the following criteria:

- *“The dimensions must be valuable*: they must be readily recognizable as the kinds of reasons for which oneself or others act. Put differently, they must be human ‘‘ends’’ rather than means only; intrinsically valued rather than only instrumentally convenient (*only* is important, for many will be both).
- *The dimensions must ‘‘combine scope with specificity’’*: each dimension should be clear—which requires specificity—yet vague—so that persons of different cultures and value systems find them to be familiar. The dimensions should not overlap.
- *The dimensions must be ‘‘critical’’ and complete*: taken together, they should encompass any human value. These include dimensions which are presently valued by some groups but not others.
- *The dimensions do not pertain to one view of the good life*: dimensions of human flourishing represent the basic values people are seeking when they ‘‘be and do and have and interact’’ – morally or immorally. They are neither virtues nor personal qualities (gentleness, self-respect).”

Alkire (2002) argues for some agreement on a multi-dimensional framework to use for human development, as without this, there is a risk that the vacuum will lead to misunderstanding and operational errors by those working in the area. When working at the local or project-planning level, a core set of well-being measures provides a structure for discussion, rather than substitutes for discussion. To improve human development the concept of ‘dimensions of human development’ can be used as a filtering tool to sift through the multitude of variables that contribute to well-being and to ensure important factors are not overlooked. At the same time, users need to be conscious of the limitations of the framework. “The process of specification should be collaborative, visible, defensible and revisable” (Alkire, 2002, p. 194), and acknowledge there are likely to be other factors that need to be taken into account to achieve human development.

2.3.3.4 Costanza et al's., interaction of human needs

Costanza et al., (2007) refer to Quality of Life (QoL) rather than well-being, with no distinction made between the two terms.[22] QoL is defined as "the extent to which objective human needs are fulfilled in relation to personal or group perceptions of subjective well-being" (Costanza et al., 2007, p. 269). The authors acknowledge, as numerous others do, that when the goal is something as elusive as QoL it is difficult to identify and measure progress. Complications include temporal and spatial scale issues. As a generalization, it can be said QoL measures the extent to which important needs, goals, and desires are satisfied.

Costanza et al., (2007) conceptualise QoL as the multi-scale, multi-dimensional combination of objective measures of human needs (sourced via statistics, measurement or financial information) with subjective well-being measures (self-assessed feelings obtained by aggregating survey responses).[23]

For Costanza et al., (2007) the opportunities people have to satisfy human needs and subjective well-being are directly linked to the different forms of built, human, social and natural capital. The element of 'time' is an additional factor required for well-being needs to be met.

---

[22] The meaning of the term 'Quality of Life' (QoL) varies with context, and the wide-spread, diverse use of the term is ambiguous. Some authors, e.g. Noll (2002), see QoL as an individual based assessment with well-being more at the societal level. The development of surveying tools and empirical studies has seen QoL move from being a concept that was regarded as individual and subjective (Haas, 1999; Kagen, 1994) to a more objective measure used to make comparisons across wider societal groups (Gravitas Research and Strategy Limited, 2005).

[23] There are also other ways to determine QoL. When distinguishing the factors that most influence QoL, Veenhoven (2010) makes the distinction between outer qualities (determined by the environment in which a person lives) and inner qualities (the personal attributes of a person). He also includes opportunity for a good life (life chances) and life results (outcomes). QoL is influenced by many of the same factors as well-being, such as personal disposition, health, employment, living conditions, and age, etc. Researchers predict change in QoL by combining subjective and objective measures as with well-being. For example, Veenhoven (2010) cites average longevity (objective) and average happiness (subjective) as measures that together show quality of life is improving in most modern societies. He attributes this to (1) reduced hunger and death rates, and (2) increased freedom in modern society that gives people more choice.

Table 2–2 lists the type of human needs people aspire to and the associated capitals that are drawn on to accommodate those needs. The list of human needs in Table 2–2 collated by Costanza et al., (2007) is derived mainly from the work of Max-Neef et al., (1991), and Nussbaum and Glover (1995).

For Costanza et al., (2007), well-being needs are fluid and dynamic across time and context with overlaps and interactions occurring between need categories. Policy and culture govern how the four types of capital are allocated to provide opportunities for humans to meet their needs. This shapes social norms, which determine the weights given to various needs and the direction of investment to improve opportunities at any given time.

Table 2-2: List of human needs (* the most important input)

Human Need	Descriptors (direct satisfiers)	Types of inputs needed
Subsidence	Food, shelter, vital ecological services (clean air and water, etc.) healthcare, rest	Built capital* Natural capital* Human capital Time Social capital
Reproduction	Nurturing of children, pregnant women Transmission of the culture Homemaking	Human capital* Time* Social capital Natural capital
Security	Enforced predictable rules of conduct Safety from violence at home and in public Security of subsistence into the future Maintain safe distance from crossing critical ecological thresholds Stewardship of nature to ensure subsistence into the future Care for the sick and elderly	Social capital* Built capital Time Natural capital ***Human capital***
Affection	"Being able to have attachments to things and persons outside ourselves; to love those who love and care for us, to grieve at their absence."(Nussbaum) Solidarity, respect, tolerance, generosity, passion, receptiveness	Time* Social capital
Understanding	Access to information Intuition and rationality	Human capital* Natural capital Built capital Time Social capital
Participation	To act meaningfully in the world Contribute to and have some control over political, community, and social life Being heard Meaningful employment Citizenship	Social capital Human capital Natural capital Time
Leisure	Recreation, relaxation, tranquillity, access to nature, travel	Time* Natural capital Built capital Social capital Human capital
Spirituality	Engaging in transcendent experiences Access to nature Participation in a community of faith	Human capital Social capital Natural capital Time
Creativity/ emotional expression	Play, imagination, inventiveness, artistic expression	Human capital* Time* Natural capital
Identity	Status, recognition, sense of belonging, differentiation, sense of place	Social capital* Natural capital
Freedom	"Being able to live one's own life and nobody else's. This means having certain guarantees of non-interference with certain choices that are especially personal and definitive of selfhood, such as choices regarding marriage, childbearing, sexual expression, speech and employment" (Nussbaum) Mobility	Social capital* Natural capital

Source: Costanza et al., (2007, p. 270) *=most important input. Italic/bold= added by researcher.

In summary, the consistent message from the different basic human needs conceptualisations of well-being is that any measure needs to acknowledge that it is not all encompassing, and it will change with time, location, and culture. Participation is a direct requirement of well-being according to Sen (1999, 2008) and Alkire (2002), and an important human need listed by Max-Neef et al., (1991) and Costanza et al., (2007). Politics and culture have a considerable influence on well-being, therefore resolving well-being issues should be a process that involves public participation and debate.

2.3.4 Sustainable development

This section discusses sustainable development and how it relates to sustainable well-being.

Literature on sustainable development is prolific, and an industry has developed deciphering and promoting what sustainable development actually means (Kates, Parris, & Leiserowitz, 2005; Pezzoli, 1997). It is a contested concept in many spaces with Pezzoli (1997) identifying 10 major categories of literature linking sustainable development to either the environment; legal and institutional terrain; culture and civil society; or the economy and technology. The ideal of sustainable development has spread and is widely institutionalised, though action might not support it, and it is usually easier to define what is unsustainable than what is sustainable (Bartelmus, 2009).

Despite the hundreds of definitions of sustainable development (Kates et al., 2005) there is no tangible, clear-cut interpretation[24] (Bartelmus, 2009; Fricker, 1998; Hjorth & Bagheri, 2006; Joint UNECE/OECD/Eurostat Working Group on Statistics for Sustainable Development, 2008; Kates et al., 2005; Manderson, 2006; Missimer, 2013; Pezzoli, 1997). The result is overuse and opaqueness (Bartelmus, 2009). It is argued the ambiguity of sustainable development has both advantages and disadvantages. Advantages include: 1) the malleability of sustainable development allows it to mean almost anything (Kates et al., 2005; Pezzoli, 1997), which makes connecting with the

[24] The most well-known definition of sustainable development is that of the Brundtland Report "development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs" (WCED, 1987, p. 43).

concept easier (Parris & Kates, 2003; Pezzoli, 1997); 2) the different interpretations promote pluralism and unique approaches that can be compared, contrasted, and implemented based on suitability (Kates et al., 2005; Pezzoli, 1997); 3) as sustainable development is regularly redefined and adapted to meet diverse needs, it constantly evolves (Kates et al., 2005); 4) open time frames such as 'now and in the future' make it flexible what to sustain and develop; and 5) as a concept, sustainable development has been successful at connecting those concerned with nature, society and the economy (Kates et al., 2005).

Some of the disadvantages of ambiguity that have been noted are: 1) it defies operational implementation (H. Daly, 2005; Fricker, 1998; Robèrt, 2002); 2) sustainable development is used by business and government to justify economic growth and business as usual (Bartelmus, 2009; J. Robinson, 2004); 3) it is anthropocentrically interpreted, so protecting nature is for human benefit only (Hector, Christensen, & Petrie, 2014) and; 4) everyone can subscribe without risk of being accountable (Bartelmus, 2009).

Sustainability can be broadly defined as maintaining the capacity to provide non-declining well-being over time (Stiglitz et al., 2009; WCED, 1987). There are competing tensions between the well-being of current and future generations (Norton, 2007). Many of the decisions made to increase current well-being reduce future sustainability (Neumayer, 2004). For example, fossil fuel use increases current consumption and well-being levels, but reduces sustainability, as fossil fuels are not available for future use, and greenhouse gas emissions increase from the burning of these finite resources. A reverse example given by Neumayer (2004) is that inequality, while not beneficial for well-being, is good for sustainability. This is because a population made up of a small number of extremely rich people and a large number of poor people will consume less than the same population made up of middle class/wealthy people. It is not correct to use current well-being measures as a measure of sustainability (Neumayer, 2007; Stiglitz et al., 2009). Current well-being is boosted by resource depletion, and the true impacts of long-term environmental damage are not felt until the future.

Within this dissertation, sustainable development is considered to be the transformative pathway to achieve sustainable well-being. Sustainable development is operationalised by defining what we want to achieve and setting the required goals to get there (Kates et al., 2005). Setting goals provides ways to assess how we measure up in day-to-day life, and allows us to change our attitude and behaviour in response. Sustainable development is about creating solutions to problems (Pezzoli, 1997). Such solutions can have a material/biophysical reduction focus (material and energy flows, resource use and assimilation capacity, life cycle assessment, product stewardship, industrial ecology, and sustainable consumption and production) or be aimed at non-material objectives that increase human and social capital without inputs that deplete nature.

The 'capitals' construct can be a yardstick for determining the success of sustainable development (Pearce, Markandya, & Barbier, 1989; World Bank, 1997). This approach necessitates managing the portfolio of wealth sufficiently to bequeath as much wealth per capita (in the form of built, natural, human and social capital) as was inherited from generation to generation (Dasgupta, 2001). This presents a considerable challenge as per capita measures require capital to grow over time if population is increasing (UNU-IHDP and UNEP, 2012, 2014). Incommensurability and non-substitutability between the different types of capital also presents problems (Pezzoli, 1997), for example, natural capital cannot be replaced by human capital.

The initial emphasis of sustainable development on environmental protection and economic development has been broadened (Kates et al., 2005). The current wide scope of sustainable development is illustrated by this excerpt from the Sustainable Development Goals draft declaration (United Nations, 2015):

> We resolve, between now and 2030, to end poverty and hunger everywhere; to combat inequalities within and among countries; to build peaceful, just and inclusive societies; to protect human rights and promote gender equality and the empowerment of women and girls; and to ensure the lasting protection of the planet and its natural resources. We resolve also to create conditions for sustainable, inclusive and sustained economic growth, shared prosperity and decent work for all, taking into account different levels of national development and capacities (p. 3).

The similarities between sustainable development and well-being include meeting the needs of humans now and in the future within the limits of the life support systems of the planet and the core principles of equity, social cohesion and provision of adequate levels of material comfort.

Current well-being is orientated to the present and affected by both economic resources (such as income) and the non-economic aspects of peoples' lives (such as what they do and what they can do, how they feel, and the natural environment they live in). Sustainable development is more future-orientated and concerned with whether levels of well-being can be sustained over time. This depends on whether stocks of capital that matter (natural, physical, human, social) are passed on to future generations (Stiglitz, Sen & Fitoussi, 2009).

The essential concern conveyed by 'sustainability' and 'sustainable development' is how decisions impact on sustainable well-being (G. Atkinson, 2008) or the ability to maintain well-being over the long term. It is possible for sustainability to be included in a well-being measure if it is assumed current generations care about their future and future generations. Such support for the rights of future generation is intrinsic in many cultures and also prominent in the philosophies of Rawls (1999), Boulding (1966) and many others, who consider humans as equal, independent of their position in time.

Sustainable well-being combines well-being concepts with the need to maintain all forms of capital such as man-made capital, human capital, natural capital and social capital because future welfare is dependent on the availability of capital. The quality and quantity of the capital assets are a key factor for both sustainable development and sustainable well-being. Therefore, the next step is to discuss the conceptual ideals incorporated in each of the four capitals – social, human, built, and natural.

2.3.5 Capital assets

Capital assets are so defined because they accumulate over time and yield benefits. The long-established theoretical foundation for the link between well-being and capital is the concept of Hicksian income, and the need to sustain the income-generating asset base if wealth is to be maintained in the long term. Hicksian income, which cannot be measured,[25] is defined as "the amount that you can spend without diminishing your ability to spend the same amount in the future" or alternatively "what wealth you can consume without impoverishing yourself" (Hicks, 1939, 1946).

There is debate about how assets should be split into capital stocks. The boundaries between capitals can be blurred, with human and social relationships being difficult to separate (International Integrated Reporting Council, 2013). Dalziel and Saunders (2014) list cultural capital as separate from social capital. Some (Hector et al., 2014; Wilson et al., 2007) separate financial (or economic) capital to create a five capitals model. Gleeson-White (2014) and the International Integrated Reporting Council[26] (IRRC) refers to six capitals: Financial capital; Manufactured capital; Intellectual capital; Human capital; Social and Relationship capital; and Natural capital.

In addition to disagreement over how capital assets are split, there are also divergent opinions on the use of the word 'capital'. Some people object to human communities and ecosystems being treated in the same way as finance, and the implied assumption that they can be drawn down or built up as is convenient (Monbiot, 2014). Victor (1991) argues against using the term capital to describe the environment because an essential feature of capital is that it can be produced by human action. The opposing opinion is the use of the term 'capital' promotes communication and understanding as it a language common to the economics and decision-making sectors (Gleeson-White, 2014; Stiglitz et al., 2009).

Difficulty measuring capital assets and flows is a recurring contentious issue. Between the mid-1950s and mid-1970s there was a lively debate on this question. This was referred to as the 'Cambridge Controversy in Capital Theory' because those involved were aligned with either Cambridge in England, or Cambridge in Massachusetts. The controversy 'died' (due to the death of some of the key debaters, i.e. Joan Robinson

[25] Hicks (1946) argued that, "It seems to follow that anyone who seeks to make a statistical calculation of social income is confronted with a dilemma. The income he can calculate is not the true income he seeks; the income he seeks cannot be calculated" (p. 178).

[26] "The International Integrated Reporting Council (IIRC) is a global coalition of regulators, investors, companies, standard setters, the accounting profession and NGOs. Together, this coalition shares the view that communication about value creation should be the next step in the evolution of corporate reporting." http://www.theiirc.org/the-iirc/

and Piero Sraffa), but the key issues debated remain unresolved (Cohen & Harcourt, 2003).

The major focus of the debate was the methodological problems associated with aggregate production functions.[27] The English side debated the validity of extrapolating a single good production function to an aggregation of heterogeneous capital goods. Due to the many different physical units of measure when there are heterogeneous capital goods, aggregation of the different goods requires conversion to monetary value. Monetary valuation can be determined by either: a) cost of production, or b) the present value of the future output stream. The problem is that both these calculations require the application of a rate of interest, and as the rate of interest is determined by capital availability, there is a circularity or bi-directional dependence. This interdependence results in what is known as the Wicksell (1911) effect, alternatively referred to in the Cambridge controversy as 'reswitching' and 'capital reversing'. These terms are used to describe how the value of capital is impacted by a time factor, which changes the interest rates; therefore, capital value is determined by time. As a result, the value of capital cannot be calculated independently of the rate of interest and the substitution effect of wages.

The Cambridge Controversy brings to the fore the issues associated with aggregating different forms of capital. It also implies static capital theories are not adequate and shows it is difficult to separate capital stocks from capital flows (as noted by Hicks in 1946). These issues are very pertinent when considering capital in such diverse forms as social, human, built and natural.

Despite capital measurement difficulties there is a strong tradition that links the maintenance of the four-capitals with human well-being (G. Atkinson, 2008; Deutsch,

[27] Neoclassical 'capital theory' uses marginal productivity to calculate return on capital. The one commodity Samuelson/Solow/Swan production function model is:

> $Q=f\ (K,L)$ where Q = produced output that can be consumed either directly or be a capital good that produces output itself over time.

Folke, & Skånberg, 2003; Ekins, 1992; Ekins, Simon, Deutsch, Folke, & De Groot, 2003; Hicks, 1939, 1946; Pearce & Atkinson, 1993).

The 'four capitals' approach is a wealth-accounting (stocks) rather than an income-based (flows) framework.[28] With the four capitals approach, capital stocks need to be maintained to consolidate wealth and ensure long-term sustainability. Flows that do not diminish the capital stocks quantify the well-being or income able to be currently enjoyed by a nation. On the other side, impacts that diminish the asset base decrease the resources available for present and future generations, and need to be compensated by investment to repair the loss.

Hartwick (1977) and Solow (1974) proposed that intergenerational equity could be achieved by maintaining a non-declining capital stock. El Serafy (1989) calculated this could be achieved if the rents derived from the exploitation of non-renewable natural resources were invested in built capital that provided dividends. These Neoclassical economists permit substitutability between natural and other capital types, and equate sustained well-being with the maintenance of the total capital stock. This is referred to as 'weak sustainability (Neumayer, 2003; Pearce & Atkinson, 1993). Ecological economics argues that that the life-support capacity of natural capital is not substitutable (Munasinghe & McNeely, 1995) and 'strong sustainability' is the goal (Costanza & Daly, 1992). 'Strong sustainability' requires the maintenance of all capital stocks without substitution (Neumayer, 2003; Pearce & Atkinson, 1993).

According to Kulig et al., (2010, p. 123) the capitals approach appeals to economists as a framework because it "is based on economic theory and distinguishes a coherent list of assets (Economic, Natural, Human and Social). In essence it is not much more than the application of the age-old production function *Y=f(E,N,H,S)."* Accountants also relate to the capital approach as it works with the language of their discipline (Gleeson-White, 2014; International Integrated Reporting Council, 2013).

[28] The GDP accounting system is flow based (H. Daly & Cobb, 1994), and does not record the depletion of capital stocks or provide an integrated framework that captures the inter-dependencies between capitals (UNU-IHDP and UNEP, 2012).

The following subsections provide a definition for each of the four capitals and a brief insight into the factors that increase or decrease the capital, and measurement options available to use.

2.3.5.1 Social capital

Definition: 'Social capital' is defined by the OECD (2001, p. 41) as "networks together with shared norms, values and understandings that facilitate cooperation within or among groups". This cooperation adds value to civic society, reduces transaction costs, and fosters information exchange, accepted behaviours, and both formal and informal assistance. It also provides a sense of belonging and a source of social interaction. Networks of humans are the "carriers of social and relationship capital"…which "includes institutions and relationships within and between communities, stakeholder groups and other networks; shared norms, common values and behaviour; trust the organisation has fostered, brand and reputation; and an organisation's social licence to operate" (Gleeson-White, 2014, p. 192).

Collective well-being is built and enhanced by institutions and the relationships within and between communities, groups of stakeholders, and other networks. Social capital is based on relationships, and reflects how collective action can be facilitated through norms and networks (Woolcock, 2001). For Woolcock, social capital as a concept makes most sense when it relates to society rather than to the individual (psychology) or political (institutional) form of organisation. Social capital combines both 'soft' elements like mutual trust (Ostrom & Walker, 2003) and hard approaches like mutual enforcement mechanisms (Ostrom, 1992) and can also be understood "as an attribute of individuals and their relationships that enhance their ability to solve collective-action problems" (Ostrum & Ahn, 2009, p. 20).

The term 'capital' is used because social capital accumulates over time and yields benefits as with other forms of capital (Helliwell, Layard, & Sachs, 2012). The concept of social capital is hard to define and can overlap with culture (D. Coyle, 2014). It is often-criticized (see Arrow, 2000), and caution is recommended with its use (Missimer, 2013). For Bryson and Mowbray (2005), 'social capital' is considered to be just the modern-day free market economics jargon for 'community'.

How social capital increases: Trust is viewed as an essential component in social capital. Trust lowers transaction costs by facilitating working together and the straight-forward exchange of goods and services.

Social capital increases in importance as society becomes more complex. Coordination of large scale actions is beyond the realm of a few individuals, and citizens need to rely on others, trusting them to make decisions and to choose viable alternatives for society as a whole (Forgie, Cheyne, & McDermott, 1999; Meijboom, Visak, & Brom, 2006). Friedman (2007, pp. 557-558) states “without trust, there is no open society, because there are not enough police to patrol every opening... it is trust that allows us to take down walls, remove barriers, and eliminate friction at borders”.

Social capital was first referred to by Jane Jacobs in her analysis of what makes great cities (Jacobs, 2002). According to Putnam, there is both a public and private aspect of social capital: “ … a well-connected individual in a poorly connected society is not as productive as a well-connected individual in a well-connected society” (Putnam, 2000, p. 20).

In *Bowling Alone*, Putnam (2000) differentiates between bridging and bonding social capital. Bridging social capital builds relationships between people who are different. This can benefit society by connecting diverse racial, socio-economic and ideological groups, which can provide the catalyst for new ideas and innovation. In addition, bridging links between communities reduce discrimination and allow outsiders to integrate, build friendships, and become part of social networks. Bonding links form homogenous groups of people with similar views. This builds links within communities, providing security, trust, social relations, and mutual support.

Social media is seen by some as the modern way of developing social capital. Through online communities, such interaction enables people who are today more transient than in the past, both to retain existing social capital and build new social capital. The longer-term implications of this movement for social capital are yet to be understood.

How social capital declines: Putnam’s (2000) research indicates that social capital, which he measures by levels of participation in clubs and civic engagement, has declined with GDP growth. This decline can be linked to factors such as time pressures, especially in two-career families; urban sprawl and commuting; electronic entertainment and the privatisation of leisure time; and generational change, with current generations less interested in civic affairs (Putnam, 2000). Social capital extends to institutions, with distrust in government having a reducing effect (Kaldaru & Parts, 2008).

Not all forms of network building and social capital are positive (Briggs, 2008; Browning, 2009; McKenzie, 2008). Bonding social capital can have the effect of reinforcing differences with other groups in society, lobbying for exclusive rights, and encouraging discrimination. In a similar vein, social media can readily bring together dissatisfied individuals and provide them with a cause – such as terrorism.

It has also been shown that trust is higher in more equal societies and therefore an increase in inequality will reduce social capital (Wilkinson & Pickett, 2009).

Measuring social capital: Social capital is usually measured by surveys that assess the level of trust in a society. Structural social capital can be estimated by membership of voluntary organisations (Kroll, 2008; Putnam, 2000).

2.3.5.2 Human capital

Definition: "Human capital is defined by the OECD as the knowledge, skills, competencies, experiences and attributes embodied in individuals that facilitate the creation of personal, social and economic well-being" (Keeley, 2009, p. 29). It is a measure of how well people can make use of available assets (D. Coyle, 2014). The human capital 'stock' incorporates the combined population's knowledge, skills, physical ability, experience, motivation, intelligence, health, productivity, support for the organisation/institution, loyalty, and the ability to lead, manage, and work together. It encompasses the human dimensions that contribute to well-being, such as happiness, as well as attributes that allow individuals to function as part of a complex society. The carrier of human capital is the individual (Gleeson-White, 2014). Human capital theory is well established in the economics discipline and goes back at least as far as Adam Smith, who recognised the contribution that skills and labour make to economic growth.

There is resistance to human capital as a concept. It is argued that people and their culture are more than just capital inputs into a system, and their value much greater than a means of promoting economic growth, which the use of the term ‘capital’ implies.

How human capital increases: The growth in human capital has been rapid since the 1750s and the start of the industrial revolution. Development of language and learning has allowed us to accumulate knowledge to advance societal goals. While it has long been known that people are an important part of the wealth of nations, the extent of this is now better understood. The ‘Inclusive Wealth’ report estimates that human capital accounts for approximately 54% of world wealth (UNU-IHDP and UNEP, 2014). Stiglitz et al., (2009) quote studies that estimate the monetary value of human capital stocks account for more than 80% of wealth. Intangibles like knowledge and information are estimated to account for four-fifths of the value of companies in the US, with physical assets accounting for only the remaining one-fifth (Keeley, 2009). Jones (2015) attributes the growth in human capital, measured in aggregate output per worker, to improved use of talent that has been brought about through reduced discrimination. An increase in the pool of ability accelerates the discovery of new ideas. Human capital, measured by the number of patents registered, indicates that since 1985 in the USA (and also globally but to a lesser extent) there has been a rapid increase in human capital (Jones, 2015). These data could, however, equally reflect a trend to patent new ideas for private gain.

The increasing value put on human abilities, knowledge and skills leads to assertions that population growth is not an issue in terms of the Earth’s carrying capacity. The more people there are, the larger the pool of intellect available to create new technologies to allow the Earth to sustain humanity (J. Simon, 1996). Human capital, it is assumed, will continue to increase if investment in health, education and skills (by the individual, family, organisation or society, or a combination of all of these) is made.

Good health is an important component of human capital, as this provides the ability to earn more over a lifetime and improves the capacity to learn. Advances in medical science and less physical work have extended longevity in most countries in the world and thereby increased human capital.

How human capital declines: Human capital can be diminished as a result of unemployment, poor health, war, famine, living or working in a polluted environment, and lack of educational opportunities. To maintain human capital over a lifetime, improvements in health care, skill development, and education need to be on-going so people can adapt as economies change. Non-use diminishes human capital. Replacing human-based skills and employment opportunities with technology will decrease human capital unless worthwhile alternatives are provided.

Measuring human capital: The main ways to measure human capital are education levels and health (often measured using life expectancy). Others methods include labour turnover, occupational health and safety, diversity, equal opportunity, patents, copyrights, skills, protocols, and knowledge and ideas (Gleeson-White, 2014). Net changes in human-health capital (the physical and mental health that form the basis on which we receive and enjoy the services yielded by physical wealth) are another way of measuring human capital stock and can be estimated through factors such as higher productivity of labour.

2.3.5.3 Built capital (also referred to as man-made capital)

Definition: "Built capital includes traditional infrastructure – housing, roads, electric grids, goods & services traded in markets, and all other elements built by humans, that comprise communities" (The Encyclopedia of Earth, 2008, p. 1). It also covers manufactured physical objects (as distinct from natural physical objects) that have been produced for consumption or further production, for example, manufacturing plants, machinery, equipment, and infrastructure such as ports, bridges, and waste-treatment plants.

As built capital is generally estimated using GDP, financial capital is often treated as part of built capital. Financial capital (money or its substitutes) is the funds available for use in the production of goods or the provision of services obtained through debt, profits, investment, equity or grants. Alternatively, it can be a separate capital (Gleeson-White, 2014) or a component of social capital as in Figure 2-3.

How built capital increases: Man-made goods and services are produced by using labour and energy to convert natural capital capital into products that are then predominantly sold in the marketplace. Wastes generated in the process are returned to nature. If assimilation capacity is exceeded this causes pollution and degradation. Technology has increased the rate at which humans convert natural capital to goods and services. This has sped up biogeochemical cycles, accelerating unwanted build-ups (N. J. Smith, McDonald, & Patterson, 2014). Growth of built capital has caused pressure on ecosystems, greenhouse gas accumulation in the atmosphere, rapid climate change, loss of biodiversity, food security issues, and degraded the quality and quantity of freshwater supplies (Costanza, Cumberland, et al., 1997; Costanza et al., 2015; Costanza, d'Arge, et al.; IPCC, 2013; Robèrt, 2000).

How built capital declines: Built capital wears out and depreciates over time. Technology (for example, computers) can be outdated in a matter of years; whereas, infrastructure like water reticulation can last for over 100 years. A more rapid destruction of built capital can also occur through earthquakes, floods, and other types of natural disasters. Civil unrest and war also decimate built capital.

Measuring built capital: "Built capital is commonly measured in two ways: as a stock (sum total of physical assets), or as a flow of assets produced and consumed over a given time period (typically measured as GDP)" (The Encyclopedia of Earth, 2008, p. 1). There is debate in the literature as to whether stocks are simply slow moving flows over longer time periods. This makes the use of a financial year to define a stock arguably meaningless, and brings to light the fundamental theoretical problems associated with stock/flow measurement. The interpretation of how these stocks and flows are measured is most important in understanding sustainability and well-being.

2.3.5.4 Natural capital

Definition: "Natural Capital consists of the goods and services provided by nature that contribute to the well-being of humans and every other species on the planet. Natural capital includes the land, water, atmosphere, and the many natural resources they contain, including ecological systems with living (biotic) and non-living (abiotic) components. Natural capital provides the energy, raw materials, and waste absorption or filtering services that are critical to the modern economy and human life on Earth" (The Encyclopedia of Earth, 2007, p. 1). Natural capital can broadly be divided into renewable and non-renewable sectors. The flow of natural resources and services from natural capital sustains human well-being and is the basis of the past, current, and future prosperity of society. The goods and services provided free by nature, through ecosystems, are the source of the provisioning, regulating, cultural and supporting services that sustain both human life and every species on the planet.

How natural capital is sustained: The quantity of natural capital available is fixed, so while the 'basket' of outputs can change and adapt with time, it will not increase. "With its huge annual turnover of many hundreds of billions of metric tonnes of material, the biosphere nevertheless posts nil growth in terms of biomass, and with that it has got by for aeons" (Vester, 2007, p. 111). Measured in human time spans, natural capital has a fundamentally permanent source of energy – the sun. This energy allows natural capital to sustain itself for on-going use. The 'renewable' part of natural capital is made up of the living species and self-organizing ecological systems that, through their functioning, yield an on-going flow of ecological goods and services. The rate of renewal is influenced by the condition of the natural capital stocks and management practices (with for instance crops and forest plantations). Replenishable natural capital (e.g., the atmosphere, potable water, fertile soils) consists of stocks that are continually recycled through their interaction with living resources over long periods, for example, the interaction between surface mineral components and living organisms that produces fertile soil (Aronson, Milton, & Blignaut, 2007). To prevent decline in ecosystem services provided by nature requires: (1) resource use be limited to rates that ultimately result in levels of waste that can be absorbed by the ecosystem; (2) renewable resources be exploited at rates that do not exceed the ability of the ecosystem to regenerate the resources; and (3) non-renewable resources not be depleted at rates that exceed the rate of development of renewable substitutes (H. Daly, 2005).

How natural capital declines in usefulness:[29] Consumption causes natural capital stocks to decline in quality and usefulness. The one-way flow of throughput in the economy depletes environmental sources and increases wastes moving from low-entropy sources to high-entropy sinks following the Second Law of Thermodynamics

[29] The material stock that makes up nature does not diminish as matter and energy are constant according to the First Law of Thermodynamics. It is the usefulness of the capital that declines in terms of human time frames.

(Georgescu-Roegen, 1971). Non-renewable natural capital (e.g., petroleum, coal, diamonds) once extracted and used is not replaced by nature in a timeframe to which humans can relate. The extraction and utilisation of non-renewable natural capital impacts on the functioning of ecosystems and the services they provide. As most ecosystem services do not have human-made (built) substitutes, and ecological thresholds are uncertain, there is risk of decline beyond repair (Costanza et al., 1997).

Measuring natural capital: Natural capital stocks are large and highly interconnected, which makes measurement difficult. Instead, the flows that reduce or increase natural capital stocks are measured (Bleys, 2008). The Cambridge controversy (discussed in section 2.3.5) highlights the issues that arise when attempting to measure natural capital.

There is no institutionalised method to measure the stock of natural capital. It is, however, known that 'strong sustainability'[30] is not achieved by most countries as biochemical cycles are appropriated at a greater rate than the biosphere's regenerative capacity (N. J. Smith et al., 2014). For example, CO_2 emissions are greater than sequestration rates, non-renewable depletion exceeds replacement by renewables, and pollution levels are higher than assimilation capacity (H. Daly, 1996; Ekins et al., 2003; Neumayer, 2007).

Methods that have been proposed for measuring natural capital include defining strong sustainability as not breaching physical thresholds set for specific natural resources (Barbier & Markandya, 2013). To maintain a safe operating space on Earth, Rockstrom et al., (2009) identify nine critical processes that need to be measured and checked. Crossing a 'threshold' for any of these processes is likely to result in 'unacceptable environmental change' – which has already happened for climate change, biodiversity loss, and the global nitrogen cycle.

Natural capital stocks need to be maintained as, according to Lawn (2013), Daly and Cobb (1989) and Costanza et al., (1997) while services may have substitutes (e.g. flood

[30] As defined by Neumayer in Table 2-3 this refers to maintaining the value of each separate capital. Weak sustainability only requires the sum of total capital to be maintained; it allows infinite substitution of capital as long as human welfare does not diminish (Beckerman, 1994).

protection can be provided by river levees rather than wetlands) there is no practical substitute for the capital that yields these services. For example, a house may provide equivalent psychic income (shelter and comfort) to the goods previously produced from the agricultural land on which it is built, but it cannot in the long-term provide a source of renewable ecosystem services such as food, carbon storage, water filtration, aquifer replenishment, etc. Therefore, when calculating a country's total well-being, methods are needed to account for the long-term loss of natural capital services.

2.3.5.5 Dependencies between capitals

Figure 2-4 below depicts how capitals are interlinked and depend on each other. The numbered link descriptions explain the connections. There are also feedback loops within the capitals themselves (i–iv).

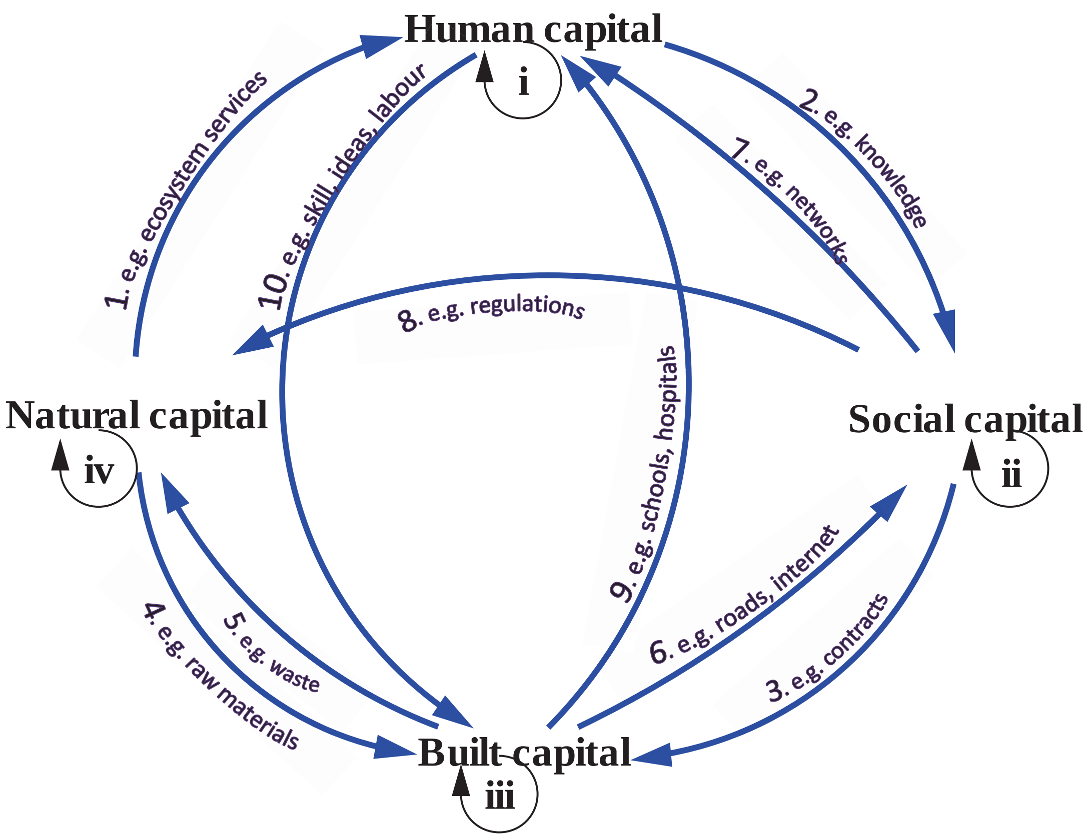


Figure 2-4: Links between the four capitals.

a) Description of the links:

1. Natural capital provides human capital with the life-support necessities for good mental and physical health (clear air, water, food), pleasure (recreation,

aesthetics) (Costanza et al., 1997), and ways to inspire innovation (biomimicry) and learning (Harman, 2013). Nature can also destroy human capital, for example, earthquakes, floods, droughts or when assimilation capacity is exceeded and biogeochemical cycles get out of sync.

2. Human capital (knowledge, health, labour, skills) fosters social capital and provides the means to co-exist and collaborate in government, business and society. Human capital provides information, data and skills for decision-making. It also boosts social benefits such as greater community involvement, better public health, and reduced crime (Keeley, 2009). Human capital through education generates new innovations, which, in turn, bring about social change. Human capital can also destroy social capital by waging war and engaging in corruption.
3. Social capital (norms, beliefs, values, culture, regulations, laws, networks, organisations, contracts) increases the efficiency and effectiveness of allocation of built capital. Productivity and creativity is increased when people expand social ties rather than work in isolation (Florida, 2008). Accepted and honoured norms for interaction increase economic efficiency, such as handshakes to seal deals, rather than requiring time-consuming, expensive legal contracts. Folke et al., (2005) claim social capital increases the flexibility of management and is the glue for adaptive capacity and collaboration. How effectively people organise collectively through political and other institutions impacts economic growth. Coyle (2014) gives the example of English colonies that inherited the English legal framework, growing faster and having higher incomes than those using the French legal framework.
4. Natural capital is the source of the raw materials that are transformed through energy inputs into built capital. This transformation changes nature into a form that is suited for human consumption and gives nature economic value. Economic activity is reliant on natural capital for the ongoing throughput of the matter and energy required for the production and maintenance of built capital.
5. Built capital generates unwanted residuals (wastes, pollutants, emissions) that are returned to natural capital to assimilate. Exceeding the rate at which

nature can assimilate waste degrades natural capital and reduces its capacity to provide ecosystem services. For example, a build-up of pollution or toxicity has an impact on the ability to produce food.

6. Built capital provides the infrastructure to boost social capital through connectivity (roads, physical networks, electricity grids, airwaves, internet, computing). Social capital is reliant on built capital to provide the support systems to network and interact for social, business and civil purposes.
7. Social capital provides social networks for knowledge (educational, scientific, medical, belief systems, values) to spread and increase human capital. In both rich and poor societies how, and on what terms, we associate with each other have significant implications (Woolcock, 2001). Social capital furthers the building of knowledge and the passing on of learning in a society. Community and social structure play significant roles in human health and have been described by Buettner (2009) as being as important as diet and lifestyle for achieving longevity.
8. Social capital (regulations, governance, norms, rules, political organisation) can limit natural capital exploitation and pollution if this is democratically mandated by society. The same social structures can sanction the exploitation and demise of natural capital – either democratically or undemocratically.
9. Built capital in the form of buildings, machinery, and technology contributes to human capital by increasing the value of knowledge and providing access to a broad range of information. Growth in human capital is strongly linked to built capital as it provides the infrastructure on which human capital depends (i.e. hospitals for health care, houses for shelter, schools and universities for education).
10. Human capital allows the exchange of knowledge and ideas while also providing the labour to increase built capital. Human capital, through education, generates new innovations, which in turn bring about economic change. The quality of human capital impacts on economic growth. Whether improved education stimulates economic growth or vice versa is debated and it is generally accepted causality operates in both directions (OECD, 2005). Education provides a skilled workforce capable of carrying out complex tasks,

innovating, and generating higher wages (Jones, 2015). The existence of such jobs (in the human and social environment) encourages people to stay in education for longer. Better-educated people enjoy higher incomes and therefore consumption levels, which in turn stimulate GDP growth. Regardless of which is the initial catalyst, the outcome is that wealthier countries have more to spend on education, which increases productivity, fuels growth, and generates a positive reinforcing feedback loop (Keeley, 2009).

There is no direct link from human capital to natural capital, as it is assumed any interaction is via built capital (e.g. technology) or social capital (e.g. institutions). Nor is there a link between natural capital and social capital. While natural capital may once have had an influence on how society was geographically organised, modern transport systems diminish such effects.

b) Feedback loops within the capitals

There are also feedback loops within the capitals. These can be positive and increase a capital or negative and result in a decrease. Examples are:

i. Human capital to human capital: Education allows people to learn how to improve their health. Better health provides the capability to learn and increase skills. Human capital, as in scientific knowledge, grows through use (Costanza et al., 2007). Population growth makes it more likely that discoveries will be made as there are more people searching for new ideas. Ideas arise through research and by chance (Jones, 2015).
ii. Social capital to social capital: Good governance and institutional functioning enhances trust, which allows further advances in governance and institutions. Social capital also grows through use, e.g. better social networks (Costanza et al., 2007).
iii. Built capital to built capital: Built capital materials can be recycled and used for different purposes, though not indefinitely, in keeping with the Second Law of thermodynamics (Georgescu-Roegen, 1971).
iv. Natural capital to natural capital: Biogeochemical cycles and ecosystem services recycle materials into the environment if assimilation capacity is not exceeded.

2.4 OVERALL GOAL: SUSTAINABLE WELL-BEING

This section draws together the discussion presented so far to explain how sustainable well-being is positioned in this dissertation. This is important, as the principal research question is: "Does understanding the relationships between indicators add value and progress sustainable well-being?" Table 2-3 summarises the sustainable well-being principles discussed in Chapter 2. The bolded and highlighted principles are considered more closely in the next chapter.

Table 2-3: Sustainable well-being principles discussed in Chapter 2

Characteristic	Principle
There is no such thing as a single list of what well-being incorporates. Both material (e.g. housing, clothing food) and non-material factors (e.g. affection, clean air to breath, ability to participate) contribute to well-being.	Well-being is multidimensional.
Achieving well-being requires access to sufficient resources to satisfy basic human needs (food, shelter, education, freedom).	Some well-being factors can be measured objectively.
Achieving well-being requires personal satisfaction with the outcomes of opportunities provided.	There are sources of well-being that can only be measured subjectively.
Well-being requires all desired attributes be met. An over-fulfilment in one area cannot compensate for a loss elsewhere (e.g. more food cannot make up for poor air quality).	**Weak well-being is an additive measure. Strong well-being satisfies all individual well-being requirements.**
There is a private/public component to well-being.	Satisfying objective and subjective well-being is the responsibility of both the individual and community/state.
Sustainable well-being is forward looking, aimed at ensuring access to similar (not necessarily the same) resources and opportunities in the future for both present and future generations.	**Requires future orientation and planning ahead.**
Concern with how current lifestyles impact future lifestyles. Both the positive and negative actions of past generation as well as our current actions impact on our well-being and the well-being of future generations and the other species dependent on humans for their existence.	Humans can control/influence sustainable well-being by their day-to-day behaviour.
Well-being is impacted by how the four capitals are maintained. The demands our current lifestyles put on the four capitals determines how well they are maintained to provide for the future.	**Four capitals need to be tracked.** Sustained well-being given current knowledge is best achieved by maintaining or growing (through new investment) the four capitals so they continue to produce dividends.

Requires resilience and adaptive capacity. Recognises uncertainty and change. Need to improve understanding of interconnections and complexity. Needs to be astute enough not to destroy the on-going system on which we depend.	**There are links between the different well-being components.** As such, they are characterised by many parts with relationships and interdependencies between them.
Societal well-being involves value judgements as to what is a fair and equitable distribution of the benefits and costs (including risks) both intra and inter-generations.	**Sustainable well-being has an equity aspect.**
As it is not possible to maximise a function with more than one variable (Daly, 2003), it is not possible to maximise all well-being components simultaneously.	Sustainable well-being is a system. There will be flux in the well-being system, and progress in sustainable well-being is best achieved by providing flexibility within established thresholds.
The establishment of thresholds is problematic because knowledge of appropriate thresholds within which we must live is limited. We do not know what uses particular ecological goods and services may provide in the future when combined with additions to current social, built, and human capital assets.	When establishing thresholds, account must be taken of: (1) Humility principle that recognises the limitations of human knowledge; (2) Precautionary principle that advocates caution when in doubt; (3) Reversibility principle that requires us not to make irreversible changes (Viedermans, 1995).
To stay within an ecological sustainable scale, economic activity must be kept within the capacity of natural capital to renew itself and absorb wastes.	The emphasis must be on developmental change rather than on biophysical growth. The way subjective well-being needs are met needs to change.

Bolded principles are those the research in this dissertation follows up.

2.5 SUMMARY

This chapter first discussed the various definitions and conceptualisations of well-being and the distinction between individual and societal well-being. Well-being was shown to be multi-dimensional, combining physical, social, and psychological needs. Both subjective and objective measures/indicators are required to assess the degree to which we are progressing in terms of well-being. A framework for well-being as a system was then provided and the different components of the framework described. The discussion covered subjective well-being and how it is assessed; the various ways basic human needs are defined and can be determined; how sustainable development connects to, and is different from, sustainable well-being; and the four capital assets that need to be maintained. It was advanced that achieving sustainable well-being depends on an integrative system of natural, social, human, and built capitals, all working together to build long-term resilience. Due to the importance of their role in achieving sustainable well-being, each capital was discussed in detail. For each capital a definition was provided, what causes an increase or decrease described, the links to others capitals discussed, and ways to measure the capital stock considered.

As sustainable well-being is a key concern of this dissertation, the final section summaries the principles identified and what is meant by 'sustainable well-being'.

The next chapter appraises well-being measures. It first discusses GDP as a proxy for measuring societal well-being. This is followed by a review of a subset of the many different well-being measures that have been developed in response to the recognised inadequacy of using GDP as a measure of societal well-being. As this dissertation views well-being as a system, the alternative measures are evaluated according to the following criteria: (1) whether they are a strong or weak well-being measure; (2) whether they cover all four capitals; (3) whether they are forward or retrospective in orientation; and (4) whether indicators are interlinked.

3 MEASURES TO ASSESS SUSTAINABLE WELL-BEING

This chapter reviews “what measures are used to assess progress in well-being?”, and how adequately they meet the principles for well-being described in Chapter 2. First, an introduction to Gross Domestic Product (GDP) is provided, as GDP is a widely used proxy for well-being. This is followed with the argument for why this is not prudent. Then, some of the major international initiatives underway to move beyond GDP and promote well-being measures more suited to the 21st century are noted.

The next section provides a précis of some of the alternative well-being measures that have been proposed to complement or replace GDP. Each of these measures is assessed for how adequately it provides a sound measure of sustainable well-being based on the discussion in Chapter 2. A critique of the alternative measures and why there has been limited uptake of ‘Beyond GDP’ measures concludes this chapter.

The rationale for investigating different well-being measures and their characteristics is the case studies in this dissertation all pertain to well-being measures.

3.1 INADEQUACY OF GDP TO MEASURE PROGRESS IN SUSTAINABLE WELL-BEING

GDP is the measure most universally used to gauge well-being. Government policy is dominated by GDP (Barbier & Markandya, 2013; D. Coyle, 2014; Dasgupta, 2001; Gleeson-White, 2014; UNU-IHDP and UNEP, 2014) and, as such, growth in GDP is the driver for many policy objectives.[31] By definition, GDP is the monetary measure of the goods and services produced annually by domestically located factors of production in an economy (Lawn, 2006; Stiglitz et al., 2009; United Nations, 1993). It is an abstract

[31] Governments also have other policy objectives, such as stable prices, a healthy trade balance, low unemployment, and for some but not all, a fair distribution of income; however, growth in GDP is generally the foremost goal.

statistic, able to increase indefinitely, and constructed to measure output in a way that is increasingly more convoluted, complex, and expensive (D. Coyle, 2014).

The current method used to calculate GDP is an artefact of the Great Depression of the 1930s and World War II (1939–1945). Both these events highlighted the lack of statistical data to help governments manage an economy. The first calculation of national income was by Simon Kuznets in 1937 for the economy of the USA. Kuznets estimated the value of goods and services produced by the economy and then subtracted expenditure such as armaments, advertising, and speculation that did not contribute to individual economic welfare. Kuznets believed economic growth should increase economic welfare so such negative adjustments were needed (Kuznets, 1962).

As US politicians were focused on the production of goods for the war, the government of the time was more interested in total output, and opted for measuring total economic activity. After the war, interventionist government policy required increased national income data. Keynes' *"General Theory"* (1946), which focused on demand management and the relationships between consumption, employment, interest rates, and government spending, dominated post-war thinking and economic policy. GDP was identified as important to direct fiscal policy, and for the last 70 years has provided governments with a useful indicator to measure economic activity (D. Coyle, 2014; Galbraith, 1987, 1999; Nasar, 2011; Sandelin et al., 2008).

While GDP was never intended to be used for any purpose other than economic management (D. Coyle, 2014; Kuznets, 1962), it has become a widely accepted benchmark for the overall progress of a society and an institutionalised measure of welfare. This is because GDP is highly correlated with factors that impact on well-being such as employment, taxes that fund health and education, and stable democracies. Another potency of GDP, according to Coyle (2014), is it is "an important measure of the freedom and human capability created by capitalist market economy. GDP indicates, although imperfectly, innovation and human possibility" (pp. 5–6).

As a statistical measure, GDP has extensive institutional support from the System of National Accounts (United Nations, 1993) and government statistics agencies (for example, Statistics New Zealand). The use of GDP is further reinforced because it is considered to have rigour, is reasonable for showing economic growth, and is highly recognised, and comparable across countries and time (D. Coyle, 2014; Parris & Kates, 2003; United Nations, 1993). It can be argued that despite GDP's acknowledged short-comings, alternatives are less proficient, and any overhaul would be so major it would be too difficult to implement.

While GDP does not claim to measure welfare or well-being, it is commonly used for this purpose. The short-comings of using GDP to measure the well-being of a nation are extensively documented (see Anielski et al., 2001; Barbier & Markandya, 2013; Boyle & Simms, 2009; Cobb, Halstead, & Rowe, 1995; Costanza et al., 2014; H. Daly, 1996, 2005; H. Daly & Cobb, 1994; L. Daly & Posner, 2011; Dasgupta, 2001; Diener, 1995; Forgie, 2007; Forgie & McDonald, 2013; Fricker, 1998; Galbraith, 1999; Kennedy, 1968; Kubiszewski et al., 2013; Kuznets, 1962; Lawn, 2003, 2006; Pearce et al., 1989; Ragnarsdottir et al., 2014; Stiglitz et al., 2009; The European Commission, European Parliament, Club of Rome, OECD, & WWF, 2007; van den Bergh, 2009). The following discussion briefly presents some of the key arguments for why GDP is considered a poor gauge of well-being.

First, a well-being accounting framework, as discussed in Chapter 2, needs to measure change in a region's/nation's capital assets. The System of National Accounts (United Nations, 1993), which sets out the process for calculating GDP, measures the economy in terms of flows (income and expenditure) over a given period of time. The asset base (or stocks) from which the flows derive is not taken into account. With little incentive to maintain the asset base, for example by taking into account depreciation as is done with man-made goods in financial accounting, GDP as a measure encourages use without maintenance (Gleeson-White, 2014). GDP is actually the antithesis of a sustainable well-being measure when it comes to natural capital. The faster the rate at which resources are consumed and the environment polluted, the faster the growth in GDP in the short-to-medium term (Bossel, 1998; Coleman, 1998; H. Daly & Cobb, 1994; UNU-IHDP and UNEP, 2014). This would not be shown as positive in a sustainable well-being measure. GDP weights in favour of current consumption rather than providing for future generations, discounting longer-term negative impacts (McDonald, 2006).

Second, well-being is a multi-dimensional concept of which income (the value-added component measured by GDP) is only one part. It has long been recognised that the ability and freedom of individuals to live a life they have reason to value is just as important as the bundle of goods and services they consume (Capra, 2005; Easterlin, 2003; Easterlin & Angelescu, 2009; Sen, 2008). Focus on income means the many goods and services essential for human survival that are not exchanged in the marketplace, for example clean air, clean water, and climate stability, are excluded from policy directives. There is also an increasing range of products that contribute to human well-being that are not included in GDP the way it is currently calculated, for example, many recent digital initiatives and social technologies (D. Coyle, 2014). An assessment of the 'wealth' base of different countries estimates that produced wealth (goods) accounts for as little as 18% of total wealth (UNU-IHDP and UNEP, 2014). Therefore, reliance on GDP as a well-being measure means decisions are made based on a very limited part of the total picture.

Not treating natural and human resources as assets subject to depletion and depreciation sends misleading signals to policy makers. However, as pointed out by Gleeson-White (2014), in a globalised world with little common moral ground and no agreement on what values are worth caring about and protecting, abdicating responsibility to the financial system and market is a convenient option.

Third, there is an increased risk that GDP growth does not contribute positively to societal well-being (H. Daly, 1996, 2005; Stone, 2010). A number of alternative developed well-being measures indicate it is possible to have uneconomic growth – where the direct benefits of economic growth (goods) are outweighed by the negative consequences (bads) of that growth[32] (Costanza, Hart, et al., 2012; Costanza et al., 2014; H. Daly, 1996, 2003; Max-Neef, 1995; Talberth, Cobb, & Slattery, 2007). As 'bads' are an inevitable by-product of producing 'goods', how they are accounted for is critical. If the accounting system registers the generation of 'bads' or 'anti-bads' as positive contributions, as is done with GDP, there is no way to determine whether a cross-over to uneconomic growth has occurred (H. Daly, 2005, 2010). For example,

[32] 'Goods' are products that contribute to well-being and utility. 'Bads' are the unwanted side-effects of growth, such as pollution, that have disutility and require sacrifices greater than the worth of the good produced (see H. Daly, 2005).

defensive expenditures[33] that cover items such as spending to clean up pollution, maintaining security in the face of increased crime, research and drugs to treat cancer as a result of increased use of chemicals, etc., are all treated as positives in GDP accounting.

Fourth, reporting with conventional economic measures, such as flow-based GDP, operates at the margin and provides no warning of impending disaster such as depletion of fish stocks, irreversible climate change, loss of ecosystem services such as pollination services, or loss of community cohesion.

Fifth, a monetary measure disregards material flows. As Daly (2013) points out, the real value unit of GDP is not money but the unit measure for the transformation of natural resources and the generation wastes associated with this conversion. Using income growth as a policy directive when producing income depletes the resource base that present and future generations will need to support themselves is flawed logic. A yard-stick that does not distinguish between economic growth that adds to well-being, and economic growth that harms well-being, makes moving to a low throughput economy difficult. When GDP is used as a measure, there is no incentive for qualitative change in economic activity, careful resource use, or the production of quality consumer durables.

Sixth, as discussed in Chapter 2, social and environmental factors contribute to long-term well-being. There are many examples of positive situations that increase the welfare of a nation but are not accounted for by GDP. These include but are not limited to: stay-at-home mothers who care for their children; voluntary community work that provides social cohesion; the stability of government; and worklife balance – all important aspects of a nation's well-being. In fact, as described by Robert Kennedy (1968), GDP measures everything but the things that make life worthwhile. Examples of social and environmental impacts that are negatives, but are treated as positives that increase GDP, include: output from heavy industry that reduces air quality and

[33] "The term 'defensive expenditures' is understood to mean outlays with which the attempt is made to eliminate, mitigate, neutralise, or anticipate and avoid damages and deterioration that the economic process of industrial societies has caused to living, working, and environmental conditions" (Leipert, 1989, p. 844).

impacts on the health of citizens; a road accident, due to the greater activity of health and emergency services and the vehicle repairs required; marriage breakdown as two households need to be supported instead of one; likewise buying bottled water because the public water supply is not of sufficiently high quality to drink.

Many other issues of concern arise when GDP is used as a measure of well-being. A major one is GDP equates well-being with consumption. Others concerns include the fact that growth in GDP does not report on whether or not the benefits accrue to a small or large number of individuals, as GDP per capita does not reflect wealth distribution. As a well-being measure, GDP does not account for factors such as how chasing a consumption-based lifestyle can make people poorer in terms of time, health and social/community relationships. When GDP is used as a well-being measure it privileges the world of the market without taking into account the real costs of producing the goods and services that are bought and sold in the market place.

The above factors discredit GDP as a well-being measure. More recently, use of GDP as an economic objective has also been questioned. GDP has serious short-comings as a measure of production with the way it accounts for technological innovation, customization, change in the quality of goods, and accurately valuing publicly provided goods and services (D. Coyle, 2014; Stiglitz et al., 2009). Changes to accounting for financial risk in the System of National Accounts (1993) have even been identified as contributing factors to the 2008 global financial crisis (D. Coyle, 2014; Gleeson-White, 2014). Coyle (2014) argues that GDP is best suited to an earlier era when the economy was based on standardised physical goods. It is not a good tool for today's complex economy that is a product of global supply chains, an increasing number of intangible goods, rapid innovation, digital services, and major sustainability issues. Instead new well-being measures are needed to promote government policies that extend beyond production and consumption (Barbier & Markandya, 2013) and take into account that we now operate in a 'full world' where population is growing, resources are depleting, and wastes are accumulating. There is an increasing sense of urgency for new government directives that embrace a broader set of policy objectives than standard GDP, welfare-economics and cost benefit analysis (Costanza, Hart, et al., 2012;

Costanza et al., 2014; H. Daly, 2010; Ragnarsdottir et al., 2014; N. Stern, 2006; Stiglitz et al., 2009).

However, the challenge is that alternative well-being measures lack universal acceptance and the ability to influence policy (Parris & Kates, 2003; Stiglitz et al., 2009). As a consequence, reliance on GDP as a proxy for well-being continues. When used for this purpose GDP is always interpreted on the basis of 'the bigger the better'.

3.1.1 International Initiatives to move beyond GDP

Recognition of the need for complements to GDP to help direct government policy to benefit the long-term interest of a nation's citizens has gained some traction, though this is not universal and remains easily side-tracked.[34] As far back as 1973 the OECD stressed that "growth is not an end in itself, but rather an instrument for creating better conditions of life" and that "increased attention must be given to the qualitative aspects of growth, and to the formulation of policies with respect to the broad economic and social choices involved in the allocation of growing resources" (OECD, 1973, p. 3). Recent major initiatives that have received international attention include:

1. The 'Commission on the Measurement of Economic Performance and Social Progress' sponsored by the French government to look into the appropriateness of current economic measures for long-term decision-making (Stiglitz et al., 2009).
2. The 'Beyond GDP' project led by the European Commission to investigate and report on the types of measures needed in the 21st century (European Commission, 2009).
3. The Organization of Economic Cooperation and Development's active involvement in ways to measure progress in societies (OECD, 2013a, 2014).
4. The United Kingdom Office for National Statistics produced the country's first set of indicators to help people understand and monitor well-being in 2014 (Office for National Statistics, 2014).

[34] Progress on developing alternative measures was jettisoned by the 2008 financial crisis, where effort was diverted into propping up GDP. Wilson & Tyedmers (2013) discuss this issue from a Canadian viewpoint.

5. 'The Future We Want' from the Rio+20 summit (United Nations, 2012). This document sets out the need for indicators to capture the independencies between goals, and not consider economic, social and environmental goals as separate. It calls for indicators to provide information pillars to trade-offs and synergies in an interrelated and holistic manner (UNU-IHDP and UNEP, 2014).
6. 'Transforming our world: the 2030 Agenda for Sustainable Development' (United Nations, 2015) puts eradicating poverty and improving the health of the planet as priorities for the next 15 years. To achieve these, 17 Sustainable Development Goals and 169 targets have been set. The goals are considered to be integrated and indivisible as well as balancing social, economic, and environmental objectives. Understanding the linkages and integrated nature of the goals and targets is considered critical to their achievement. The declaration makes a commitment to the development of broader measures of progress that complement GDP.

As what is measured becomes what is prioritised in policy, finding acceptable well-being metrics is critical. The dominance of GDP accounting methods orients government policy towards consumption and the production of goods and services, as opposed to broader well-being goals. As pointed out by Stiglitz et al., (2009, p. 47), "What we measure affects what we do; and if our measurements are flawed, our decisions may be distorted". Kenneth Galbraith said the same thing, "if it isn't counted, it tends not to be noticed" (cited by Boyle & Simms, 2009, p. 41). Effort therefore needs to go to making the unquantified aspects of well-being more visible so they are taken into account.

3.2 ALTERNATIVE WELL-BEING MEASURES

It is generally accepted that well-being requires a different metric to measures of production such as GDP. There are many different disciplinary perspectives on well-being, including: Health (e.g. Steptoe, Deaton, & Stone, 2015); Sociology (e.g. McLanahan & Adams, 1987); Philosophy (e.g. Griffin, Crisp, & Hooker, 2000); Religion (e.g. Donahue & Benson, 1995); Economics (e.g. Dasgupta, 1995; Frey & Stutzer, 2002a); Psychology (e.g. Diener, 1984; Easterlin, 2003); Politics (e.g. Przeworski, Alvarez, Cheibub, & Limongi, 2000), Ecosystems (e.g. Millennium Ecosystem

Assessment, 2003). Each of these perspectives addresses the subject of well-being, applying their own epistemology; however, it is not possible to cover them all in the context of this dissertation.

While many alternative well-being measures have been advanced at the community, national, and international level (Hall et al., 2010), no measure or conceptualisation has gained general acceptance (McGillivray, 2007; Stiglitz et al., 2009). The selection of alternative well-being measures briefly reviewed in this section is grouped into monetary measures and non-monetary measures. The list of alternative well-being measures reviewed here is not exhaustive. For a more comprehensive coverage refer to Stiglitz et al., (2009).

3.2.1 Monetary measures

Well-being measures that are expressed in monetary units are popular because they communicate in the language of economists and allow comparison with GDP.

3.2.1.1 Genuine Progress Indicator[35]

The Genuine Progress Indicator is intended to better account for the positive and negative impacts generated by economic activity (Cobb et al., 1995; Forgie & McDonald, 2013; Kubiszewski et al., 2013; Lawn & Clarke, 2006; Talberth & Cobb, 2010). Foundation tenets of genuine progress incorporate the beliefs that well-being is an entitlement of both the present and future generations, equitable distribution is desirable, and pollution and resource exhaustion are economic liabilities (H. Daly & Cobb, 1994). Genuine Progress Indicators are constructed by adjusting the personal consumption component of GDP to reflect inequality in society. Following this, positive adjustments are made for additions that enhance well-being, which can include childcare, housework, volunteering, services delivered by public infrastructure, and, in some cases, the services from household capital. Negative costs associated with economic production are deducted, for example, the cost of pollution, loss of leisure time, destruction of ecosystems, and the depletion of resources. In some measures adjustments are made for the net change in the international debt of a country. The

[35] The Index of Sustainable Economic Welfare (ISEW) developed by H. Daly & Cobb (1989) is a similar measure. Much of the ground-breaking work was done by Redefining Progress based in San Francisco.

Genuine Progress Indicator attempts to ascertain the real level of well-being for the accounting period. It does this by including current contributions to well-being that are ignored, and incorporating deferred costs (such as resource depletion and long term environmental damage) that impact on future well-being. The relationship between GDP and the Genuine Progress Indicator is likened to that between a company's gross and net profit. If the financial cost of environmental degradation and social breakdown is greater than the value of economic production genuine progress declines.

The USA states of Vermont (http://www.vtgpi.org/about.html) and Maryland (http://www.dnr.maryland.gov/mdgpi/) have legislated the Genuine Progress Indicator as an official reporting statistic. A Dynamic Genuine Progress Indicator (DGPI) was developed for the State of Maryland to model future impacts of proposed policy and investments on the economy, environment and society. This dynamic tool allowed policymakers and citizens to simulate how investment and decision changes to one indicator flowed on to impact other indicators. The model ran scenarios for green jobs, smart growth, and clean energy. The webpage (http://www.dnr.maryland.gov/mdgpi/model.asp accessed in 2011) with this model was no longer available as of August 2015.

A DGPI Accounting Model was constructed as a research project for the Nelson Tasman regions and Motueka Catchment of New Zealand (Cole & Patterson, 2013). The DGPI calculates an annual figure to compare with GDP using a 28 sector Economic Input-output model. Energy, ecosystem services and biophysical data are linked to each sector. The socio-economic data included covers population and labour.

Genuine Progress Indicators have been constructed for more than 17 countries (Kubiszewski et al., 2013). Recent legislative changes in the USA demonstrate a greater acceptance of the Genuine Progress Indicators; however, there are serious issues with practical use (D. Coyle, 2014; Neumayer, 2007; Stiglitz et al., 2009). These issues include: use of inappropriate valuation methods; substitutability between capitals; the limited and selected categories that are included; lack of 'convention' and data quality (Dietz & Neumayer, 2006; Forgie, 2007; Kubiszewski et al., 2013); and the treatment of inequality (Barbier & Markandya, 2013).

3.2.1.2 Inclusive Wealth

This measure differs from others as it focuses on the asset base that determines well-being, as opposed to the outcomes that reflect well-being (UNU-IHDP and UNEP, 2014). The inclusive wealth index is a stock rather than flow based measure. Human capital, which is measured by the skills and education of the population, accounted for 54% of inclusive wealth in the UNU-IHDP and UNEP 2014 report, which analysed 140 countries between 1992 and 2010. Produced capital, which measures manufactured capital such as roads, buildings, machines, and equipment, accounted for 18% of the total. Natural capital, which includes sub-soil resources, ecosystems, and the atmosphere, accounted for 28% of inclusive wealth. Social capital aspects, such as knowledge, institutions, culture, and religion are treated as enabling assets that support the other capitals (UNU-IHDP and UNEP, 2014) and are not included.

The monetary value put on inclusive wealth is calculated as the sum of the social (or shadow) prices multiplied by physical quantities for each capital type. The three capitals, summed and divided by population, determine the wealth of a country per capita. For a country to be on a sustainable trajectory there needs to be growth in inclusive wealth if the population is increasing. Data for 1992–2010 for the 140 countries identify population growth and natural capital depletion as the main causes of loss of wealth. Inclusive wealth utilises scenario analysis to make connections across the various capital stocks and quantify impacts on the different capital stocks.

The 2014 report (UNU-IHDP and UNEP, 2014) shows that for the period 1990–2010, there was positive growth for 85 out of 140 countries and a small overall increase in world wealth. A big increase in produced capital (a similar trend to GDP) and small increase in human capital was offset by a large loss of natural capital.

A limitation of the reporting is the selectiveness of data. As an example, health, which is a very significant component of human capital and the wealth of nations, is excluded as it swamps the other aspects (UNU-IHDP and UNEP, 2014).

3.2.1.3 Adjusted Net Savings (or Genuine Savings)

The World Bank calculates and reports Adjusted Net Savings (ANS) (previously known as Genuine Savings) as part of their World Development Indicators (The World Bank, 2007). To ensure future actions and opportunities are not compromised by present day behaviour, ANS requires the sum of wealth passed on in the form of capital to be at least as great as that inherited.

ANS first estimates gross savings from investment in human-made physical capital. The depreciation of fixed capital is then deducted and education expenditure (investment in human capital) added. Estimates for the depletion of natural resources and pollution damage (including on human health) are subtracted to give ANS. If ANS is greater than zero (as measured in $US), a country is supposedly investing for the future. However, even if the value of ANS is positive, this is not a guarantee the economic welfare currently enjoyed can be sustained in the long term (Lawn, 2006).

An ANS value of less than zero means a country is diminishing its total capital base. Persistent negative results indicate a country is on an unsustainable path (Schepelmann et al., 2010). By failing to compensate for the depletion of natural capital and/or human capital the ANS has shown that some countries have become poorer while at the same time increasing their GDP (Lawn, 2007; The European Commission et al., 2007).

3.2.2 Non-monetary measures

Non-monetary well-being measures collect data in both monetary and non-monetary units and overcome commensuration issues through indexing.

3.2.2.1 Human Development Index

The Human Development Index (HDI), developed in 1993 by the United Nations Development Programme, is a socio-economic indicator used to report the development of nations worldwide. The index covers health (measured by life expectancy), knowledge (measured by adult literacy rates and education enrolment ratios), and standard of living (measured by GDP per capita) (UNDP, 2007). Reports also cover issues such as gender equity (UNDP, 2007).

The HDI composite measure does have limitations. It does not cover the environment, and excludes many aspects of economic and social development, however despite this it is a useful first proxy in the assessment of well-being and progress (Shmelev, 2011). It is generally regarded as more relevant for developing than developed countries.

3.2.2.2 Genuine Progress Index (GP Index)

The Genuine Progress Index (GP Index) calculates a composite index (or multiple composite indices covering the economic, social, environmental and cultural aspects), by aggregating indexed values for each indicator included (Coleman, 1998; Michalos et al., 2011). This multi-dimensional measure aggregates data trends for activities with a beneficial impact on well-being with the data trends for activities with a negative impact. To enable a comparison, GDP is also indexed. Specific disadvantages of the GP Index include: (1) subjectivity of the benchmark year selected; (2) outlier data points impact on the index scores; and (3) replacing raw data with an index results in the loss of important real information (Durling, 2011).

3.2.2.3 OECD Better Life Index

The focus of the Better Life Index is to measure progress in society based on the aspects of life that are important to people and impact their quality of life. The OECD framework has three distinct domains: material conditions, quality of life, and sustainability. The 11 topics the Better Life Index uses to measure well-being and progress are: Education (measured by years in education, educational attainment, student skills); Jobs (measured by personal earnings, long-term unemployment rate, employment rate, job security); Health (measured by life expectancy, self-reported health); Income (measured by household net financial wealth, household net adjusted disposable income); Safety (measured by assault rate, homicide rate); Community (measured by quality of support network); Worklife balance (measured by employees working very long hours, time devoted to leisure & personal care); Environment (measured by air pollution, water quality); Life satisfaction (measured by happiness surveys); Housing affordability (measured by dwellings without basic facilities, housing expenditure, rooms per person); Civic engagement (measured by voter turnout, consultation on rule-making).

The indicators combine both subjective and objective measures. The measures are indexed, and each topic is reported separately. An interactive web-site allows people to rank topics by importance to them (www.oecd.betterlife). No attempt is made to understand the relationships between indicators.

3.2.2.4 Happy Planet Index

The Happy Planet Index (HPI) combines both objective and subjective measures in an index to show the ecological efficiency of supporting well-being (measured in good health and positive life experience) in a given country. The index combines three statistics: high life expectancy using data from the Human Development Index Report; high life satisfaction using data from Gallup Polls and World Values Surveys; and low ecological footprint with data from the Living Planet Report. Life satisfaction (scored between 1 and 10) is multiplied by statistical life expectancy. The product is then divided by the ecological footprint, which is an indicator for the land area needed to sequester the greenhouse gas emissions generated by a country in the year. The result is an HPI measure that can be compared with other countries.

A criticism of the HPI is that it does not consider the many social and economic criteria likely to involve direct relationships between a political action and happiness, such as education. The name of the index has also led to misunderstandings about what the index measures (Schepelmann et al., 2010).

3.2.2.5 Gross National Happiness

Gross National Happiness (GNH), developed in Bhutan in the early 1970s, attempts to quantify well-being in psychological terms. Rather than focusing on economic indicators, the GNH measure values societal and individual happiness. Data come from surveys of representative samples of the population carried out at the household level. Respondents score 124 variables grouped into nine domains (psychological well-being, time use, community vitality, cultural diversity, ecological resilience, living standard, health, education, and good governance).

According to Barbier and Markandya (2013) this index provides useful information for different groups within Bhutan society, and allows comparisons within the country for given groups. Low education levels and limited access to information mean this subjective well-being measure does not provide a comprehensive evaluation of societal well-being. The large number of Bhutanese refugees being resettled in other countries indicates GNH is not achieving the well-being goals to which it aspires.

On the positive side, GNH has been used for economic and political decision-making and has facilitated both social and environmental progress. Happiness is seen as a collective responsibility and is an explicit criterion to be considered in development projects and programmes.

3.2.2.6 Fondazione Eni Enrico Mattei (FEEM) Sustainability Index

FEEM is a not-for-profit Italian research institution that studies sustainable development and global governance. Since 2009, FEEM has biennially released its sustainability index (FEEM SI) assessing worldwide progress in well-being. FEEM SI models economic activity with environmental and social impacts and allows evaluation of policies that alter economic activity.

The FEEM SI is an index of 23 indicators from social, environment, and economic themes, which are normalised (with a ranking between 0 and 1) before comparison and aggregation. The FEEM SI is a model-based index where future trends are simulated to 2030 based on a recursive-dynamic computable general equilibrium model. All the indicators are projected into the future and aggregated into the composite trend. This allows evaluation of the impacts of policies for the indicators that are modelled (http://www.feemsi.org/pag/methodology.php).

Disadvantages of this index include the small number of indicators that can be modelled in a restricted economic framework and the limited social aspects included. As with all composite indicators, weighting can be questioned (Barbier & Markandya, 2013).

3.2.2.7 Social Progress Index

The Social Progress Index (Porter & Stern, 2014) focuses on a country's social performance. The framework aims to capture an interrelated set of key factors that, when aggregated, will provide an indicator of social progress. The approach uses indexing and aggregating to rank countries. The Social Progress Indicator is based on three questions:

1. Does a country provide for the basic human needs of its population (nutrition and basic medical care, water and sanitation, shelter, personal safety)?

2. Are the building blocks in place for individuals and communities to enhance and sustain well-being (access to basic knowledge, access to information and communications, health and wellness, ecosystem sustainability)?
3. Is there opportunity for all individuals to reach their capabilities/full potential (personal rights, personal freedom and choice, tolerance and inclusion, access to advanced education)?

The selection of the 3 dimensions, 12 components, and 54 indicators was achieved using an iterative process involving the review of literature and input from the Social Progress Imperative Advisory Board (S. Stern, Wares, Orzell, & O'Sullivan, 2014). While it only aims to be a Social Progress Index, a short-coming as a well-being measure is that many of the components measured are directly dependent on a healthy economy and environment and this is not taken into account.

3.2.3 Assessment of well-being measures

For the purpose of this research the ten measures described here were evaluated for how well they met the following criteria. These criteria are selected from the working definition requirements for well-being and sustainable well-being set-out in **Error! Reference source not found.**. The four criteria were chosen for their relevance to the issues that arise and questions of interest when linking indicators in a sustainable well-being system.

1. Is the measure of well-being weak or strong? A strong measure of well-being requires no aggregation of the four capitals.
2. Is the cover of well-being issues comprehensive, with all four capitals represented?
3. Is the well-being measure forward or retrospective in orientation? Indicators that record only what has happened and take no account of what might happen are less useful for decision-making. A retrospective view provides an accurate way of describing *what* happened and *when*, but little insight into *how* things happened and *why*. A well-being measure to explore alternative ways of viewing the world and different future options needs to be forward looking.
4. Are relationships between indicators and time delays taken into account? It is known that the four capitals impact on each other and any change to a capital

will have feedback effects in the overall well-being system. Time factors in indicator measures allow differentiation between short-term issues and long-term impacts.

Table 3-1: Assessment of well-being measures

	Strong or weak well-being measure	**Four capitals covered**	**Forward/retrospective oriented**	**Interlinks indicators and time delays**
Genuine Progress Indicator	Weak measure. Indicators are reported aggregated.	Yes.	Both. Mainly retrospective. The DGPIs have projection capability.	Mostly no. DGPIs link indicators and allow for delays
Inclusive Wealth	Weak. Indicators aggregated.	Social capital not measured as treated as an enabling asset. Health is excluded from Human capital.	Both. Retrospective – based on past trends Forward-looking with scenarios.	Yes, with scenarios
Aggregated Net Savings	Weak. Aggregated total.	Social excluded.	Retrospective – based on past trends.	No
Human Development Index	Weak. An aggregated composite measure.	Natural and Social capital not included.	Retrospective – based on past trends.	No
Genuine Progress Index	Weak as does not take stocks into account. Data are aggregated.	Yes.	Retrospective –based on past trends.	No
OECD Better Life Index	Strong, as each topic is separately reported. Does not take account of stocks.	Yes.	Retrospective – based on past. No trends are produced.	No
Happy Planet Index	Weak. An aggregated measure.	Social not covered. Indicators for other capitals limited.	Retrospective – based on past trends.	No
Gross National Happiness	Weak. Aggregated measure.	Yes	Retrospective – based on past trends.	No
FEEM Sustainability Index	Weak. Aggregated and weighted index.	Yes–society covers human capital indicators.	Forward projections modelled.	Yes
Social Progress Indicator	Weak. Index is aggregated.	Economic excluded. Natural capital limited.	Retrospective – based on past trends.	No
Total	Weak:9 Strong: 1 (OECD)	All four capitals:5 Not four capitals: 5	Retrospective: 8 Forward: 2	Linked:2 Some linked:1 No links: 7

Based on the four criteria selected to rate the 10 different well-being measures reviewed, it can be concluded that most are weak well-being measures. All but one, allow substitution as they aggregate into a composite measure.

Only half the measures used indicators that covered all four capitals. While every indicator framework is normative by definition and applies its own value base to select indicators, for a well-being measure all four capitals should be covered.

Most measures are retrospective in that they report what has happened in the past rather than provide insights into how things happen, or might happen, and why.

A positive is that three of the measures attempted to fully link indicators. In all cases the linking was done using expert-based dynamic modelling with the capability to simulate scenarios.

The assessment of well-being measures as set out in Table 3-1 to some extent explains why there has been limited use and uptake of new well-being metrics. From this evaluation it is relatively clear that despite the considerable effort put into the development of alternative measures short-comings still exist

Some of the many issues that need to be resolved before a transition away from the use of GDP can take place are discussed next.

3.3 CRITIQUE OF ALTERNATIVE WELL-BEING MEASURES

There are many reasons put forward for the lack of adoption of alternative well-being measures to GDP (see for example, Lawn & Clarke, 2008; Seaford, 2013; Stiglitz et al., 2009). Some of these have been covered in the discussion of how GDP is institutionalised. This section provides additional explanations for the lack of up-take under the sub-headings of: (1) Theoretical and conceptual issues; (2) Data issues; and (3) Construction issues.

3.3.1 Theoretical and conceptual issues

The most regular criticism of the alternative well-being measures proposed is that they lack a sound theoretical foundation. According to the OECD, “The quality of indicators and the soundness of the message provided are dependent on the framework and data used and the transparency of the entire construction process" (2008, p. 137). Without a sound framework the measures are the product of the producers who decide which items to include in the index, and which valuation methods to employ (D. Coyle, 2014; Forgie, 2007; Talberth et al., 2007).

Lack of theoretical foundation can lead to well-being measures becoming 'absent referent' (Fricker, 1998), with the original intent lost in a plethora of uses that devalue usefulness in a similar way to the injudicious use of GDP. An example of this is the frequent reference to well-being measures as measures of sustainability. Most well-being measures, as illustrated in Table 3-1, do not require the maintenance and growth (to keep pace with population increase) of each capital; instead, they aggregate information that masks depletion – a serious concern with natural capital. In addition, current well-being is boosted by the depletion of non-renewable resources and other forms of capital, while costs are passed on to future generations (Dietz & Neumayer, 2006; Lawn, 2005; Neumayer, 2003).

Measures that depend on GDP (such as the Genuine Progress Indicator, or Human Development Index) are slated for modifying/using a measure that is in itself flawed (Dietz & Neumayer, 2006; Ferrer-i-Carbonella & Gowdy, 2007; Kahneman & Sugden, 2005). It is also argued that the adjustments to GDP are very selective, with a focus on deductions and not positive additions for the many innovations that have increased well-being beyond the transacted monetary measure (such as antibiotics, air-conditioning, Skype, and the internet) (D. Coyle, 2014).

An additional issue is that the 'values set' that underpins well-being is subject to change through time, meaning any formalised theoretical foundation will need to be updated regularly. This makes trends difficult to detect.

3.3.2 Data

Data availability often drives the indicators included in a well-being measure. This can be a problem, especially in the environmental area where data are lacking. Data inadequacy forces practitioners to make heroic assumptions to include critical items (Lawn, 2005; Talberth & Cobb, 2010). The argument is that this is better than excluding components that cannot be readily quantified and thereby assigning them zero value

(Ford, 2010). Discounting is also a contentious issue. Questions arise concerning intergenerational equity when environmental damage is discounted and deemed to be of less importance because impacts are in the future rather than the present (Shmelev, 2011; N. Stern, 2006). There are also fundamental issues at the micro data level where converting into constant dollars/indices requires equivalence. As an example, while the number of jobs may be comparable between years, the productivity of a job can differ.

Compatibility issues arise between locations. As comparability influences the usefulness of well-being measures, how benchmarks are set is important. If contrasts are to be made between nations the lack of international standardised data collection systems becomes an issue. Even methods using international data sets have been shown to be unreliable if there is no vetting system (Andrew & Forgie, 2011). A key focus of the well-being debate is what appropriate components to include. Using a participatory approach is often proposed as the solution, but this introduces the issue of scale, as what is important for well-being at the local level may not extrapolate to regional, national or global scales.

Data uncertainty means that well-being measures are best constructed to provide a range of feasible values; however, this can be problematic for decision-makers who prefer to work with definite numbers. Lack of data documentation can also be an issue with well-being measures, making replication and validation difficult.

3.3.3 Construction issues

Significant issues arise when constructing well-being measures. System boundaries (i.e. spatial boundaries, temporal boundaries, definitional boundaries) are a major issue as they determine what to include or exclude. Boundaries are particularly problematic when calculating environmental costs. For example, New Zealand does not produce or consume a high volume of ozone-depleting substances, but, due to geographical location, the nation's well-being is impacted by damage to the ozone layer caused by other countries (Forgie & McDonald, 2013). Similar boundary issues arise with greenhouse gas emissions where benefits derived differ from the location at which costs are incurred (Andrew & Forgie, 2008). A country/region's well-being can be artificially boosted by externalising costs and exporting negative impacts to other locations (Posner & Costanza, 2011).

When well-being is being assessed, the selection of an appropriate base year from which to measure or index is of concern. With indexing, problems also arise with scale equivalence. For example, adult literacy always has a scale between 0% and 100%, whereas an income scale can change over time (McGillivray, 2007). The valuation of components such as loss and damage to terrestrial ecosystems and loss of soils rely on accurately determining the point in time when the marginal benefits gained from depleting (or drawing down) an environmental good/service become less than the marginal costs incurred as a result of the loss of that resource (Forgie & McDonald, 2013). This involves understanding lag and cumulative effects, a difficulty compounded by data paucity. Indicators like inequality are measured using a baseline chosen by the researcher, or the use of the lowest level in the study period. Neither option resolves the issue of what level of income inequality is in the best interest of societal well-being. Inappropriate baselines lead to inappropriate policy decisions (Posner & Costanza, 2011).

Placing an economic value on social and environmental goods and services is problematic for measures that are monetary-based. Assumptions made for estimation are strongly contested (Costanza et al., 2004; Costanza & Faber, 2002; Lawn, 2003; Neumayer, 2000). Frequently, value depends on implied or imputed benefits/costs – but sometimes these do not exist. The benefits derived from ecosystem services, such as climate regulation, cannot be adequately captured by pseudo-markets due to the intangible nature of the services provided. In this case, economists typically rely on non-market valuation techniques such as willingness-to-pay, hedonic pricing, and travel cost methods. The limitations associated with the application of these methods are well-known and long-standing (Henderson, 1994). Additionally, many commentators question the appropriateness of putting an economic value on cultural, social and environmental goods and services that are 'invaluable' or of significant passive value (i.e. have intrinsic, option, existence and bequeath value).

In many cases, the indexes combine incommensurable items measured in different units. For example, the Human Development Index uses 'GDP' measured in US dollars per capita, and 'life expectancy' measured in years. Combining to an aggregate measure requires standardisation, as there is no compatible exchange rate between these two indicators. Statistical methods, such as indexing relative to upper and lower limits can be used, but caution is needed with the measure. Combining incommensurable measures makes it hard to say what they exactly indicate, and thus makes it difficult to make decisions based on them. Issues associated with composite indicators are well documented (Boyle & Simms, 2009; Costanza, 2000; Jollands, 2003; OECD, 2008; Rijpma, 2014), including: item aggregation leading to information loss (Schepelmann et al., 2010); no limits to substitution; obscured trade-offs; arbitrary use of weights; and aggregation bias, which can lead to distorted interpretations. Despite these acknowledged problems, the use of aggregated indices is common-place because such indices are easy to communicate.

If indicators are not aggregated, policy usefulness can be limited. A large number of indicators make it difficult to identify trends, hard to compare and weigh-up the many individual components, and increases the time required for interpretation. An intermediate step is to use a 'dash board' or 'traffic light' approach. While the composite indicator problems still apply, trade-offs become more visible. The 'dash board' or 'traffic light' system allows thresholds for the different components and highlights problems even if the overall score is high (Boyle & Simms, 2009).

Insufficient information on feedback loops and lags in the well-being system limits the value derived from alternative well-being measures. While the literature referred to the need to interlink indicators, this is not generally done. Finding ways to interlink indicators remains on the research agenda (L. Hunt, MacLeod, Moller, Reid, & Rosin, 2014). As a rule, a report card approach[36] is used, which treats each variable as independent and not impacted by changes in the other variables. This compounds categorization, pigeonholing and hierarchical problems. Relationships in the well-being system are lost and cause-and-effect impacts ignored.

3.4 BARRIERS TO UPTAKE OF 'BEYOND GDP' WELL-BEING MEASURES

The proliferation of different well-being measures contributes to the problem of finding an accepted alternative to GDP (McGillivray, 2007). Each measure has strengths

[36] An example is the social well-being tool produced by Statistics New Zealand. This interactive tool allows a user to choose what aspects he/she thinks are important to life satisfaction and the model then aggregates data to show the effect on the life satisfaction of NZ adults.

and weaknesses. At present, comparison across countries remains difficult and no single alternative has emerged to stand alongside GDP (Barbier & Markandya, 2013; Stiglitz et al., 2009).

For most of the population living in the developed world, current living standards are sufficient for policy priorities to move towards improving people's non-material lives. The biggest issue is the lack of political commitment to the establishment of a 'convention' for measuring well-being. Such a process is needed to decide what to measure and how. Once agreed on, systems can be established for data collection.

GDP had similar issues to well-being measures when first instigated. The System of National Accounts was established by the 1944 Bretton Woods agreement and the procedure for calculation has been refined over a 70-year period. This proves measurement problems are tractable given enough time and effort. Effort to overcome problems will pay dividends if it results in a 'compass' that will point societies in the right direction (Boyle & Simms, 2009).

In 2012 the United Nations Secretary-General's High Level Panel on Global Sustainability concluded that a shift in thinking was required for the up-take of 'Beyond GDP' measures, and that without the political process embracing the sustainable development paradigm, no progress would be achieved (United Nations Secretary-General's High-Level Panel on Global Sustainability, 2012). Galvanising change is a challenge when vested interests are opposed (Costanza et al., 2004; Wilson & Tyedmers, 2013). As far back as 1994, Hazel Henderson (1994, p. 5) wrote "[Gross National Product] GNP/GDP indexes have become a chief bulwark sustaining existing power centres in both business and government and their academic apologists. Such measurements underlie the entire Western/industrial way of life. "

Canada, a long-time leader in the development of alternative well-being metrics, has not been able to make political progress (Wilson & Tyedmers, 2013). In fact, the opposite can be concluded from decisions to no longer report key environmental indicators, which "imply a strategic interest to restrict tracking and reporting data that may contradict the current Conservative government's economic priorities" (Wilson & Tyedmers, 2013, p. 196).

The European Union-funded "Bringing Alternative Indicators into Policy" (BRAINPOoL) project identified key barriers to using alternative 'Beyond GDP' indicators to guide policy, and some of the ways these barriers could be overcome. The report identified 12 barriers, grouped into the 5 main categories listed below (Seaford, 2013). The research undertaken for this dissertation endeavours to contribute towards overcoming the **bolded** barriers in the following list:

1. Resources: **budget constraints**, data problems. [The budget constraint barrier is overcome by developing a method that is inexpensive to use, as described in Chapter 6].
2. Resistance: natural conservatism, beyond GDP is redundant.
3. Communication: **ignorance or confusion about indicators**, lack of a strong narrative that engages the public, language and politics associated with 'Beyond GDP'. [The opportunity to discuss and analyse indicators and how they interconnect is part of the method set out in Chapter 6].
4. Complexity: lack of a single Beyond GDP indicator with the salience of GDP, and, the **complexity and uncertainty of Beyond GDP policy analysis**. [Considering indicators from a systems perspective moves policy analysis into the complexity/uncertainty realm, as shown in Chapters 7 and 8].
5. Organisation: lack of 'indicator entrepreneurs', **difficulty of working across silos and organisations**, human resource shortages. [The workshop process brings people together, as described in Chapters 7 and 8].

Broader research on resistance to moving away from GDP found scientists and academics, especially with neo-classical backgrounds, were wary of 'Beyond GDP' indicators. Social scientists and younger people were more likely to view progress indicators positively. BRAINPOoL listed barriers specific to the policy/context area as:

- Inability to align with political agendas and problems that can be solved
- Ideology and concern regarding greater government 'interference'
- Vested interests are likely to be displaced if alternative measures are used
- Lack of public pressure and public interest

The use of GDP as a measure of well-being has created a strong reinforcing feedback loop. As noted by Coyle (2014), GDP primacy is challenged more by those who regard it as a symbol of what is wrong with capitalist market economics than by politicians and economists. When well-being is conceptualised in terms of higher incomes, technological innovation, and higher living standards, achieving these goals provides an incentive for more of the same. That well-being deteriorates as a result of life becoming more stressful, less healthy, and actually unenjoyable is overlooked (Boyle & Simms, 2009).

An argument can be made to use methodological pluralism when it comes to well-being. Methodological pluralism acknowledges that there are many viewpoints, and that each viewpoint has its inherent biases and flaws. As no one viewpoint is absolute, a more holistic perception of an issue can be gained by considering multiple viewpoints, being conscious of the advantages and disadvantages associated with each, and conceding the need for different approaches (Norgaard, 1989).

3.5 SUMMARY

This chapter outlined why GDP is not an adequate measure for sustainable well-being – despite being used for this purpose. It then provided a review of selected measures promoted as alternatives to GDP. These were analysed according to whether they are a weak or strong well-being measure, comprehensively cover all four capitals, are forward or retrospective in orientation, and take into account the relationships between indicators.

To explain why there has been limited uptake of 'Beyond GDP' measures, the main difficulties associated with their use were summarised. The multitude of different measures and lack of understanding of the relationships between the indicators in the measures are prominent weaknesses. There are also resourcing, communication, complexity, organisational and political barriers.

The next chapter introduces systems theory and the systems approach. The purpose is to provide the theoretical foundations for the method developed to interlink indicators presented later in Chapter 6. This is a prerequisite to determining whether understanding the relationships between indicators can add value and progress sustainable well-being, which is tested in the empirical part of this dissertation contained in Chapters 7, 8, and 9.

4 A SYSTEMS APPROACH TO SUSTAINABLE WELL-BEING

Chapter 2 identified that sustainable well-being can be conceptualised as an integrative part of a system. The system comprises interlinked objective and subjective measures and the fours capitals that need to be sustainably managed. In Chapter 3 it was shown that the majority of well-being measures are not structured as interlinked systems but use the more conventional approach of aggregating indicators. The research aim of this dissertation is to find out if understanding the relationships between indicators adds value and progresses sustainable well-being. This requires finding ways to make the relationships between indicators visible. The question of interest considered in Chapter 4 is: "Can a systems approach be used to understand the relationships between well-being indicators?"

Systems thinking and system approaches provide the theoretical foundation for the method developed to link indicators in this dissertation. This chapter, therefore, builds a case for why systems theory is considered appropriate to use and then describes the family of methods available.

The purpose of using a systems approach[37] for sustainable well-being is to provide a new option that is progressive in design and can guide future action. First, a definition of 'a system' is provided as a reference point. As Chapter 2 conceptualised well-being as a complex system, the distinguishing characteristics of complex systems and the issues that arise when complexity is underestimated are explained. Next, systems thinking and system dynamics are described. Finally, the various systems concepts applied to develop interlinked thinking in Chapter 6 and applied in the case studies (Chapters 7, 8 and 9) are set out.

[37] System-based approaches are used in many disciplines from education to operations research, as well as in many types of modelling, e.g. System Dynamics and Dynamical Systems.

4.1 A SYSTEM

The Oxford Dictionary[38] defines a system as “[A] a set of things working together as parts of a mechanism or an interconnecting network; a complex whole”. The following definitions (Table 4-1) emphasise that a system is the interconnectivity of its parts in an organised way. How parts are ordered and arranged impacts on the performance of the system. Systems are also defined by their aim. The aim determines the system identity and the value a system provides, and thereby what needs to be maintained and improved.

Table 4-1: Definitions of a system

Meadows (2008, p. 11) (italics original)	A system is an interconnected set of elements that is coherently organized in a way that achieves something … [it] must consist of three things: “*elements*, *interconnections*, and a *function* or *purpose*”.
Bossel (2000, p.338)	the term ‘system’ usually refers to a self-organizing system responding to challenges from its system environment.
Deming (1997, pp. 95–96)	…a system is a network of interdependent components that work together to try to accomplish the aim of the system. A system must have an aim. Without an aim there is no system.
Northrop & Connor (2013, p. 17)	…a group of interacting, interrelated, or interdependent elements (also agents, entities, parts, states) forming or regarded as forming a collective entity.
Kim (1999, p. 19)	systems must have a purpose that is a property of the system as a whole, not of its parts. For a system to carry out its purpose optimally all parts must be present, and it is not possible to remove a part without affecting functioning.
Maani & Cavana (2007, p. 7)	A system is a collection of parts that interact with one another to function as a *whole*. However, a system is not the sum of its parts – it is the product of their *interactions* (Ackoff, 1999) … A system subsumes its parts and can itself be part of a larger system.
Hanneman (1988, p. 27)	in the broadest sense of the term, a ’system’ is nothing more than an ordering or relating of a set of parts into a whole. A ’system’ is composed of both the ’things’ (’elements’ or ’parts’) and the relation among them.

With a system, the requirement of each part is to contribute its best to the system overall, rather than maximise its own goals (Deming, 1997). The better the parts work together, the more likely it is that there are wins/gains in the long term (Deming,

[38] From: http://www.oxforddictionaries.com/definition/english/system. The origin of the word is the Greek sustēma, of which the base elements are sun- ‘with’ and histanai ‘set up’.

1997). It is therefore acceptable for parts of the system to operate at less than maximum to achieve the overall system effectiveness.

The aim (i.e. long-term purpose, vision, mission, goals) of the system needs to be specific and clear. It is common for the aim of a system to change over time as all living (social) and natural systems evolve. This change in aim can be either temporary or permanent (Kim, 1999) and may necessitate a change in the boundary of the system (Deming, 1997). With systems, the bigger the boundaries, the more difficult they are to manage, but the greater the potential benefits (Deming, 1997).

Systems are characterised by uncertainty, change, and surprise, therefore, working with systems requires flexibility and adaptability. Variation is considered a natural part of a system's functioning and by definition dynamic systems do not work towards equilibrium (Capra, 1996). All the parts of the system require the flexibility to move within the threshold limits set to enable the system to adapt and change over time. To survive systems need to maintain flexibility and evolve. Feedback loops are the mechanisms by which systems retain stability and adaptability.

With systems, the accepted wisdom is that genuine knowledge can only be achieved by studying the system as an entity. To achieve system improvement continuous study of the whole is required to generate new knowledge (Deming, 1997). The learning process from a systems perspective involves: 1) forming a theory; 2) making predictions based on past experiences (the reference trend); 3) testing the theory; and (4) checking results (Forrester 1975; Deming, 1997; Sterman, 2000). This process needs to be iterated under different conditions to increase knowledge and understanding of the system. It is the discrepancies between formal and mental models that stimulate improvements in both (Forrester, 1985).

By putting information into a systems framework the objective is to see general patterns not shown otherwise. This allows us to gain understanding of the effects distanced in time and space from their causes. The human mind cannot easily assess the consequences associated with complex, interrelated components within a system (Forrester, 1994; H. Simon, 1972; Sterman, 2002). Our minds can conceptualise that the systems exists, but the patterns it produces are often beyond our ability to assess without a computer model, particularly once feedback loops are involved. The relationships in a system and the complex patterns of interconnections are revealed via feedback loops. How the feedback loops in the system operate can provide potential learning about both the system and the consequences of intervention in the system.

According to Deming (1997), the greater the interdependence between components, the greater the need is for communication and cooperation between them. Failure to comprehend interdependence is a major source of unintended consequences. The more interdependence there is in a system, the more complex it becomes.

4.1.1 The development of systems thought

Early instigators of systems approaches include Ludwig von Bertalanffy who in 1945 published *"General Systems Theory"* (von Bertalanffy, 1945), where he describes a "logical-mathematical field which deals with the new scientific doctrines of wholeness, dynamic interaction, and organization" (Gray & Rizzo, 1969, p. 7).

For von Bertalanffy the impetus for general systems theory came from the inadequacy of the then universal physics-based model used for science (Gray & Rizzo, 1969). von Bertalanffy argued that neither biology nor the behavioural sciences could be understood using a mechanistic approach and instead advocated for the use of model building and abstract generalisations.

von Bertalanffy was interested in studying concepts of goal and purpose. He focused on the living, human aspects of systems and combined organismic biology (which recognised living organisms are organised entities and need to be treated as such) and his theory of open systems.[39] Whether dealing with living organisms, or a society, there was a need to consider notions "of wholeness, growth, differentiation, integration, hierarchical order, dominance, control, competition, centralization, leading part, finality, equifinality and others"[40] (Gray & Rizzo, 1969, p. 12).

---

[39] von Bertalanffy drew attention to the difference between closed and open systems, noting that physics only deals with closed systems (Hutchins, 1996).

[40] Equifinality describes how regulating systems can get to the end or goal in a number of different ways and reach different ends from the same start point (Hutchins, 1996).

Important contributions from general systems theory include the notion of complexity (Ashby, 1958), and its integrative rather than compartmentalised method. von Bertalanffy was concerned at the time – a concern that still remains – that science was becoming too fragmented and scientists were losing the ability to communicate and synthesise knowledge.

General systems theory was not the only development occurring in the field of systems at this time. Gray & Rizzo (1969) list other research that occurred in parallel with the development of general systems theory:

- Operations research: where systems are studied as they are found in business. Upshots include inventory allocation, queuing, sequencing, routing, replacement search theory.
- Cybernetics: developed to describe organisational complexity and focus on the science of communication and control. Upshots include information theory.
- Mathematical General Systems Theory: that fuses mechanistic and organismic approaches and utilises the advantages of each. Upshots include set theory, decision theory, organisational theory system analysis, systems design, systems engineering.

4.1.2 Complex systems

Systems that are complex are characterised as being made up of many parts that are related and interdependent. Complex systems co-evolve by adapting over time in response to changes in their environment.

Intervention in a complex system is not a trivial matter and can result in unexpected outcomes that may be beneficial, adverse or have no effect. The outcomes are not easily predicted, as the synergistic effects of the parts can produce unforeseen behaviour by the system. Unexpected dynamics, often referred to as the 'law of unintended consequences' (Northrop, 2011; H. Simon & Cilliers, 2005), or 'counterintuitive behavior' (Sterman, 2000; 2002) results in policy action that is ineffective (Dörner, 1997; Meadows, 1982). One of the main reasons for studying complex systems is to better understand in advance the potential counterintuitive, indirect effects of interventions in order to avoid or mitigate them (Forrester, 1973; Wolstenholme, 2003).

Most social and natural systems on which humans rely are complex systems. The extent of system complexity is a function of the number of interconnections and the number of different variables, as set out in Figure 4-1. A low number of variables not highly linked can be described as a ‘simple’ system. A system with more variables that are not highly linked is a ‘complicated’ system. A few variables with a large number of linkages quickly become ‘confounded’, with the interactions between variables driving the system behaviour. A large number of variables that are highly interlinked are a ‘complex’ system.

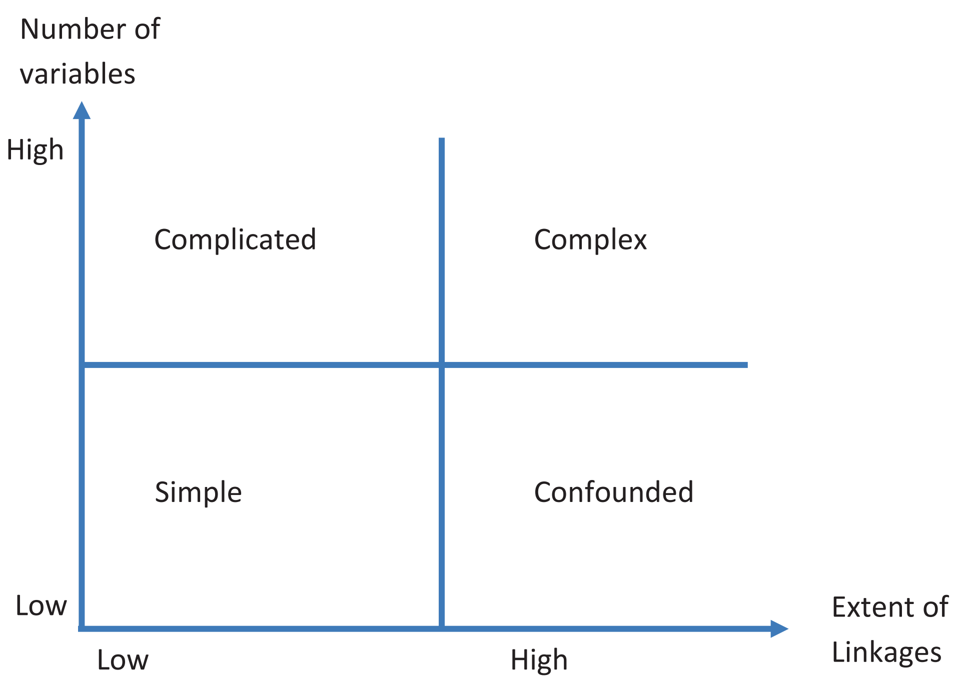


Figure 4-1: How variables and linkages combine to form complex systems. (Own diagram.)

The general pattern with systems is that as they evolve they increase in complexity (Holling, Gunderson, & Ludwig, 2002). As the number of system components increases, the pattern of interrelationships between components gets more elaborate.

Factors such as globalization, ecosystem exploitation, population growth, increased diversity, travel, migration, technological developments, etc., increase the number of relationships. All these factors are interrelated, and impact on each other, and, as a result, complexity grows.

With complexity, routine decisions become dynamic in nature as each component is capable of acting in multiple ways depending on the chain reaction. As a consequence, major decisions in complex systems are far reaching. This can mean a sequence of decisions is needed rather than one decision, as decisions are interdependent, and the context of the decision changes with each decision made (Karakul & Qudrat-Ullah, 2008).

According to Shmelev (2011) insights into policy implications are only possible through understanding the links between different parts of a system and the emergent properties of that system. If the community, or decision-makers, do not like a specific trend, the scope for making change is likely to be constrained or amplified by the relationships in the system. Making interrelationships visible and explicit is a way to show what is driving trends and how to best address change (Kim, 1999).

4.1.3 Issues associated with underestimating complexity

There has been significant research into people's inability to deal with complex, dynamic systems (see among others Bossel, 1998; Dörner, 1997; Kahneman, 2011; Karakul & Qudrat-Ullah, 2008; Meadows, 2008; Norman, 1983; Senge, 2006; Senge, Smith, Kruschwitz, Laur, & Schley, 2008; H. Simon, 1972; Sterman, 2000; Vester, 2007). The research signals that humans simplify problems for a range of reasons, including: time pressures, imperfect knowledge, intuitive reaction, lack of cognitive ability to deal with multiple factors, misperception of risks, etc. There is a tendency to draw on past experience and implement a previously successful method, despite a change in circumstances or to block out information that does not confirm the proposed solution. Furthermore, when an individual tries to mentally project into the future, it is done in a linear rather than a dynamic way. A linear projection extrapolates the present into the future, whereas a dynamic approach makes allowances for feedback loops and time lags. The lack of ability to deal with complex problems results in people falling into 'logic traps'. Dörner (1997) identifies the main traps as:

- failure to state and prioritise specific goals and inability to re-prioritise goals when events change
- under-estimating the side-effects of interventions and not anticipating potential long term consequences
- making short-term decisions based on linear projections of the current situation
- dealing with isolated problems rather than the system
- spending too much time on irrelevant areas where decision-makers feel comfortable and not overwhelmed
- not allowing a sufficient period to account for time lags between interventions and effects, resulting in over-steering and overreacting. When feedback loops and time lags are not understood, stronger action is applied when no immediate effect occurs. This can require stronger corrective action and cause instability in the system
- decision-makers believing they understand the system and interfere rather than allow a system to self-regulate.

Complex systems are challenging to function in and, as Dörner (1997) identified, require a long-term perspective. The difficulties arise because dealing with the immediate problems brings greater rewards, and slowly occurring changes can be ignored or adapted to without their being incorporated into immediate decisions.

An additional consideration is that complexity is not always recognised. Senge et al., (2008) argue that most people react at the 'events' level because this is most apparent. However, events are usually just the 'tip of the iceberg' and to act appropriately requires finding out the underlying causes which requires understanding of patterns/trends, systemic structures, and mental models. Senge et al., (2008) present the way humans explain reality as a four-step process (see Figure 4-2).

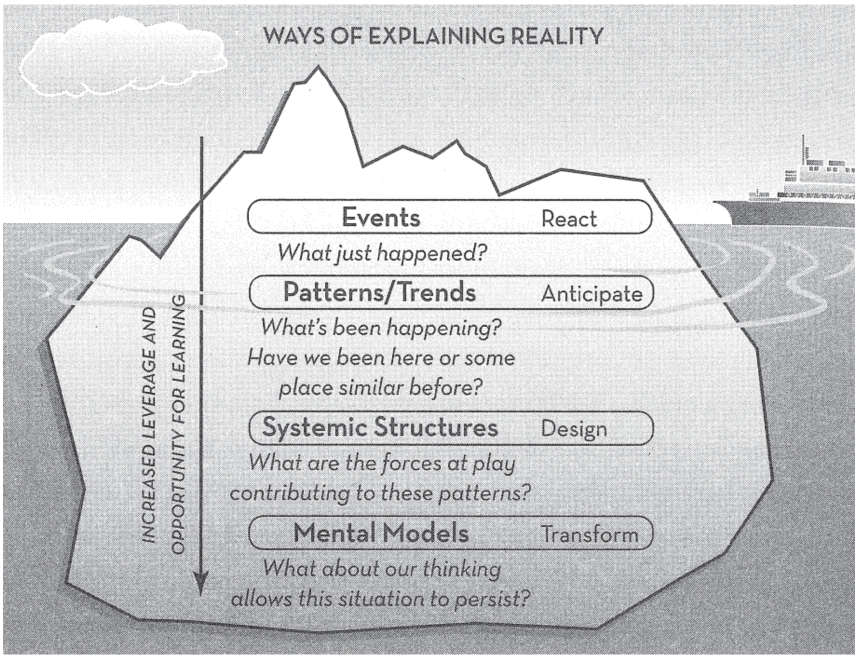


Figure 4-2: Ways humans can explain reality. (Source: Senge et al., 2008, p.174).

Complex problems cannot be tackled by working at the event level or using linear thinking (Forrester, 1961; Mirchi, Madani, Watkins, & Ahmad, 2012; Richmond, 1993; Sterman, 2000). Learning about complexity and systems theory allows people to better understand the events, patterns/trends, systemic structures and mental models. As you move down the iceberg and understanding grows, more opportunity is provided to identify the best leverage points to bring about desired change, and thereby function, in complex systems.

4.1.4 Working with complex systems

How complex systems are managed is a different process from the management of simple or complicated systems. With complex systems there is a high degree of uncertainty concerning the actions needed and what the potential outcome will be. This justifies an adaptive management approach of adjusting practices in response to new learning, while at the same time ensuring adjustments stay in line with the overall system goal.

Working with complex systems can benefit from collaborative processes that bring people together to discuss, learn and improve the way the wider system is trending (van den Belt, 2004). Collaboration can help understand the events that are associated with systems, and the structure of the system itself (as in Senge et al., 2008), but collaboration does not necessary mean that issues will be resolved or addressed. The response is not to seek a 'fix' to the immediate problem, but instead to look at the different leverage points where a change can improve the overall system. This is counter to the 'Fordist' industrial model of specialisation and 'one-right-answer' thinking. Table 4-2 sets out how Allen (n. d.) interprets the different decision-making roles in the different types of systems.

Table 4-2: Different leadership tasks for different systems

Complicated systems	Complex adaptive systems
Role defining–setting job and task descriptions	Relationship building–working with patterns of interaction
Decision making–find the 'best' choice	Sense making–collective interpretation
Tight structuring–use chain of command and prioritise or limit simple actions	Loose coupling–support communities of practice and add more degrees of freedom
Knowing–decide and tell others what to do	Learning–act/learn/plan at the same time
Staying the course–align and maintain focus	Notice emergent directions–building on what works

Source: (Allen, n.d.)

Trying to manage, control, or manipulate complex systems is very challenging (Dörner, 1997; Forrester, 1973; Grosskurth, 2007; Meadows, 2009; Sterman, 1994), and skills and tools are therefore increasingly needed, given reality is not a set of independent problems (Hjorth & Bagheri, 2006). To minimise unintended consequences, ways to describe, analyse, and model relationships need to be found to build understanding and explore in advance the potential impacts of change (Maxwell, 2005).

4.2 SYSTEMS METHODS

There is ample evidence that complex systems require different approaches to the commonly favoured reductionist analytical approach (Capra, 1996; Dörner, 1997; Kim, 1999). Sterman (2000, p. 5) asserts that successful ways to learn about complex systems require:

(1) "tools to elicit and represent the mental models we hold about the nature of difficult problems;

(2) formal models and simulation methods to test and improve our mental models, design new policies, and practice new skills; and

(3) methods to sharpen scientific reasoning skills, improve group processes, and overcome defensive routines for individuals and teams."

The System Dynamics computer modelling and simulation fraternity have developed methods to promote better understanding of complex systems and operate more effectively[41] (Kim, 1999; Maani & Cavana, 2009; Meadows, 2008; Senge, 2006). These methods include systems analysis, causal loop diagrams, stock and flow diagrams, flow charts, and simulation models/system dynamics. They can be categorised broadly under the headings 'systems thinking' and 'system dynamics'. A systems thinking approach is qualitative and is used in this dissertation to better understand the interlinking of the indicators used to measure well-being. What follows is first a description of systems thinking and justification for its use. Then, the method of system dynamics and the value it provides are discussed. As systems thinking and system dynamics approaches are complementary (Maani & Cavana, 2007; Wolstenholme, 2004) they can be applied separately or together.

4.2.1 Systems thinking

Systems thinking emphasises relationships in the structure of a complex system as these determine system behaviour. The more visible and better understood the relationships, are the greater the insight into how things work in the real world. The typical human response to the difficulty of working with a complex system is to draw tight boundaries around an individual part and specialise. For instance, in academia there has been a proliferation of disciplines and multiple journals are published that cater for very narrow discourses that use highly specialised language. This proliferates the Anglo-Saxon reductionist science and multiple disciplinary perspectives (Noll, 2002). However, taking apart and analysing in detail does not provide the information that shows the patterns of organisation that allow the collective to function (Buchanan, 2002) and systems cannot be understood by more detailed information about the parts as stated by Capra (1996, pp. 29-30):

[41] Systems methods are used in many different areas. In planning, for example, the Soft Systems Method developed by Peter Checkland (1993) is used. Other areas include ecology, computing, operations research, social sciences, psychiatry, and medicine. This list is far from exhaustive.

> The great shock of twentieth-century science has been that systems cannot be understood by analysis. The properties of the parts are not intrinsic properties, but can be understood only within the context of the larger whole. Thus the relationship between the parts and the whole has been reversed. In the systems approach, the properties of the parts can be understood only from the organization of the whole. Accordingly, systems thinking does not concentrate on basic building blocks but rather on basic principles of organization. Systems thinking is ‘contextual’, which is the opposite of analytical thinking. Analysis means taking something apart in order to understand it; systems thinking means putting it into the context of a larger whole.

Building on this view, it can be argued that the complexity of modern day problems requires expertise in both analysis and synthesis, as well as the development of appropriate tools to achieve this. Both synthesis and analysis are used in systems thinking (Hutchins, 1996).

The definitions in Table 4-3 provide an overview of what systems thinking sets out to achieve.

Table 4-3: Systems thinking definitions

Kim (1999, p. 19 & p. 2)	Systems thinking is a school of thought that focuses on recognizing the interconnections between the parts of the system and synthesizing them into a unified view of the whole… Systems thinking is a way of seeing and talking about reality that helps us better understand and work with systems to influence the quality of our lives.
Maani & Cavana, (2009, p. 7)	Systems thinking is a scientific field of knowledge for understanding change and complexity through the study of dynamic cause-and-effect over time. Complexity underlies most business, economic, natural and social systems. System thinking has three distinct but related dimensions: paradigm, language and methodology, …
Maani & Cavana (2000, p. 135)	… is the ability to see things as a whole. It combines the art of seeing interconnections and the science of explaining complexity.
Richmond (1994, p. 6)	Systems Thinking is the art and science of making reliable inferences about behaviour by developing an increasingly deep understanding of underlying structure.
Sterman (2000, p. 4)	Systems thinking – the ability to see the world as a complex system, in which we understand that "you can't just do one thing" and that "everything is connected to everything else."
Meadows (2008, p. 2)	Systems thinking helps us manage, adapt, and identify the wide range of choices we have. It is a way of thinking that gives us the freedom to identify root causes of problems and see new opportunities.
Senge, (2006, pp. 68 & 69)	Systems thinking is a discipline for seeing wholes. It is a framework for seeing interrealtionships rather than things, for seeing patterns of change rather than static "snapshots." … is a discipline for seeing the "structures" that underlie complex situations, and for discerning high from low leverage change.
Capra (1996, p. 30)	Systems thinking is synthesis and 'contextual', rather than analytical thinking. Analysis means taking something apart in order to understand it; systems thinking means putting it into the context of a larger whole.

Systems thinking uses tools such as causal loop diagrams and behavior-over-time graphs to visualize and build the skills required to identify and understand relationships and feedback loops in systems. Such tools are helpful as dynamic learning is difficult (Sterman, 2000), and people, while not inherently incapable, usually lack the requisite expertise to think in systems (Forrester, 1975; Karakul & Qudrat-Ullah, 2008).

The roots of systems approaches are based in biology, cybernetics, and ecology (Bateson, 1972; Churchman, Ackoff, & Arnoff, 1957; Vester, 1988; von Bertalanffy, 1945). Reservations have been expressed as to how transferable a systems approach that was developed in the natural systems is for social systems (Ulrich, 2005). This view is not shared by everyone and many systems models exist that integrate human behaviour (e.g. Forrester, 1971; Sterman, 2000).

4.2.2 System dynamics

System dynamics involves the construction of quantitative stock and flow models to show accumulation over time and the dynamics that occur as a result of delays inherent in a system. The strength of system dynamics is the model simulation capability that reveals the behaviour of the system over time, and how the long-term effects of an intervention might play out (Ford, 2010; Forrester, 1994; Hürlimann, 2009; Morecroft, 2007; Sterman, 2000). Without simulation, it is argued, it is not possible to demonstrate the logical implications of a model and compare this with reality (Hovmand, 2014; Sterman, 2000). Even if there are significant uncertainties regarding data and how to include soft variables, quantitative models, it is argued add value over and above qualitative models (Ford, 2010; Homer & Oliva, 2001). A quantitative model can be validated against data, which boosts confidence in the model's explanatory powers (Robèrt, 2000; van den Belt, 2004). Regardless of whether the outputs are correct or incorrect simulation models are seen to be useful ways to explore the nature and relationships of a system and provide insights on feedback loops (Robèrt, 2000). Additionally, quantification provides an opportunity to learn about the order of magnitude of different variables, it provides a reality, and is a way to identify gaps in understanding and data (van den Belt, 2004).

System dynamics modelling is a powerful and valuable tool but was not applied with this research due to the large number of variables that influence sustainable well-being. Instead a systems thinking approach is used.

4.2.3 Research rationale

The research approach taken in this dissertation is to provide insights into well-being interactions and behaviour through better understanding of the structure of the well-being system rather than trying to explain phenomena with increased levels of detail and data. Dealing with complexity by using more advanced computing ability and data it is argued is the wrong approach (Dryzek, 2005; Northrop, 2011; Vester, 2007). The resultant flood of information creates both insecurity and confusion, leading to a situation where information is interpreted as knowledge (Deming, 1997; Dryzek, 2005; Northrop, 2011; Senge, 2006; Vester, 2007).

With this research initial efforts to build a system dynamics model of well-being confirmed the findings of Smith (2010) that systems models can rapidly advance to a level of complexity at which understanding breaks down. Figure 4-3 from Robinson (2011) sets out the diminishing returns in terms of accuracy as levels of complexity increase. An additional research obstacle was lack of data on how the various indicators inter-link resulted in the need for a large number of assumptions to be made. This was problematic, as a wrong assumption makes the accuracy of a model decline rapidly.

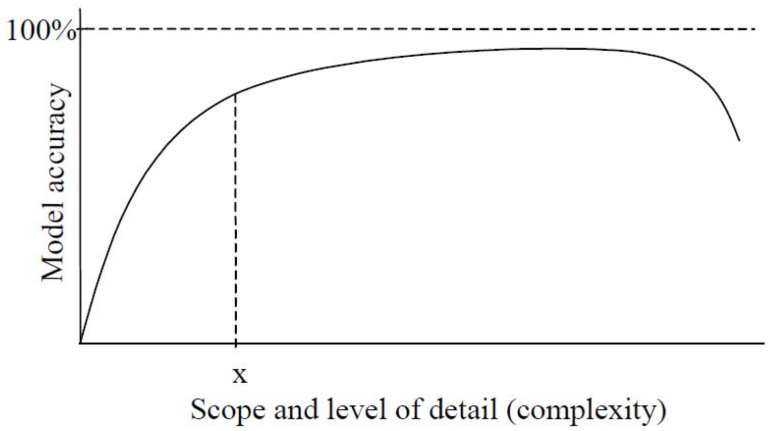


Figure 4-3: Simulation model complexity and accuracy. (Source: Robinson, 2011, p. 1429).

An accepted alternative systems approach is to work with stakeholders through dialogue using a process that is flexible and transparent (Hovmand, 2014; Hürlimann, 2009; van den Belt, 2004; Vester, 2007). This is the approach applied here. It involves implementing a number of commonly used systems techniques that support integrated thinking and learning. These tools are set out in the next section.

4.3 SYSTEMS CONCEPTS FOR INTERLINKING WELL-BEING INDICATORS

This section provides a brief overview of the systems tools that will be used to understand relationships between well-being indicators. First, participatory modelling is discussed as this is a mechanism used to bring people together to evaluate whether or not understanding the relationships between indicators adds value and progresses sustainable well-being. Each person brings their personal mental model to the participatory modelling. This model is based on their own life experiences, knowledge, background, and expertise. Sharing and influencing mental models is a key reason for undertaking a modelling process. The discussion then progresses to causal loop diagrams, which are the qualitative mapping tool widely used in systems thinking and applied in this research. Last, the concept of leverage points and where to intervene in a system is outlined. Despite uncertainty being a characteristic of complex decision-making, the goal still remains to understand the system and the leverage points by which the desired system change can be brought about.

4.3.1 Participatory modelling

Participatory modelling[42] involves working with participants to build models. As any abstract representation of reality can be described as a 'model', participatory modelling can cover activities as diverse as working together to draw maps, to creating large-scale simulation models. Participatory modelling, as described here, is the bringing together of participants to build models using systems thinking or system dynamics tools. As shown in Figure 4-4, there is scope both for participation to occur at different stages of the model building and for variation of the extent to which people are involved.

[42] The many different names used for this decision-support process ware discussed in van den Belt et al., (2010).

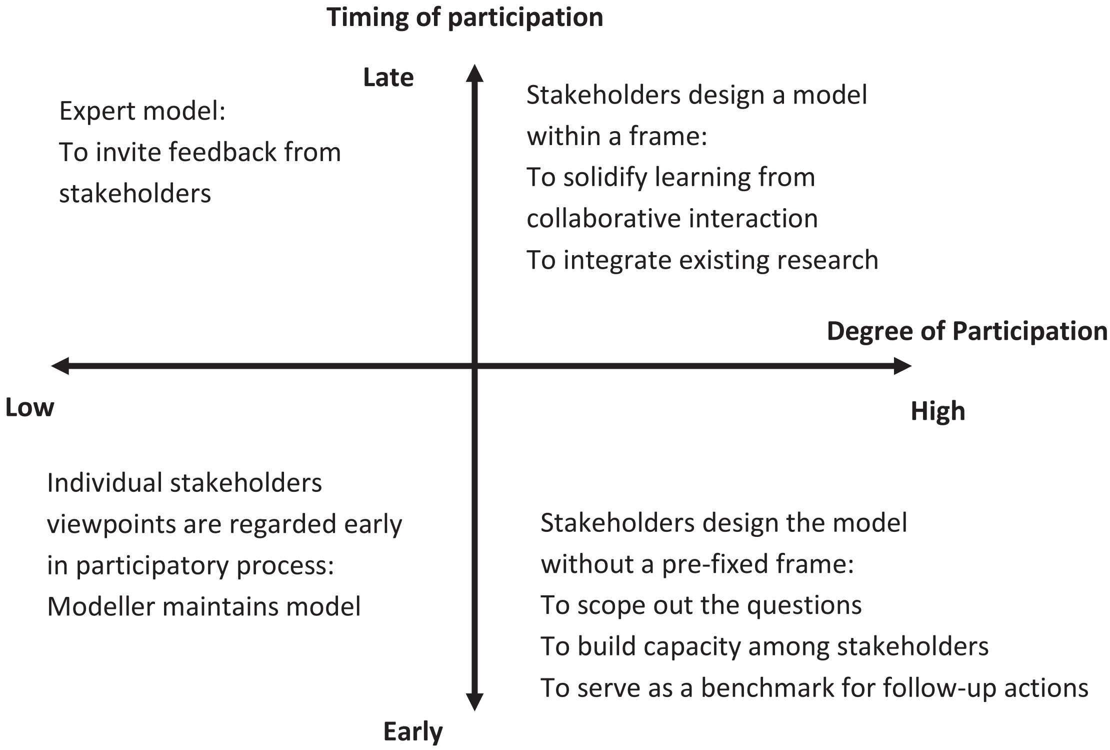


Figure 4-4: Different levels of participation in model building. (Source: van den Belt, 2004, p. 16).

The process of participatory modelling has been reported by researchers as producing a range of positive outcomes (Hovmand, 2014; Rouwette, Vennix, & van Mullekom, 2002; van den Belt, 2004; Vennix & Rouwette, 2000). Based on a study of 12 participants working in New Zealand government agencies (a similar cohort to that worked with for this research) and a qualitative modelling process, Scott et al., (2015) identified the following outcomes as rating[43] as important: commitment to conclusion, communication quality, consensus, enduring mental model change, mental model alignment, effective strategy implementation, enduring alignment, mental model change, persuasive content, power levelling, and insight. These are all desired outcomes from the research undertaken for this dissertation.

4.3.2 Mental models

Mental models are central to systems thinking, systems dynamics, and practice (Doyle & Ford, 1998; Groesser & Schaffernicht, 2012; Maani & Cavana, 2007; Scott, Cavana, & Cameron, 2013; Senge, 2006; Sterman, 2002). According to Doyle and Ford (1998, p. 4):

[43] The rating was relative to ‘neutral’ and ‘mean’ responses.

> Mental models are [thus] the stock in trade of research and practice in system dynamics: they are the "product" that modelers take from students and clients, disassemble, reconfigure, add to, subtract from, and return with value added.

In Forrester's (1961) view, all decisions are based on models that are usually of the mental models kind. The intent of most systems-oriented projects is to enhance mental models to improve the quality of decision-making (Doyle & Ford, 1998; Hyunjung, 2009; Scott et al., 2013).

The concept of a mental model extends back as far as the 1940s, when Craik (1943) described 'thinking' as the manipulation of a person's internal representation of the world. Johnson-Laird (1983, 2001) later recognised the tendency of humans to develop and use mental models to increase their own understanding and solve problems. Seel (2001) supported this and theorised that a mental model serves the purpose of organising facts and the relationships between facts, so that logical assertions can be made to infer consequences and arrive at a conclusion that is valid for the circumstances considered.

There are definite crossovers between these conceptualisations of mental models and those used by the system dynamics fraternity. There is general agreement that mental models are internal and affect how a person acts (Rook, 2013; Senge, 2006; Sterman, 2000) and that they are also abstract representations of situations that individuals maintain in their minds. Mental models are also seen to "reflect the beliefs, values, and assumptions that we personally hold, and they underlie our reasons for doing things the way we do" (Maani & Cavana, 2007, p. 15).

A significant difference is that, from a systems perspective, mental models are considered to be part of a continuous closed loop process where an effect is capable of looping back to influence its own cause (i.e. makes a feedback loop). This involves loop learning and contrasts with how mental models are perceived in other areas – as static, cause-and-effect and event based (Groesser & Schaffernicht, 2012). System dynamics and systems thinking recognise and attempt to deal with the cognitive limits and problems people have when dealing with multiple mental models and dynamically complex systems. A specialised toolkit of qualitative mapping and computer simulation modelling has been developed as a way to access mental models and allow the exploration of the structure of mental models, see how mental models change over time, and provide insight into the reasons for these changes (Hodgkinson & Healey, 2008; Schaffernicht, 2006).

Understanding and sharing mental models can be achieved using both qualitative and quantitative systems (Doyle & Ford, 1998; Maani & Cavana, 2007). The widely accepted definition of a 'mental model of dynamic systems' is that proposed by Doyle & Ford (1999, p. 414):

> a mental model of a dynamic system is a relatively enduring and accessible, but limited, internal conceptual representation of an external system whose structure is analogous to the perceived structure of that system.

Groesser & Schaffernicht (2012) more recently suggested the need to clarify the phrase "whose structure is analogous to the perceived structure of that system". They put forward Figure 4-5 to set out the conceptual structure of the components of a mental model of a dynamic system.

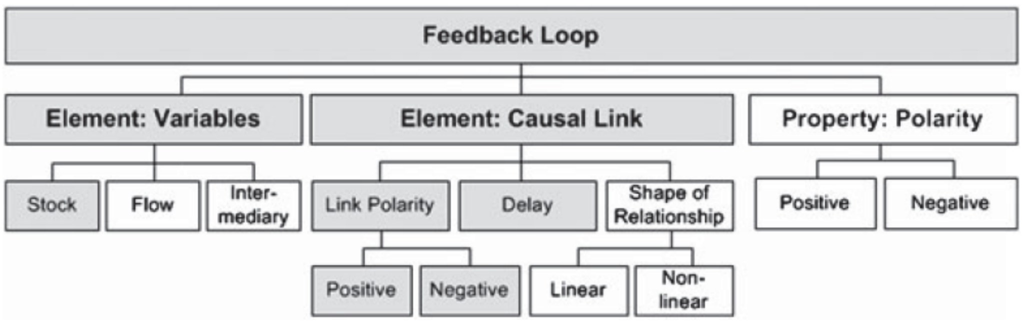


Figure 4-5: Conceptual structure of a mental model of a dynamic system. (Source: Groesser & Schaffernicht, 2012, p. 60).

Note: the grey areas are widely recognised conceptual components in the systems dynamics literature, while the white areas indicate new conceptual components added.

As shown in Figure 4-5, the building blocks of mental models of dynamic systems are considered to consist of variables, causal links with their polarities and significant delays, as well as feedback loops, their polarity and their nonlinearities. It is not necessary for mental models of dynamic systems to account for every conceptual component (Groesser & Schaffernicht, 2012).

Mental models are shaped by one's experience, actions, beliefs, and social and cultural norms. Because understanding is always partial, and intelligence is distributed (Bateson, 1972), from a systems perspective the internal nature of mental models is an issue. There is much to be gained from the sharing of mental models as a means of increasing learning and knowledge (Kim, 1999; Senge, 2006; van den Belt, 2004). The mental models of individuals, according to Forrester (1973), can be characterised as: fuzzy; incomplete (as based on selected concepts and relationships); imprecisely stated, not always correct; and changeable (over time or as quickly as during a single conversation). In addition, they are unable to handle complexity (H. Simon, 1972; Sterman, 2000; Tversky & Kahneman, 1973; Vester, 2007); are vast simplifications that are dynamically deficient (Sterman, 2000), and critically 'mostly wrong' (D. Meadows, 2008).

The positive attributes of sharing mental models are that they 'contain rich information' (Vazquez, Liz , & Aracil, 1996); the interaction and communication between group members provide a group understanding of how a system operates (Hovmand, 2014; Senge, 2006; van den Belt, 2004); and a high level of convergence in mental models is considered more likely to predict behaviour (Druskat & Pescosolido, 2002; Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000). Altering and aligning mental models is a basic requirement for organisational learning (Maani & Cavana, 2007).

4.3.3 Causal loop diagrams (CLDs)

Well-being models become complex very quickly as they cover most aspects of life. The complexity associated with well-being, therefore, calls for 'structural' thinking. CLDs have been identified as a useful tool for this purpose. Systems theory posits that a system's behaviour emerges from its underlying causal feedback structure (Forrester, 1961; Richardson, 1997). In system theory both causal maps and formal models are legitimate ways to make mental models explicit, and test hypotheses about the way we think systems behave (Groesser & Schaffernicht, 2012; Hovmand, 2014).

In a CLD, each link has a causal interpretation that provides a way to conceptualise and communicate the structure of the system. CLDs provide a way of recognising and taking into account feedback loops in a system. Feedbacks are closed loops that start and end at the same point; they are also the structural elements that most determine the stability of a system (Richardson, 1995). A change that occurs at the start point of a feedback loop will impact on all subsequent variables as well as change the start variable itself. CLDs can be used by themselves or as a step towards constructing a simulation model; though stock and flow diagrams are considered better suited for this purpose as they show accumulations and more closely reflect the mathematical representation required for computer simulation models (Hovmand, 2014).

The real world is an interconnected system of causes-and-effects and behaves accordingly. Outcomes are different from those anticipated when each component is studied in isolation. CLDs are an important tool in the system analysis toolkit to better understand the complex relationships in a system (refer to among others: Maani & Cavana, 2009; Meadows, 2008; Senge, 2006). They are used extensively in participatory approaches, and to include stakeholders in the process of model building (Sedlacko, Martinuzzi, Røpke, Videira, & Antunes, 2014; van den Belt, 2004; Videira et al., 2014).

CLDs have many advantages, including the fact they are intuitive to use. They are one of the main tools of systems thinking (Lane, 2008; Schaffernicht, 2010; Senge, 2006) and have their own specific concepts and diagramming language. CLDs are used to increase understanding through 'conceptualisation' of the system being studied. They can also be used to help communicate outcomes for the post-analysis of quantitative models (Lane, 2008; Wolstenholme, 2003).

How Causal Loop Diagrams work

The objective of CLDs is to better understand the causal chain of events. Causal refers to the cause-and-effect relationships between variables in a closed loop that create feedbacks (Ford, 2010; Maani & Cavana, 2007). "The basis of these causal relationships can vary from conjecture to evidence supported by rigorous research" (Hovmand, 2014, p. 2).

When drawing a CLD, variables are linked together if there is a relationship between them, with an arrow to show the direction of influence. CLDs are constructed following specific rules to ensure consistency and precise meaning. Variable names are generic and should not predetermine movement in any one direction. They have a qualitative orientation and are able to increase or decrease. With CLDs, an arrow going from A to B indicates that A causes B. The arrow in a CLD can symbolize either a causal influence, which can be a policy or information link or alternatively an addition or subtraction from an accumulation which is a physical process (Manni & Cavana, 2007). There are four types of cause-and-effect relationships possible between variables in a CLD:

1. The cause *increases* and the effect of the given change is an *increase* (notated with '**+**' or '**s**' to show that change is in the same direction).
2. The cause *decreases* and the effect of the given change is a *decrease* (notated with '**+**' or '**s**' to show that change is in the same direction).
3. The cause *increases* and the effect of the given change is a *decrease* (notated with '**-**' or '**o**' to show that change is in the opposite direction).
4. The cause *decreases* and the effect of the given change is an *increase* (notated with a '**-**' or '**o**' to show that change is in the opposite direction).

When interpreting a CLD, the understanding is that the change that results from the cause to effect is more than it would otherwise have been, had everything else been held in place (Richardson, 1995).

When linked variables form a loop, this is called a feedback, and these show the changes over time (or dynamics) in the system. Loops are labelled according to whether they act to counteract change (usually labelled '**B**' for a balancing or negative feedback loop), or reinforce change (usually labelled '**R**' for a reinforcing or positive feedback loop). A balancing loop has an uneven number of '**-**' or '**o**' in the loop when counted up. A reinforcing loop has an even number or no '**-**' or '**o**' in the loop. Delays are noted (with an // on the arrow) as the effect of these can be significant.

Figure 4-6a is an example of a CLD that shows the impact of pesticide use on horticulture productivity. Figure 4-6b graphs the expected trend over time for horticulture productivity.

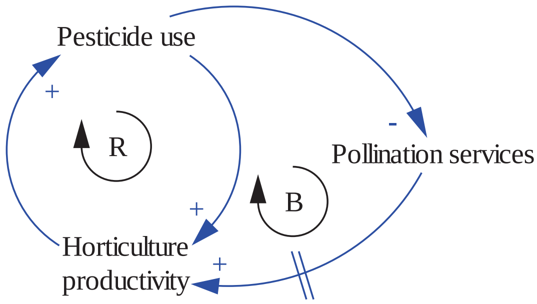


Figure 4-6a: Causal loop diagram example.

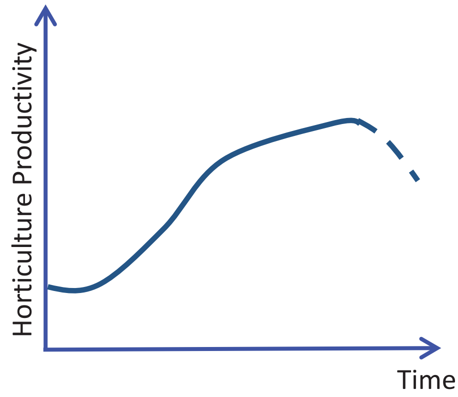


Figure 4-6b: Behaviour-over-time graph example.

Figure 4-6a has two loops. The loop 'R' is a reinforcing loop that says: An *increase* in 'Pesticide use' will *increase* 'Horticulture productivity', which will *increase* the need for 'Pesticide use'. There are no '-' in this loop. The loop 'B' is a balancing loop that says: An *increase* in 'Pesticide use' will *decrease* the 'Pollination services', and after a delay (notated with \\) this will *decrease* 'Horticulture productivity'. There is an uneven number (one) '-' in this loop, which makes it balancing.

The graph (Figure 4-6b) shows what happens to pollination services over time as a result of increased pesticide use. This behaviour-over-time graph shows the expected patterns or trend of a variable over the long as opposed to short-term (Ford, 2010; Sterman, 2000).

With CLDs, polarity (or the direction of influence) can be used to convert structure into behaviour. However, this cannot show how the current stock of a variable influences behaviour and in turn structure (Schaffernicht, 2010). Also, inconsistency with the logic can sometimes occur when an increase (or decrease) does not result in the same effect but rather in a lower level of increase (or decrease). Maani & Cavana (2007) suggest using the terminology of 'add to' or 'subtract from' to avoid this.

The use of CLDs is not unanimously supported. A critique of the use of CLDs is included as part of the Discussion in Chapter 10.

4.3.4 Leverage/intervention points

Leverage points are "points of power" (Meadows, 2008, p. 145) or the places where small changes can result in large impacts/effects on a system (Meadows, 2009). They have long-term impacts that change the system rather than remove a problem symptom (Maani & Cavanna, 2007). Leverage/intervention points are of particular interest in complex system analysis as they often identify places where policy should be directed, and provide insights for decision-making.

The generally accepted systems dynamics theory is that leverage points should reduce the strength of reinforcing loops that produce vicious cycles and promote balancing loops to achieve stability in the system (Lounsbury, Hirsch, Vega, & Schwartz, 2014).

There are many different types of leverage points in a system, with some being more effectual than others (Sterman, 2002). Meadows (1999, 2007) sets out 12 different types of leverage points and ranks their ability to bring about systemic change. They are by order of least effective to most effective as shown in the following box.

The more you advance towards the top leverage point (Level 1), the more resistant the system is to change (Meadows, 2008, 2009) so the more difficult it is to achieve the desired outcome. By the time you reach Levels 1 and 2, a substantial change in values is required rather than marginal changes to an existing paradigm.

As interventions in one area have the potential to have multiple impacts in other areas and at different time scales, having a better grasp of the implications of such changes will increase the likelihood of taking the best possible action. Meadows (2009) suggests that another good reason for understanding a system structure is that it allows altering or inserting new feedback loops, which can be an effective and low-cost option to bring about desired behaviour change.

12 Constants, parameters, and numbers. Meadows believes numbers do not bring about change and are therefore not worth the effort put into collating. Numbers provide information not knowledge.

11 The sizes of buffers and other stabilizing stocks, relative to their flows. Increasing buffers can stabilise a system but making them too big or inflexible slows reactions. As buffers are usually physical entities, they are not easy to change, and therefore, they do not make good leverage points.

10 The physical structure of material stocks and flows in the system. Changing physical structures once in place is difficult, so good design in the first place is important.

9 The lengths of delays, relative to the rate of change in the system. Feedback loops govern the net change in a stock. A delay in a feedback process impacts the net change, as a system cannot respond to short-term changes if it is governed by long-term delays. In systems, delay length is usually difficult to control.

8 The strength of balancing (self-correcting) feedback loops, relative to the impacts they are trying to correct against. Balancing feedback loops work towards a goal and are critical for the long-term welfare of a system. Therefore, knowing the goal, monitoring to detect deviation from the goal, and understanding the self-correcting response mechanism are important.

7 The gain from driving positive feedback loops. Providing interventions that reduce the self-multiplying effects of reinforcing feedback loops requires less impact than strengthening balancing loops.

6 The structure of information flows. Missing information flows are a common cause of malfunction in a system. Identifying missing information flows can provide leverage.

5 The rules of the system and who has control over them is important for the functioning of a system. Therefore, changing the rules can bring about leverage. Rules determine what is included/excluded.

4 The power to add, change, evolve or self-organise the system structure gives the system resilience. Such systems can survive by changing to fit with new balancing or reinforcing loops or rules. For example, social systems can self-organise to create new structures and behaviours and biological systems can evolve.

3 The goals of the system. Understanding the goals of the system and how feedback loops support that goal can provide insights and leverage points.

2 The mindset or deep seated beliefs of how things work (i.e. paradigm), which are the foundation for the system. Paradigms determine the systems goals, structure, rules, delays, and parameters but are unstated because everyone assumes they are known. Paradigms can be changed by building models of systems that allow people to step outside and see the system as a whole.

1 The power to transcend paradigms. There is a need to remain flexible as no paradigm is true. All paradigms are reflections of our limited understanding of an immense and amazing universe.

4.4 SUMMARY

Chapters 2 and 3 put forward the case for why well-being should be conceptualised in a systems framework. This chapter has built on this by providing a background to the type of thinking and tools that can be used with a systems approach. Different methods are required with a systems perspective as component parts can be sometimes connected unexpected ways. More importance is placed on the additional value and information obtained from synthesis and contextual thinking, rather than on the detailed analysis of each individual indicator.

Well-being is viewed as a complex system. Therefore, complex systems theory and the type of problems that arise when complexity is underestimated were introduced. The difference between systems thinking and system dynamics was overviewed and why the qualitative systems thinking approach is preferred for this research discussed. The main reason for this preference is that the complexity associated with well-being as a system makes deducting meaningful insights difficult, as everything is interconnected.

The different tools that can be used with a systems thinking approach were detailed. CLDs were identified as an important tool to better understand complex relationships in a system. They are used extensively in participatory processes to include stakeholders in the process of model-building. A structure such as a CLD makes visible the direct links that are active in a system and provides a way to follow the chain of effects and feedback loops. The positive loops (that reinforce each other in the same direction) and negative loops (that have a self-regulating/absorbing changes/balancing effect) in the system can be identified. As Videira et al., (2014) point out, balancing and reinforcing loops can illustrate path dependence, where changes early in the system lead to those changes being amplified and to the existing system becoming hard to change. CLDs show the nature and direction of the interactions between variables and potential leverage points in the system.

The goals of decision-making are very different for a complex system as opposed to a collection of individual parts. With a systems approach, an overview of the whole system is required before a solution can be sought. Even so, intervention in a complex system needs to be based on accepting uncertainty and change, while also recognising that the system will make adjustments independent of the implemented policy.

This chapter has described tools that can be used to link components working in a participatory context. The next step is to determine what the best components to interlink are when well-being is set in a systems framework. This is investigated in Chapter 5.

5 INDICATOR SELECTION USING A SYSTEMS APPROACH

Chapter 5 considers the question “are there specific requirements that indicators need to comply with when part of a system?” To answer this question, this chapter will compare the usual criteria for selecting indicators for composite or dashboard well-being measures with three methods that select indicators from a systems perspective.

Indicator selection appraisal is an important component of this dissertation as the research question of interest is whether understanding the relationships between indicators can add value and progress sustainable well-being. To answer this question first requires deciding which indicators to link. While the usual practice is to select indicators based on individual criteria, this chapter investigates whether different criteria need to be applied when selecting indicators based on their context as part of a system. Furthermore, if this is the situation, are there general recommendations that can be made?

This chapter starts by defining an indicator, then reviews the standard process used to select indicators to measure well-being trends. Following this selection, some of the issues identified as problematic in this process are noted. Three approaches from the literature for determining indicators to represent a system are then described: (1) The bio-cybernetic approach of Vester (1988, 2004, 2007); (2) The Natural Step approach of Robèrt (2000, 2002); and (3) The Orientor approach of Bossel (1998, 1999, 2000). The specific requirements identified are then compared with the standard indicator selection procedure.

Indicators take on greater importance the more complex our lives become. As noted in previous chapters, there are multiple factors such as globalisation, ecosystem exploitation, population growth, increased diversity, travel, migration, new technology, etc., that add to the complexity of everyday life. The greater the complexity, the more we rely on indicators to make sense of our lives, cope with change in dynamic systems, and ensure we are acting in accordance with our best interests and intentions (Senge, 2008; Bossel, 1998). This heightened dependency on indicators puts more importance on the need to know whether the indicators on which we rely are fit-for-purpose. Understanding the relationships between indicators may increase confidence in the indicators we use. Rigour and transparency in the indicator selection process will improve both the value and scientific credibility of the reported outcomes (Niemeijer & de Groot, 2008).

The indicator literature is extensive and the intention of this chapter is to provide some guidance on how indicators should be selected when they are the component parts of an integrated system, rather providing an exhaustive cover of indicator theory.

5.1 WHAT IS AN INDICATOR

Indicator[44] tracking is the most commonly employed technique to measure changes in well-being. Depending on the context and the goal of the well-being measure, indicators are chosen and monitored accordingly. As noted in Chapter 3, where different well-being measures were reviewed, indicators are generally aggregated to gauge overall well-being.

Indicators are also used extensively for management and policy to assist and guide decisions impacting on well-being. Trends in indicators can be used both to raise awareness of new issues and to evaluate the effectiveness of implemented policy. Indicators also serve as a good performance measure as they allow comparison both within and between countries.

Economic indicators are well established, and have been used since in the 1940s (i.e. GDP. Environmental indicators are more recent. According to Hammond et al., (1995) the Canadian government instigated the development of environmental indicators in the late 1980s to simplify information and improve communication on the state of the

[44] According to (Hammond et al., 1995, p. 1) the word indicator comes from “the Latin verb *indicare*, meaning to disclose or point out, to announce or make publicly known, or to estimate or put a price on”.

environment. Around the same time, the Dutch government[45] undertook similar measures, and started using indicators to report to the public on how successfully environmental goals were being met. A request from the G-7 economic summit in 1989 resulted in the OECD developing environmental indicators.

The term 'social indicators' is traced to Bauer's (1966) edited book with this title. Despite social data being recorded for some time, data were not collated into statistics until the early 1970s. This provided quantitative descriptions of social conditions and trends to direct policy in the USA (Duncan, 1974). Around the same time the OECD initiated similar efforts to use social data to improve policy. The report *"List of Social Concerns Common to Most OECD Countries*" (1973) was a response to the need articulated at the 1970 OECD meeting for increased attention to be given "to the qualitative aspects of growth, and to the formulation of policies with respect to the broad economic and social choices involved in the allocation of growing resources" (OECD, 1973, p. 3). Table 5-1 offers a selection of definitions that describe the roles and purposes of indicators.

Table 5-1: Indicator definitions

Advisory Committee on Official Statistics (2009, p. 5)	An indicator is a summary measure related to a key issue or phenomenon that can be used to show positive or negative change. The evaluative nature of an indicator distinguishes it from the descriptive nature of statistics.
Hammond et al., (1995, p. 1)	[An indicator is] something that provides a clue to a matter of larger significance or makes perceptible a trend or phenomenon that is not immediately detectable.
OECD (2008, p. 13)	An indicator is a quantitative or a qualitative measure derived from a series of observed facts that can reveal relative positions… evaluated at regular intervals, an indicator can point out the direction of change across different units and through time.
United Nations	Indicators provide a simple summary of a complex picture, abstracting and presenting in a clear manner the most important features needed to support informed decision-making.
Patterson and Jolland (2004, p. 319)	… an indicator is not merely a number or a statistic. It is a carefully selected operational measurement of some theoretical concept or idea. It is selected to inform the decisions of a clearly defined audience and attempts to measure the essential characteristics of a concept in the most efficient

[45] Led by Albert Adriaanse from the Dutch Ministry of Housing, Physical Planning, and Environment, who has written extensively on environmental indicators.

	way possible.
Hunt et al., (2014, p. 153)	[Indicators] are used as a vehicle for communicating information in a summary form about issues important to stakeholders. Therefore, the choice of indicators must not only match public and political needs, but also be analytically sound, measurable and easy to interpret.

These definitions show there are many ways to describe an indicator. In general it is agreed that an indicator is intended as a summary measure to show change and inform decision-making.

5.1.1 Indicator and variable terminology

For future clarity, a brief pause to discuss the use of the words ‘variable’ and ‘indicator’ is necessary. The distinction is not always clear in the literature especially in relation to systems.

Bossel (1998) refers to ‘indicator’ to assess the system state. In contrast, Vester (2007) prefers to use ‘variable’ to describe the nodal points in a system that are flexible and change over time as a result of interacting. The word ‘indicator’ is reserved to describe variables that show quick rates of change. Hürlimann (2009) likewise uses the term ‘indicator’ specifically to describe variables that can be measured to show change over time.

The word ‘variable’ can also be used to describe an aggregation of indicators (Vester, 2007; Hürlimann, 2009). It is also possible for an ‘indicator’ to be broken down in more detail, at which point the indicator becomes a ‘variable’. Therefore, depending on the level at which you are operating, the words ‘variable’ and ‘indicator’ can be considered to be the same. Indicators and variables can be either qualitative or quantitative measures. The terms ‘variable’ and ‘indicator’ are used interchangeably in the literature. In this dissertation both words are used to describe the components that interlink in a system.

5.2 INDICATOR SELECTION FOR MEASURING SUSTAINABLE WELL-BEING

As previously discussed in Chapter 2 many different theoretical frameworks have been synthesised that set out the important prerequisites for a satisfying life (such as: Alkire, 2002; Max-Neef, 1995; Max-Neef et al., 1991; Sen, 1999, 2008). As Alkire points out, all such theoretical frameworks are valid. The frameworks have been designed for a specific purpose and this in itself validates the choice of what is, or is not, incorporated into a measure of well-being; each relates to its own context. Constructing universally accepted measures for well-being (akin to GDP for economic growth) is a difficult task as such measures need to provide a unifying alternative vision, while simultaneously respecting the diversity and complexity of well-being (Gasper, 2007).

There is general agreement that well-being comprises both subjective and objective measures and is multi-dimensional in nature. Whether well-being can be captured with a composite measure or a dash board of composite measures is disputed. Gasper (2007) argues that, due to plurality, incommensurability, and the need to consider context and purpose, a single measure for well-being is not possible. That others disagree is shown by the different composite measures to gauge well-being outlined in Chapter 3. Regardless of this debate, indicator selection is a critical part of any well-being measure.

Indicator selection is acknowledged to be a subjective process with different underlying values that influence choice (Costanza, 2007; Bossel, 1998; Kettle, 2006; Alkire, 2002; plus many others). Each society needs to have indicator sets that reflect their unique histories, traditions, governance, environment, and cultures. The potential list of indicators that can be used to track well-being is immense. Alkire lists 39 different well-being measures (included as Appendix 1) that all claim to capture the fundamental, irreducible aspects of living that need to be incorporated into any measure to show how well-being is faring. This is just a small sample of the many in existence. As any reported outcome is dependent on the indicators selected for use, it is possible for very similar situations to be reported differently which is both confusing and misleading (Niemeijer & de Groot, 2008).

While it is accepted that the actual indicators included are likely to vary, the key guidelines that should be adhered to when determining a set of well-being indicators are now put forward.

5.2.1 Key concepts for selecting indicator sets

The extensive literature on indicators provides suggestions for developing a 'set of indicators' to measure well-being. From this literature the following important requirements have been identified:

Conceptual framework: Defining what the well-being concept to be measured is, and why, is the first step in the process of determining a set of indicators. This is followed by demarcation of the conceptual framework to be used. A theoretical framework provides the basis for the selection and combination of the indicators into a meaningful 'fit-for-purpose' measure. The use of a framework structures the indicator selection so that it is not arbitrary (J. Becker, 2010) and provides a yardstick to determine the relevance of the indicators selected, as well as their credibility and interpretability. According to the OECD (2008), the quality of indicators and the soundness of the message provided are dependent on the framework and data used.

Transparency: The selection process for indicators needs to be robust and transparent, which requires that it be clearly established at the outset. This step includes putting in place how the metadata will be documented and how assumptions and limitations will be communicated.

Participatory: Ideally, the indicator selection process is participatory because an inclusive and collaborative process will achieve greater acceptance (McGillivray, 2007, Alkire, 2002). A participatory approach will also ensure a wider range of knowledge sets are considered and the indicator set is more relevant for analytical and policy needs. As indicator development is not an *ad hoc* process, bottom-up participatory processes also require the knowledge input of scientific and management experts (Harshaw, Sheppard, & Lewis, 2007).

Indicator coverage: As both subjective and objective well-being measures are required, both quantitative and qualitative indicators are needed.

Selection criteria: This is required to decide whether an indicator should be included in the set of indicators to measure well-being. Criteria include the type of measure and whether it is an input or independent measure, an output or dependent measure, or a process measure (OECD, 2008). Which indicator to use is determined by the goal. For example, to evaluate improved education the indicator should measure higher levels of literacy (output) rather than increased expenditure on education (input). In the same vein, a well-being measure should be clear as to whether the set of indicators measures means (e. g. literacy) or ends (e. g. life expectancy) and is not a combination of both (McGillivray & Noorbakhsh, 2007). Policy interventions are designed on a basis of means and what needs to be done (Harshaw et al., 2007; Morris, 1979). Ends/outcomes-based indicators are better for evaluating if goals have been achieved (Harshaw et al., 2007; Veenhoven, 1996).

Comprehensiveness of sub-groups: Well-being as a multi-dimensional concept will comprise a number of subgroups. The comprehensiveness of these subgroups is important for the accuracy of the well-being measure. According to the OECD Handbook on Constructing Composite Indicators (OECD, 2008, p. 22), "These sub-groups need not be (statistically) independent of each other and existing linkages should be described theoretically or empirically to the greatest extent possible."

Correlation and compensability: If indicators are to be aggregated they need to be able to produce meaningful and relevant trends that can ideally be compared with other known measures or relevant phenomena (OECD, 2008). To avoid internal contradictions and double counting, the degree of correlation and compensability between indicators needs to be considered and corrected for, or made apparent in the analysis.

Number of indicators: Indicators chosen need to be sufficient to provide a disaggregated picture. This picture must highlight different aspects of life (Gasper, 2007) while at the same time being limited enough to be manageable to use (Lancker & Nijkamp, 1999). Alkire (2002) uses the concept of 'dimensions of human development' to reduce the multitude of variables, while at the same time ensuring important factors are not overlooked. Sen (1999, 2008) does not identify any specific number of functionings (or subset of functionings) as being of critical importance. He argues that with the capabilities approach, selection is value based, and, therefore needs to be made by a transparent process such as public debate.

Reviewable: The extent to which an indicator set can provide time-series analysis needs to be considered. Well-being and the satisfaction of basic needs are relative to time and place. Therefore, indicator sets need a review process to ensure they remain relevant and current.

5.2.2 Criticisms of indicator selection

As exemplified in Chapter 3 there is a proliferation of indicator sets in use to measure well-being. Widespread endorsement of these measures has not been achieved for many different reasons, including the more common criticisms briefly considered below:

The scientific basis for indicator selection is inadequate: A lack of robust procedures for selecting indicators makes the information provided difficult to validate (Bartelmus, 2009; Dale & Beyeler, 2001; Parris & Kates, 2003). Measuring well-being is acknowledged as a difficult task on account of its multi-dimensional nature. While there have been significant advances made in recent years, especially with regard to subjective well-being measures (Costanza et al., 2007), issues still remain with the usability and accuracy of these measures. As a consequence, even recognised well-being measures should be interpreted and used with great care (McGillivray, 2007).

Lack of a theoretical framework: In many instances there is no theoretical framework so the choice of indicators is *ad hoc* and unsystematic (Bossel, 1998; Diener, 1995; Niemeijer & de Groot, 2008; Noll, 2002). When frameworks are used, rather than providing a theoretical justification for indicator choice, they instead present the indicators chosen and show the extent of coverage.

Individualist rather than context-based indicator criteria: When an indicator selection criterion is used, it is predominantly based on the attributes of the individual indicator. This results in the indicator being selected for discrete characteristics, rather than in relation to the context of the system of which it is a part (Niemeijer & de Groot, 2008). As a result, indicators are selected to achieve comprehensive cover of mutually exclusive categories rather than for their ability to provide vital links in the system (Harshaw et al., 2007; Niemi & McDonald, 2004). Multiple guidelines set out the technical characteristics required of individual indicators; for instance, the indicators must be analytically sound, perceptible to change, quantifiable, cost-efficient, policy responsive simple, monitorable, specific, etc. (see as examples; Niemeijer & de Groot, 2008; OECD, 2008; Statistics New Zealand, n.d.). In contrast, when considering a set of indicators how they interrelate through causality needs to be interpreted (Bossel, 2001; Niemeijer & de Groot, 2008). According to Niemeijer & de Groot (2008, p. 23), "An indicator by itself is like a single data point in a graph, if there are no other data points in the graph there is no way of knowing the direction of the slope."

Indicator selection is driven by data availability: When data availability, ease of collection, and measurability are the rationale for selection (Bossel, 1998; Frashure, Bowen, & Chen, 2012; Parris & Kates, 2003), overly dense indicator representation in some areas, and sparse or completely overlooking coverage in other areas, can result. Collection problems lead to issues such as the lack of coverage of capital stocks (required to be maintained for sustained well-being). When data availability is a determinant of indicator selection, quantitative measures rather than qualitative measures take precedence.

Indicators do not measure the concept they are supposed to: Often the indicator used is only a partial or representative measure of the issue being considered, and there are many other aspects that are not taken into account. For example, using the indicator 'employed' with a definition of 'working more than one paid hour per week'[46] does not account for the prevalent problem of underemployment.

Indicators used are based on what has been done in the past: Basing the indicator set on historical practice and regulation is a widely used method for selection (Niemeijer & de Groot, 2008). For example, the indicators for the FEEM Sustainability Index are, "those used in international initiatives and other institutions sourced from relevant sustainability literature" (FEEM, online). Reliance on established templates can also be an issue if the categories used are not appropriate. For instance, with the Genuine Progress Indicator, the subcategories included are not relevant for every country and need to be adjusted accordingly. A common practice is for a range of indicators to be selected using a systematic literature search, then an expert panel evaluates and

[46] http://www.stats.govt.nz/searchresults.aspx?q=how%20many%20hours%20does%20an%20employed%20person%20work%20by%20definition%20in%20nz

selects the best indicators (Bossel, 2001; Muhajarine, Labonte, & Winquist, 2012; Niemeijer & de Groot, 2008; Stordeur et al., 2012). This reinforces continued use of existing indicators.

Boundary and scale issues: Accommodating the full impact of externalities may not be possible but those that have strong localised effects may dictate a community's well-being. It is a challenge to get indicators to characterise a whole system while at the same time being simple enough to monitor and model adequately (Dale & Beyeler, 2001). There is always a tension between selecting indicators broad enough to encompass all situations, without being too broad for use in specific situations.

Indicator sets are determined by developer preference: Indicators are chosen based on the specific expertise and research interest of the instigators. Alternatively, indicator choice is based on issues of concern to government and political groups, relevant policy issues, academic sources, end-users and credibility (Rothman, Robinson, & Briggs, 2002). When indicators are selected to align with policy there can be problems such as lack of theoretical robustness, lack of comprehensiveness, and inconsistency when political goals change (Kulig et al., 2010).

Indicator sets based on consultation lead to 'consensus science': The result is a list of indicators where definitional differences and conceptual validation are downplayed in the interest of getting an agreed common set (Kates et al., 2005). Rather than being the outcome of a rigorous process, the final choice reflects the varied aspirations of those involved (Kates et al., 2005; Vidal-Abarca et al., 2014).

The conceptual framework that meets the desired end result is too narrow: Human well-being comprises social, economic, and environmental factors, so well-being measures should ideally cover each of these. Any arbitrary separation is problematic (Harshaw et al., 2007). If indicators are selected to meet a specific management goal they can align to a problem rather than the well-being system. Many measures do not take into account the contribution of natural capital to well-being. Neither the 'dimensions of human development' presented by Alkire (2002) nor the 'capabilities' approach of Sen (1999) make reference to the contribution of natural capital.

Thresholds are not set: Each indicator should have a threshold and target to guide political and social action, but these are hard to determine. If a systems approach is not used there is a risk that focusing on targets and improvements will promote progress in individual indicators that is contradictory or detrimental to others (J. Becker, 2010).

Static and backward reporting: Indicator sets suffer from being static in nature and not interactive when the system is known to be dynamic (Rothman et al., 2002). As a result, indicator trends are historic, and report on the past rather than project into the future. While the OECD handbook (2008) recommends taking into account the inter-relationships between indicators, this is not generally done because it is difficult (Bossel, 1998).

These criticisms relate to the principal research question of this dissertation, and highlight why finding accessible methods to link indicators is considered important. The multitude of indicators in use is indicative of the confusion and uncertainty about what needs to be measured when it comes to well-being. While the pluralistic nature of well-being may mean there is no such thing as a universal indicator set (Alkire, 2002; Niemeijer & de Groot, 2008), wider agreement on core measures would help the search for alternatives to GDP.

The rationale for placing well-being indicators in a systems framework is to better understand the interrelationship between indicators and their interdependence. Ideally, this will contribute additional knowledge on the well-being system, and, from a policy perspective, indicate if and when to intervene.

5.3 INDICATOR SELECTION FROM A SYSTEMS PERSPECTIVE

While it is frequently acknowledged that well-being indicators are part of a system (Durling, 2011; Michalos et al., 2011) and that linkages need to be taken into account (OECD, 2008), this seldom leads to systems theory being used as the theoretical foundation for well-being indicator selection.

A brief summary of three theoretical methods that have been proposed to determine indicator selection using a systems approach are presented in this section. All three are 'sustainability' rather than 'well-being' focused, as no theoretical approaches to selecting well-being indicators using a systems approach were found in the literature search.[47] The approaches covered are: (1) The Bio-cybernetics method (Vester, 2007); (2) The Natural Step Approach (Robèrt, 2000); and, (3) The Orientor approach (Bossel, 1998, 1999, 2000).

As a precursor to indicator selection, the boundary definition issue is addressed first. There are different types of boundaries and they can change often (Wolstenholme, 2003). Boundaries exist in both physical (e.g. territorial) and non-physical (e.g. accounting, disciplinary) forms. They can be between organisations and the environment, different organisations, or different parts of the same organisations. Mental or cultural divides between individuals also form boundaries.

Application of a systems approach requires strong *a priori* assumptions about what belongs in the system and its domain. A boundary change influences what is included or excluded, who is likely to be impacted, and the facts and information relevant to the system (Ulrich, 2000). Transparent boundary selection is necessary; however, the appropriateness of a boundary judgement can only be determined by those whom it affects (Ulrich, 1987). Reference to data availability or accepted current boundaries is

---

[47] The following searches were undertaken to find literature that provided a theoretical basis for selecting well-being indicators from a systems perspective. The first was a 'Scopus' database search as follows:

1. Keywords Level 1: Wellbeing OR "quality of life" OR "well being" OR "life satisfaction"
2. AND Level 2: system*
3. AND Level 3: indicator w/20 select*
4. AND NOT Level 4: animal

In the subject areas 'Social Sciences' and 'Environmental Sciences', 42 publications were identified. All abstracts were checked, and the full publication read where the abstract was relevant to the search topic. Second was the 'Web of Science': Search was done with as Scopus except NEAR substituted for w/20. Results identified 67 publications in the Social Science subject area. These were checked as per Scopus. Third was 'Discover': Search done as with Scopus, except AND substituted for w/20. Results identified 620 publications in total. Ranked by relevance, the first 100 publications were checked as per Scopus. Fourth was 'Google Scholar": Keywords Level 1: Wellbeing OR "quality of life" OR well being" OR "life satisfaction" AND system* AND indicator. This provided 96,400 results. The 4th result identified the work published by Bossel. In addition to the database search, 175 articles that relate to indicators in the dissertation end note library have been checked.

insufficient, as systems need to include what 'ought to be' there as well as 'what is' there (Ulrich, 1987).

Critical Systems Heuristics (CSH), which combines systems thinking with practical philosophy, is Ulrich's (1987) solution to resolving boundary issues. CSH requires the answering of 12 questions covering four distinct areas (sources of motivation; power; knowledge; and legitimacy) in both the 'is' and 'ought' mode. While it is acknowledged that boundary judgements are subjective, according to Ulrich (2000, p. 258) by answering these questions, "it is possible to unfold the partiality (selectivity) of an assumed system of concern from multiple perspectives, so that both its empirical content (assumptions of fact) and its normative content (value assumptions) can be identified and can be evaluated without any illusion of objectivity".

Once boundary issues are resolved, indicators need to be selected for their ability to comprehensively cover all the key elements of a system, and do so in a way that does not exceed information-processing ability (Vester, 2007; Meadows, 2008; Hürlimann, 2007).

5.3.1 Bio-cybernetics

The underlying foundation for Vester's (1988, 2004, 2007) bio-cybernetics[48] approach is that a system has the same attributes as a living structure, so therefore good systems practice can be based on what happens in nature. The work of Frederic Vester[49] has become more internationally known since the 2007 translation of his book '*The Art of Interconnected Thinking*' into English, and the commercial availability

[48] According to Pangaro (1991), cybernetics comes from the Greek word *kybernetes* meaning the "art of steering" and relates to having a goal and taking action to achieve that goal. The word 'governor' is also derived from the same root. The concept of feedback comes from cybernetics, as to know if you have reached your goal or are getting closer requires information to come back to you. In 1948, Norbert Wiener wrote 'Cybernetics' about the science of control. Powerful descriptions are the most important result for those that practice cybernetics. Models of organizations, feedback, goals, and conversation can all be used to understand the capacity and limits of a system whether it is technological, biological, or social.

[49] Vester (1925–2003) a German professor of biochemistry, and a member of the Club of Rome.

of the systems-based strategic planning software developed by Vester & Hester (1980).[50]

As with nature, the pre-determined goal of any system is to enhance its viability (Vester, 2004). Vester's criteria for system viability is based on eight rules derived from nature: self-regulation, growth independency, orientation to functions, the Jiu-Jitsu principle,[51] multiple utilisation, recycling, symbiosis, and biological design. These rules incorporate the necessary checks and balances for a symbiotic relationship between humans and the environment. In addition, complying with these rules, in Vester's opinion, provides a way to ensure a system is represented comprehensively.

Vester (1988) believes, as did Dörner (1997) and systems theorists like Forester, Meadows, and Senge, that no problem can be solved without understanding the system in which it is embedded. Lack of wider system understanding results in poor goal description that focuses on the immediately visible problems or isolated components, and does not take into account unintended consequences. The typical response is over reacting and intervention, rather than creating possibilities for self-regulation and improved viability.

For Vester (2007) variables chosen to portray a system need to: (1) be quantities that can change; (2) be system nodal points; and (3) allow the interactions between the variables to reveal the structure of the system. To represent a system, variables need to cover a spectrum of activities including economic and environmental factors, as well as the feelings and actions of those active in the system – referred to as spheres of life. Variables also need to cover different physical bases, different dynamic bases, and system-relatedness and control. Detail in one area does not compensate for missing data in another area as the lack of information results in a gap in understanding of the overall system. The number of variables in the system should be minimised, with the ideal number of variables to represent a complex system somewhere between 20 and

---

[50] The software is sold as *Malik Sensitivity Model®Prof.Vester*. The price for a Professional version licence for 5 years in 2013 was €25,000 or $\$_{NZ}$41,000.

[51] Vester describes this as using clever leverage techniques where a small amount of controlled energy can be applied to change the direction of a large force.

40.[52] However, the actual number of variables used is not as critical as their combined composition. The overall combination needs to make the correct links and represent all important variables at a similar level of detail. Understanding of the system is revealed based on pattern recognition (Churchman, 1974; Vester, 2007), therefore the goal is to see the 'face' or pattern of the system rather than be obsessed with the detail – which is not possible with a complex system. When modelling a system, Vester proposes not being concerned with quantitative data, but instead applying 'fuzzy logic'[53] to get a whole picture of the system. The goal is to understand not only the interconnections, but also the strength, nature, and direction of the interaction between parts.

This concept is illustrated in Figure 5-1 where it is possible to recognise Abraham Lincoln without the detail of a full photograph.

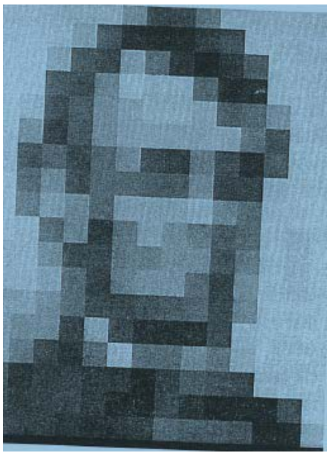


Figure 5-1: Computer portrait of Abraham Lincoln (Source: Vester, 2007, p. 54).

According to Vester (2007) a system can be sufficiently represented if it covers the principle system criteria of the "Criteria Matrix" set out in Table 5-2. At a minimum, all seven spheres of life and their associated matter, energy and information flows must be covered.

[52] According to Vester (2007), the group theory of mathematics and the synergetic studies of Haken (2004) indicate that it is possible to show even very complex systems with a small number of variables as long as the right criteria are covered and the right connections made.

[53] The theory of 'fuzzy logic' is attributed to Zadeh (1965). Fuzzy logic is a way to make use of imprecise knowledge that cannot be measured accurately but where relativities are known such as 'slightly greater than' or 'slightly less than'.

Table 5-2: Vester's Criteria matrix for variable selection

Questions to identify system variables to cover the Spheres of Life	
Participants	Variables that are people related. Who are they? Who is present? The people involved/Participants/Population/the parties, e.g. population structure and dynamics, working people, age structure.
Activities	Variables that are activities. What is taking place? What are they doing? E.g. structure of economy, activities, capital, production, debt.
Area	Variables that are place based. Where does it happen? What happens where? E.g. location, use of buildings, land use, place.
Mood/feelings	Variables that relate to how people feel, e.g. social structure, quality of life, security, education, health, how people feel, state of feelings.
Natural balance	Variables that show how participants affect natural resources. What is the natural balance/relation to the environment? How does the resource budget function? Environmental relations – how does the distribution of resources work? Exchange with the environment – consumption of raw materials, energy and water, recycling, waste, harmless products, soil quality, climate influence.
Interconnections	Variables that allow participants to connect. What channels of communication are there to allow participants to connect? E.g. infrastructure, transport and access, telecommunications, traffic, information processing.
Organisational structure	Variables that show how participants are organised/regulated? Organisational structure/Communal life/Internal order. What rules apply? What are the rules, laws and culture? How is everything regulated? How are participants organised and regulated? E.g. local government, taxes, legislation, planning procedures.
Questions to identify system variables that are physical	
Material/Matter	Variables primarily material in character, e.g. buildings, raw materials, means of production, people, animals, plants, vehicles, food supply, transport routes, etc.
Energy	Variables primarily energy-related/energetic in character, e.g. power consumption, workers, energy carriers, financial strength, decision-making authority.
Information	Variables primarily information-related and communication-related in character, e.g. media, decisions, exchange of information, orders, perception, acceptance, attractiveness, explication, decision-making processes.
Questions to identify system variables that are dynamic	
Flow determinants	Variables express primarily flows of matter, energy, or information within the system, e.g. power consumption, traffic, commuters, instructions. Concerned with flows rather than stocks.
Structural determinants	Variables serving to determine structure rather than flow, e.g. green spaces, population densities, traffic network, diversity of jobs.
Temporal dynamics	Variables that at the same location change at a given time or that possess a temporal dynamic, e.g. seasonal activity, elections, climatic factors, transport timetables.
Spatial dynamics	Variables that differ depending on location, e.g. waste water, infrastructure, traffic, land use, ecosystems.
Questions to identify system variables that are system-related	
Opens system to input	Variables that open the system to input through outside influences, e.g. rainfall, imports, tourism, national legislation.

Opens system to output	Variables that open the system to output through inside influences, e.g. commuters leaving the city, exports, national taxes. These variables have an impact on adjourning systems and influence surrounding parts of the system.
Endogenous control	Variables that are influenced or controlled by internal processes or actions. Among other things, these are a measure of the system's self-sufficiency or autarky. These are endogenously controlled, internally influenced variables that are controllable through decision-making processes or actions taking place inside the system under study.
Exogenous control	Variables that are influenced or controlled by external processes or actions. Among other things, these are a measure of the system's dependency. Exogenous control/influenced externally/variables which are subject to/controlled by decision-making processes or actions taking place outside the system under study.

Source with changes, Vester (2007, pp. 212–214)

The Criteria Matrix provides a checklist to ensure variable selection is comprehensive. It is possible for one variable to cover a number of criteria. If a zero appears in the criteria matrix vertical sum, or the totals have an unusual distribution, this indicates important variables may be either overlooked or over-represented. If this occurs, variables need to be redefined to capture the diverse picture of the system under study. The process of variable identification and criteria matrix examination is recursive until a well-structured system is defined. This can be accomplished by bringing together stakeholders.

The key points for Vester (2007, pp. 53–60) when selecting variables to represent a system can be summarised as:

1. Not mixing up the different levels of a system and trying to capture all data. An excess of information, is not more enlightening than an absence of information. With an excess of information important dimensions of interconnections (direct, indirect, feedback loops and time delays) are unnoticed. Detail does not help grasp reality, as detail means the brain goes into analytical mode rather than the pattern-recognition mode, which is required to make key systemic connections. Pattern recognition requires data to be stripped back to key components that interconnect.
2. Avoiding compartmentalisation, as this does not represent reality. The role of a sector in a system can only be determined by the interrelationships in the system – not from detailed information about that sector. Appreciating the

network of effects in a system as a result of linkages helps users understand potential unintended consequences, and why past well-planned interventions did not play out as intended. An isolated study of a sector is considered to be of limited practical use for decision-making.

3. The variables selected should be indispensable to adequately describe the system under consideration and the questions of interest.
4. Variables should cover both qualitative and quantitative influences, as both are required to understand the behaviour of the system.
5. Variables should not be selected to fine-tune the system but to monitor flexibility to adapt to disruption.
6. Variables should not be chosen on their ability to be projected or extrapolated as quantitative values, as this is not appropriate for understanding the long-term behaviour of a complex system.
7. Interpretation of the system does not rely on the variables themselves, but on cybernetics of their interdependence. When the interplay between variables is understood, this allows answering in a qualitative way such questions as:
    a. Which effects will be provoked if certain variables in the system are modified?
    b. What are the effective leverage points in the system that allow modifying variables to achieve the desired changes and innovations within the whole system?
8. Determining variables selection is context dependent. According to Vester (2007, p. 218), even very similar systems will always be 'one-offs' and vary from location to location. There is therefore, a strong argument for using a bottom-up/participatory process.

For Vester (2007), a systems approach is about understanding the qualities and development potential of a system, to see how the system behaves and copes with change in order to become more resilient and to enhance the viability of the system. Therefore, a sustainable pattern of development should be based on a logistic S-curve[54] rather than the exponential curve that most societies have displayed since the Industrial Revolution (Vester, 1988). This theory is supported by many works, for example Holling & Gunderson (2002) and Diamond (2005). The growth of any entity causes the organisational structure to change from quantities to interconnected systems, and new 'systemic laws' to evolve. Problems that arise in such systems are not overcome by more data capture, but by the application of cybernetic rules that emphasise self-regulation, vulnerability to disturbance, irreversibilities, and limits. Vester (2007) has used his systems approach (in diverse applications that cover city and regional planning, ecology and business strategies) to facilitate a move away from experts tackling separate projects with detailed precision, to understanding and learning from the overall context.

5.3.2 The Natural Step (TNS)

The Natural Step (Robèrt, 2002) philosophy recognises the importance of using a systems approach to deal with complex issues, and as a means to increase knowledge without 'drowning in information'. Detailed knowledge of any part of the system is considered less important than identification of the relevant and essential aspects of the system and its purpose. Using a systems approach is promoted as a way to solve problems upstream and proactively deal with problem causes, rather than continually providing short-term fixes to downstream symptoms (Robèrt, 2002).

The underlying foundation for TNS is the 'Four System Conditions' which are basic sustainability principles that place importance on using resources efficiently, and at a pace that does not exceed the rate of regeneration and waste assimilation. According to Robèrt (2002, pp. 65–74), nature cannot be subject to systematically increasing:

1. concentrations of substances extracted from the Earth's crust,
2. concentrations of substances produced by society, and
3. degradation by physical means.

[54] With a sigmoidal (S) curve there is exponential growth at first that slows and converges to the resource base (carrying capacity) to avoid overshoot and collapse. At the inflection point there is a shift in loop dominance from a reinforcing loop to a balancing loop. When the demand is small relative to the resource base and limits are distant, the positive loop dominates. As the adequacy of the resource base declines the balancing loop becomes dominant.

The fourth condition is in a sustainable society humans are not subject to conditions that systematically undermines their capacity to meet their needs.

'The Five Level model' set out in Table 5-3, structures the process to use when applying the TNS approach to selecting indicators to ensure it is not *ad hoc*.

Table 5-3: The Five Level model

Levels	Process
The Systems level (1): Principles for the *constitution* of the system (e.g. ecological and social principles)	Describe **the system** and the key flows and connections within the system essential to the overall functioning of the system.
The Success level (2): Principles for a favourable *outcome* of planning within the system (e.g. principles for sustainability)	Understand how the system works to **identify conditions for success.** Success requires a clear definition of the objective.
The Strategic level (3): Principles for the *process* to reach this outcome (e.g. to meet principles for sustainable development)	Set **strategic guidelines** to be used for all decisions to ensure change is in the right direction and provide guidelines for how to strategically approach the objective.
The Actions level (4): *Actions, i.e. concrete measures* that comply with the principles for the process to reach a favourable outcome in the system (e.g. recycling and switching to renewable energy)	Determine **actions** to make progress, provide solutions, build capacity, help learn and evaluate progress. Every action should be assessed in terms of the strategic guidelines before implementation.
The Tools level (5): Tools to monitor and audit	With the various **tools** (techniques, models, procedures and measuring methods, including indicators) monitor the actions (level 4); ensure they align with the strategy (level 3) to achieve the objectives (level 2) for the system (level 1).

Sources with changes: (Cook, 2004; Kettle, 2006)

TNS emphasises the need, when working with a complex system, to have a robust definition of the objective of the system. This definition provides a lens for the identification of the relevant and essential aspects to include (Ny, MacDonald, Broman, Yamamoto, & Robért, 2006). Purpose can be used as a way to determine boundary issues and ensure the key essentials for arriving at the system objective are taken into account (Missimer, 2013). Flexibility needs to be maintained to allow creativity, as sustainability principles can be successfully achieved in different ways. The high level principles are a means of ensuring a consistent approach is applied, while at the lower levels there is the flexibility to choose the indicators most appropriate to the system under review (Kettle, 2006).

TNS has been used and refined over a period of more than 20 years by practitioners from business and government (see, e.g. Robèrt 2000; Robèrt et al., 2002; Ny et al., 2006, Missimer, 2013). As with Vester's approach, the TNS takes its lead from nature, and emphasises the resilience in the cycles of nature, and why we must respect and live within these limits.

5.3.3 The Orientor approach

Bossel (1998, 1999, 2001) asks orientor questions to determine system indicators. Using a hierarchical approach, indicators are selected to determine first the viable state of the component parts, and then the contribution of the component parts to the performance of the overall system. Bossel, as with Vester and Robert, advocates the use of a stepped approach to selecting indicators for a system. The steps involved are (Bossel, 1998, p. 98):

1. Make clear the *ultimate* goal, which is the reason for the need for indicators in the first place
2. Make clear the *ethical* reference in terms of the relationships with other systems that humans depend on (e.g. ecosystems) or whose fate humans determine (e.g. other species)[55]
3. Determine the important *subsystems* to include. Important subsystems are identified thorough the collation of knowledge about the subsystems, their relationship to the total system, and the appropriate system boundary
4. Define indicators that satisfy orientors (concerning existence, effectiveness, freedom of action, security, adaptability, coexistence, and psychological needs) adequately, for both the subsystem and the whole system.

Indicators need to answer the orientor questions set out in Table 5-4 to provide information about the degree to which each orientor is being satisfied. The answers to these questions can be sought in two ways – through qualitative information from people with an understanding of the topic, or through the use of quantitative data. The first six orientors (or guideline questions) are a checklist for what is important in a system, and apply equally to all self-organising systems at all scales (individual, community, region, nation). The last orientor question is specific to human systems (Bossel, 1999). Each orientor is a unique requirement that must be maintained at a

[55] Bossel (1998) advocates adopting a partnership ethic that recognises all unique and irreplaceable systems have an equal right to exist and develop.

minimum level of satisfaction. A deficit in one area cannot be compensated for by a surplus somewhere else. For instance loss of 'soil quality' cannot be compensated for by better 'air quality'. Only when all indicator requirements have been met can the overall system performance be raised by improving the situation of an individual orientor.

For Bossel (1998), indicator choice for a system is dictated first by the need to provide a 'picture' and essential information about the health and viability of the system. With the orientor approach, a system needs to operate within its 'environment' to be viable. A viable system is defined as one that can survive and sustain itself in the environment to which it adapts. This requires functioning within the following environmental conditions:

- The *normal environmental state*, which can vary within a certain range and still remain normal
- *Resource scarcity*
- *Variety* due to the different processes and patterns that naturally occur in a system
- *Variability* resulting in occasional fluctuations outside normal range
- *Change* over time, which is part of the evolutionary process
- *Other systems*, the behaviour of which has system-specific significance

Second, indicators are required to meet the interests, needs, or objectives of users, and to provide sufficient information to intervene in a system. This intervention needs to accord with the system's objectives, and allow the assessment of how successful the changes imposed were.

With subsystem indicators these need to show the trend of the subsystem, and prove that in itself, it is independently viable. Because systems are by nature nested, Bossel (2000) proposes two sets of questions.[56] The first relates to the viability and health of the subsystem, and the second to how the subsystem contributes to the viability of the total system. In complex systems there are likely to be multiple layers to consider.

[56] This is not always done see Bossel, 1999, Table 3. p. 40

Table 5-4: General scheme for finding indicators

Orientors to determine how well the system/subsystem functioning in its environment	**Subsystem performance** ***What does the current state of the sector system imply for the integrity, viability, and sustainability of the subsystem?***	**Contribution to total system** ***What does the current state of the sector system imply for the integrity, viability, and sustainability of the total system?***
Existence:[57] The system must be compatible with and able to exists in *the normal environmental state*. Therefore information, energy, and material inputs to sustain the system must be available (as with Vester). People must be able to live comfortably where they reside.	Is the system able to exist and subsist in its environment?	Does the subsystem contribute its specific share to existence and subsistence of the total system?
Effectiveness: The system should on balance (over the long term) be effective and to a lesser extent efficient in its efforts to secure required *scarce resources* (information, matter, energy) and to exert influence on its environment. The system must have the resources to create habitable environments (effective) and minimise the use of time and resources (efficient)	Is it effective and efficient?	Does the subsystem contribute to the effective and efficient operation of the total system?
Freedom of action: The system must have the ability to cope in various ways with the challenges posed by environmental *variety*. The system needs flexibility to choose best option to achieve goals.	Does it have the necessary freedom to respond and react as needed?	Does the subsystem contribute to the freedom of action of the total system?
Security: The system must be able to protect itself from the detrimental effects of environmental *variability*, i.e., the variable, fluctuating and unpredictable conditions outside the normal environmental state. The system can protect itself and deal with unexpected or extreme change	Is it secure, safe, stable?	Does the subsystem contribute to the security, safety, and stability of the total system?
Adaptability: The system should be able to learn, adapt and self-organize to generate more appropriate responses to challenges posed by environmental *change*. The system must be able to gradually change to fit imposed circumstances	Can it adapt to new challenges?	Does the subsystem contribute to the flexibility and adaptability of the total system?
Coexistence: The system must be able to modify its behaviour to account for behaviour and interests (orientors) of *other systems* in its environment. Other actors impact on a system's behaviour.	Is it compatible with interacting subsystems?	Does the subsystem contribute to the compatibility of the total system with its partner systems?
Psychological needs: Sentient beings have psychological needs that must be satisfied.	Is it compatible with psychological needs and culture?	Does the subsystem contribute to the psychological well-being of people?

Source with changes: Bossel (1998, Table 4. 5; p. 99) and Bossel (1999, p. 31). Italics indicate the environmental condition.

[57] This includes the need to be able to reproduce.

Indicators chosen must cover all orientor questions.[58] Bossel believes that with a systems approach, indicators should not be grouped or aggregated. It is possible to simplify reporting by saying that if all indicators (representing the orientors) are in a satisfactory state, the system is 'viable' or 'healthy'.

Bossel's approach is described by Kettle (2006) as 'esoteric' and difficult to implement. Bossel himself acknowledges that determining suitable indicators for a system is difficult, and that complexity prevents gaining a full understanding of any total system (Bossel, 1999). However, he argues even limited understanding of connectivity more closely replicates the real world in which decisions are made, and as such systems approaches are worth pursuing. Indicators function to increase understanding of self-organisation, and the change of behaviour required to respond to feedback loops in a system rather than trying to predict future outcomes (Bossel, pp. 62 & 64).

According to Bossel (1998) the orientor questions cover the essential systems aspects of any self-organising system, human or not. The basic orientors are similar to the basic needs of Max-Neef et al., (1991) discussed in Chapter 3. Bossel's framework for systemic indicator selection can also be considered to cover similar criteria to Vester, according to Schianetz & Kavanagh (2008).

5.4 SYSTEM COMPARED TO NOT-SYSTEM INDICATOR SELECTION

The discussion of the different approaches of Vester, Robèrt, and Bossel to identifying indicators from a systems perspective highlights some distinguishing attributes that set them apart from selecting indicators for composite or dashboard type well-being measures (i.e. not a system perspective). Table 5-5 sets out guidelines for indicator selection and identifies some of the commonalities and distinctions.

[58] To answer the seven different orientor questions for three subsystem classes[58] for subsystem performance, and the contribution to total system, results in at least 42 indicators (3x7x2=42).

Table 5-5: Indicator selection guidelines differentiating between system and not-system indicator selection

Indicator selection guidelines	**System**	**Not-system**
The ultimate goal needs to be explicit. The first step is to describe the purpose/aim of the measure the indicators contribute to and the key components that need to be tracked.	✓	✓
If indicators cover different dimensions (e.g. the environmental, social and economic dimensions of sustainability) there should be a balanced number of indicators measuring each dimension.	✓	✓
The ethical reference point you are working from needs to be stated. Ethical choice is reflected in indicator selection.	✓	✓
The value from indicators is largely determined by the appropriateness of the indicators used and how well they fit with the theoretical concept being measured.	✓	✓
The selection of indicators to use is determined by the system itself, as indicators need to provide a balanced picture of the system. Indicators should be similar in their level of importance to the overall system.	✓	
Indicator selection is subjective and the final choice should be a structured participatory process.	✓	✓
The selection of indicators to use is determined by the users, as indicators provide information for successful intervention and a way to monitor success.		✓
The minimum number of indicators that capture the main components should be used. Only indicators that provide essential information that cannot be obtained from clever use of other indicators should be included.	✓	✓
Rates of change provide the most important information about change in the system and are, therefore, important candidates for indicators.	✓	✓
The ideal indicators provide essential information about the health (viability) of the system and its rate of change, and about how that contributes to the systems goals.	✓	
Thresholds are required so indicator deficit/surplus can be evaluated.	✓	
Relatedness and interdependence is key criteria for being part of a system, therefore selected indicators must all interrelate.	✓	
Indicators need to be easily recognisable, their role clear, and whether they are a positive or negative measure made explicit.	✓	✓
There needs to be understanding of the systemic and dynamic nature of processes and boundaries, as all systems will be embedded in a larger total system containing many feedback loops.	✓	
The actual number of variables is less important than their proper composition because if you embark on a system analysis with an incomplete picture the analysis will be biased.	✓	
If only qualitative knowledge is available, for example, the standard is acceptable/not acceptable this should be used, as it can be included. This type of information cannot be aggregated into a composite or dashboard measure but with a systems approach can provide input without expensive and time-consuming quantitative measurements.	✓	
Capturing key components rather than data availability is the criteria for selection. This reduces biasing towards conventional thinking rather than	✓	✓

what is needed for future problem solving/decision-making. Effort should go into improving accuracy and comparability, rather than using lack of availability/reliability as an argument.		
Qualities in one indicator should not be duplicated in another to avoid double-counting.	✓	✓
Indicators should not be selected to direct a system to an optimal point as this implies a static destination. Instead, indicators should show progress towards a more complex, resilient, and viable system. It can be said if all indicators are in a satisfactory state the system is 'viable' or 'healthy'.	✓	
If the system has identifiable subsystems each needs to be 'healthy' and 'viable' for the overall system to be 'healthy' and 'viable', i.e. resilient.	✓	
A deficit in one indicator cannot be compensated by an over-achievement of another.	✓	

Analysing the similarities and differences in Table 5-5 identifies that there are specific requirements with which indicators need to comply when they are part of an interlinked system.

The system itself drives the indicators selected for use, as a balanced picture of the entire system needs is required. There needs to be understanding of the systemic and dynamic nature of processes and boundaries, as all systems will be embedded in a larger total system containing many feedback loops. The actual number of variables is less important than that their proper composition provides a complete picture, able to show whether the system is 'healthy' and 'viable' and how it is changing. If there are subsystems, each must have indicators that show the subsystem is 'healthy' and 'viable'.

Indicators should ideally have thresholds to identify any 'deficit' or 'surplus'. The occurrence of either of these two situations is considered a limiting factor in the system that needs to be addressed.

Relatedness and interdependence are criteria for being part of a system. Therefore, selected indicators must interrelate. Indicators should all be similar in their level of importance to the overall system. Aggregation into an overall score is not an objective, as each part of the system is in itself of importance.

When selecting indicators from a systems perspective, qualitative indicators can be included (this is not possible with aggregated composite or dashboard measures).

Indicators are not chosen to optimize the system but instead to guide progress towards a more complex, resilient, and viable system.

5.5 SUMMARY

This chapter has considered the procedure for selecting well-being indicators based on their role in an interlinked system.

It first set out the attributes of an indicator and then overviewed the standard recommendations for selecting well-being indicators. There is a substantial amount of literature on indicators and indicator selection, and this discussion focuses on high-level principles for selecting indicator sets, rather than on the required attributes of individual indicators. It also identified some of the commonly recognised problems associated with selecting indicators to measure well-being.

Three approaches for selecting indicators from a system perspective were presented. These were sustainability centred, but considered equally applicable to well-being. Distilled from the three approaches were specific requirements when selecting indicators from a systems perspective. These were then compared and contrasted with the standard approach to selecting well-being indicators to identify key differences. From this it was concluded that there are additional requirements with which indicators need to comply when they are chosen to represent a system.

The next chapter outlines the method developed to interlink indicators, which is implemented in the three different case studies undertaken as part of this research. In the WR-GPI case study (Chapter 7) indicator selection from a systems perspective is applied.

6 METHOD FOR INTERLINKING INDICATORS

To answer the principal research question: "*Does understanding the relationships between indicators add value and progress sustainable well-being*?" a way is needed to link indicators. The challenge addressed in Chapter 6 is: "What method can be used to determine the links between indicators, and better understand the resultant cause-and-effect relationships?"

This chapter describes the method developed. It combines CLDs and matrices and is referred to as 'interlinked thinking'. Interlinked thinking aims to meet the needs of groups, or individuals, who are non-technical and do not have the systems modelling and simulation skills, such as those used by the system dynamics community. These people are aware of the external processes that impact on their work responsibilities and want these to be more visible and explicit, but do not have accessible tools and/or the technical knowhow to progress along this pathway

First, the philosophy on which interlinked thinking is based is briefly revisited. The steps undertaken to use 'interlinked thinking' are then described and a worked example provided. Graph theory is briefly covered as the matrix approach used has its origins in graph theory. This is followed by a summary of the outputs from interlinked thinking and an argument for why this method has value.

6.1 INTERLINKED THINKING PHILOSOPHY

The method for interlinked thinking reflects the philosophy of Meadows (1989, 2008), Vester (2007), Hjorth & Bagheri (2006), Northrop & Connor (2013), Hürlimann (2009), Olaya (2012), and others, that the right approach to dealing with complexity is not greater data capture for increasingly detailed analysis, but a more holistic understanding of the system structure and the important interrelationships. Instead of dealing with complexity by storing and evaluating more information and data, the approach is to understand how the system structure (its interlinkages) determines the behaviour (Hovmand, 2014; Meadows, 2008). In line with this view Hovmand (2014) states:

> When we can understand a system by understanding its component parts and then infer what a system will do, what matters most are strength of associations between causes and effects … it is less important what the actual harvest rate is or what the actual birth rate is than the fact that it is positive and embedded within a feedback loop. Changes in the strength of association will generally have little impact on system behavior, whereas changing the structure will. (p. 9)

Complex system problems are hard to understand because the emergent behaviour of the parts interacting as a system respond in ways that cannot be predicted by the properties of the individual components (Hovmand, 2014; Senge, 2006; Sterman, 1994; Vester, 2007). It is also possible for the same structure to produce different system behaviour and for a structure that generates desirable outcomes in one time period to generate unwanted behaviour in another. For example, a reinforcing feedback loop can produce exponential growth or exponential decline. It is also possible for entirely new structures to emerge as a result of the dynamics that exist within a system.

The interlinked thinking method focuses on structural rather than dynamic complexity. While understanding dynamic system behaviour over time is important, a core assumption of the systems paradigm is "that behavior arises out of system structure" (Meadows, 1989, p. 70). A failure to recognize feedback loops distant in time and space impacts quality decision-making (Moxnes, 2004). Better comprehension of potential long-term change allows alternative strategies to be considered by decision-makers. The provision of "better tools to understand and simplify structural complexity will permit a more efficient policy design process" (Oliva, 2004, p. 331). Interlinked thinking is intended as an additional tool to improve understanding of the structural complexities and strategic inter-relationships in a system.

6.2 THE INTERLINKED THINKING METHOD

This section describes the process to carry out the interlinked thinking method. It is ideally used in a participatory context, but can also be a desktop exercise. The steps are described as they would be completed over two workshop sessions. The steps and how they relate are set out in Figure 6-1. Then each step is described in detail.

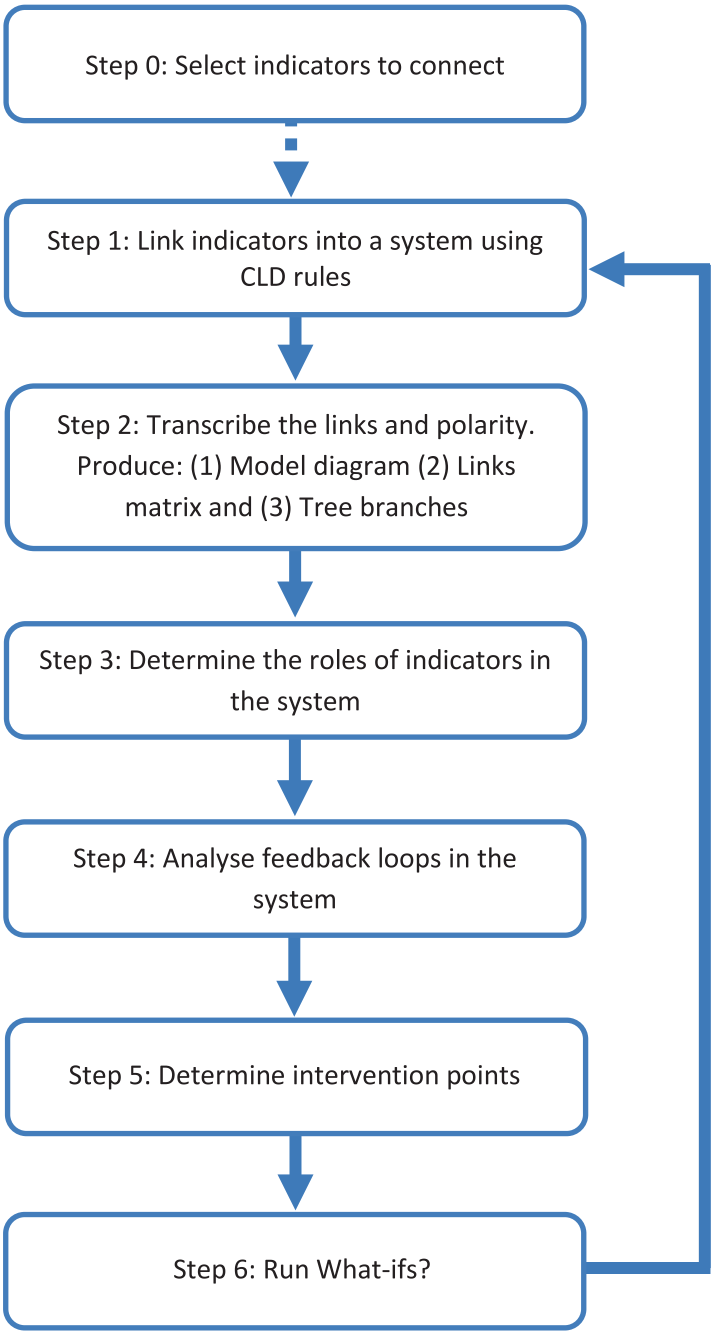


Figure 6-1: The interlinked thinking method.

6.2.1 Step 0: Select indicators for the system

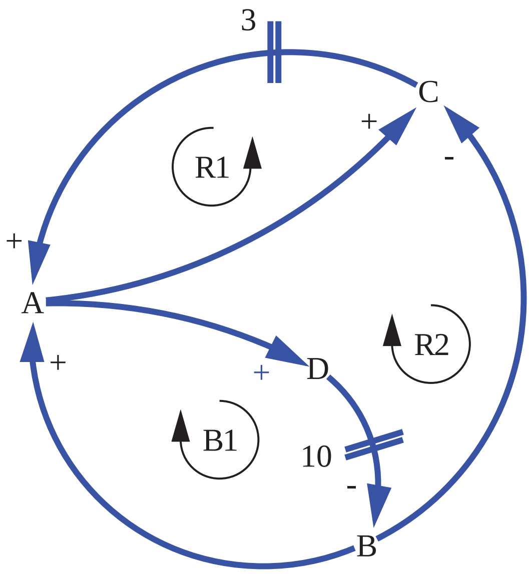
If indicators are not already decided, the guidelines set out in Chapter 5 can be used to determine the indicators to link. Chapter 7 provides a worked example of how to apply the guidelines.

6.2.2 Step 1: Link indicators into a system using CLD rules

Participants connect the indicators chosen to represent the system following the rules for constructing CLDs described in Chapter 4. The process is as follows:

1. Participants are provided with the indicators to connect, which are printed randomly on large sheets of paper.
2. Participants connect indicators by drawing in the *direct* links and designating the polarity of the links (i.e. whether the effect is an increase or decrease with an increase in the initial indicator). If the effect is likely to take place over time, the approximate length of that delay is indicated. The appropriate time unit depends of the system being studied and can represent hours, days, years, or any other weighting. Units are not important for the outcome. For the worked example in this chapter, the following were used to represent years:
    a. No delay = 1
    b. Short delay = 3
    c. Long delay = 10
3. The rationale for each link is documented (as per Links Sheet, Appendix 6h). With the interlinked thinking method CLDs are not constructed by experts with input from participants. Instead, participants work together and determine the links they consider important. Documenting the links is especially valuable when links are debated or less intuitive.

Figure 6-2 is a worked example of the outcome of Step 1.



There are four indicators in this system A, B, C and D connected by six links with polarities shown by '+' or '-'. The // indicates delays, of 3 and 10 time units.

R1 and R2 are reinforcing feedback loops. B1 is a balancing loop.

Figure 6-2: Worked example of Step 1. The CLD.

6.2.3 Step 2: Transcribe links and polarity

Next, the links are transcribed for further analysis as follows:

1. Based on the CLD, a *links matrix* spreadsheet is constructed to show the links in the system. Links are shown with a '1' where an increase/decrease results in an increase/decrease and '–1' where an increase/decrease results in a decrease/increase.
2. Based on the CLD diagram, tree branches[59] are created. These branches show the indicators that link to and from each specific indicator. The expanding branch ends when: (i) there are no predecessors or, (ii) an indicator has already been identified in the tree structure (this is shown with brackets). Cause trees give the backward links that feed into that indicator. Use trees give the forward links that flow from that indicator.

Table 6-1 and Figure 6-3 show the outcomes from Step 2.

[59] Vensim™ has functionality to generate CLD diagrams as well as use and cause tree branches. Vensim™ also provides information on loops generated, which can be used as a check to make sure that no links have been missed/incorrectly transcribed.

Table 6-1: Worked example of Step 2: The links matrix

	A	B	C	D
A			1	1
B	1		-1	
C	1			
D		-1		

In the matrix, the ‘1’ at the intersection of row A and column C shows a link between indicators A and C that is in the same direction. The ‘–1’, at the intersection of row B and column C shows a link between indicators B and C that is in the opposite direction.

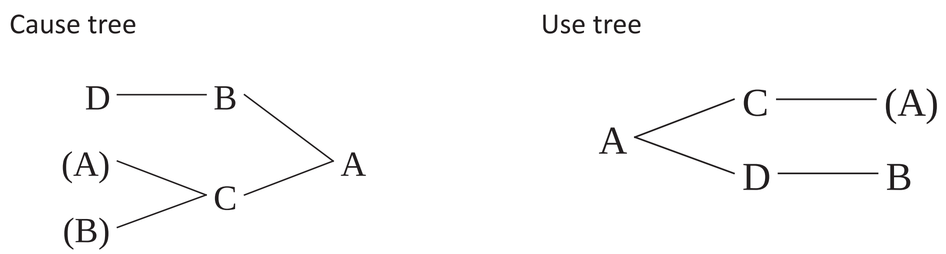


Figure 6-3: Worked example of Step 2: The tree branches.

The trees branches make it possible to move backwards or forwards to see the influences between indicators. For example, if the desire is to impact on A, the cause tree shows this can be done through either B or C.

6.2.4 Step 3: Determine the roles of indicators in the system

To determine the role of an indicator and how strongly it impacts the overall system the links matrix is used (Vester, 2007; Hürlimann, 2009). Taking the absolute values in the links matrix spreadsheet, the rows and columns of the Influence matrix are summed to determine four types of roles in the system. These key roles are important as “they are likely to have a bearing on a large number of issues and research questions” (Niemeijer & de Groot, 2008, p. 22)[60]. Key roles are:

a. *Active* – Indicators with a high row sum have an ‘active’ role in the system. These indicators are of major importance as they trigger change and

[60] For indicator analysis, Niemeijer & de Groot (2008) apply a process they refer to as causal networks.

development in the system. They are indicators that can be steered to influence the system and have considerable leverage on other indicators. The higher the active score, the more the variable impacts on the system's performance.

b. *Passive* – Passive indicators are calculated by summing the column numbers in the matrix. Indicators with a high column sum are sensitive and react strongly to changes in the system. They are useful to determine the response of the system. A small change elsewhere will result in considerable change to a passive indicator, but passive indicators have limited ability to influence other system factors.

c. *Critical* – Critical indicators are determined by multiplying the active sum by the passive sum. A high product signifies a critical indicator. Critical indicators have a strong role in the system as they have a major impact on the system through feedback effects on other indicators. They influence and are strongly influenced by other system factors. They are usually essential for the survival of the system and removal may result in the system's partial or complete collapse (Schonenberger et al., 2014).

d. *Buffer* – When the active sum multiplied by the passive sum produces a low product this indicates a buffer indicator. These indicators have the capacity to absorb impacts and slow the effects of change.

If additional information about the strength of the impact is available it is possible to include this weighting[61] in the matrix. Table 6-2 is an example of a role matrix which is the outcome of Step 3.

[61] Vester (2007) uses weighting (e.g. 0, 1, 2 and 3) but, as pointed out by Hürlimann (2009), this assumes an active sum made up of 3 links (1+1+1) is equal to one link of strength 3, which may be false. I therefore restrict my analysis to the use of 1 and –1.

Table 6-2: Worked example outcome of step 3. The role matrix

	A	B	C	D	Active	Critical and *Buffer*
A			1	1	**2**	**4**
B	1		-1		**2**	2
C	1				1	2
D		-1			1	***1***
Passive	**2**	1	**2**	1		

Bold = Identified active, passive and critical indicators. *Italic* = buffer indicator

6.2.5 Step 4: Analyse feedback loops in the system

Analysis of feedback loops is accomplished by running the computer algorithm[62] detailed in Appendix 2. Using the codified links matrix as input, a report summary is generated that gives:

(i) the number of feedback loops of which an indicator is part and the number of links 'to' and 'from' that indicator;

(ii) all the unique loops in the system and whether they are balancing or reinforcing;

(iii) loops for each indicator and whether the loop is reinforcing or balancing;

(iv) what happens to the system when an indicator is removed. This is shown by the number and percentage of the loops that remain in the system and

---

[62] The code for the algorithm that generates the reporting spreadsheet (in Excel) was separately commissioned as part of this research. It was written in python by Tomas Burleigh Behrens. Hürlimann's Section B.5.2 pseudocode in VBA written in German was used as a start point (see Hürlimann, 2009, p. 226; Section B.5.2 Used pseudocode in VBA). Hürlimann uses a number of different algorithms in his work. The coding done by Tomas Burleigh Behrens was to my specification. At my request it does all the analysis in one run and is in a format that is easy to distribute to other users. It also extends the analysis beyond that of Hürlimann by calculating balancing and reinforcing loops and providing a link count.
In his book (based on his PhD) *"Dealing with Real-World Complexity. Limits, Enhancements and New Approaches for Policy Makers",* Hürlimann (2009) demonstrates the use of different types of matrices to analyse the relationship between the variables. He sets out the theory for using (i) cross-time-matrix, (ii) cross delay matrix, (iii) cross-effect-matrix, and (iv) path analysis to give more insights into the relationships between elements of a system and determine intervention points. Hürlimann's theory is that in the real world policy-makers description of the relationship between cause-and-effect is fuzzy and that matrices provide a semi-quantitative method to help make relationships visible. By Hürlimann's own account (2009, p. xi) the matrices approach "… can be used when searching for the best possible indicators or the right intervention, without the need for constructing a simulation model." See Hürlimann Chapter 7 for more detail.

provides an indication of how essential a specific indicator is to the structure of the system; and,

(v) the link counts that show the number of times a link is traversed in the system. From the large number of interacting indicators these isolate a smaller number of links that control the system.

Table 6-3: Worked example outcome from Step 4: Report summary from algorithm

(i) Summary of loops by indicator and links to and from each indicator.

Indicator	Loops indicator belongs to	Links to	Links from
A	3	2	2
B	2	1	2
C	2	2	1
D	2	1	1
Total loops in system	3		

(ii) All unique feedback loops in the system.

Reinforcing (R1)	A	C		
Balancing (B1)	A	D	B	
Reinforcing (R2)	A	D	B	C

(iii) The feedback loops each indicator is in. The example shown is for indicator A.

Loops that start with A				
Reinforcing (R1)	A	C		
Balancing (B2)	A	D	B	
Reinforcing (R2)	A	D	B	C

(iv) What happens when an indicator is removed? If A is removed no feedback loops remain in this example.

Indicator removed	Number of feedback loops	Number of reinforcing loops	Number of balancing loops	% remaining
Intact	3	0	3	100.0
A	0	0	0	0.0
B	1	1	0	33.3
C	1	0	1	33.3
D	1	1	0	33.3

(v) Link count showing number of times a link is traversed.

From Indicator	To Indicator	Count
A	D	2
C	A	2
D	B	2
A	C	1
B	A	1

The analysis of feedback loops is carried out to see the patterns in a system and understand its structure. Feedback loops can be interpreted to show the following:

1. *System behaviour.* The total number of feedback loops gives an insight into how the system will behave. A small number of feedback loops suggests the system is dependent on external factors. A large number of feedback loops suggest a self-sufficient system (Vester, 2007).
2. *Short and long feedback loops.* Many indicators in a feedback loop highlight a time lag for response to the initial indicator change. If unnoticed, long time lags may result in unpreventable repercussions. Short loops indicate a more swift reaction (Vester, 2007).
3. *Importance of indicators to the whole system.* The importance of a specific indicator to the whole system can be determined from the number of feedbacks that remain in the system if the indicator is removed (Vester, 2007).
4. *Interlinked structure.* In an interlinked structure, 'essential interconnections' and 'points of emphasis' in the system can be identified by the number of links into and out of an indicator (i.e. active, passive, critical and buffer) (Vester, 2007).
5. *Long-term behaviour through feedback loops.* Reinforcing and balancing feedback loops show the way the system behaves in the longer term. If balancing feedback loops dominate the system it is self-regulating and more likely to remain stable when disturbances occur (Vester, 2007). If reinforcing feedback loops dominate the system it is less stable and at risk of not remaining viable in its current state. It is the feedback structural elements of a system that mostly determine stability (Schoenenberger, Schenker-Wicki, & Beck, 2014). Reinforcing feedback loops are a source of growth or decline in systems, while balancing feedback loops are self-correcting[63] (Videira et al., 2014). Insufficient stabilising balancing loops means the system develops in an

[63] While it is generally true that negative feedback loops stabilise a given system and large numbers of positive feedbacks can destabilize a given system the behaviour between extremes is more complicated (Cinquin & Demongoet, 2002). Cinquin & Demongoet (2002) provide examples where negative feedback can lead to expanding oscillations due to over correction and become a source of instability, and positive feedback can be stabilising. This paper focuses on biological (processing of information at cellular level) and chemical reactions (autocatalysis).

uncontrolled manner and is at risk of collapse (Beck, Schoenenberger, & Schenker-Wicki, 2012; Cinquin & Demongeot, 2002; Ford, 2010; Schoenenberger et al., 2014). At some point a balancing (or negative effect) will always come into force as no system can grow unabated forever (Ford, 2010; Vester, 2007).

On its own the proportion of balancing and reinforcing do not indicate if a system is stable (or not) as this depends on the nature of the balancing loops. A small number of balancing loops can keep a system stable if they are well designed and effective. The ratio of balancing to reinforcing loops can be used to show the system complexity and level of uncertainty. To test more categorically if a system is stable requires a quantitative system dynamics model.

Stability according to Vester (2007) can be influenced by how balancing and reinforcing feedback loops are distributed between long or short cycles. If the balancing effect is a short cycle this can generate a swift reaction for a quick return to stability. By experimenting with removing individual indicators it is possible to see how this impacts the ratio of balancing and reinforcing feedback loops, and gain insights into how the system is controlled.

The indicators indispensable to preserve the stability of the entire system can be determined by taking an indicator out of the system (Beck et al., 2012; Schoenenberger et al., 2014; Vester, 2007). If a variable can be removed with no or little influence on the overall feedback structure it has little influence overall (Vester, 2007). A potential way of determining change in stability within the system is by comparing the ratio of remaining negative to positive feedback loops with the corresponding ratio in the intact system (Beck et al., 2012).

6. *Pattern of interconnections.* If a part of the system has only a small number of close interconnections this may be a subsystem that depends on the system but does not influence it (Vester, 2007).

6.2.6 Step 5: Determine intervention points

Intervention points are calculated to allow consideration of potential places to intervene in a system. Any identified intervention point is determined relative to the other indicators in the system and needs to be considered in this context before action is taken. Intervention points can be calculated in two ways through the use of interlinked thinking: the Vester method and the Hürlimann method.

6.2.6.1 Vester method

The Vester method for identifying intervention points is based on the role of the indicator. Active indicators that also have a high active/passive quotient value can be considered as potential intervention points in a system (e.g. indicator B in Table 6-4). Active indicators are preferred because they are more 'manageable' in that they have a strong influence on other components, without the system having a strong influence on them. A high quotient provides a way to select between the different 'active' indicators. It is possible for some 'active' indicators to also be categorised as 'passive'– if they have a large number of links that go to them (e.g. indicator A in Table 6-4). A low quotient identifies these indicators as not suited for intervention due to their high degrees of connectivity in the system. Any intervention via this indicator will be difficult to manage due to the higher level of uncertainty in the system.

Table 6-4 is a worked example of the Vester approach to intervention points in a system.

Table 6-4: Worked example of the Vester approach to intervention points in a system

	A	B	C	D	Active	Active/ Passive Quotient
A			1	1	2	1
B	1		-1		**2**	**2**
C	1				1	0.5
D		-1			1	1
Passive	2	1	2	1		

Bold = recommended intervention point (indicator B).

6.2.6.2 Hürlimann method

The Hürlimann (2009) method uses a separate matrix that is called the cross-time matrix (CTM). This is constructed from the 'role matrix' (see Table 6-2). Each link in the role matrix is assigned a time period (e.g. no delay = 1; short delay = 3; or long delay = 10) and this becomes the CTM. The mean value of the row is calculated to give the delay produced (DP), and the mean value of the column calculated to show the received delay (RD).

An indicator with a low DP transmits stimuli quickly through on-going links, whereas an indicator with a high DP transmits stimuli slowly. Likewise, an indicator with a low RD quickly receives a pulse through the system, whereas a high RD receives an impulse more slowly. Overall, a system with high DP and RD values reacts slowly to change, whereas low DP and RD values mean change occurs more quickly (Beck et al., 2012). Table 6-5 is a worked example of a CTM. In this matrix the delay between indicators C and A is three times that between B and A. The average received delay for indicator A is 2.

Table 6-5: Worked example of the cross-time matrix (CTM)

	A	B	C	D	DP
A			1	1	1
B	1		1		1
C	3				3
D		10			10
RD	2	10	1	1	

The next step in the Hürlimann method is to plot the active sum for each indicator (from the role matrix as in Table 6-2) against the DP mean value for each indicator (from the CTM as in Table 6-5). Graph quadrants are drawn based on the median of the active sum (y-axis) and the median of the delay produced values (x-axis). Figure 6-4 provides the final output as generated by the Hürlimann approach.

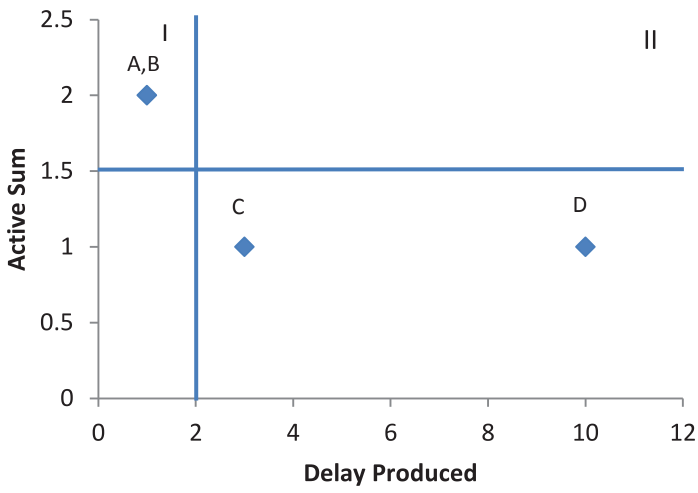


Figure 6-4: Worked example of Hürlimann approach to intervention points in a system.

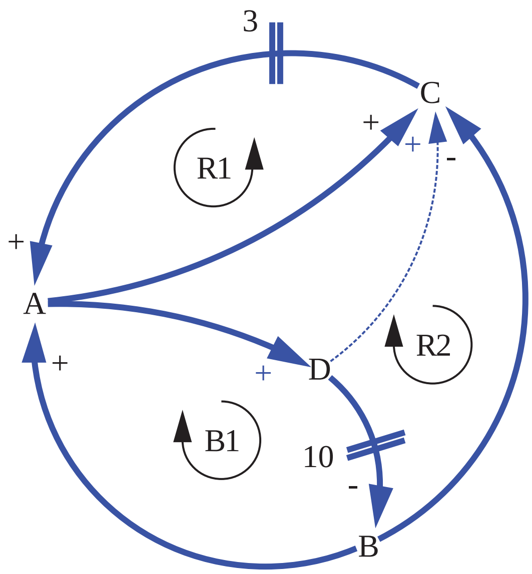
If an intervention point with a short execution time is desired, the preferred indicators are those with a high 'active' sum and low DP (found in Quadrant I). In some situations it can be more desirable for an effect to diffuse slowly so a combination of high 'active' sum and high DP works best (Hürlimann, 2009). These indicators are located in Quadrant II.

By including a time component in the form of delays, the CTM allows for the fact that not all impacts are immediate. Limited dynamics are thereby included in the interlinked thinking method. The CTM matrix also provides information on how fast impacts spread through a system, and the liveliness or sluggishness of the system overall (Beck et al., 2012; Hürlimann, 2009; Schoenenberger et al., 2014).

With all intervention points it is important to consider whether the indicator is directly controllable. Only indicators that can be controlled by the decision-makers are suitable intervention points in a system (Beck et al., 2012).

6.2.7 Step 6: What-ifs

The linked models developed by participants can be used in conjunction with the algorithm and reporting output to explore different what-ifs. A base what-if can be run and then changes can be made that allow comparisons. The models can be manipulated by adding or removing links, adding or removing an indicator, changing an indicator definition, changing the polarity of a link, etc. Figure 6-5 shows how the model can be changed by adding a link.



What-if: How does the system change if a new link (dotted) is added?

Figure 6-5: Worked example of Step 6: The what-if model.

What-if analysis is a tool to promote visualisation of cause-and-effect and explore closed-loop thinking. A what-if incorporates all of the feedback loops for the indicator of interest. By separating off interesting parts of the system for further analysis individual feedback loops and the assumptions behind relationships can be examined in detail (Vester, 2007).

What-ifs can provide a deeper understanding of how a given system will operate under alternative assumptions in a real world context. Hypothesis can be tested and explored; for example what happens if a polarity is reversed? The objective is to prompt people to explore potential outcomes and widen their thinking on an issue beyond their immediate sphere of interest. Examining loops and adding dialogue can add value and generate insights (Sedlacko et al., 2014).

The starting point for what-if analysis is the particular question of interest and the relevant indicators and links. What-if analysis provides a flexible way to explore intervention points and see the path dependency (Videira et al., 2014). What is important is showing the environment, the relationships and the pattern of effects when a change in one indicator sets off a chain of reaction.

Alternative what-if questions are followed through links to see what happens. When individual models are constructed with different links by separate groups comparing the what-if outcomes shows how mental models generate different results. Multiple iterations can be done adjusting indicators and links to see the system effects and to deepen understanding. Qualitative what-ifs are done for the same purposes as quantitative system dynamics model simulation runs.

There are a number limitations associated with what-ifs. Some indicators can have a large number of feedback loops which makes manual analysis challenging. As with scenario analysis using system dynamics models what-ifs are run purely for understanding and not to predict what is going to happen. The what-if process is manual rather than computer simulated which limits the extent to which outcomes of a partial system can be tested under alternative sets of assumptions. What-if are not dynamic therefore only take into account the first 'cause-and-effect' stage. What-ifs emphasise the role of feedback loops and overlook the important role of accumulations in a system (Richardson, 1997; Lane, 2008). With what-ifs, as with other forms of modelling, there is always the risk of drawing the wrong conclusion.

6.3 GRAPH THEORY

This section provides a brief introduction to graph theory as the matrices approach applies this technique to determine feedback loops in the system.

The mathematical sub-discipline of graph theory[64] is a recognised method to analyse the structure of interactions between variables (Wenger, Harris, Sivanpillai, & DeVault,

---

[64] In a similar way to graph theory, network analysis can be used to understand complex systems. Newman (2003) documented a wide range of situations where the network analysis approach has been successfully used for this purpose. It has been used extensively to depict social structures and show how social ties are an important means to transmit behaviour, attitudes, information, and goods (de Nooy, Mrvar, & Batagelj, 2011). Network analyses are considered to be powerful when rapid learning is required about a system and there is limited knowledge (Bezuidenhout, Bodhanya, Sanjika, Sibomana, & Boote, 2012).While the foundations come from graph theory, network analysis also employs ideas and methods from algebra and statistics (Bezuidenhout et al., 2012, p. 1841). The study of networks is part of the general scientific area of complexity theory (Buchanan, 2002). As with graph theory, when you apply network analysis you start with a graph that is a set of vertices and a set of lines between pairs of vertices. "A network consists of a graph and additional information on the vertices or the lines of the graph." (de Nooy et al., 2011, p. 8). Network analysis provides a way to visualise a system as well as a tool for systematically assessing links in a system and identifying critical points where interventions can be targeted (Bezuidenhout et al., 2012).

1999). With graph theory, relationships are portrayed using directed graphs (or digraphs) that have vertices (or nodes) connected by arcs. Directed graphs present each variable as a vertex that is linked to another variable via a directed arc such that: "if variable A_i has an impact on variable B_j a directed arc is drawn from A_i to B_j" (Wenger et al., 1999, p. 111). A signed digraph includes (+) plus or (-) minus signs which makes it possible to establish if the effect is augmenting or diminishing. A vertex that has a lot of 'arcs' and is centrally located responds to many other parts of the system. Therefore the sum of outgoing arcs for each vertex can be used to show the degree of leverage that particular vertex provides. A path refers to the number of directed arcs from one vertex to another and its length is the number of arcs. A positive path has an even number of minus (-) signs and a negative path and uneven number. A closed path starts and ends at the same place and is called a 'loop'.

Matrix algebra can be used to generate the direct and indirect links between variables in the system. Digraphs can be formatted as Adjacency matrices. An Adjacency Matrix (a_{ij}) is defined as:

a_{ij}= 1 if A_1 has an impact on B_j . If A_1 has no impact on B_j then a_{ij}= 0.

Analysis of the matrix can also be done visually, with clusters in the matrix indicating subgroups. The generation of loops among the variables allows exploration of diminishing and amplifying pathways.

Wenger et al., (1999) used graph theory to analyse the structure of interactions among ecosystem stressors. This example investigated the interrelationships between ecosystem stressors and the extent to which this increases risk. A binary scale was used to assign numerical values (according to whether they are 'strong', 'unilateral', 'weak' or 'disconnected') to stressors based on the degree to which they contribute to ecosystem risk. Wenger et al., (1999) proposed analysis of the paths and loops in the system as a step towards understanding the complexity of a system and moving "beyond the 'single stressor-single endpoint' paradigm by taking into account the combined actions of multiple stressors and by focusing on multiple assessment endpoints" (Wenger et al., 1999, pp. 110-111).

Matrices have also been used effectively to analyse the structure of systems dynamics models. Klaassen, Ooms & Paelinck (1978) reduced J. W. Forrester's world model to a system of five equations with the use of matrices, and showed how the complexity was a result of feedback loops in the model.

6.4 OUTPUTS FROM INTERLINKED THINKING

The interlinked thinking method was designed to meet the expectations of the stakeholders who participated in the Greater Wellington Region Mediated Modelling workshops. It is also possible to use interlinked thinking in any situation where people want to explore the connections between different components, but do not have systems expertise or much time to invest. Interlinked thinking provides:

1. A visual representation of the system and its links to help people understand the system in which they are operating.
2. The indicators the system is highly dependent on. This output is provided by the algorithm giving the number of feedbacks an indicator is part of, and the percentage remaining in the system if the indicator is removed. When the removal of an indicator results in the loss of a large number of balancing loops the system becomes less stable.
3. A way to trace how a proposed change in the system initiates actions via multiple paths that loop back to the indicator that generated the initial change.
4. How cause-and-effect progresses through the system to impact other indicators linked to the changed indicator.
5. Whether the impact happens quickly (a small number of indicators in the feedback loop), or over a long period of time (a large number of indicators in a feedback loop so a time lag). This can also be calculated based on time, if delays are included.
6. The different roles indicators have in the system, e.g. active, passive, critical, buffer.
7. 'What-if' options that can be experimented with (as described in section 6.2.7). For example what is the impact of a change in the polarity of an indicator (e.g. from + to -) or adding or removing a link?
8. Potential intervention points in the system.

9. The strong connections in the system.
10. Whether the system is stable or unstable as shown by the balancing to reinforcing loops generated (as described in section 6.2.4)
11. The degree of complexity in the system as measured by the number of feedback loops and links.
12. A method that can include any desired indicators as a system. It is not defined by what is measurable.

The main contributions made by models are to facilitate the scope to explore and understand key relationships (Rothman et al., 2002). These outputs all support this contention.

6.5 DISTINGISHING CHARACTERISTICS OF INTERLINKED THINKING

The combination of CLDs and matrices has been used by others (see for example: Beck et al., 2012; Hürlimann, 2009; Schoenenberger et al., 2014; Vester, 2004, 2007; Videira et al., 2014). However, these applications have not been in the well-being area or applied in the same way as interlinked thinking. Some have involved stakeholders (Vester, 2007; Videira et al., 2014), while others have been more theoretical in nature (Hürlimann, 2009; Schoenenberger et al., 2014; Beck et al., 2012). The interlinked thinking method can be distinguished from other applications in the following ways:

How CLDs are derived: CLDs are not constructed by an expert with input from participants. Instead, participants work together and debate the links they consider important. Links are transcribed into a matrix and an algorithm is used to generate the CLDs.

Participants readily share their mental models: Only two workshops sessions of a maximum of 180 minutes duration are required. These can be run within a few days of each other. Participants can work as one group or in separate groups. Separate groups allow comparisons between different models and thereby further opportunity to expose diverse mental models.

A large number of links can be included: Links in the system represent the agreed on direct seminal links considered of most importance to the system by the participants involved. The input of the participant therefore determines the outcomes. Interlinked thinking has the capacity to incorporate a large number of links, thereby more closely reflecting the situation in reality. It does not try to simplify issues down to the bare bones.

Easily communicated: As how outputs are generated is very transparent they can be readily communicated to the end-user, or the general public. Outputs are not data dependent. Indicators and links can be input into software, such as Vensim™, to enhance visualization of the system being studied and generate 'use' and 'cause' trees. The matrix outputs are easily presented in a spreadsheet, and show all the feedback loops in the system for every indicator. With the interlinked thinking method, the strength of association remains visible even when, for example, they extend to 9^{th} or 10^{th} order effects at the end of long causal chains.

Understanding the ways indicators interlink is the aim: Interlinked thinking focuses on understanding the interaction of indicators and potential impacts. It does not require a defined problem as the start point. At the same time, interlinked thinking can be problem-oriented if this is the stipulated purpose of undertaking the study.

Strong links in the system are calculated: Interlinked thinking calculates strong links based on the number of times a specific link is traversed by the different feedback loops.

Does not require experts or specialist software to run: Vester's method, for example, requires the purchase of the expensive Sensitivity Modelling software and involves an extended series of workshops. The outputs from interlinked thinking can be achieved with a spreadsheet and a computer algorithm available free on request. Vensim™ is an optional enhancement for presentation.

Can be uplifted and applied for multiple uses: The interlinked thinking method is not restricted to well-being, but can be uplifted and applied by any individual or group wanting to consider their area of interest from the perspective of an integrated 'whole' and work with, rather than ignore, complexity.

6.6 SUMMARY

This chapter first described the philosophy underlying the method developed for interlinked thinking.

The six steps of the interlinked thinking method were then outlined. Interlinked thinking provides an innovative, comprehensive, and systems approach to linking indicators. It uses causal loop diagramming to determine links between indicators and then analyses those links using graph theory.

How workshops involving participants are run was described, and the typical outcomes listed. Because it is not data dependent, interlinked thinking is useful for a complex system, such as the well-being system to which the case studies for this dissertation relate. Complex systems do not necessarily obey laws that can be uncovered by data analysis (Olaya, 2012).

The distinguishing characteristics of interlinked thinking were outlined to clarify the contribution made by this research. A significant difference with the interlinked thinking method is that connections between indicators are made first, and then the analysis of the feedback loops is undertaken. Outputs from this analysis inform participants about the key indicators in the system, the number of feedback loops and potential intervention points in the system.

Interlinked thinking advances beyond qualitative modelling to provide a semi-quantitative analysis. The interlinked thinking method developed as part of this dissertation fills a need by providing an innovative process to connect indicators, whilst also having the scope to involve participants and be easily implemented. It is of most value when time is limited and participants are not familiar with systems analysis.

The case studies to follow (in Chapters, 7, 8 and 9) highlight different features of interlinked thinking. Interlinked thinking can be used in a participatory context (to be described in the case studies of Chapter 7 and 8) or carried out as an independent desk-top exercise (to be described in the case study in Chapter 9). Chapters 7 and 9 consider indicator selection requirements from a systems perspective (as was described in Chapter 5). The case study described in Chapter 8 demonstrates the differences between groups that can occur when interlinked thinking is used. The Chapter 9 case study illustrates the application of cause and use trees.

The next chapter describes the WR-GPI, the first of the three case studies undertaken to test interlinked thinking.

7 GREATER WELLINGTON REGIONAL COUNCIL CASE STUDY

The Greater Wellington Regional Council case study, detailed in in this chapter, focuses on the question: “How do you select the appropriate indicators to measure well-being, and, what insights can be gained from applying the method developed to understand the relationships between these indicators?” This case study brings together the material previously discussed in Chapters 4, 5, and 6 to provide an answer. Chapter 4 discussed systems theory and its value when working in the context of complex systems such as well-being. Chapter 5 considered the issue of selecting indicators from a systems perspective and what specific criteria apply. Chapter 6 then described the interlinked thinking method as a way to connect indicators.

The lack of understanding of how the various indicators interact is an acknowledged limitation of the Wellington Region Genuine Progress Index (WR-GPI) (Wellington Regional Strategy Office, 2011, p. 9):

> There is also interaction among all aspects of the framework, although we are far from knowing all the constituents and determinants of these interactions

Stakeholders participating in the Wellington Region Mediated Modelling workshops as part of the SP2 project identified that research was needed to provide an integrated picture of how the indicators used to measure well-being in the Wellington region impact each other.

Lack of understanding of how indicators interrelate comes up regularly in the literature on well-being (Self et al., 2012) and indicator use (OECD, 2008). The authors of the Canadian Index of Well-being, recognised leaders in the measurement of well-being, state explicitly that they are far from knowing all the constituents and determinants of what contributes to human well-being and the extent of the interaction among the factors (Michalos et al., 2011, p. 7).

As pointed out by Coleman (1998) a goal of a Genuine Progress Index is to integrate social, economic and environmental realities to show their interdependence. The objective of interlinking indicators is, therefore, to bring together in a systems structure the different indicators used to measure well-being to better understand how the indicators impact on each other and the resultant behavioural patterns.

This chapter first provides the context for the case study. It then looks at different options for determining the indicators to use to measure well-being in the Wellington Region. This is followed by a description of the workshop process undertaken with participants to consider the relationships between the WR-GPI indicators. The outcomes of the analysis undertaken using interlinked thinking are then provided.

7.1 THE WR-GPI CASE STUDY CONTEXT

The WR-GPI was developed as part of the Wellington Regional Strategy (WRS) and is a joint project between the nine territorial authorities and the regional council.[65] The WR-GPI is used to track and report on changes in well-being in the region. It was first published in 2011 and updated in 2014. The existing WR-GPI framework is based on the nine community outcomes categories in the WRS as depicted in Figure 7-1.

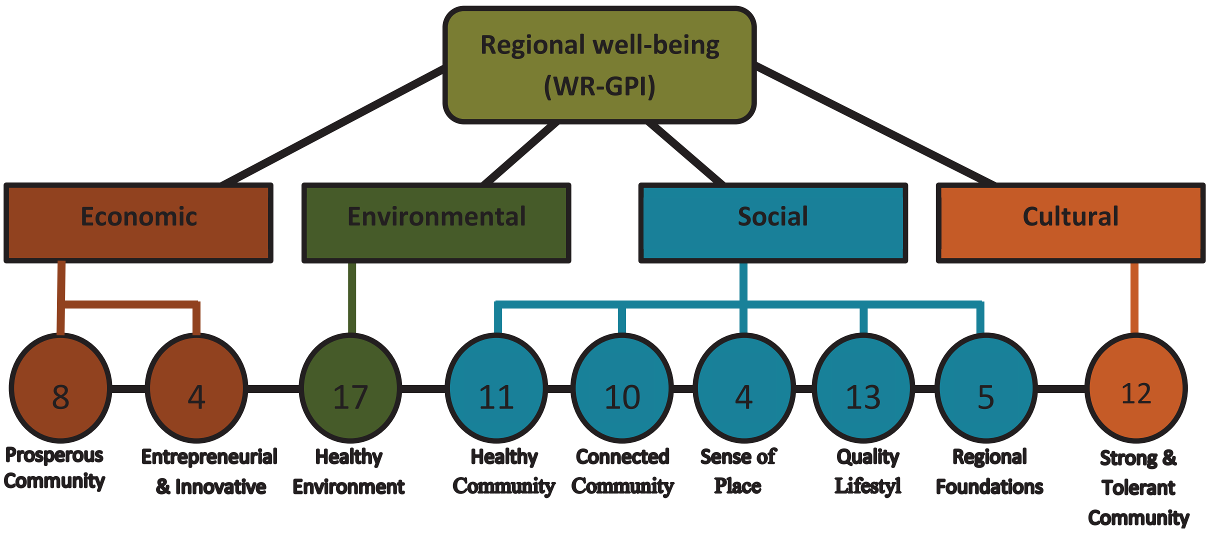


Figure 7-1: Wellington Region Genuine Progress Index Structure. (Source: Wellington Regional Strategy Office, 2011). The Indicator numbers in the circles have been added.

[65] In New Zealand local government is made up of territorial authorities that comprise city and district councils and regional councils.

Each of the nine community outcomes has indicators (circles in Figure 7-1 give the number of each) that are used to measure if the current trend direction is desirable or not.

To select indicators, the criteria used were: (i) whether the data came from a reliable or official source; (ii) whether it clearly showed change over time; and (iii) whether it was easy to understand (Wellington Regional Strategy Office, 2011). In addition, data were required to be valid, repeatable, able to be aggregated or disaggregated, culturally meaningful and relevant, available, and cost effective (Durling, 2011). According to Packard (2009) these criteria were developed by assessing the selection criteria for indicators used by other organisations, such as the Ministry of Social Development and Te Puni Kōkiri.[66]

The process of deciding which indicators to use for the WR-GPI was done via a series of workshops. The process was top-down, involving experts, staff and invited groups, rather than a bottom-up community participation exercise (as was done, for example, for the construction of the Nova Scotia GPI). Stakeholders invited to be involved were: the Wellington Regional Strategy Committee; Greater Wellington's Sustainability Committee; Ara Tahi[67]; Population Health Division of the Planning and Funding Directorate of the Capital and Coast District Health Board; Greater Wellington staff responsible for the Regional Policy Statement, and 16 expert commentators (Packard, 2009).

Greater Wellington staff decided on the final indicator set. For a number of suggested indicators there were no data or inadequate data. This led either to the dropping of indicators or to future data collection being prioritised. Stakeholders considered weighting indicators, but as no statistical or empirical grounds were established for assigning any indicator a greater or lesser value, all indicators were given equal weighting.

---

[66] The Government's principal adviser on the Crown's relationship with iwi, hapū, and Māori, and on key Government policies as they affect Maori.

[67] Ara Tahi is a leadership forum of Greater Wellington Regional Council and its six mana whenua partners.

Data for each indicator are collected annually where possible. These data are then indexed and aggregated in different ways. For example:

- Across the 'regional' level to compare the indexed GPI trends in well-being with regional indexed GDP.
- At the 'aspect' level (i.e. economic, environmental, social, and cultural as shown in Figure 7-2).
- At the 'community outcome' level (i.e. the bottom nine categories in Figure 7-1).

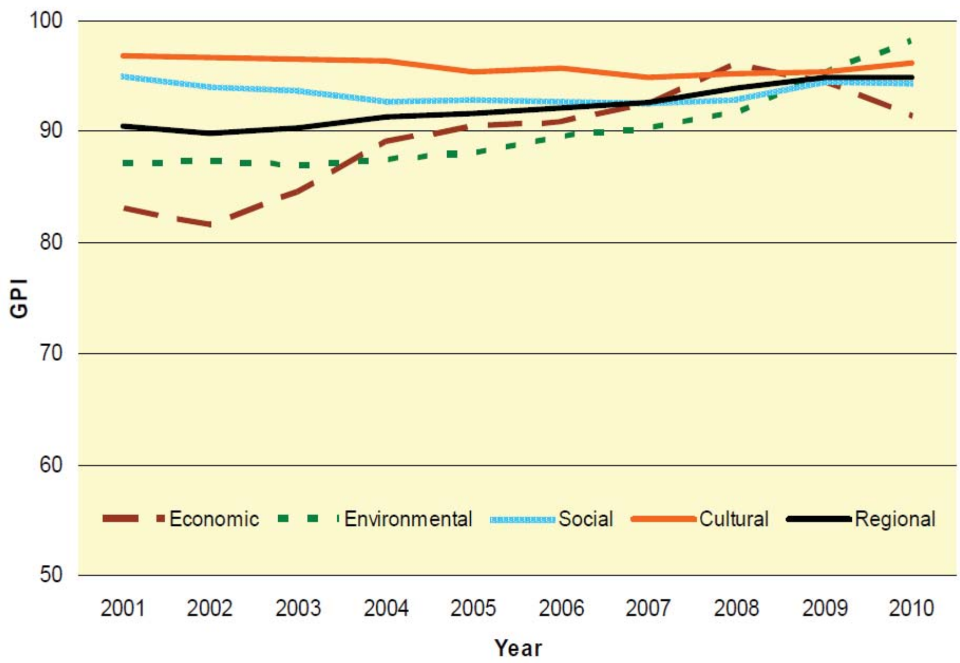


Figure 7-2: Overall WR-GPI trend and Economic, Environmental, Social and Cultural trends 2001–2010. (Source: Wellington Regional Strategy Office, 2011).

As part of the 2014 update of the WR-GPI this research reviewed the method of constructing the WR-GPI well-being measure. Questions that were considered included:

1. Are the indicators selected to measure well-being in the region the most appropriate?
2. Should the number of indicators used be more or less?
3. Are the indicators measuring the right thing to determine well-being? For example, in the WR-GPI a decrease in 'Total energy consumption per capita' is positive. If energy consumption decreases but the fossil fuel component

increases this is not a desired outcome. A better measure would be fossil fuel use per capita.

4. Are the indicators grouped correctly? Trends are determined by how the indicators are aggregated. Does aggregation obscure important information? For instance, when data are indexed and aggregated, the economic trend as shown in Figure 7-2 implies unemployment can be compensated in terms of well-being by more household and community work. Are the trends produced the result of cause-and-effect? For instance, unemployment can increase household and community work.
5. Are the indicators aggregated of similar importance as they have equal weighting? For example, with the WR-GPI the indicators 'Perception that graffiti, vandalism and litter is a problem' and '**Perception of the role of culture and cultural activities in forming a sense of national identity' rate as of equal importance to 'Percentage of population living in deprivation' and 'Life expectancy'.
6. Is the right story being told about well-being when objective and subjective measures for the same thing are aggregated? For instance, the measured data for 'Air quality' in the region, which indicate that air pollution is improving, are countered when aggregated with 'Residents rating of air quality', which shows the trend as getting worse.

These issues with the current WR-GPI framework were all discussed as part of the WR-GPI workshops on interlinked thinking.

7.2 THE WR-GPI CASE STUDY PROCESS

The case study for the WR-GPI was undertaken in two separate stages. The first stage was a desktop analysis of the indicators used in the WR-GPI, undertaken by the researcher as a precursor to applying interlinked thinking. The 86 indicators used in the 2011 report were analysed using different techniques (detailed in section 7.2.1) to decide what should be included or excluded in an ideal well-being measure. The output was a reduced set of indictors to use in the workshops as it was not feasible to interlink all 86 indicators.

When the need to use a reduced indicator set was first raised doubt was expressed by a Wellington Regional Council staff member that the WR-GPI indicator set could be further refined and agreed on. Concern was also expressed that any systems model developed while useful to indicate interconnections, would not be sensitive enough to reflect gradual change and therefore of no use for policy purposes.

The second stage (detailed in section 7.3) describes the two workshops hosted by Greater Wellington Regional Council where the interlinked thinking method as described in Chapter 6 was tested. Participants were members of the WR-GPI working group who were reviewing the WR-GPI framework and indicators. These workshops follow the steps set-out in Figure 6-1.

7.2.1 Analysis of indicators used in the WR-GPI (Step 0)

As discussed in Chapter 3, there are many different ways and measures used to determine if well-being is moving in a desirable direction. Some measures, such as the Genuine Progress Indicator, make monetary adjustment to the personal consumption component of GDP to compensate for unacknowledged impacts on society and the environment caused by economic activity. Other methods use selected indicators that are indexed and aggregated to generate composite measures.

There are no fixed criteria to determine which indicators should or should not be included in well-being measures (Alkire, 2002; Forgie, 2007; McGillivray, 2007). As a result there is considerable variation in both the number and type of indicators used to measure well-being both in New Zealand and in other countries. As the first step when linking indicators is to determine which indicators to link, the following approaches were tested to see if they could provide an acceptable rationale for indicator inclusion:

1. Commonality
2. Influence matrix analysis
3. Principal component analysis
4. Systems criteria

7.2.1.1 Commonality approach[68]

The commonality approach justifies indicator selection based on what is done elsewhere. This approach is frequently used in the absence of a conceptual framework that provides a sound theoretical foundation for indicator selection. To test this approach, the WR-GPI and nine other well-being[69] measures were analysed to determine common indicators. The measures compared were:

1. NZ Genuine Progress Indicator (Forgie & McDonald, 2013). The data covers each year for the 1970-2006 period and uses 20 indicators.
2. Working Towards Higher Living Standards for New Zealanders: May 2011 (The Treasury, 2011). The data covers the 1970 to 2010 period but not for every year. There are 44 different indicators.
3. Measuring New Zealand's Progress Using a Sustainable Development Approach: 2008 (Statistics New Zealand, 2011). The data covers the 1987 to 2010 period but not for every year. There are 85 different indicators grouped under 15 topics.
4. Measuring and Reporting Community Outcomes (Waikato Regional Council, 2012). Data cover the 2000–2011 period. In total, 117 indicators are used, grouped by 5 high-level topics, and 43 sub-categories.
5. NZ Institute "nzahead" Sept 2010 (The New Zealand Institute, 2010). The data cover the 1990–2008 period, but not for every year. The 60 indicators are grouped under 16 topic headings.
6. Wellington Region Genuine Progress Index (Wellington Regional Strategy Office, 2011). The data cover the 2001–2010 period. The 86 indicators are grouped under 9 community outcomes.
7. Quality of Life Survey Six Councils Report (2012) (ACNielson, 2013). For this biannual survey 28 indicators are used.

[68] The analysis undertaken for commonality was presented at an indicator workshop hosted by Statistics New Zealand in 2014. The report can be found at: http://www.sp2.org.nz/assets/Documents/Report-for-Statistics-New-Zealand.pdf

[69] The measures are all well-being related though referred to by a range of names, e.g. well-being, better living, genuine progress, sustainability, etc.

8. Canadian Index of Wellbeing[70] (Michalos et al., 2011) The data cover the 1994–2008 period. The 64 indicators (or headliners) are grouped in 8 domains.

9. OECD Better Life Index (OECD). Data are for 2014 only. 24 indicators are grouped in 11 topics.

10. Sustainable Australia Report 2013 (National Sustainability Council, 2013) The data cover a range of time spans between 1880 and 2012. There are 48 key indicators and 8 contextual indicators.

The review of the ten well-being measures showed that each had its own unique structure for indicator selection and grouping.[71] The process of analysis involved two stages. The first stage was to determine the top level 'domains' that were used by the various well-being measures. The colour coding in the table indicates which domain the subject sphere was assigned to. The 18 different 'domains' and the number of measures in each 'domain' are summarised at the bottom of Table 7-1. The next stage required allocating the indicators used to one of those domains.

---

[70] This was included as is a model national project in the OECD's 'Measuring the Progress of Societies'.

[71] The terminology used to refer to the different subject spheres varies. The terms 'topics', 'outcomes', 'themes', and 'domains' are all used. Domain is used in this dissertation. A domain is an organising idea or concept (Spradley, 1979).

Table 7-1: Indicator top level descriptions and domain groupings

Indicator Framework	No.	Top Level Description Used for Indicator Grouping Classified by Subject Sphere															
NZ Institute **"nzahead"** Sept (2010) 60 indicators (Data varies 1990-2008)	16	Household wealth x4	Economic measures GDP per capita x4	Unemployment x4	Innovation and business sophistication x4	Labour productivity x4	Educational achievement x4	Life expectancy x4	Suicide x4	Assault mortality x4	Inequality x5	Net migration of citizens x4	Agriculture and forestry land per capita x4	Water quality x4	CO2 concentration in atmosphere x1	CO2 emissions per capita x2	Invasive species x4
Wellington Region Genuine Progress Index (2011) 86 indicators (Data 2001-2010)	9	Prosperous community x8	Entrepreneurial & Innovative community x4	Healthy community x11	Quality lifestyle x13	Regional foundations x5	Strong & tolerant community x12	Sense of place x6	Connected community x10				Healthy environment x17				
Treasury- Working towards higher living standards (2011) 44 indicators (Data varies 1970-2010)	10	Income x8	Wealth x4	Employment x4	Education /Skills x4	Health x4	Subjective well-being x4	Leisure x4	Security x4	Trust x4			Environment x4				
Stats NZ - Measuring NZ's Progress Using a Sustainable Development Approach (2008) 85 indicators (Data varies 1987-2010)	15	Economic resilience x6	Innovation x4	Health x7	Work, knowledge & skills x8	Culture & identity x4	Social connection & governance x6	Energy x6	Living conditions x6	Transport x5	Population x5		Waste x3	Biodiversity x5	Air and atmosphere x6	Water x7	Land use x6
MARCO - Waikato Regional Council, 43 sub-topics 117 indicators (Data 2000-2011)	5	Sustainable economy x8 (19)	Quality of Life x8 (24)	Participation & equity x2 (5)	Culture & identity x5 (10)								water quality and biodiversity x14 (29)	Other environment x6 (30)			
The Canadian Index of Wellbeing (2011) - 64 indicators (Data 1994-2008)	8	Living standards x8	Education x8	Healthy Populations x8	Community vitality x8	Democratic engagement x8	Leisure & culture x8	Time use x8					Environment x8				
Quality of Life Survey Six Councils Report (2012) 28 indicators	8	Health and Wellbeing x7	Quality of Life x2	Crime and Safety x3	Community Culture and Social Networks x6	Council Processes x1	Built and Natural Environment x4	Public Transport x2	Lifestyle x3				(Quality of Life in Big Cities 2007 56 indicators in 11 topics)				
OECD Better Life Index (2014) 24 indicators	11	Income x2	Work availability x4	Educational attainment x3	Health standards x2	Life Satisfaction x1	Community Support x1	Sense of Safety x2	Housing x3	Work-Life Balance x2	Civic engagement x2		Environment x2				
Genuine Progress Indicator for NZ, AC,WRC 20 indicators (Data 1970-2006)	20	Services of public capital and consumption x2	Under/unemployment x2	Health (private) x1	Consumption adjusted for inequality	Overwork x1	Commuting x1	Household/ community work x1	Property related crime x1				Environment x10				
Sustainable Australia (2013) 48 indicators + 8 contextual indicators (Data varies 1880-2012)	15 + 4	Wealth and Income x3	Employment x4	Productivity and Innovation x2	Skills and Education x4	Health x5	Security x3	Housing x2	Transport and Communications x4	Community Engagement x5			Climate Change x4	Atmosphere x1	Land, Ecosystems and Biodiversity x3	Water x3	Waste x2

Domains

Economic Measures (9)	Environment (9)	Health (9)	Safety (6)	Education (6)	Life satisfaction/ QoL (6)	Transport (5)	Jobs & Employment (5)	Community (5)
Worklife Balance/ Leisure (5)	Culture (4)	Entrepreneurial activity/productivity/ innovation (4)	Population (3)	Infrastructure/Council services (3)	Equity (2)	Democracy/Civic engagement (2)	Housing (2)	Voluntary/Unpaid work (1)

Allocating the 576 indicators used by the 10 different well-being measures into the 18 domains was done in a spreadsheet. The indicators common to three, or more, well-being measures are listed in Table 7-2. The domain 'Environment' had the most indicators, with 11 general areas covered by a minimum of three well-being measures. 'Culture' and 'Health' rated next with five areas covered. The WR-GPI indicator that best corresponds with the indicator description is listed in the 'WR-GPI' column.

Table 7-2: Indicators most frequently used in 10 well-being measures analysed

Domain	**Most frequently used indicators**	**WR-GPI**[72]
Economic Measures	1. Household disposable income. Per capita personal consumption x8 **2. Household wealth x6**	PC5
Environment	1. Water quality/quantity x9 2. GHG emissions/Climate Change x8 3. Soil quality/quantity x7 4. Biodiversity x7 5. Air quality x6 6. Waste/contaminated sites/recycling x5 7. Energy related x4 **8. Fish stocks x3** 9. Composite measure (EF, GPI, Living planet) x3 **10. Ozone x3** 11. **Non-renewables x3**	HE 3,4,5,6,7 RF1 HE 16 HE 8, 9,13 HE 12,17 HE 1,2 HE 10,11 HE 15 HE 14
Health	1. Life expectancy x7 (Measured by ethnicity, gender, healthy life expectancy, health expenditure) 2. Self-reported health x5 3. Mental health (stress, suicide) x4 4. Obesity x3 5. General Practitioners visits/availability x3	HC 8 HC 6 HC 7 HC 1 HC 9
Safety	1. Assault, violent crime, victimisation x8 2. Sense/perception of safety x7 3. Crime against property x4	QL 9 QL 8 QL 10
Education	1. Educational attainment (preschool/ primary/secondary/tertiary/adult) x8	EI 4, PC 8 ST 12
Life satisfaction/Quality of Life	1. Satisfaction with life survey x4 2. Quality of life assessment x3	QL 6 QL 5
Transport+Infrastructure/ Council services	1. Transport to work (travel time, cost, mode) x3 2. Public transport (boardings, perception) x3 3. Internet/Broadband access x2	RF3, 4 CC 5,6,7 CC 9,10
Jobs & Employment	1. Unemployment rate (also expressed as employment rate. Measured by youth, age cohort) x9 2. Labour force participation rate x3	PC 2 PC 1

[72] See Appendix 3a for indicator identifiers and descriptions.

Community & Voluntary	1. Perception of social support x5 2. Sense of community x3 3. Pride in city/town and a great place to live x3 4. Volunteering rates x3	ST 1 SP 4 SP1,3 SP6
Unpaid Work	1. Unpaid work outside home (covers value of and hours) x5	PC6
Worklife Balance/Leisure	1. Time devoted to leisure and personal care/exercise (includes arts and cultural activities. Measured by % of day, by age, income, ethnicity, gender) x3 2. Satisfaction with worklife balance x3	QL12, ST11 QL7
Culture	1. Ethnic/Cultural diversity x5 2. Cultural activities and facilities x4 3. Speakers of te reo[73]/Learning te reo x3 **4. Participation in sport/organised activity x3** 5. Heritage places x3	ST 5 ST 10 ST6 STC8
Entrepreneurial activity/productivity/ innovation	1. Research and development expenditure x4 2. Business innovation x4 **3. Labour productivity x3**	EI 1 EI 2
Equity	1. Income inequality measures x 7	QL 1, PC 4
Democracy/Civic engagement	1. Voter turnout x5 2. Influence & involvement in council decision-making x4 3. Trust in government x3 **4. Representation of women x3**	ST 2 ST 3,4
Housing	1. Housing affordability x6 2. Household crowding x3	QL 2 QL 3
Total indicators	51	44

Table 7-2 shows that 51 indicators were common to three, or more, of the well-being measures. No one indicator was common to all measures. Employment-related and water quality indicators appeared most frequently (in 9 out of 10 measures). If it can be assumed that commonality of use, by three or more well-being measures, provides a sufficient rationale to justify indicator inclusion, then the WR-GPI indicators are a reasonable match. As shown in the right hand column, the WR-GPI has 44 of the 51 indicators covered. Some areas have multiple indicator measures (e.g. water quality), while seven areas were missing in the WR-GPI indicator set (highlighted in red/bold in Table 7-2). Using commonality as a criterion could reduce the 86 indicators to 51 (or even 44 if the omitted indicators were not considered important for the Wellington region).

[73] Te reo is Māori language speakers.

While frequently used in practice, commonality as a technique for indicator selection has the disadvantage of introducing 'group think'. It also allows the current indicator set to perpetuate itself over time rather than respond to changes in the well-being system.

7.2.1.2 Influence matrix analysis approach

The Influence matrix method of Vester (2007) was used to analyse the role each indicator plays in the WR-GPI to see if this could be used to determine the indicators key to measuring well-being.

The Influence matrix assigns indicators to the same categories as the role matrix (Active, Passive, Critical, and Buffer as described in section 6.2.4). However, the process of calculation is different. The role matrix includes only direct links as determined by participants, whereas the Influence matrix assigns a 'strength' to every relationship indicator to indicator in the system. The strength of the relationship is estimated based on known direct and indirect impacts.

For this experiment, strength of relationship was measured on a scale of 1–5 with: weak = 1; weak to moderate = 2; moderate = 3; moderate to strong = 4; and strong = 5. There were 7396 permutations to consider (the matrix size is 86 rows x 86 columns) so this exercise, which ideally would be a participatory endeavour, was solely carried out by the researcher. The influence of each indicator in the WR-GPI system is based on the row total which gives the 'Active Sum' and the column total which gives the 'Passive Sum'. As previously identified the different roles as set out by Vester (2007) are:

- Active indicators strongly affect the rest of the system. An indicator with a high active total will bring about significant change in the system with a small movement. If the active total is low much needs to happen to that indicator before change occurs in the system.
- Passive indicators react to change in the system. An indicator with a high passive total will react strongly if a change occurs in the system. A low passive total means a great deal has to happen in the system before this indicator is affected.

- Critical indicators are influential in that they are accelerators and catalysts capable of getting things going. They can have strong and unpredictable effects. Therefore use in policy needs to be approached with care.
- Buffer indicators absorb change and maintain stability.

Appendix 3b provides the full analysis of how each indicator ranks in the Active, Passive and Critical/Buffer roles in bar chart format. A summary of the analysis is provided by Table 7-3.

Table 7-3: Analysis of WR-GPI indicators using the Influence matrix method[74]

Active (high active sum)	**Passive (high passive sum)**	**Critical (Active*Passive = High product)**	**Buffer (Active*Passive = Low product**
Unemployment rate (PC 175); **People live and work same area, local employment (PC 173)**; **Business start-ups (EI 171)**; **Workforce employed in high skill occupations (EI 160)**; Pop living in deprivation (QL 160); Access to motor vehicle (CC 156); **Purchasing power Hshold median weekly income (PC 142);** Crimes against persons (HC 137); Ease of walking around region (CC 137); **P80/P20 ratio gross weekly household income i.e. equity (PC 136)**	**Positive about QoL (QL 203); Rating of Happiness (QL 186);** Satisfied with council services (RF 157); Pride in city look and feel (SP 150); **Perception of health as good (HC 150); Satisfied work/life balance (QL 150);** Contact with friends/family (SP 148); **Participation in social activities (QL 144); Residents experiencing regular stress (HC 141); Life expectancy (HC 141); Sense of safety (QL 138) Avoidable hospital admissions (HC 138)**	**Positive about QoL (QL 25984)**; **Rating of Happiness (QL 22878); Unemployment rate (PC 22750); Business start-ups and closures (EI 20520); Pop living in deprivation (QL 19520);** Perception of health as good (HC 18000); **People live and work same area - local employment (PC 17473)**; **Satisfied work/life balance (QL 17100);** Pride in city looks & feel (SP 17094); **Workforce employed in high skill occupations (EI 16960).**	**Soil q outside target drystock farms (HE 7644); Perception can influence council d/m (ST 7830); Soil q outside target dairy farms (HE 7896); Groundwater quality median Nitrate conc >3mg/L (HE 7998); Per capita material recyc (HE 8010); Material to landfill (HE 8091); Perception understands council d/m (ST 8096); Per capita water supply (HE 8099); Avg voter turnout local elections (ST 8148)** GDP spent on research and development (EI 8190)

Bold= most common categories. See footnote for calculation.

Based on an analysis of the top 10 ranks it can be said that the indicators that play an 'Active' role in the WR-GPI system are mostly 'Economic' (bolded in Table 7-3.

[74] Categories: PC = Prosperous Community; EI = Entrepreneurial & Innovative (these add to Economic as per Figure 7-1). HE = Healthy Environment (this is Environment as per Figure 7-1); HC = Healthy Community; CC = Connected Community; SP = Sense of Place; QL = Quality Lifestyle; RF = Regional Foundations (these add to Social as per Figure 7-1); ST = Strong and Tolerant Community (this is Cultural as per Figure 7-1). Numbers give the active sum, passive sum and product respectively.

'Economic' is the Prosperous Community (PC) and Entrepreneurial & Innovative (EI) categories combined). The 'Passive' indicators that respond most to change are 'Social' and mostly in the 'Healthy Community' and 'Quality of Life' areas (bolded in Table 7-3). As circumstances change, factors such as being positive about 'Quality of Life' and 'Ratings of Happiness' fluctuate accordingly.

The 'Critical' roles in the WR-GPI system are predominantly a mix of 'Quality of Life' and 'Economic' indicators.

Interestingly, the indicators that play a 'Buffering' role in the system mostly relate to the environment and the institution of local government. The functions these indicators measure provide the often unacknowledged foundation for well-being in a region (a healthy environment and sound local government).

Based on not having roles that rank in the top 20 as Active, Passive, Critical or Buffer, the 28 indicators listed in Table 7-4 could be removed from the WR-GPI indicator set. This would reduce the 86 indicators down to 58.

Table 7-4: Indicators that do not have significant active, passive, critical or buffer roles

WR-GPI Indicator
Hsholds on Housing NZ waiting list
Peak AM/PM congestion rates
Access to internet
Access to broadband (fast internet)
Active mode share of travel
Stream and river health MCI
School leavers with> NCEA level 2
Attending arts events
Sense of local community
Perception of cultural role in national identity
GHG emissions /capita
Hazardous drinking
Labour Force participation rate
Residents rating air quality a problem
Positive perception of rich and diverse arts scene
Reported road injuries
Volunteerism rate (from census)
Overweight and obesity
FTE GPs (access to health care)
Value of building consents
Perception graffiti, vandalism, litter problem
Value of hshld and community work (unpaid work)
Smoking

Working age with no qualification
Access to local parks/green space
Total energy consumption / capita
Air quality PM10 days good/ex
Crimes against property

With the Influence matrix approach the roles of the indicators are based solely on the assigned 'strength' of the interconnections between indicators. While interesting as an approach and a useful way to identify the role indicators play when they are interlinked, the Influence matrix as applied here, cannot be considered a definitive way to determine the indicators to include/exclude in the WR-GPI. Important environmental conditions like air quality would not be taken into account if the indicators listed in Table 7-4 were excluded. If the process used was participatory then perhaps there could be more confidence in the final indicator choice. Other disadvantages with the Influence matrix approach include not being able to identify important missing indicators, and that indicator roles are determined relative to the other indicators being considered, so that any addition/removal of indicators will change the assigned roles of the other indicators.

7.2.1.3 Principal component analysis approach

Principal component analysis (PCA) is a mathematical technique used to reduce a large set of possibly correlated indicators into a smaller set of unrelated indicators while still retaining the information incorporated in the large set, the principal components. A representative indicator subset is selected using the indicators with the highest correlation.

PCA was explored as a possible tool for determining how the WR-GPI indicators relate to each other and reducing the WR-GPI dataset into a new set of uncorrelated indicators. Data for the 86 different indicators were entered on an Excel spreadsheet and PCA software used across the data set both to reduce it to a more manageable number and to remove occurrences of double counting. Results showed this statistical technique could not be reliably applied in this instance. For the WR-GPI, there are 86 different indicators with at most ten data points each. For some indicators there were as few as two data points. Multi-variate analysis is not reliable when the sample is small compared with the number of indicators (OECD, 2008).

7.2.1.4 Systems criteria approach

The indicators currently used for the WR-GPI were not selected based on systems theory. Evaluating the WR-GPI indicators through a systems lens was therefore undertaken to see how well the indicators selected conform to the requirements of using a systems approach using the methods previously described in Chapter 5: (1) the Bio-cybernetic approach (Vester 2007); (2) The Natural Step (Robèrt, 2002); and (3) the Orientor approach (Bossel, 1998, 1999, 2000).

The Bio-cybernetic approach

For Vester (2007), indicators used to describe a system should cover, at approximately the same level of detail, the different categories covered by the (1) Spheres of Life criteria, (2) Physical criteria, (3) Dynamic criteria, and (4) Systems Relations criteria. In a spreadsheet, the WR-GPI indicators were assigned to each of these criteria. The results are set out in Table 7-5.

Table 7-5: WR-GPI indicators aligned with the Vester bio-cybernetic criteria

Criteria	Categories	Number of WR-GPI Indicators*	WR-GPI community outcomes categories covered ‡
Spheres of Life	Participants (P)	**54**	PC,EI,HE,HC,CC, SP,QL,RF,ST
	Activities (A)	22	PC,EI,HE,HC,CC, RF
	Area/Space (S)	23.5	PC,EI,HE, CC, SP,QL,ST
	Mood/feelings (M)	26	PC, HE,HC,CC, SP,QL,RF,ST
	Natural balance (N)	20.5	PC, HE, QL,RF
	Interconnections (I)	18	HC,CC, SP,QL,RF
	Organisational structure (O)	26	PC,EI,HE,HC,CC, QL,RF,ST
Physical	Material/Matter (Ma)	**44**	PC,EI,HE,HC,CC,SP,QL,RF,ST
	Energy (E)	14	PC,EI,HE,HC,CC, ST
	Information (If)	**42**	PC,EI,HE,HC,CC, SP,QL,RF,ST
Dynamic	Flow determinant (F)	11	EI,HE,HC,CC, QL, ST
	Structural determinant (St)	8	PC,EI,HE, CC, QL, ST
	Temporal dynamics (T)	14	PC,HE,CC, RF,ST
	Spatial dynamics (Sd)	**59**	PC,EI,HE,HC,CC, SP,QL,RF,ST
System relations	Opens system to input (In)	4	PC,EI,HE, QL
	Opens system to output (Out)	0	
	Endogenous control (En)	**73.5**	PC,EI,HE,HC,CC, SP,QL,RF,ST
	Exogenous control (Ex)	7	PC,EI, HC,CC, QL

*indicators can be allocated more than once. Values assigned: 1 = fully applicable; .5 = partially applicable; 0 = not applicable. Bold = system areas over-represented by indicators.

‡ PC = Prosperous Community; EI = Entrepreneurial & Innovative; HE = Healthy Environment; HC = Healthy Community; CC = Connected Community; SP = Sense of Place; QL = Quality Lifestyle; RF = Regional Foundations, and ST = String and Tolerant Community

This assessment showed that in terms of the bio-cybernetic systems approach the WR-GPI cannot be considered a comprehensive system. As shown in Table 7-5, the ‘spheres of life’ and ‘physical criteria’ are adequately covered. The dynamic criteria are underrepresented in all categories other than ‘spatial dynamics’. The biggest deficit occurs in the system relations criteria. There are a large number of indicators for ‘Endogenous control’ and a shortage of indicators in the other three system relations criteria. This is not unexpected as the focus of the WR-GPI is on components that are controllable within the region and the indicator set reflects this. Influences from outside the region are not taken into account. This reveals a gap from a systems perspective as influences such as climate change and imports are not considered to impact on the well-being of the region. Likewise, influences such as exports leaving the region, and taxes collected in the region that are spent elsewhere in New Zealand are not considered to impact on the well-being of the region. Vester’s requirement that the categories be reasonably well balanced indicates that ‘Endogenous control’, Spatial dynamics’, ‘Participants’, ‘Material/Matter’ and ‘Information’ are over-represented in the WR-GPI system.

The Natural Step (TNS) approach

The application of TNS framework to the WR-GPI takes as a starting point that all four capitals (social, human, built, and natural) need to be maintained or increased for sustainable well-being. This is a ‘strong well-being’ approach, which contrasts with the ‘weak well-being’ approach that allows substitution between capitals. The maintenance of all capitals in a world seeking higher living standards presents significant policy challenges. Most well-being measures do not even aspire to this goal.

As described in Chapter 5, the Five Level Model has a stepped process starting at Level 1 and working to Level 5. It does not detail the actual indicators to use other than that they should measure the actions chosen in Level 4 to achieve favourable outcomes in the system. Table 7-6 sets out how the ‘Five Level Model’ and the four capitals (discussed in Chapter 2) were used to guide indicator selection.

Table 7-6: The Five Level model for the WR-GPI

<table>
<tr><td>Level 1
Principles for the constitution of the system.</td><td colspan="4">The provision of well-being in the Wellington region comes from the growth, maintenance and inter-relationships of the four capitals – social, human, man-made and natural capital. These capitals together form a system in which each plays an important role. Well-being requires the four capitals to be kept in balance to maintain resilience. A substantial loss in one capital cannot be satisfied by a substantial increase in another if well-being is to be sustained.</td></tr>
<tr><td></td><td>Social Capital</td><td>Human Capital</td><td>Built Capital</td><td>Natural Capital</td></tr>
<tr><td>Level 2
Principles for a favourable outcome from planning within the system. The descriptions come from the WR-GPI community outcomes (Durling, 2011, p. 16)</td><td>People are important. All members of our community are empowered to participate in decision-making and to contribute to society. We celebrate diversity and welcome newcomers, while recognising the special role of tangata whenua.</td><td>A thriving business sector attracts and retains a skilled and productive workforce. Our physical and mental health is protected. Living and working environments are safe, and everyone has access to health care.</td><td>All members of our community prosper from a strong and growing economy. Innovation, creativity and new endeavours are welcomed and encouraged. Our connections and access are efficient, quick, and easy –locally, nationally and internationally. High quality and secure infrastructure and services meet our everyday need.</td><td>We have clean water, fresh air and healthy soils. Well-functioning and diverse ecosystems make up an environment that can support our needs. Resources are used efficiently. There is minimum waste and pollution.</td></tr>
<tr><td>Level 3
Principles for the process to reach this outcome</td><td>Sound institutions and good support networks</td><td>Provision of education and health facilities. Recognition of unpaid work contribution.</td><td>Economic growth and employment to provide income for people in the region to buy goods and services. Infrastructure and communications for employment and social connection.</td><td>Protection of ecosystems. Renewable resources used where possible and regenerated. Waste generation limited to assimilation capacity.</td></tr>
<tr><td>Level 4
Actions, i.e. concrete measures that comply with the principles for the process to reach a favourable outcome in the system</td><td>Increase volunteering. Transport (public and private) infrastructure to allow contact with friends/family. Cultural activities for understanding. Good democratic practice. Committed public servants.</td><td>Encourage healthy lifestyles. Facilitate access to education and re-education. Access to internet. Reduce inequality through education and health provision.</td><td>Provide infrastructure that has lowest impact on natural capital. Encourage job creation.</td><td>Switch to renewable energy. Increase recycling, Decrease pressure on soils water and air. Tax pollution and resource extraction.</td></tr>
<tr><td>Level 5
Tools to monitor and audit.</td><td>Social capital Indicators
21</td><td>Human capital Indicators
20</td><td>Built capital indicators
26</td><td>Natural capital indicators
19</td></tr>
</table>

Based on TNS approach, the WR-GPI indicator set had 21 indicators to track social capital, 20 to track human capital, 26 to track built capital and 19 to track natural capital. Other than built capital being slightly over-represented the balance is reasonable.

Figure 7-3 shows how the WR-GPI indicators were assigned to each of the four capitals. The domain levels (coloured segments), are those commonly used (as listed at the bottom of Table 7-2) and included to experiment with how the indicators align at this level.

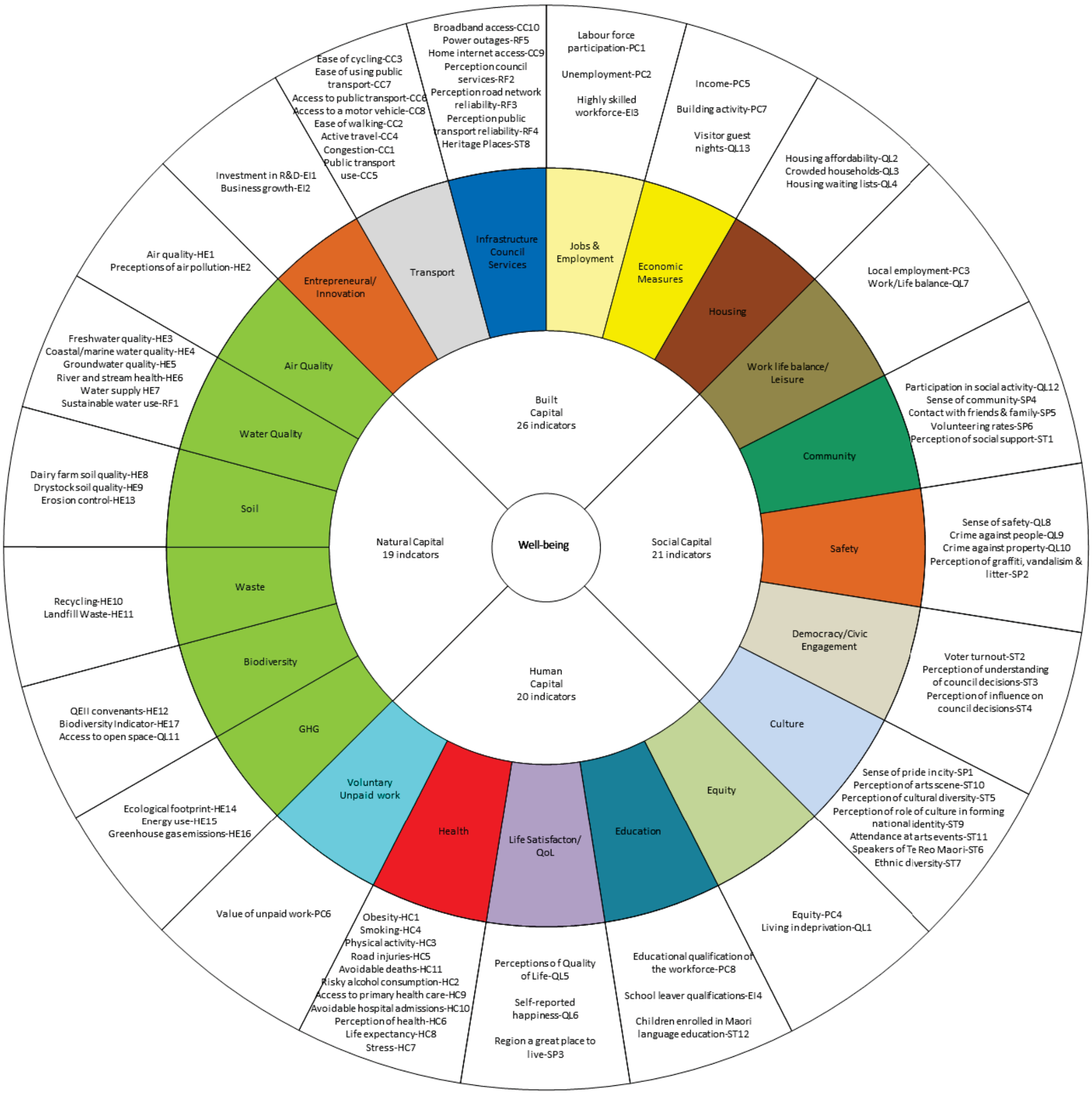


Figure 7-3: WR-GPI indicators aligned with the four capitals.

Figure 7-3 shows that while at the aggregated capital level coverage is reasonably balanced, at the domain level the number of indicators is uneven. ‘Health’, for example, has 11 indicators, whereas ‘Voluntary unpaid work’ has one indicator.

The Orientor approach

According to Bossel (1998) subsystem specific indicators can be selected by answering the orientor questions in Table 7-7. The Bossel approach is to say: if all orientors are adequately satisfied, the interests of the system are met and the system can be described as healthy, or viable (Bossel, 1998).

To monitor sustainability, Bossel (1998, p. 103) works with three subsystems: ‘Society’ (comprising social system, individual development, and government); ‘Support’ (comprising infrastructure and economic system); and ‘Nature’ (comprising resources and environment). For this research the orientor questions are used to test whether the WR-GPI indicators meet the requirements for a viable system based on the four capitals as subsystems. According to Bossel (1998), the orientor questions can be answered using quantitative or qualitative data. The orientors were aligned with the WR-GPI indicators by the researcher. In theory, each subsystem needs to have sufficient indicators to show it is in good order and functioning well enough to support the total system.

Table 7-7: Orientors to assign the current WR-GPI 85 indicators

Requirement	Subsystem	Indicator Number*
Existence: People living in the Wellington Region must be able to ‘exist’ compatibly with their natural, physical, social and economic environment. They need to be able to access shelter, clean air, potable water, information, goods, services, food and required resources.	Man-made	18
	Human	17
	Social	9
	Natural	13
Effectiveness: The Wellington Region must be able to access and use scarce resources effectively and efficiently. People need to able to earn money, buy food, fuel, and goods, and obtain water, sanitation, and medical services, all with a reasonable effort.	Man-made	19
	Human	6
	Social	3
	Natural	15
Freedom of action: The Wellington Region need to be able to cope with a variety of different situations appropriately, i.e. different people, different situations at home, at work and elsewhere.	Man-made	0
	Human	29
	Social	17
	Natural	0
Security: The Wellington Region must be able to protect itself from unpredictable sudden fluctuations of its normal environment such as accident or illness, loss of job, and interruption of water, power or food.	Man-made	6
	Human	32
	Social	20
	Natural	5

Adaptability: The Wellington Region needs to prepare for possible change by securing a broad range of education and job qualifications, and have the ability to adopt a different lifestyle, if necessary.	Man-made	6
	Human	12
	Social	9
	Natural	1
Co-existence: Individuals/families/ethnicities in Wellington Region need to live alongside each other and be part of communities which requires social skills and consideration of the interests of others.	Man-made	3
	Human	22
	Social	29
	Natural	0
Psychological needs People in Wellington Region have needs such as belonging, self-realisation, avoidance of pain and stress, and these must be satisfied.	Man-made	1
	Human	36
	Social	33
	Natural	0
Totals	**Man-made**	**53**
	Human	**154**
	Social	**120**
	Natural	**34**

*Indicators can be allocated more than once.

Bossel's orientor questions infer the WR-GPI indicators are skewed towards the human and social subsystems. As a deficit in one subsystem cannot be compensated for by an excess elsewhere, the WR-GPI is not a 'viable' system. The Bossel approach (similar to Vester and Robèrt) works as a checklist of what 'should' be covered as opposed to establishing a definitive set of indicators to use.

7.2.2 Indicators to interlink based on analysis of indicators used in the WR-GPI

None of the 4 tested approaches (Commonality, Influence matrix analysis, Principal component analysis, Systems criteria) provided a definitive way to determine indicators to include/exclude in the WR-GPI. Perhaps the most straightforward approach is Commonality. The advantage of this approach is that the indicators selected can be considered as 'tried and true'. The disadvantage is that it is not a systems approach to well-being, and new areas of interest that need to be monitored are not easily identified. It is also very time consuming because of the very large number of indicators used to measure well-being.

The systems-oriented approaches reinforced the need to identify the key subsystems and make sure that the indicators selected represent each adequately. If the social, economic, environmental, and cultural (as in Figure 7-1) subsystems are considered to be of equal importance to the aggregated WR-GPI, each should have a similar number of indicators to track change. The systems approach provides specific criteria that should be covered and emphasises the need for indicators to be relatively balanced across subsystems.

The extensive literature on indicator selection stresses that it should be a participatory process involving the community of interest. This process at the same time needs to be guided by principles, as without these it is difficult to apply rigor to indicator selection.

A more manageable reduced set of indicators was needed for the interlinked thinking workshops. The final set of indicators chosen to link the WR-GPI workshops was informed by the above indicator selection process and drew on the guidelines set out in Chapter 5. As anticipated at the outset, there was reluctance by council officials to reduce the WR-GPI indicator set. In late 2014, before the workshops with stakeholders, and in conjunction with a Greater Wellington Regional Council staff member, the updated WR-GPI indicator set (Wellington Regional Strategy Office, 2014) of 85 indicators was reduced to 59 indicators for the purpose of interlinking. The main reasons for the reduction were:

1. Double-counting. For example ‘CC9 Households with internet access’ and ‘CC10 Broadband internet access’ were considered to measure a similar thing. When both these measures are indexed and aggregated into the WR-GPI, this double counting is not transparent.
1. Similar linkages expected in the system. For example, ‘Erosion control’, ‘Dairy farm soil quality’, and ‘Drystock soil quality' were combined into ‘Soil quality’.
2. Not at a similar level of importance. For example, ‘Perception of graffiti, vandalism and litter problems’ was not considered of equal importance, for instance, to ‘Region considered a great place to live’. In the existing WR-GPI, when these indicators are indexed and aggregated into a trend they are given equal importance.
3. Not aggregating objective and subjective measures for the same thing. This is a form of ‘cancelling out’ and does not provide useful information from a systems or any other perspective.
4. The role of the indicator is not clear. For example, the use of ‘HE15 Total energy consumption per capita’, where a decrease is not always a positive outcome for well-being. Other excluded indicators were those that cover

public perception of council services, the road network, and public transport. These can be considered less indicators of well-being than ways to report on council performance.

Two additional changes were made to the reduced set of 59 indicators used in the workshops: (1) 'Unemployment rate' was replaced with 'Employment rate'[75] as employment rather than unemployment is considered to be the driver of well-being; and (2) 'Security of electricity', which was part of the 2000–2010 indicator set but had been dropped through lack of data, was included to see if participants identified this indicator as important to sustainable well-being in the region. The next section describes the interlinking process undertaken.

7.2.3 Workshop process

Two workshops were hosted by Greater Wellington Regional Council (28 November[76] and 4 December[77] 2014). The purpose of the workshops was to: 1) review the indicator set used in the 2001-2013 Wellington Region Genuine Progress Index (WR-GPI) (Wellington Regional Strategy Office, 2014) and, 2) apply the interlinked thinking method with the WR-GPI indicators to get a better understanding of the relationships between the indicators used to measure well-being in the Wellington Region.

At the first workshop, the set of indicators used to measure well-being in the WR-GPI was discussed and then the reduced indicator set to link agreed on. This was followed by an introduction to systems thinking and instructions on how to construct CLDs.

The steps set out in Figure 6-1 and described in the method (Chapter 6) were then followed.

---

[75] Also variable names for CLDs should be the positive interpretation (Maani & Cavana, 2007).

[76] The 10 participants at the workshop were from Greater Wellington (3), Statistics New Zealand (2), Porirua City Council (2), Wellington City Council (1), Wellington Chamber of Commerce (1), and Hutt Valley District Health Board (1).

[77] The seven participants at the workshop were from Greater Wellington (2), Statistics New Zealand (2), Wellington City Council (1), Wellington Chamber of Commerce (1), and Hutt Valley District Health Board (1). This attendance was less than expected due to the on-the-day announcement of a proposal to combine territorial local authorities and the regional council into one organisation. This resulted in last minute apologies from the two Porirua City Council participants and a Greater Wellington participant.

Results were presented to participants at the second workshop, which was followed by a discussion.

Participants were surveyed at the start of the first workshop and at the end of the second workshop to get their views on the interlinked thinking method and establish whether they considered it added value or not. The discussion covering the questionnaire responses is included in Chapter 10.

7.3 THE WR-GPI CASE STUDY CONTENT

This section describes the results generated for the WR-GPI case study when the method as set out in Figure 6-1 was followed.

7.3.1 Link indicators into a system (Step 1)

Three groups were formed with three or four participants in each group. A1 sheets of paper with the 59 indicators printed on were provided to each group.

Workshop participants worked for approximately 90 minutes[78] to link indicators, mark polarity and time delays on the A1 sheets, and record the logic of the links drawn. Only direct links considered by the members of the group as important were drawn.

7.3.2 Transcribe the links and polarity (Step 2)

Analysis of the 3 different A1 charts of linkages was carried out by the researcher in the week between Workshop 1 and Workshop 2. Links were combined to construct one model using Vensim™ software, as shown in Figure 7–4. The links from this model were transcribed into the links matrix.

[78] Until they deemed the links in their model were complete at a similar level of detail.

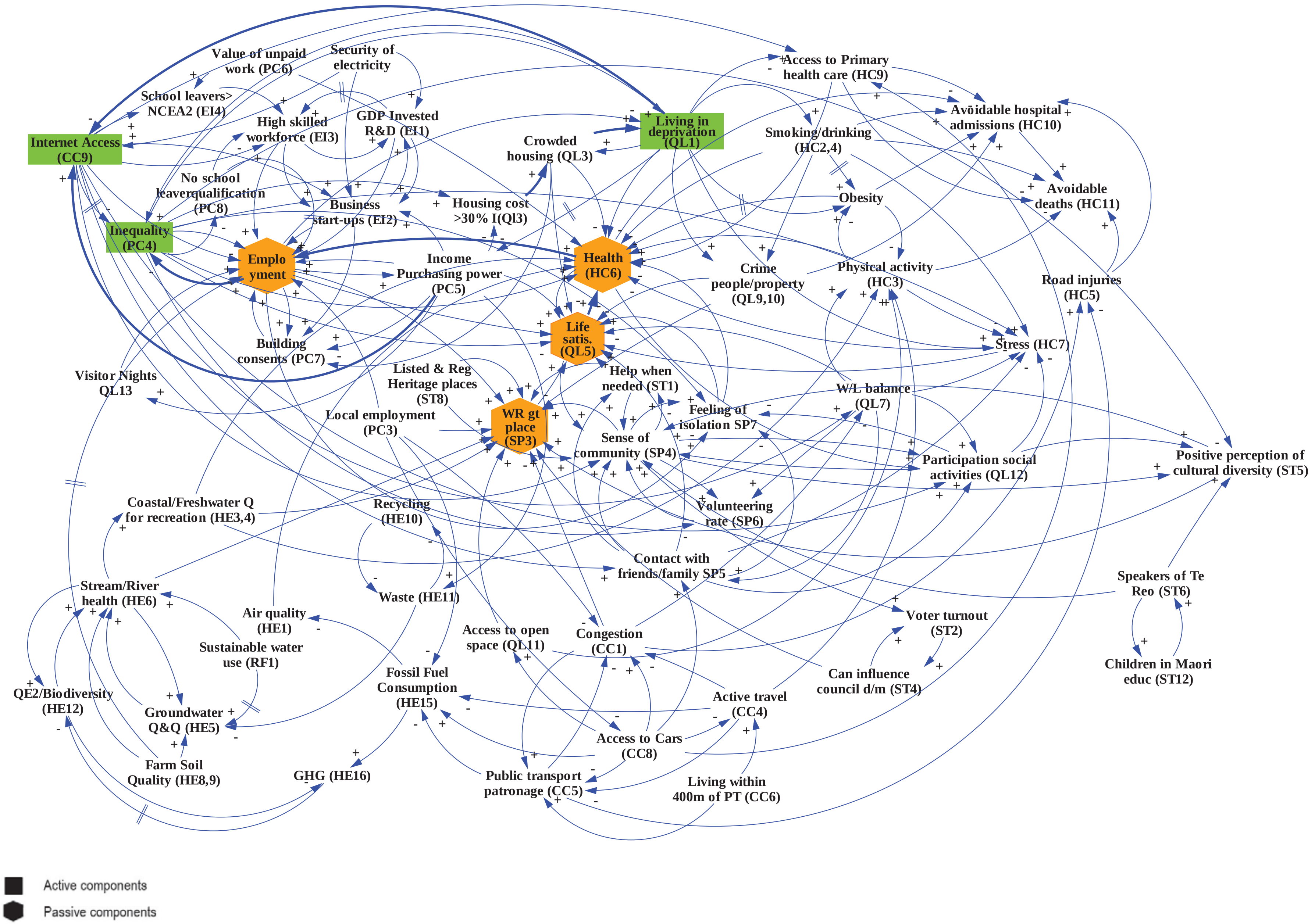


Figure 7-4: WR-GPI linked indicator model.

7.3.3 Determine the roles of indicators in the system (Step 3)

The algorithm extracted the information set out in Table 7–8 from the links for the combined model depicted in Figure 7–4.

Table 7-8: WR-GPI indicator analysis

Indicator	Loops	Passive	Active	Active/ Passive	Critical/ *Buffer*
Employment rate	2505	**12**	7	0. 58	**84**
Perception of health as good (HC6)	2274	**13**	4	0. 31	**52**
Population living in deprivation (QL1)	2143	3	**10**	3. 33	30
Access to internet (CC9)	2054	3	**10**	3. 33	30
Life sat (QL5)	1778	**12**	2	0. 17	24
Sense of local community (SP4)	1725	9	7	0. 78	**63**
Purchasing power Hshld median weekly income (PC5)	1548	2	8	**4. 00**	16
P80/P20 ratio gross weekly Hshld income (Inequality PC4)	1471	3	**10**	3. 33	30
Participation in social activities (QL12)	1299	5	4	0. 80	20
Contact with friends/family (SP5)	976	3	6	2. 00	18
Population living in crowded housing (QL3)	968	2	4	2. 00	8
Feeling of isolation (SP7)	960	5	2	0. 40	10
Spend >30% disposable income on housing (QL2)	949	2	1	0. 50	*2*
Satisfied work/life balance (QL7)	856	2	6	3. 00	12
WR great place to live (SP3)	758	**12**	1	0. 08	12
Residents experiencing regular stress (HC7)	636	7	2	0. 29	14
Perception of availability support (ST1)	515	2	3	1. 50	6
Positive perception of cultural diversity (ST5)	509	4	2	0. 50	8
Volunteerism rate (SP6)	181	3	1	0. 33	3
Workforce employed in high skill occupations (EI3)	175	4	3	0. 75	12
Business start-ups and closures (EI2)	165	5	3	0. 60	15
Participation in regular physical activity (HC3)	133	5	4	0. 80	20
Average voter turnout local elections (ST2)	130	2	1	0. 50	*2*
Perception can influence council d/m (ST4)	130	1	2	2. 00	*2*
GDP spent on research and development (EI1)	119	3	3	1. 00	9
Hazardous smoking/drinking (HC2,4)	114	1	6	**6. 00**	6
Crimes against persons/property (QL9,10)	96	2	3	1. 50	6
Overweight and obesity (HC1)	85	3	3	1. 00	9
Value of building consents (PC7)	74	4	1	0. 25	4
Stream and river health MCI (HE6)	62	4	4	1. 00	16
Groundwater quality median Nitrate conc >3mg/L (HE5)	61	4	1	0. 25	4
Material to landfill (HE11)	61	2	2	1. 00	4
Working age with no qualification (PC8)	56	1	2	2. 00	*2*
School leavers with> NCEA level 2 (EI4)	56	2	1	0. 50	*2*
Coastal/Freshwater suitable for recreation (HE3,4)	44	1	3	3. 00	3
FTE GPs (access to health care HC9)	14	3	3	1. 00	9
Visitor guest nights (QL13)	4	1	1	1. 00	*1*
Total QEII land (HE12) Proxy biodiversity	2	2	2	1. 00	4
Per capita material recycled (HE10)	1	1	1	1. 00	*1*
GHG emissions /capita (HE16)	1	2	1	0. 50	*2*
Peak AM/PM congestion rates (CC1)	1	4	4	1. 00	16
Public transport patronage (CC5)	1	4	3	0. 75	12
Can speak Te Reo Māori (ST6)	1	1	3	3. 00	3
Children attending Māori schools (ST12)	1	1	1	1. 00	*1*
People live and work same area (local employment) (PC3)	0	0	5		*0*
Value of Hshld and community work (unpaid work PC6)	0	0	2		*0*
Security of electricity	0	0	3		*0*

Air quality PM10 days good/ex (HE1)	0	1	1	1. 00	*1*
Soil quality outside target dairy/drystock farms (HE8,9)	0	0	3		*0*
FF consumption /capita (HE15)	0	4	2	0. 50	8
Reported road injuries (HC5)	0	2	2	1. 00	4
Avoidable hospital admissions (HC10)	0	6	1	0. 17	6
Avoidable deaths (HC11)	0	5	0		*0*
Active mode share of travel (CC4)	0	2	4	2. 00	8
People within 400m transport stop (CC6)	0	0	2		*0*
Access to motor vehicle (CC8)	0	1	7	**7. 00**	7
Access to local parks/green space (QL11)	0	1	2	2. 00	*2*
Water allocation compared to total resource (RF1)	0	0	2		*0*
Listed and registered heritage places (ST8)	0	0	2		*0*
Total loops	2562				

The active total provides an indication of how strongly an indicator influences the rest of the system. The **active** indicators capable of triggering change in the well-being system with little change in themselves are: (i) P80/P20 ratio gross weekly household income (Inequality PC4) (10); (ii) Access to internet (CC9) (10); and (iii) Population living in deprivation (QL1) (10).

Passive indicators highly responsive to a small change elsewhere are: (i) Perception of health as good (13); (ii) Employment rate (12); (iii) WR great place to live (12); and (iv) Life satisfaction (12).

Critical indicators with a strong influence on the system, and, highly influenced by system factors are: (i) Employment rate (84); (ii) Sense of local community (63); and (iii) Perception of health as good (52).

Indicators play a **buffer** role in the system by absorbing impacts from elsewhere. They are less connected in the system. The buffer (red/italic) indicators identified are: (i=)[79] Listed and registered heritage places (ST8) (0); Water allocation cf total resource (RF1) (0); People within 400m transport stop (CC6) (0); Avoidable deaths (HC11) (0); Soil q outside target dairy/drystock farms (HE8,9) (0); Security of electricity (0); Value of Hshld and community work (unpaid work PC6) (0); People within 400m transport stop (CC6) (0); People live and work same area, local employment (PC3) (0); (ii=) Air quality PM10 days good/ex (HE1) (1); Children attending Māori schools (ST12) (1); Visitor guest nights (QL13) (1); (iii=) Access to local parks/green space (QL11) (2); GHG emissions /capita (HE16) (2); School leavers with> NCEA level 2 (EI4) (2); Perception

[79] (i =) signifies these buffer variables had an equal score of 0. (ii =) signifies these buffer variables had an equal score of 1. (ii i=) signifies these buffer variables had an equal score of 2.

can influence council d/m (ST4) (2); Avg voter turnout local elections (ST2) (2); Spend >30% disposable income on housing (QL2).

7.3.4 Analyse feedback loops in the system (Step 4)

Table 7–8 shows that 'Employment rate' is the most connected indicator in the system. It appears in 2505 of the 2562 total loops. When 'Employment rate' is removed from the system, only 57 (2. 22%) of loops remain.

Whether the overall system is stable or not can be found from the ratio of reinforcing to balancing loops. The WR-GPI system is heavily orientated towards **reinforcing** loops, with 2445 of the total 2562 reinforcing and only 60 **balancing** loops. This indicates the system is not stable in the long term and is oriented to growth or decline.

Strong links in the system provide insights into where policy might be effective. Table 7-9 gives the links that are traversed most frequently in the WR-GPI system and therefore are important relationships to consider. The logic is that if these links are crossed many times by the CLDs that are the structure of the WR-GPI system they are very influential in the overall system.

Table 7-9: WR-GPI Strong links in the system

From indicator	To indicator	Total
Perception of health as good (HC6)	Employment rate	2248
Life satisfaction (QL5)	Perception of health as good (HC6)	1185
Employment rate	P80/P20 ratio gross weekly household income (PC4 Inequality)	1075
Purchasing power Hshld median weekly income (PC5)	Access to internet (CC9)	1072
Population living in deprivation (QL1)	Access to internet (CC9)	982
Spend >30% disposable income on housing (QL2)	Population living in crowded housing (QL3)	949
Population living in crowded housing (QL3)	Population living in deprivation (QL1)	902

Table 7-9 indicates that the strongest relationship in the WR-GPI system is that between 'Perception of health as good' and 'Employment rate'. This link is traversed 2248 times in the system and reveals the importance between good health and employment to well-being in the region. This is an interesting outcome, as the policy focus for employment is generally education and skills. With an ageing population, good health is likely to have a greater impact on employment, so this may well be significant to consider. 'Life satisfaction' in turn is an important determinant of

‘Perception of health as good’, which indicates that people who are happy and positive about their quality of life are more likely to be healthy. Again, this is an interesting link as it is the inverse relationship that is usually highlighted; but, given this is a regional analysis, the positive health of the community is what is modelled. ‘Employment rate’ is an important determinant of inequality as inability to work reduces social and earning opportunities. Purchasing power is a key to providing internet access. Living in deprivation is a significant cause of lack of access to the internet. Spending a large proportion of income on housing results in overcrowding and this in turn adds to the number of people living in deprivation.

The individual models revealed that the mental models of the groups differed considerably, with only 14% of links the same in all three groups.

System dynamics puts great importance on accounting for the impacts of change over time. This is one of the significant contributions made by quantitative modelling. With interlinked thinking the simple way to include time is to count the number of indicators in a loop. Long loops show that changes take place over a long period of time in the system. The longest WR-GPI system reinforcing loop connects 17 different indicators, which provide a significantly longer time scale than is generally taken into account with the linear cause-and-effect approach. The longest balancing loop also connected 17 different indicators.

7.3.5 Determine intervention points (Step 5)

Potential intervention points were explored using two different approaches:

(1) The Vester (2007) approach is to use active indicators with a high quotient value.

Good **intervention** indicators are active indicators that do not have a high passive value. The greater degree of interconnectivity means intervention via any indicator with both a high active and passive value has an increased degree of uncertainty and the risk of a destabilising effect. If a high active indicator has a low passive score (giving a high quotient) this is considered a good control lever.

The active indicators identified as good intervention points[80] in the WR-GPI system are: (i) P80/P20 ratio gross weekly household income (Inequality PC4); (ii) Access to internet (CC9); (iii) Population living in deprivation (QL1); (iv) Purchasing power Hshld median weekly income (PC5); (v) Hazardous smoking/drinking (HC2,4); (vi) Satisfied work/life balance (QL7).

These are potential intervention points only as other factors also need to be taken into consideration such as whether or not the indicator is controllable by the decision-maker. For example, increasing household income through tax redistribution or access to the internet are potential direct interventions. In contrast, 'Living in Deprivation' is more difficult to manage as this is the outcome of multiple direct and indirect factors.

(2) The Hürlimann (2009) method is to add a time dimension using a cross-time matrix (CTM).

The time delays used were marked on the A1 sheets by the WR-GPI workshop participants. The intervention points are shown in Figure 7-5 and listed in Table 7-10.

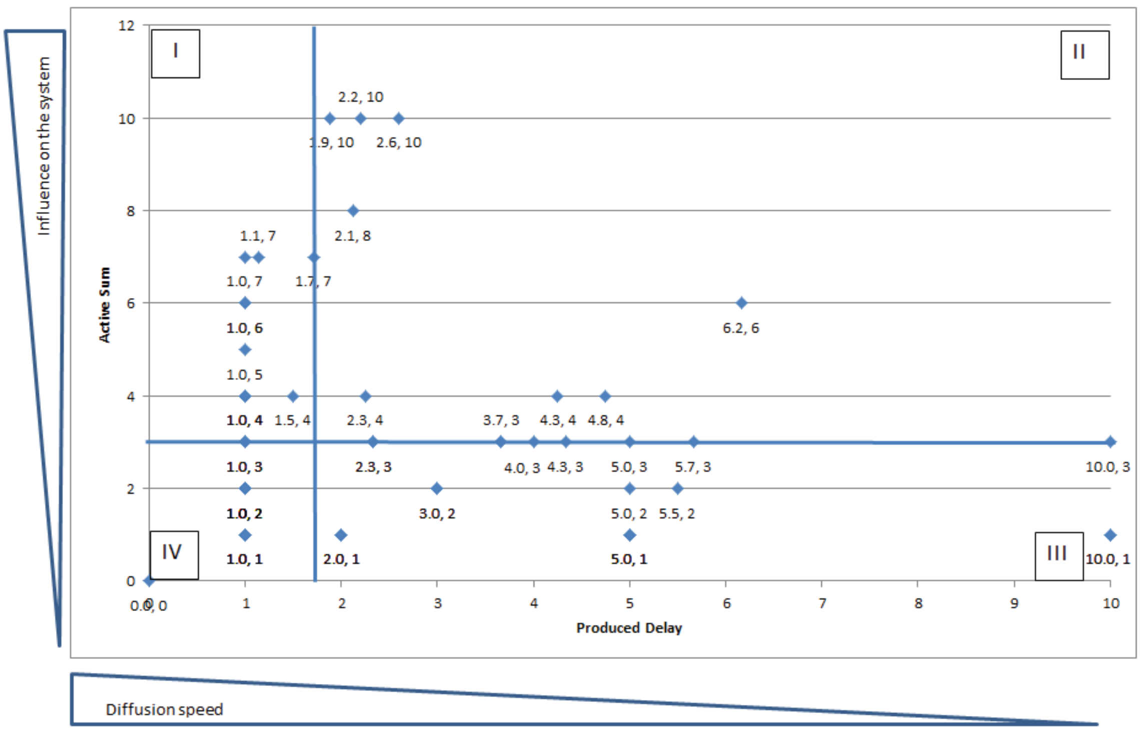


Figure 7-5: Possible intervention points when delays in the system are included. Data point names given in Tables 7-10.

[80]Cut off points were: active ≥5; active/passive ≥2.5.

Key:

I	High Active Sum (AS) and low Produced Delay (PD) value. High impact and react very quickly to change. Possible intervention points if the goal is quick change
II	High AS and PD values. High impact but longer paths or slow spread through system. Appropriate intervention point if goal is slow but substantial change
III	Low AS value, high PD value. No impact and a delayed reaction. Not appropriate for intervention
IV	Low AS and PD values act quickly to changes, but low impact. Not well suited for intervention as do not change system in a meaningful way.

As shown in Figure 7-5 there are a greater number of possible intervention points to consider with this approach than with the Vester approach. These include all the indicators located in Quadrants I and II. With the exception of 'Satisfied work/life balance', all the intervention points identified using the Vester approach are located in Quadrant II.

Table 7-10: Short-term and longer-term intervention points in the WR-GPI system

Short term Quadrant 1	**Longer term Quadrant II**
(1.0, 4) Perception health is good	*(1.9, 10) P80/P20 ratio gross weekly household income (Inequality)*
(1.0, 4) Active mode share of travel	*(2.1, 8) Purchasing power Hshld median weekly income*
(1.0, 4) Participation in social activity	*(2.2, 10) Access to internet*
(1.0, 5) Contact with friends & family	(2.3, 4) Population living in crowded housing
(1.0, 5) Live and work in same area	*(2.6, 10) Population living in deprivation*
(1.0 ,6) Satisfied work/life balance	(4.3, 4) FTE GPs (access to health care)
(1.0, 7) Access to cars	(4.3, 4) Stream and river health
(1.1, 7) Sense of local community	(4.8, 4) Participation in regular physical activity
(1.5, 4) AM/PM congestion rates	*(6.2, 6) Hazardous smoking and drinking*
(1.7, 7) Employment	

Italics = identified also by Vester approach

Introducing a time dynamic increases the number of intervention possibilities and changes the order of priority for intervention. In general, policy and decision-makers prefer quick responses as they are easier to measure and manage. However, more fundamental changes may be necessary that require policy people to think longer term (Quadrant II) if issues such as equity, distribution, fairness, sustainability, etc. are to be addressed.

Again, this analysis identifies possible intervention points only. The actual choice depends on the outcomes decision-makers are trying to achieve. The decision will have to take into account many other factors, including the extent to which an indicator can be influenced and the reliability of the time estimates.

7.3.6 Run What-ifs (Step 6)

What-if analysis demonstrates the use of well-being indicators in a more proactive manner to consider potential future situations and consequences without system dynamics modelling expertise. To foster dialogue and understanding, a what-if based on the cause-and-effect the impacts for the Wellington region of a loss of skilled jobs was worked through with the workshop participants. This what-if has occurred in the region as a result of restructuring by Central Government and the movement of skilled jobs to the Auckland region. It is also of interest because of the rate at which technology is reducing both skilled and unskilled jobs. Skilled jobs such as accountancy, architecture, and research are being automated, and this development is expected to increase (Anthony, 2015; Brinsden, 2015; The Economist, 2014). The interlinked model, as constructed by participants, has a link that shows an increase in the ‘High skilled workforce’ will lead to more ‘Employment’. This aligns with the general mental model of people in which it is accepted that better education provides more employment. Current regional data confirm this, with labour force participation being higher for people with qualifications (Department of Labour, 2007).

All the 175 loops that involved the indicator ‘High skilled workforce’ are reinforcing, and the current path dependency is that more high skilled workers have a positive impact on well-being (or alternatively a loss of high skilled workers will have a negative impact).

To explore this scenario the polarity was changed from + to – (indicated in red on Figure 7-6). Analysis of loops in Figure 7-6 then showed that 35 of the 175 loops involving ‘High skilled workforce’ changed to balancing.

Following the changed feedback loops allows the potential impacts to be surmised. For example, the loop labelled B1 (bold/green links) shows what happens when an increase in ‘High skilled workforce’ results in a decrease in ‘Employment’. With this loop there is an increase in ‘Inequality’, due to lack of income. The flow-on effect is an increase in ‘No school leaver qualification’. This results in a less ‘High skilled workforce’ and creates a balancing feedback loop in the system so that employment and skill level can better align. This is likely to be at a lower overall employment level.

The loop B2 (bold/green links) shows that a decrease in 'Employment' will also have wider impacts in the region. Loss of employment will decrease 'Income purchasing power', which will decrease both 'Business start-ups' and 'GDP invested in R & D' and thereby further decrease the 'High skilled workforce'.

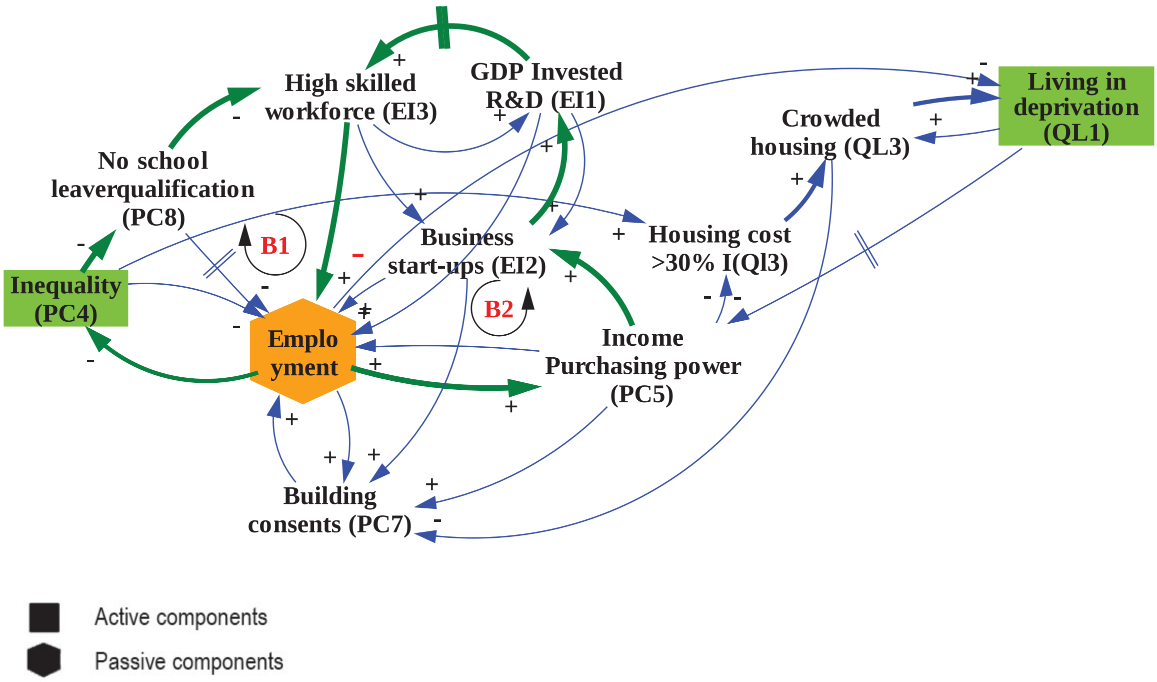


Figure 7-6: What-if where high skilled people are unemployed.

The long-term implication for the well-being of the Wellington Region if there is no high-skilled workforce, and how best to address this in the longer term, can be experimented with using Figure 7–4 and Figure 7–6. Other what-ifs of interest can also be explored.

7.4 SUMMARY

This chapter first tested different approaches for selecting WR-GPI indicators to measure well-being. These were (1) Commonality; (2) the Influence matrix approach; and (3) using Systems criteria. Commonality as a selection technique identified 51 core indicators that are widely used in the sustainability/well-being area. The WR-GPI had all but seven of these covered. The analysis based on the Influence matrix approach identified the different roles of the indicators and reduced the 86 indicators down to

58 based on excluding those that did not have a role identified as Active, Passive or Critical/Buffer.

When evaluated using the Vester and Bossel systems criteria to select indicators, short-comings were identified in the WR-GPI indicators indicator set as it currently stands. The Natural Step approach provided a better fit, with the current selection of indicators providing a reasonably balanced representation of the four capitals. None of the approaches tested were considered convincing enough to provide an alternative to the current set of WR-GPI indicators to interlink. Therefore, the WR-GPI indicators were used with the number reduced based on the guidelines set out in Section 5.5.

To determine what insights can be gained from better understanding the relationships between indicators, two workshops were held where participants tested the interlinked thinking method using the reduced set of WR-GPI indicators (59 instead of 86). The first part of workshop 1 discussed the process of indicator elimination and covered some of the issues identified as problematic with the current WR-GPI. This included the large number of indicators, the way indicators are aggregated, and the obscuring of key information.

The interlinked thinking method, when applied, showed that the well-being in the Wellington Region was a highly complex system. The analysis identified (1) Inequality PC4; (2) Access to internet (CC9); and (3) Population living in deprivation (QL1) as active indicators and also good intervention points to bring about change. The ratio of reinforcing to balancing loops identified that the Wellington Region is driven by a desire for growth and that this is inherently unstable.

Participants involved in the workshops increased their understanding of the relationships between indicators and the different roles indicators can play in a system. A full discussion of the questionnaire responses is provided in Chapter 10.

To test the interlinked thinking method more extensively it was also applied in a different context. The case study using the indicators for measuring social progress in New Zealand is discussed in the next chapter.

8 SOCIAL REPORT CASE STUDY

This chapter addresses the question: "Is the method developed to understand relationships between indicators able to be used with different indicator sets?" To answer the question two workshops were held using the Ministry of Social Development 'Social Report' indicators to test interlinked thinking. The workshops were a very collaborative exercise. They were organised by Statistics New Zealand (SNZ), the indicators were supplied by the Ministry of Social Development (MSD) and the Social Policy Evaluation and Research Unit (SUPERU) provided the venue. The idea and coordination came from a SNZ participant who, after attending the WR-GPI workshops, could see the merit in undertaking a similar exercise with the indicators under review for the 2015 Social Report/Te pūrongo oranga tangata:

> I have had strong interest from MSD, Treasury and Families Commission who are all currently working to develop indicator sets so felt this exercise would be really useful… [MSD] will send through the current set of Social Report [SR] indicators tomorrow and I think it is useful for people considering developing additional sets to start by considering the inter-relationships within the SR indicators. (Philip Walker, pers. comm. 17/2/2015)

The workshops followed a similar, though not identical, format to the WR-GPI workshops. The variation was the result of meeting the needs of the Social Report participants and implementing suggested improvements made by participants involved in the WR-GPI workshops. The description of the workshops given here, as with the WR-GPI workshops, is the process followed that participants were surveyed on. From a research perspective a unique aspect of this case study was the focus on differences between groups when using interlinked thinking.

8.1 THE SOCIAL REPORT CASE STUDY CONTEXT

The Social Report is produced by the Ministry of Social Development to provide "a picture of progress towards better social outcomes for New Zealanders. It uses a set of statistical indicators to monitor trends across key dimensions of people's lives at national, regional and territorial authority levels" (Ministry of Social Development, 2010, p. 4). The stated purpose of the Social Report is:

- to report on social indicators that complement existing economic and environmental indicators
- to compare New Zealand with other countries on measures of wellbeing
- to contribute to better-informed public debate
- to aid planning and decision making and to help identify key areas for action. (2010, p. 4)

The Social Report was first published in 2001 and subsequent reports were produced in 2003, 2007, and 2010. After 2010, funding to produce the report was not provided by central government. An OECD review of New Zealand governance criticised the lack of reporting across social outcomes and as a consequence funding was reinstated in 2015.

The indicators used in the 2010 Social Report are as shown in Figure 8-1. The Social Report data are collected across a number of central government agencies. The workshops to interlink indicators were viewed as a way to demonstrate to participants how their work contributed to a wider perspective and to determine the indicator set that best gives a balanced view of social well-being. Previous work and reporting on the social indicators has always been on an individual basis, with indicators considered independent, stand-alone measures that are not interlinked. Change is measured for each indicator separately as shown in Figure 8-1.

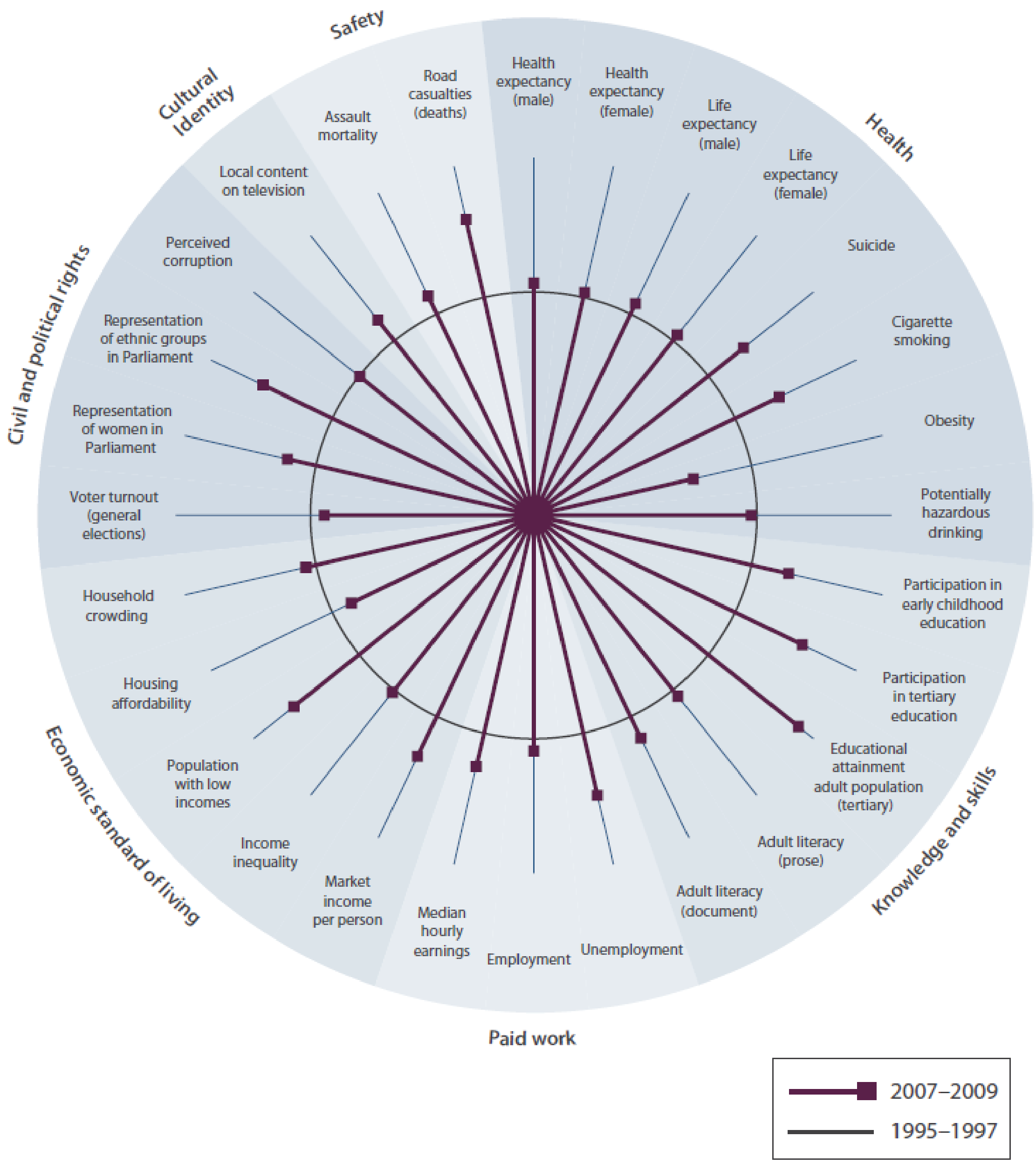


Figure 8-1: Changes in social well-being, 1995–1997 to 2007–2009. (Source: Ministry of Social Development, 2010, p. 130).[81]

[81] The circle represents average outcomes for each indicator between 1995 and 1997, and the spokes represent outcomes between 2007 and 2009. Where possible, the data are averaged over the 3 years in each period. A spoke extending beyond the circle means the outcome for this indicator has improved between the two periods. The further the spoke is outside the circle, the greater the improvement. Where a spoke falls within the circle, the outcome for this indicator has deteriorated over the decade. The further the spoke is inside the circle, the more pronounced the deterioration. An important limitation on this style of presentation is that we cannot directly compare the size of changes for different indicators. Also, the absence of longer-term trend data for some indicators limits the number of indicators we can display. Most of the latest data are for 2007, 2008 or 2009, with the exception of suicide and assault mortality (both 2005–2007) and adult literacy (2006).

Working within the case study context the specific goals of the workshops were to:

1. review the current Social Report indicators
2. conceptualise the Social Report indicators as a system
3. provide an opportunity for participants to discuss and document important relationships between indicators
4. consider how the relationships between indicators impact the work situation of different participants
5. discuss potential intervention points in the social system to inform planning, decision-making and key areas for action.

8.2 THE SOCIAL REPORT CASE STUDY PROCESS

A list of the Social Report indicators being considered for the 2015 report was provided to the researcher by MSD. This list of 73 potential indicators was reduced to 38 indicators by the researcher and the list sent to MSD and SNZ to check they agreed with it. Reasons for indicators being eliminated included:

1. Inverse relationships (e.g. 'Employment' and 'Unemployment')
2. Duplication of the same measure (e.g. 'Cigarette smoking 1' and 'Cigarette smoking 2')
3. Similarity of impacts (e.g. 'Representation of ethnic groups in government' and 'Representation of women in government'). The links and cause-and-effect were considered to be very similar.

The steps followed with the WR-GPI to identify indicators from a well-being systems perspective were not undertaken as the indicators to be interlinked were specifically for reporting social outcomes. The absence of environmental indicators was raised as an issue as environmental degradation does have social impacts. Air and water quality indicators were previously included in the Social Report, but these were dropped at the instructions of the Social Development Minister. The process of interconnecting indicators was undertaken on the understanding the system being considered (social) was in fact a subsystem. Participants were given the option to add any new indicators they thought relevant for reporting on the social subsystem.

Two workshops were held a week apart (February 26 and March 5th, 2015). The 14 participants at the first workshop were from Statistics New Zealand (7), Ministry of Social Development (3), Treasury (2), SUPERU (2). There were more participants at workshop 2 due to the interest generated at workshop 1. In total there were 18 participants at the workshop from Statistics New Zealand (8), Ministry of Social Development (3), The Treasury (3), SUPERU (3), and Greater Wellington Regional Council (1).

First, the set of indicators in the Social Report was discussed and the reduced set of indicators agreed. This was followed by an introduction to systems thinking and instructions on how to construct CLDs. The steps set out in Figure 6-1 and described in the method (Chapter 6) were then followed. Results were presented to participants at the second workshop, and this was followed by a discussion.

Participants were surveyed at the start of the first workshop and at the end of the second workshop to get their views on the methodology developed as part of this research and establish whether they considered it did or did not add value. The discussion of the questionnaire responses is included in Chapter 10.

8.3 THE SOCIAL REPORT CASE STUDY CONTENT

This section describes the results generated for the Social Report case study when the method in Figure 6-1 was followed.

8.3.1 Link indicators into a system (Step 1)

Staff members (from central and local government agencies) were mixed to form three groups (4–5 per group). The 38 Social Report indicators were provided on A1 sheets to each group so they could draw the links (following the CLD rules) they considered existed between the different indicators.

Workshop participants worked for approximately 90 minutes[82] to link indicators, mark polarity and time delays on the A1 sheets, and record the logic of the links drawn. Only direct links considered by the members of the group as important were drawn.

[82] Until they deemed the links in their model were complete at a similar level of detail.

8.3.2 Transcribe the links and polarity (Step 2)

Between workshops analysis of the links was carried out by the researcher. The models made by each group were drawn using Vensim™ software. Three links matrices were constructed. Then the links from the three different groups were transcribed into one model in Vensim™ as shown in Figure 8–2. When combined, there were 183 links, which resulted in a model with a very high degree of connectedness. These links were transcribed into the combined links matrix.

The links from each group were first analysed individually to evaluate the extent to which the mental models of the groups differed (referred to as: SR Group 1, SR Group 2, SR Group 3). Over the three groups, only 36 links (20%) were the same. Two groups had 46 links (25%) the same. There were 101 (55%) unique links that were made by one group only.

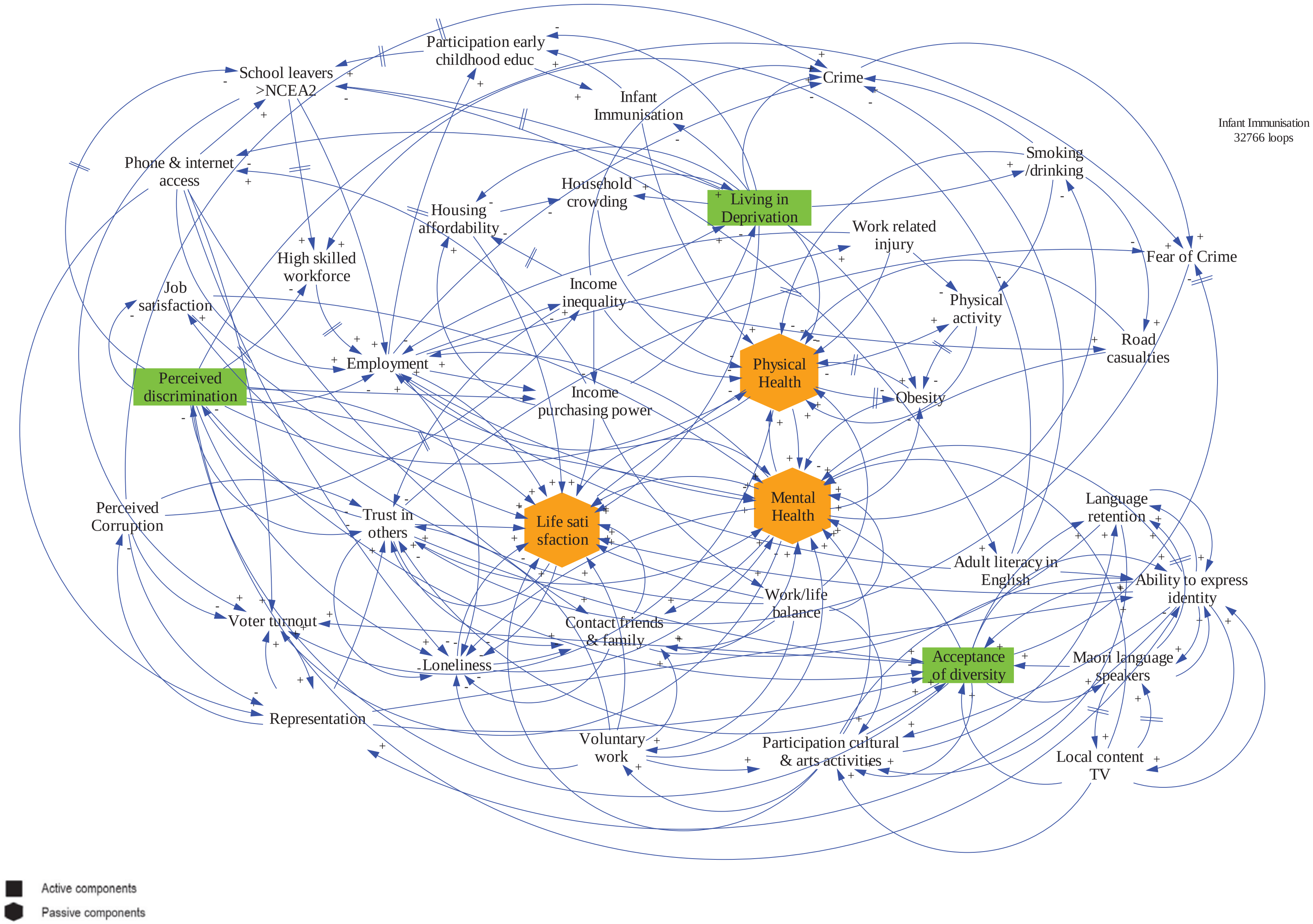


Figure 8-2: Social Report linked indicator model.

8.3.2.1 SR Group 1. Determine the roles of indicators in the system (Step 3)

Based on their understanding and mental models, SR Group 1 made 123 links between indicators. From these links the outputs in Table 8-1 were generated.

Table 8-1: SR Group 1 Indicator analysis

Indicator	Loops	Passive	Active	Active/Passive	Critical/ *Buffer*
Employment	2583	**7**	**7**	1. 00	**49**
Mental health	2375	**12**	5	0. 42	**60**
Trust in others	2252	6	6	1. 00	**36**
Life satisfaction	2099	**14**	3	0. 21	**42**
Income purchasing power	1776	2	4	2. 00	8
Physical health	1606	**9**	4	0. 44	**36**
Income inequality	1476	1	**7**	**7. 00**	7
Acceptance of diversity	1393	3	3	1. 00	9
Loneliness	1201	**7**	2	0. 29	14
Living in deprivation	1182	2	**8**	**4. 00**	16
Perceived discrimination	1158	2	4	2. 00	8
Language retention	1036	3	3	1. 00	9
Obesity	986	3	1	0. 33	3
Work/life balance	844	1	**7**	**7. 00**	7
Participation culture & arts	726	3	3	1. 00	9
Ability to express identity	607	3	4	1. 33	12
Fear of crime	601	2	1	0. 50	*2*
Crime	600	5	1	0. 20	5
Contact friends & family	438	4	2	0. 50	8
Smoking/drinking	414	1	4	4. 00	4
Particip. early childhood educ.	296	2	2	1. 00	4
Local content TV	293	2	4	2. 00	8
Housing affordability	276	3	2	0. 67	6
School leavers>NCEA2	216	2	4	2. 00	8
Adult literacy in English	208	1	3	3. 00	3
Voluntary work	204	1	4	4. 00	4
Household crowding	180	2	1	0. 50	*2*
Physical activity	160	2	2	1. 00	4
Infant immunisation	140	2	1	0. 50	*2*
Road casualties	112	2	2	1. 00	4
Māori language speakers	76	1	4	4. 00	4
Job satisfaction	68	1	2	2. 00	*2*
Work related injury	61	1	3	3. 00	3
Perceived corruption	49	1	2	2. 00	*2*
Representation	49	2	2	1. 00	4
High Skilled workforce	8	2	1	0. 50	*2*
Phone & internet access	0	0	5		*0*
Voter turnout	0	6	0		*0*
Total Loops	2639				

Indicators with a high **active** total relative to other indicators are: (i) Living in Deprivation (8); (ii) Employment (7); (iii) Income inequality (7); and, (iv) Work/life balance (7).

Indicators with a high **passive** total relative to other indicators are: (i) Life satisfaction (14); (ii) Mental health (12); and (iii) Physical health (9).

Critical indicators that play a significant role in the system are: (i) Mental health (60); (ii) Employment (49); (iii) Life satisfaction (42); Trust in others (36); and (v) Physical health (36).

The **buffer** (red/italic) indicators identified are: (i =) Phone & internet access (0); Voter turnout (0); (ii =) High Skilled workforce (2); Perceived corruption (2); Job satisfaction (2); Infant immunisation (2); Household crowding (2); and Fear of crime (2).

8.3.2.2 SR Group 1. Analyse the feedback loops in the system (Step 4)

Table 8-1 shows that 'Employment' is the most connected indicator in the system, as it is in 2583 of the 2639 total loops. The system is very dependent on 'Employment'; when this is removed only 56 (2. 12%) of loops remain.

Whether the system is stable or not can be determined from the ratio of reinforcing to balancing loops. The SR Group 1 system is heavily orientated towards **reinforcing** loops with 2578 of the total 2639 reinforcing and only 61 **balancing** loops. This indicates the system is not stable in the long-term.

Strong links in the system also provide useful information on where policy might be effective. Table 8-2 provides the links that are traversed most frequently in the SR Group 1 system. For SR Group 1 the most important relationships in their system are that of 'Employment' to 'Income inequality'; 'Life satisfaction' to 'Trust in others'; 'Mental health' to 'Employment' and 'Trust in others' to 'Acceptance of diversity'.

Table 8-2: SR Group 1 Strong links in the system

From indicator	To indicator	Total
Employment	Income inequality	1476
Life satisfaction	Trust in others	1441
Mental health	Employment	1281
Trust in others	Acceptance of diversity	1247
Obesity	Physical health	986
Employment	Income purchasing power	888
Income inequality	Income purchasing power	888

Looking at the **time** factor, the longest reinforcing loop goes through 'Employment' and connects 19 indicators. The longest balancing loop connects 12 different indicators.

8.3.2.3 SR Group 2. Determine the roles of indicators in the system (Step 3)

Based on their understanding and mental models SR Group 2 made 93 links between indicators. From these links the outputs in Table 8-2 were generated.

Table 8-3: SR Group 2 Indicator analysis

Indicator	Loops	Passive	Active	Active/Passive	Critical/ *Buffer*
Living in deprivation	52	3	**7**	2. 33	**21**
Mental health	45	**6**	4	0. 67	**24**
Smoking/drinking	42	1	4	**4. 00**	4
School leavers>NCEA2	38	3	2	0. 67	6
Employment	35	5	4	0. 80	20
Income purchasing power	28	2	5	2. 50	10
High Skilled workforce	24	2	3	1. 50	6
Loneliness	23	3	2	0. 67	6
Infant immunisation	20	1	2	2. 00	2
Physical health	20	**10**	2	0. 20	20
Particip. early childhood education	19	1	1	1. 00	*1*
Voluntary work	17	3	3	1. 00	9
Adult literacy in English	14	1	1	1. 00	*1*
Household crowding	13	3	1	0. 33	3
Income inequality	10	3	2	0. 67	6
Phone & internet access	9	1	2	2. 00	2
Work/life balance	9	2	2	1. 00	4
Housing affordability	7	1	1	1. 00	*1*
Contact friends & family	4	2	2	1. 00	4
Obesity	3	2	2	1. 00	4
Language retention	3	2	1	0. 50	2
Ability to express identity	3	4	**6**	1. 50	**24**
Physical activity	2	1	2	2. 00	2
Māori language speakers	2	2	1	0. 50	2
Participation culture & arts	1	3	1	0. 33	3
Road casualties	1	1	1	1. 00	1
Local content TV	1	1	2	2. 00	2
Job satisfaction	0	1	2	2. 00	2
Trust in others	0	3	1	0. 33	3
Perceived discrimination	0	0	**11**		*0*
Perceived corruption	0	0	5		*0*
Voter turnout	0	2	0		*0*
Representation	0	1	4	**4. 00**	4
Life satisfaction	0	**9**	0		*0*
Work related injury	0	0	1		*0*
Crime	0	3	1	0. 33	3
Fear of crime	0	3	0		*0*
Acceptance of diversity	0	2	2	1. 00	4
Total Loops	62				

Indicators with a high **active** total relative to other indicators are: (i) Perceived discrimination (11); (ii) Living in Deprivation (7); and (iii) Ability to express identity (6).

Indicators with a high **passive** total relative to other indicators are: (i) Physical health (10); (ii) Life satisfaction (9); and (iii) Mental health (6).

Critical indicators that play a significant role in the system are: (i) Mental health (24); (ii) Ability to express identity (24); and (iii) Living in deprivation (21).

The **buffer** (red/italic) indicators identified are: (i =) Fear of crime (0); Work related injury (0); Life satisfaction (0); Perceived discrimination (0); Perceived corruption (0); Voter turnout (0); (ii =) Road casualties (1); Housing affordability (1); Adult literacy in English (1); and, Participation early childhood education (1).

8.3.2.4 SR Group 2. Analyse the feedback loops in the system (Step 4)

Table 8-2 shows that 'Living in Deprivation' is the most connected indicator in the system as it is in 52, of the 62 total loops. When this indicator is taken out of the system only 10 (16%) loops remain.

The SR Group 2 system has no balancing loops. All 62 are **reinforcing** loops, which indicate the system has no stabilising capacity over the long term.

For SR Group 2 the **strong links** in the system are as set out in Table 8-4. These are important relationship in their system that can achieve extensive results because of the number of times that relationship occurs. For SR Group 2, the strong links are 'Mental health' to 'Smoking/drinking'; Smoking/drinking to 'Living in deprivation'; and 'School leavers>NCEA2 (i.e. education)' to 'High skilled workforce'.

Table 8-4: SR Group 2 Strong links in the system

From indicator	To indicator	Total
Mental health	Smoking/drinking	42
Smoking/drinking	Living in deprivation	40
School leavers>NCEA2	High Skilled workforce	24
Loneliness	Mental health	23
Employment	Income purchasing power	20
Living in deprivation	Infant immunisation	20
Physical health	Mental health	20

Looking at the **time** factor, the longest reinforcing loops all go through 'Employment' and connect 12 different indicators.

8.3.2.5 SR Group 3. Determine the roles of indicators in the system (Step 3)

Based on their understanding and mental models, SR Group 3 made 85 links between indicators. From these links the outputs in Table 8-5 were generated.

Table 8-5: SR Group 3 Indicator analysis

Indicator	Loops	Passive	Active	Active/Passive	Critical/ *Buffer*
Mental health	41	**7**	**5**	0. 71	**35**
Physical health	39	**8**	4	0. 50	**32**
Physical activity	28	5	3	0. 60	15
Employment	27	2	3	1. 50	6
Income purchasing power	23	1	4	**4. 00**	4
Life satisfaction	23	**9**	1	0. 11	9
Contact friends & family	21	4	3	0. 75	12
Phone & internet access	18	1	2	2. 00	2
Obesity	18	2	3	1. 50	6
Loneliness	17	6	2	0. 33	12
Acceptance of diversity	8	6	**7**	1. 17	**42**
Living in deprivation	4	2	3	1. 50	6
Trust in others	3	2	**5**	**2. 50**	10
Representation	3	2	2	1. 00	4
Household crowding	3	2	1	0. 50	2
Ability to express identity	3	4	1	0. 25	4
Perceived corruption	2	1	2	2. 00	2
Voter turnout	2	2	1	0. 50	2
Housing affordability	2	2	1	0. 50	2
Participation culture & arts	2	3	2	0. 67	6
Māori language speakers	2	2	3	1. 50	6
Income inequality	1	1	1	1. 00	*1*
School leavers>NCEA2	0	1	3	**3. 00**	3
High Skilled workforce	0	1	1	1. 00	*1*
Job satisfaction	0	1	1	1. 00	1
Perceived discrimination	0	1	3	**3. 00**	3
Particip. early childhood educ	0	0	1		*0*
Infant immunisation	0	0	1		*0*
Voluntary work	0	1	2	2. 00	2
Work/life balance	0	0	4		*0*
Work related injury	0	0	2		*0*
Crime	0	1	1	1. 00	*1*
Fear of crime	0	2	0		*0*
Smoking/drinking	0	0	3		*0*
Road casualties	0	1	1	1. 00	*1*
Language retention	0	1	0		*0*
Adult literacy in English	0	1	0		*0*
Local content TV	0	0	3		*0*
Total loops	61				

Indicators with a high **active** total relative to other indicators are: (i) Acceptance of diversity (7); (ii) Trust in others (5); and (iii) Mental health (5).

Indicators with a high **passive** total relative to other indicators are: (i) Life satisfaction (9); (ii) Physical Health (8); (iii) and Mental health (7).

Critical indicators that play a significant role in the system are: (i) Acceptance of diversity (42); (ii) Mental health (35); (iii) and Physical health (32).

The **buffer** (red/italic) indicators identified are: (i =) Work/life balance (0); Work related injury (0); Fear of crime (0); Smoking/drinking (0); Language retention (0); Adult literacy in English (0); Local content TV (0); Infant immunisation (0); Participation early childhood education (0); (ii =) Crime (1); Road casualties (1); Job satisfaction (1); High Skilled workforce (1); and, Income inequality (1).

8.3.2.6 SR Group 3. Analyse the feedback loops in the system (Step 4)

Table 8-5 shows 'Mental health' is the most connected indicator in the system. 'Mental health' is in 41 of the 61 total loops. When this indicator is taken out of the system only 10 (32. 78%) loops remain.

The SR Group 3 system has no balancing loops. All 61 are **reinforcing** loops. This indicates the system is not stable in the long-term.

Table 8-6 shows the **strong links** traversed most frequently in the SR Group 3 system. For SR Group 3 the strongest relationship in their system is that from 'Physical health' to 'Employment'.

Table 8-6: SR Group 3 Strong links in the system

From indicator	To indicator	Total
Physical health	Employment	27
Employment	Income purchasing power	23
Life satisfaction	Mental health	23
Mental health	Physical activity	21
Income purchasing power	Phone & internet access	18
Mental health	Physical health	13
Physical activity	Obesity	13

Looking at the time factor, the longest reinforcing loop goes through Mental Health and connects 10 indicators.

8.3.2.7 Combined Groups. Determine the roles of indicators in the system (Step 3)

The links made by each of the three groups were combined into one model. This was done (as with the WR-GPI links) to construct a model that had all the relationships participants considered important in the system. When combined there were 183 links. From these links the outputs in Table 8-7 were generated.

Table 8-7: Combined group indicator analysis

Indicator	Passive	Active	Active/Passive	Critical/ *Buffer*
Mental health	**17**	**9**	0. 53	**153**
Employment	9	8	0. 89	**72**
Physical health	**12**	6	0. 50	**72**
Trust in others	8	8	1. 00	**64**
Acceptance of diversity	7	**9**	1. 29	**63**
Ability to express identity	7	8	1. 14	56
Life satisfaction	**15**	3	0. 20	45
Living in deprivation	4	**11**	2. 75	44
Participation culture & arts	6	6	1. 00	36
Perceived discrimination	2	**13**	**6. 50**	26
Representation	5	5	1. 00	25
Loneliness	8	3	0. 38	24
Income inequality	3	8	2. 67	24
Contact friends & family	7	3	0. 43	21
Income purchasing power	3	6	2. 00	18
Voluntary work	3	6	2. 00	18
School leavers>NCEA2	4	4	1. 00	16
Physical activity	5	3	0. 60	15
Work/life balance	2	7	**3. 50**	14
Phone & internet access	2	6	**3. 00**	12
High Skilled workforce	3	4	1. 33	12
Obesity	4	3	0. 75	12
Language retention	4	3	0. 75	12
Māori language speakers	3	4	1. 33	12
Perceived corruption	2	5	2. 50	10
Smoking/drinking	2	5	2. 50	10
Local content TV	2	5	2. 50	10
Job satisfaction	3	3	1. 00	9
Voter turnout	6	1	0. 17	6
Participation early childhood educ	3	2	0. 67	6
Housing affordability	3	2	0. 67	6
Household crowding	3	2	0. 67	6
Crime	6	1	0. 17	6
Infant immunisation	2	2	1. 00	*4*
Fear of crime	4	1	0. 25	*4*
Road casualties	2	2	1. 00	*4*
Work related injury	1	3	**3. 00**	*3*
Adult literacy in English	1	3	**3. 00**	*3*

In the combined model indicators with a high **active** total relative to other indicators are: (i) Perceived discrimination (13); (ii) Living in deprivation (11); (iii) Acceptance of diversity (9); and (iv) Mental health (9).

Indicators with a high **passive** total relative to other indicators are: (i) Mental health (17); (ii) Life satisfaction (15); and (iii) Physical health (12).

Critical indicators that play a significant role in the system are: (i) Mental health (153); (ii) Employment (72); (iii) Physical health (72); Trust in others (64); and, Acceptance of diversity (63).

The buffer (red/italic) indicators identified are: (i =) Adult literacy in English (3); Work related injury (3); (ii =) Road casualties (4); Fear of crime (4); and, Infant immunisation (4).

8.3.2.8 Combined Groups. Analyse the feedback loops in the system (Step 4)

The analysis of feedback loops using the algorithm could not be done due to the very large number of loops in the combined system. As noted on Figure 8-2, 'Infant immunisation', which is not highly linked, was part of 32,755 feedback loops.

8.3.2.9 Consistency across SR interlinked models

Additional analysis was carried out to determine the degree of consistency between the models constructed by the different groups.

Table 8-8 lists the top indicators identified by the three groups both individually and when the links made by all groups were combined. Italics show where indicators were included in 3 out of the 4 models.

There was variation across the groups in terms of the selected **active** indicators in their models. 'Living in Deprivation' was the only indicator in 3 out of the 4 models.

The **passive** indicators that react quickly relative to other indicators in the system were consistent across all models: 'Mental health', 'Physical health' and 'Life satisfaction'.

Critical indicator analysis showed 'Mental health' plays a critical role in all 4 well-being models and 'Physical health' in 3 models.

The buffer indicators that absorb impacts and slow down the effects of change are reasonably consistency with ‘Fear of crime’ a buffer in all 4 models. ‘Work related injury’, ‘Adult literacy in English’, ‘Road casualties’, ‘Participation early childhood education’, and ‘Voter turnout’ appearing as buffer indicators in 3 different models.

Table 8-8: Common indicators identified by each group and in the combined model

Combined links	SR Group 1	SR Group 2	SR Group 3
Active			
Perceived discrimination (13)	*Living in Deprivation (8)*	Perceived discrimination (11)	Acceptance of diversity (7)
Living in deprivation (11)	Employment (7)	*Living in Deprivation (7)*	Trust in others (5)
Acceptance of diversity (9)	Income inequality (7)	Ability to express identity (6)	Mental health (5)
Mental health (9)	Work/life balance (7)		
Passive			
Mental health (17)	*Life satisfaction (14)*	*Physical health (10)*	*Life satisfaction (9)*
Life satisfaction (15;	*Mental health (12)*	*Life satisfaction (9)*	*Physical Health (8)*
Physical Health (12)	*Physical health(9)*	*Mental health (6)*	*Mental health (7.*
Critical			
Mental health (153)	*Mental health (60)*	*Mental health (24)*	Acceptance of diversity (42)
Physical health (72)	Employment (49)	Ability to express identity (24)	*Mental health (35)*
Employment (72)	Life satisfaction (42)	Living in deprivation (21)	*Physical health (32)*
Trust in others (64)	*Physical health (36)*	*Physical health (20)*	Physical activity (15)
Buffer			
Work-related injury (3)	*Voter turnout (0)*	*Fear of crime (0);*	Work/life balance (0)
Adult literacy in English (3)	Phone & internet access (0)	*Work related injury (0)*	*Work related injury (0)*
Road casualties (4)	High Skilled workforce (2)	Life satisfaction (0)	*Fear of crime (0)*
Fear of crime (4)	Perceived corruption (2)	Perceived discrimination (0)	Smoking/drinking (0)
Crime (6)	Infant immunisation (2)	*Voter turnout (0)*	*Adult literacy in English (0)*
Household crowding (6)	Household crowding (2)	*Road casualties (1)*	Local content TV (0)
Housing affordability (6)	*Fear of crime (2)*	Housing affordability (1)	Infant immunisation (0)
Participation early childhood education (6)		*Adult literacy in English (1)*	*Participation early childhood education (0)*
Voter turnout (6)		*Participation early childhood education (1)*	Crime (1)
			Road casualties (1)
			Job satisfaction (1)
			High Skilled workforce (1)
			Income inequality (1)

Italics = in 3 or more models.

8.3.2.10 Determine intervention points (Step 5)

Potential intervention points were explored for the individual and combined models.

Using the Vester (2007) approach, the intervention points[83] identified are as shown in Table 8-9. There was no common intervention point across all models. Three intervention points were common to two models.

Table 8-9: Intervention points in the Social Report systems using the Vester method

Combined links	SR Group 1	SR Group 2	SR Group 3
Perceived discrimination	**Living in deprivation**	Income purchasing power	Trust in others
Work/life balance	**Income inequality**		
Phone and internet access	**Work/life balance**		
Living in deprivation			
Income inequality			
Perceived corruption			
Smoking/drinking			
Local content TV			

Bold = common to two models.

The Hürlimann (2009) method adding a time dimension using a cross-time matrix (CTM) was applied for the combined-groups model. The time delays were as marked on the A1 sheets by the SR workshop participants. The potential intervention points identified are shown in Figure 8-3 and Table 8–10.

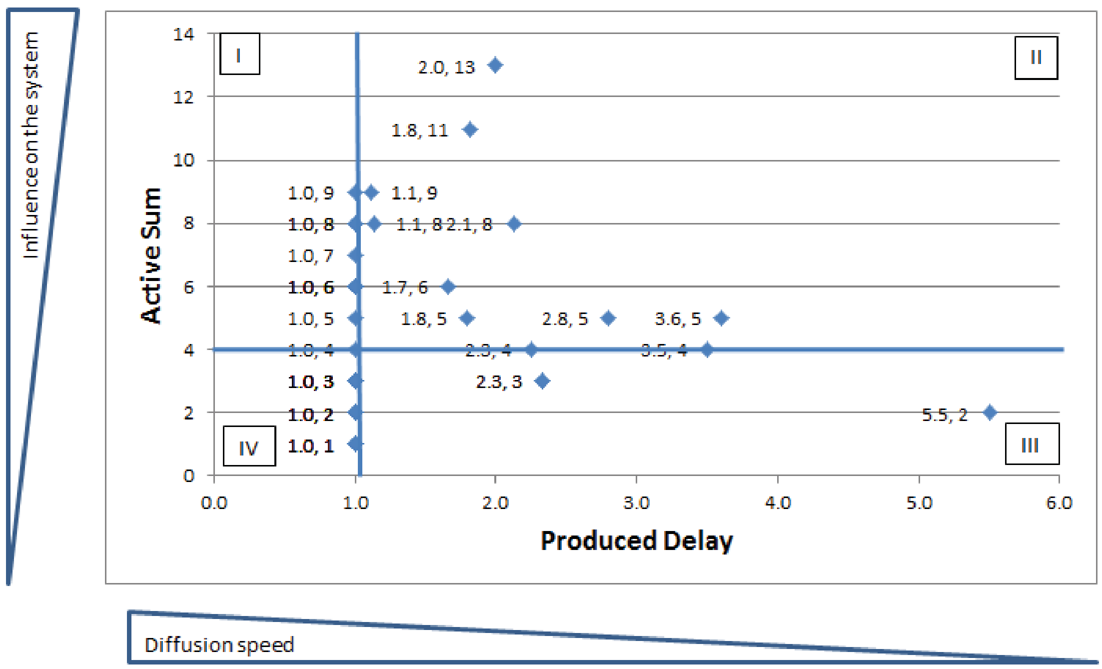


Figure 8-3: Possible intervention points when delays in the system are included. Data point names given in Tables 8-10.

[83] Using the cut-off of active ≥5 ; active/passive ≥2.5.

Key:

I	High Active Sum (AS) and low Produced Delay (PD) value. High impact and react very quickly to change. Possible intervention points if the goal is quick change
II	High AS and PD values. High impact but longer paths or slow spread through system. Appropriate intervention point if goal is slow but substantial change
III	Low AS value, high PD value. No impact and a delayed reaction. Not appropriate for intervention
IV	Low AS and PD values act quickly to changes, but low impact. Not well suited for intervention as do not change system in a meaningful way.

As Figure 8-3 shows, there are a greater number of possible intervention points to consider with this approach than with the Vester quotient approach.

In addition, introducing a time dynamic changes the order of priority for intervention in the system. The distribution of the intervention points identified using the Vester quotient approach was mixed between Quadrants I and II. In general, policy and decision-makers prefer quick responses as they are easier to measure and manage.

Table 8-10: Short-term and longer-term intervention points in the Social Report system using the Hürlimann method

Short term	Longer term
(1.0, 9) Mental Health	*(1.1, 8) Income inequality*
(1.0, 8) Ability to express identity	(1.1, 9) Acceptance of diversity
(1.0, 8) Trust in others	(1.7, 6) Physical health
(1.0, 7) Work/life balance	*(1.8, 5) Smoking/drinking*
(1.0, 6) Participation culture & arts	*(1.8, 11) Living in deprivation*
(1.0, 6) Voluntary work	*(2.0, 13) Perceived discrimination*
(1.0, 6) Income purchasing power	(2.1, 8) Employment
(1.0, 6) Phone & internet access	*(2.8, 5) Local content TV*
(1.0, 5) Representation	*(3.6, 5) Perceived corruption*

Italics = identified also by Vester approach

Again, this analysis identifies only possible intervention points. The actual choice depends on the outcomes decision-makers are trying to achieve. The decision will have to take into account many other factors, including the extent to which an indicator can be influenced by policy makers and the reliability of the time estimates.

8.3.2.11 Run What-if (Step 6)

Based on the linkages model produced by SR Group 2, which had the most loops linking to the indicator 'Living in Deprivation' a what-if was run to look at the impact of providing phone and internet access to people living in deprivation. All the loops that involved the indicator ‘Living in Deprivation’ are reinforcing and the path dependency is that living in deprivation leads to continued living in deprivation.

The polarity of the link between ‘Living in Deprivation’ and ‘Phone & internet access’ was changed from negative to positive for this what-if. Analysis of loops in Figure 8-4 showed that nine of the 52 loops involving ‘Living in Deprivation’ changed to balancing.

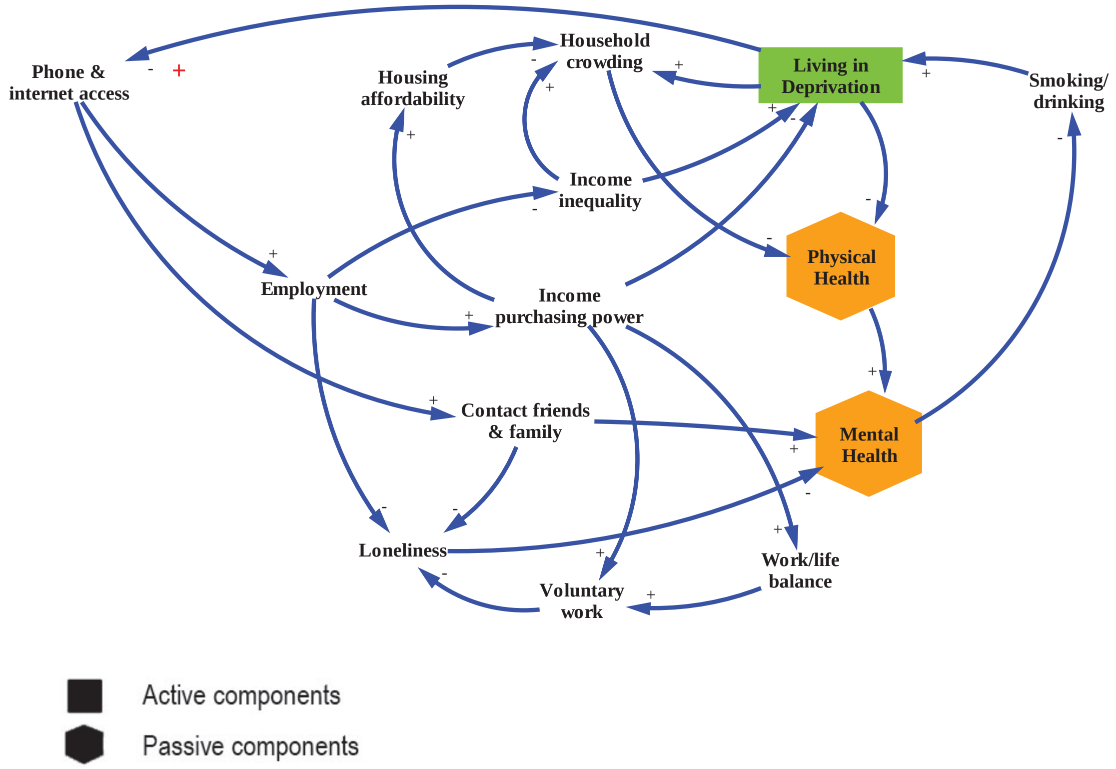


Figure 8-4: What-if: Providing phone and internet access to people living in deprivation.

The following are the nine balancing feedback loops that reduce ‘Living in Deprivation’ if access to phone and internet is provided:

Loop 1: Living in deprivation→Phone & internet access (+)→Contact friends & family (+)→Loneliness (-)→Mental health (-)→Smoking/drinking (-)→Living in deprivation (+)

Loop 2: Living in deprivation→Phone & internet access (+)→Contact friends & family (+)→Mental health (+)→Smoking/drinking (-)→Living in deprivation (+)

Loop 3: Living in deprivation→Phone & internet access (+)→Employment (+)→Income inequality (-)→Living in deprivation (+)

Loop 4: Living in deprivation→Phone & internet access (+)→Employment (+) -> Income inequality (-)→Household crowding (+)→Physical health (-)→Mental health (+)→Smoking/drinking (-)→Living in deprivation (+)

Loop 5: Living in deprivation→Phone & internet access (+)→Employment (+)→Income purchasing power (-)→Living in deprivation (+)

Loop 6: Living in deprivation-> Phone & internet access (+)→Employment (+)→Income purchasing power (+)→Housing affordability (+)→Household crowding (-)→Physical health (-)→Mental health->Smoking/drinking (-) ->Living in deprivation (+)

Loop 7: Living in deprivation→Phone & internet access (+)→Employment (+)→Income purchasing power→(+) Voluntary work (+)→Loneliness (-)→Mental health (-)→Smoking/drinking (-)→Living in deprivation (+)

Loop 8: Living in deprivation→Phone & internet access (+)→Employment (+)→Income purchasing power (+)→Work/life balance (+)→Voluntary work (+)→Loneliness (-)→Mental health (-)→Smoking/drinking (-)→Living in deprivation (+)

Loop 9: Living in deprivation→Phone & internet access (+)→Employment (+)→Loneliness (-)→Mental health (-)→Smoking/drinking (-)→Living in deprivation (+)

This what-if shows that for those 'Living in deprivation' the provision of 'Phone & internet access' can have a positive impact on well-being by increasing 'Employment' and providing more 'Contact with family and friends'. The ratio of reinforcing to balancing loops remains high at 43:9. Therefore, there will still be strong drivers towards continued deprivation as a consequence of other factors such as increased 'Household crowding' and decreased 'Physical health'.

8.3.3 Weighting

Because the literature (see for example, OECD, 2008) considers weighting can be an issue for indicators, an additional investigation was undertaken for this case study. This is not part of the interlinked thinking method. The combined links matrix was used to test whether the role of an indicator differed markedly if weighting is used with interlinking. The first analysis had all links with a weighting of 1. The second analysis was carried out with links having a weighting of '3' if all groups included this link; '2' if two groups included this link; or '1' if only 1 group included this link. The results listed in Table 8-11 indicate that weighting did not make a big difference to the indicators roles of 'active', 'passive', and 'critical'; the order of ranking only changing slightly. For example, with weighting in the active category, 'Acceptance of diversity' with a score of 12 would rank after 'Employment' with a score of 14. With weighting two 'active' indicators 'Income purchasing power (13) and 'Work/life balance' (13), (not listed in

Table 8-11), rank more highly than ‘Trust in others’ (12) and ‘Ability to express identity’ (11).

With the passive indicators, ‘Mental health’ moved from first to third and ‘Loneliness’ ranked before ‘Employment’. The **critical** indicators stayed the same, with no change in order.

Table 8-11: Comparison of weighted and unweighted scores

Indicator Role	**Indicators by rank***
Active	Perceived discrimination (13, 18); Living in deprivation (11, 18); Mental health (9, 14); Acceptance of diversity (9, *12*); Employment (8, 14); Trust in others (8, *12*); Ability to express identity (8, *11*).
Passive	Mental Health (17, *25*) Life satisfaction (15, 32); Physical health (12, 27); Employment (9, 14); Trust in other (8, 11); Loneliness (8, *16*); Contact with friends and family (7, 10); Acceptance of diversity (7, 11); Ability to express identity (7, 11).
Critical	Mental health (153, 350); Physical health (72, 270); Employment (72, 196); Trust in others (64, 132); Acceptance of diversity (63, 132); Ability to express identity (56, 121); Life satisfaction (44, 128); Living in deprivation (44, 126)

* First number in brackets is unweighted score and second is weighted score. Changed ranking in italics

From the consistency in the indicators it could be assumed that weighting does not make a significant difference to the role an indicator plays in a system.

8.4 SUMMARY

The workshops using the Social Report indicators showed the interlinked thinking method developed to understand relationships between indicators could be used with indicator sets other than the WR-GPI indicators.

The decision to analyse each model individually, and then the combined models, provided some interesting insights. First, the process revealed how differently each group saw the interrelationships between the indicators and the extent to which their mental models differed. The large number of participants involved in the Social Report workshops led to a lively discussion within the groups and diverse links made as a result. Inclusion of groups such as NGOs that are outside government, would potentially have added further to the richness of the links produced.

Despite the different models generated, the CLD analysis process revealed some consistent outcomes. ‘Living in deprivation’ was an important active indicator across the three group models and the combined model. The three top ‘Passive’ indicators were the same across all models (Mental health, Life satisfaction and Physical health). Critical indicators also had a degree of consistency with ‘Mental health’ and ‘Physical health’ in all four models; and ‘Employment’ in three out of the four. Buffer indicators also had cross-overs. The feedback loop analysis of the separate group models showed all were heavily orientated to reinforcing so lacked stability and resilience. There were no balancing loops in two of the models and a much greater number of reinforcing loops than of balancing loops in the third.

While the number of links modelled was much greater than can usually be incorporated in a systems model, the workshop process revealed there is a limit to the number of links that can be handled with the interlinked thinking method. This was demonstrated with the combined model, where the number of loops generated was so great the algorithm could not cope with the size.

There was some consistency with the WR-GPI indicators in the ‘Passive’ and ‘Critical’ roles, even though the indicator sets used were different. This, plus issues such as participants not taking the opportunity to add or delete indicators, will be covered in Chapter 10.

The next chapter tests the interlinked thinking method in a non-participatory context. For this case study, the OECD Better Life indicators were interlinked in a desktop exercise.

9 OECD BETTER LIFE CASE STUDY

Chapter 9 considers, “Is the method developed to understand relationships between indicators able to be used in a non-participatory context?” To answer this question the interlinked thinking method is applied in a third case study using the Organisation for Economic Cooperation and Development (OECD) Better Life Index. The OECD’s ‘Better Life Index: Measuring Well-being and Progress’ (http://www.oecdbetterlifeindex.org/) uses 11 topics to measure well-being. The OECD considers these topics sufficient to cover the material living and quality of life conditions that determine whether or not life is getting better.

The OECD well-being measure has each of the topics as independent. There is, however, no way to truly understand a society’s well-being without taking into account how a change in one area flows-on to change the many other components that also contribute to well-being. It is the dynamics of the interdependencies between the topics that determines well-being. Policy interventions to improve well-being require understanding the interlinked structure and the multiple feedback loops of which each component is part.

This chapter first provides an introduction to the OECD Better Life Index and the case study process that was followed. An assessment of whether or not the OECD Better Life topics conform to the requirements for indicators from a systems perspective is then undertaken. Next, the logic for the links made between topics is explained. The interlinked thinking method is applied to the model constructed and the results analysed as for the previous two case studies. This case study also illustrates the application of cause and use trees.

9.1 THE OECD CASE STUDY CONTEXT

The OECD definition of social progress is "improvements in the well-being of people and households."[84] The intent of the Better Life Index is to measure progress in society based on the aspects of life that are important to people and impact their quality of life. Using a broader appraisal than GDP is required, as "… public policies can only deliver best fruit if they are based on reliable tools to measure the improvement they seek to produce in our lives."[85]

The OECD framework has three distinct domains: (1) material conditions; (2) quality of life; and (3) sustainability. The 11 topics (referred to in this dissertation from here on as indicators for consistency) used by the Better Life Index to measure well-being and progress are set out in Figure 9–1.

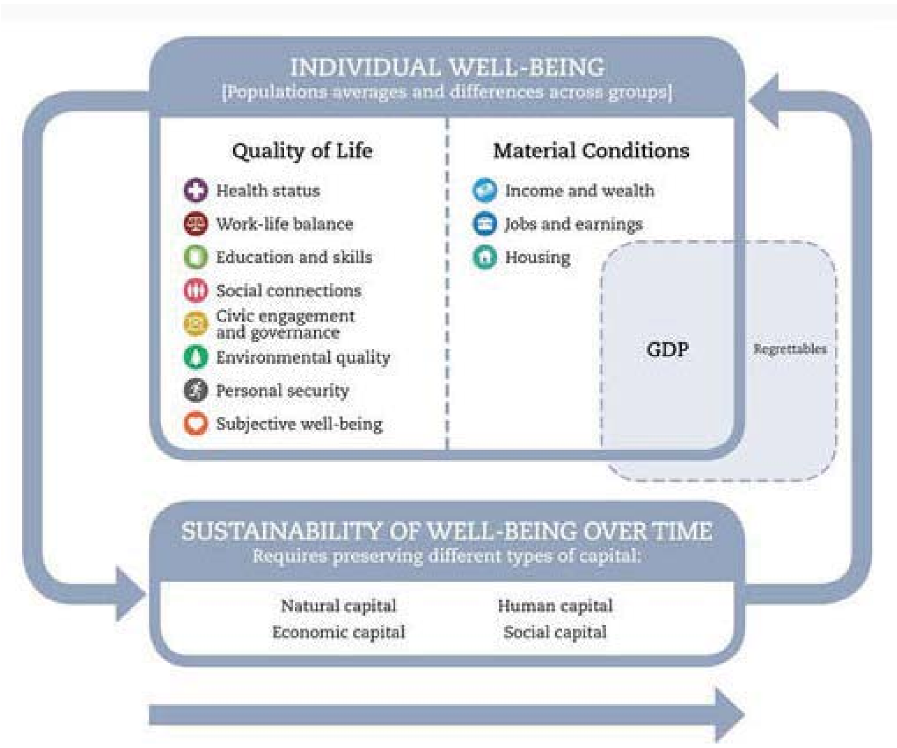


Figure 9-1: OECD Framework for measuring well-being and progress. (Source: OECD, 2013 http://www.oecd.org/statistics/measuring-well-being-and-progress.htm).

There are eight 'Quality of Life' indicators and three indicators that cover the 'Material Conditions' of life to which that GDP contributes. The framework includes preserving

[84] http://www.oecd.org/statistics/measuring-well-being-and-progress.htm

[85] Secretary-General of the OECD http://www.oecd.org/social/yourbetterlifeindex.htm

the four capitals over time as a measure of sustainability, though how this is to be incorporated into the OECD Better Life Index has not yet been determined (OECD, 2013a).

The indicators used have been selected to increase understanding of what drives the well-being of people and nations and how greater progress for all can be achieved. According to the website,[86] the OECD Better Life Index:

- "Helps to inform policy making to improve quality of life
- Connects policy to people's lives
- Generates support for needed policy measures
- Improves civic engagement by encouraging the public to create their own index and share their preferences
- Empowers the public by improving their understanding of policy-making."

An interactive website (http://www.oecdbetterlifeindex.org/) allows comparison of how life is experienced in the 34 OECD countries and two non-OECD countries (Brazil and Russia). Figure 9-2 shows the 2015 edition of the Better Life measures across the different countries.[87] New Zealand results are the accentuated bars. Data are also presented as petals (Figure 9-3) using the same colour legend as in Figure 9-2. The length of the petal represents a country's score as calculated by the quantitative data; the width represents the importance assigned to the indicator by on-line users.

[86] http://www.oecd.org/statistics/measuringwell-beingandprogressunderstandingtheissue.htm
[87] Found at http://stats.oecd.org/Index.aspx?DataSetCode=BLI2014 downloaded 22 May 2015. Note that this is the latest combined data set. Not all data relate to the year 2015.

Figure 9-2: New Zealand compared to other OECD countries 2015 edition.

Figure 9-3: New Zealand by indicator 2015.

It can be seen in Figure 9-2 that for New Zealand income is very low compared with other OECD countries. ‘Health’, ‘Environment’, and ‘Civic engagement’ rank highly. The information provided does not attempt to show how the indicators interlink, or for policy purposes, the potential leverage points in the well-being system. For example, a cursory analysis of Figure 9-2 may lead to a decision to focus on income levels as a way to improve well-being in New Zealand. However, this may have negative impacts on other measures, such as ‘Health’ or the ‘Environment’. Lack of understanding of cause-and-effect may result in a lower overall level of well-being for the country.

The OECD website (http://www.oecdbetterlifeindex.org/) refers to relationships between well-being and these are described using both qualitative and quantitative data. The text of the OECD (2014, p. 33) Society at a Glance 2014 report refers to the compounding and follow-on effects of the Great Recession of 2008-9 and graphs indicators against each other (e.g. Figure 1. 8, p.34) with the proviso that the graphs do not prove causal relationships. An objective of this case study is to reach a better understanding of what the cause-and-effect relationships might be.

9.2 THE OECD CASE STUDY PROCESS

The case study using the OECD Better life Index indicators was a desktop exercise done without participants. The first step was for the researcher to link the indicators (as set out in Appendix 4a). This was done using information on the OECD Better Life website (http://www.oecdbetterlifeindex.org/) and other literature as referenced in Appendix 4b).

Analysis of the links is as per the method set out in Chapter 6. No estimates for delays in the system were made, so intervention points were not calculated using the Hürlimann approach. The results from the analysis were compared with those generated by OECD Better Life Index on-line users. A full discussion of the results is done in conjunction with the other two case studies in Chapter 10.

9.2.1 The OECD indicators

A consultation process with OECD member countries was carried out to select the indicators used by the OECD Better Life Index to measure well-being. According to the OECD, the indicators cover dimensions of well-being that are universal and relevant to all peoples. It is, however, acknowledged that a country may want to include context-specific measures for their national level analysis, and that the indicator set may change in the future (http://www.oecdbetterlifeindex.org/).

Other considerations were statistical criteria such as relevance (i.e. face-validity, depth, policy relevance) and data quality (i.e. predictive validity, coverage, timeliness, cross-country comparability, etc.) (http://www.oecdbetterlifeindex.org/). The Better Life well-being indicators have between one and four sub-indicators (see Table 9-1). The score for each indicator is calculated by normalising (between values of 0 for worst outcome and 1 for best outcome) and taking an average.[88]

Table 9-1: Indicator definitions and sub-indicators used in the OECD Better Life Index

Indicator	**OECD indicator description and the sub-indicators used for measurement (italics)**
Education	Education = your education and what you get out of it. (*Years in education, Educational attainment, Student skills)*
Jobs	Jobs = earnings, job security and unemployment. *(Personal earnings, Long-term unemployment rate, Employment rate, Job security)*
Health	Health = how healthy are you. *(Life expectancy, Self-reported health)*
Income	Income = household income and financial wealth. *(Household net financial wealth, Household net adjusted disposable income)*
Safety	Safety = murder and assault rates. *(Assault rate, Homicide rate)*
Community	Community = Quality of support network
Worklife balance	Worklife balance = how much you work/play. *(Employees working very long hours, Time devoted to leisure & personal care)*
Environment	Environment = quality of your environment. *(Air pollution, Water quality)*
Life satisfaction	Life satisfaction = how happy are you?
Housing affordability	Housing = your housing conditions and spending. *(Dwellings without basic facilities, Housing expenditure, Rooms per person)*
Civic engagement	Civic engagement = your involvement in democracy *(Voter turnout, Consultation on rule-making)*

For this research, the first attempt to link indicators was made at the sub-indicator level (italics in Table 9-1) as this was more detailed. This was not successful because the sub-indicators measure the same concept as the averaged indicator and therefore multiple links were duplicated. For example, for education, ‘Years in education’, ‘Educational attainment’, ‘Student skills’ link to other indicators in the same way. Additionally, working at the sub-indicator level introduced unintended weighting to

[88] As per http://www.oecdbetterlifeindex.org/about/better-life-initiative/#question11

the analysis as some indicators have only one measure (e.g. Community), whereas others have up to four (e.g. Jobs).

9.2.2 The OECD indicators from a systems perspective (Step 0)

As a systems approach to well-being is being used for the OECD Better Life Index, the Vester (2007) criteria matrix was used to check if the system's requirements are met. As discussed in Chapter 5, 18 criteria need to be covered to ensure the system picture is not distorted. Values (1 = fully present; 0. 5 = partially present; 0 = not present) were assigned by the researcher to each of the 11 indicators according to how well they meet the 18 criteria matrix descriptions. All criteria need to be represented, and the columns, when added, need to be reasonably balanced. If all areas are adequately covered this can indicate (but, as Vester emphasizes, does not prove) a system is present. When Vester's bio-cybernetic method was applied to the OECD indicators all areas were covered, though some were covered more extensively than others. The totals ranged from 5.5 to 11, as shown in Table 9-2. The requirement that the seven 'Spheres of Life' have a minimum of three criteria (Savelsberg, 2008) was also met. Based on this assessment the OECD indicator set, while at a high level, does provide a systemic representation of well-being.

Table 9-2: OECD Better Life Index tested against matrix criteria questions

OECD Better Life Indicators	Spheres of Life						Physical categories			
Criteria Questions	*Participants/Pop/the parties (who is present). Who is there? - the persons involved. Who are they? e.g. population structure and dynamics, working people, age structure*	*Activities/Economy. What are they doing? What is taking place? e.g. structure of economy, capital, production, debt*	*Area/Land utilisation/the place. Where does it happen? What happens where? e.g. location and use of buildings, land use*	*Mood/feelings :Human ecology/(how do they feel about it?). State of feelings. How do people feel? e.g. social structure, quality of life, security, education, health*	*Natural balance/relation to the environment (how does the resource budget function? Environmental relations - how does the distribution of resources work? Exchange with the environment - consumption of raw materials, energy and water, recycling, waste, harmless products)*	*Interconnections/Infrastructure/internal processes (what communication channels exist?). What ways of communication exist? Transport and access roads, processing of information and communication. What channels of communication are there to allow participants to connect? e.g. infrastructure, transport and access, telecommunications, traffic*	*Organisational structure/Communal life/Internal order (what rules apply?). What are the rules (laws and culture) How is everything regulated? How are participants organised/regulated ? e.g. local government, taxes, legislation, planning procedures*	*Material/matter (variables predominantly material in character). Variables having a primarily material character (eg buildings, raw materials, means of prod, people, animals, plants, buildings) food supply, transport route etc*	*Energy (variables predominantly energetic in character). Variables having a primarily energy-related character (eg power consumption, workers, energy carriers, financial strength, decision-making authority)*	*Information (variables predominantly informative and communicative in character). Variables having a primarily information related and communications related character (eg media, decisions, explication, exchange of information, orders, perception, acceptance, attractiveness) includes decision-making processes*
Housing Affordability	1	0.5	1	1	0.5		1	1	0.5	0.5
Income	1	1	1	1	1	1	1	1	1	1
Jobs	1	1	1	1	1	1	1	1	1	1
Community	1	1	0.5	1	0.5	1	1	1	1	1
Education	1		0.5	1	0.5	1	1	1	0.5	1
Civic engagement	1		1	1		1	1	1	1	1
Health	1	1		1		1	0.5			0.5
Life satisfaction	1	1		1	1	1	1	1	1	1
Safety	1	1	1	1	0.5	0.5	1	1		1
Worklife balance	1	1	1	1	1	1	1	1	1	1
Environment	1	1	0.5	1	1	1	1	1	0	1
Total	11	8.5	7.5	11	7	9.5	10.5	10	7	10

Key: 1 = Fully present; 0. 5 = Partially present, blank not present

Table 9–2: OECD Better Life Index tested against matrix criteria questions continued…

OECD Better Life Index	System Dynamic criteria				System relationships of a variable			
Criteria Questions	*Flow determinant/Flow quantity. E.g. energy consumption, traffic, commuters, orders, instructions. Variables expressing primarily flows of matter, energy, or information within the system. "Flows rather than stocks"*	*Structural determinants/Structural quantity. Variables serving to determine structure rather than flow, e.g. green spaces, population densities, traffic network, diversity of jobs*	*Temporal dynamics. Variables that at the same location change at a given time or that possess a temporal dynamics, e.g. seasonal activity, elections, climatic factors, transport timetables*	*Spatial dynamics. Variables that differ depending on location, e.g. waste water, infrastructure, traffic, land use, ecosystems*	*Open system to input/variable opens system through outside influence. Variables that open the system through influences that are outside e.g. rainfall, imports national legislation*	*Open system to outputs/variables has an impact on adjourning systems. Variables that influence surrounding parts of the system. Variables that open the system through influences that are inside, e.g. commuters leaving the city, exports, national taxes*	*Endogenous control/Influenced internally/variables that are controllable through decision-making processes or actions taking place inside the system under study. Yardstick for autarky of system*	*Exogenous control/Influenced externally/variables which are subject to/controlled by decision-making processes or actions taking place outside the system under study. Yardstick for the dependency of system.*
Housing Affordability		0. 5		1	0. 5		0. 5	0. 5
Income	1	1	0. 5	1	1	1	1	1
Jobs	1	1	0. 5	1	1	1	1	1
Community	1		1	1			1	
Education	1		0. 5	1	1	1	0. 5	0. 5
Civic engagement	1		1	1		1	1	
Health	0. 5	1	1	1	0. 5		1	
Life satisfaction	1	1	1	1	1	1	0. 5	0. 5
Safety		0. 5		1	0. 5		1	
Worklife balance	1	1	1	1	0. 5		0. 5	1
Environment	1	1	1	1		1	1	1
Total	8. 5	7	7. 5	11	6	6	9	5. 5

Key: 1 = Fully present; 0. 5 = Partially present, blank not present

9.3 THE OECD CASE STUDY CONTENT

This section describes the results generated for the OECD case study when the method as set out in Figure 6-1 was followed.

9.3.1 Link indicators into a system (Step 1)

The OECD Better Life website (http://www.oecdbetterlifeindex.org/) is rich in the number of references it makes to linkages between indicators in the text. This information, plus other literature was used to justify the links made between indicators. Appendix 4a is a spread sheet of the numbered links. Appendix 4b 'Rationale for OECD links' provides the explanation for the links made between indicators. Only direct links are included as indirect links are picked up by the loops generated. For example, there is no link between 'Safety' and 'Life Satisfaction' as the assumed relationship is that 'Safety' impacts on 'Health', which impacts on 'Life Satisfaction'. In a similar way there is no link from 'Education' to 'Life Satisfaction' as the impact comes via 'Income', 'Jobs', 'Health', etc.

9.3.2 Transcribe the links and polarity (Step 2)

The links between indicators made in the OECD model are shown in Figure 9-4. There are 41 links in total.

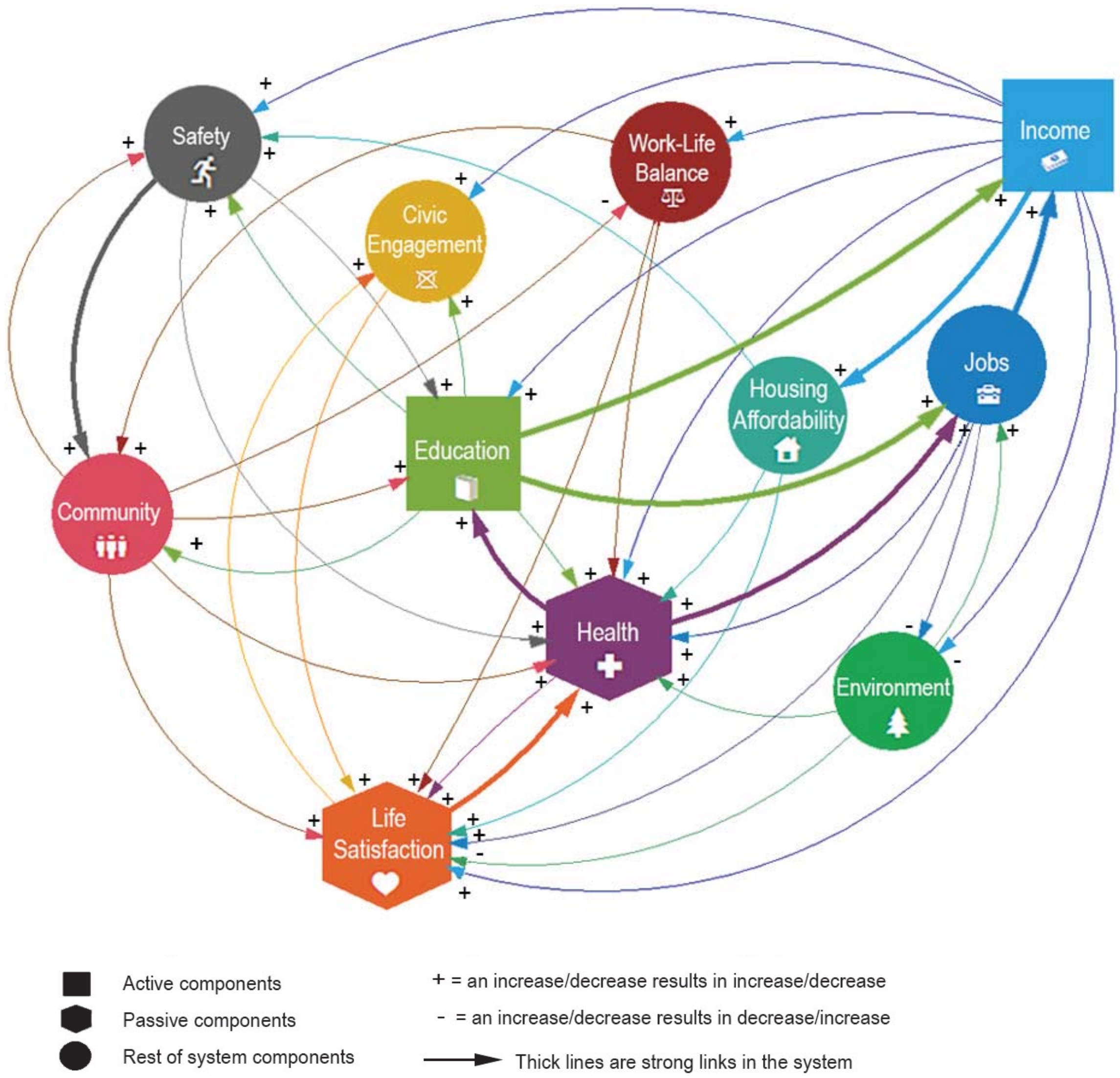


Figure 9-4: Relationships between indicators.

Cause and use trees provide another way to visualize links in a system. This feature of the Vensim™ software was used in all the case studies and shown to participants at the workshops.

Figure 9-5 uses the indicator 'Education' as an example and shows the indicators going forward two links. The brackets show that an indicator has been linked previously. Following through the 'Education' example is a way to show how a change in 'Education' will filter through the system and when it will impact on other indicators. In Figure 9-5 'Education' impacts six indicators directly but many others indirectly. At the second link level, for instance, it can be seen that 'Education' impacts indirectly on 'Life satisfaction' through: Civic engagement; Community, Health; Income; and Jobs. Education has fast feedback loops to itself via: Community, Health; Income; and Safety.

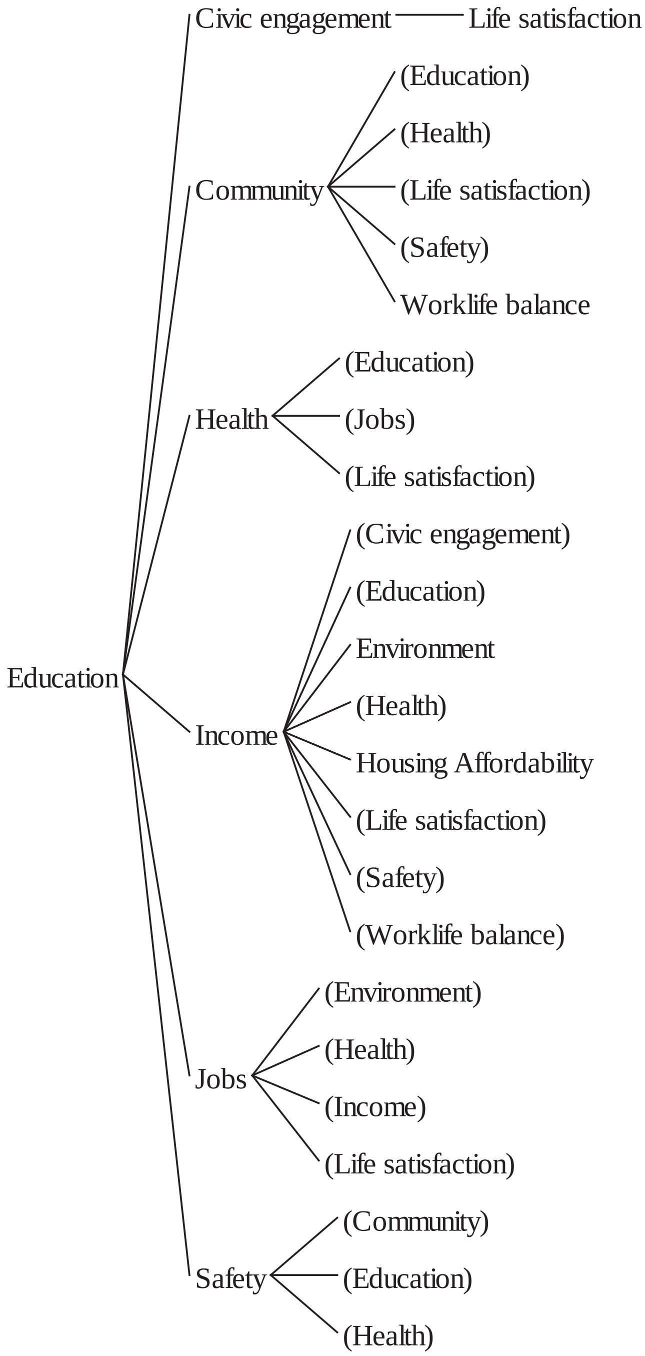


Figure 9-5: Forward links from Education in the OECD Better Life system.

Figure 9-6 shows the indicators that link to Education back two links. The cause and use tree visual depiction helps follow the links in the system more easily.

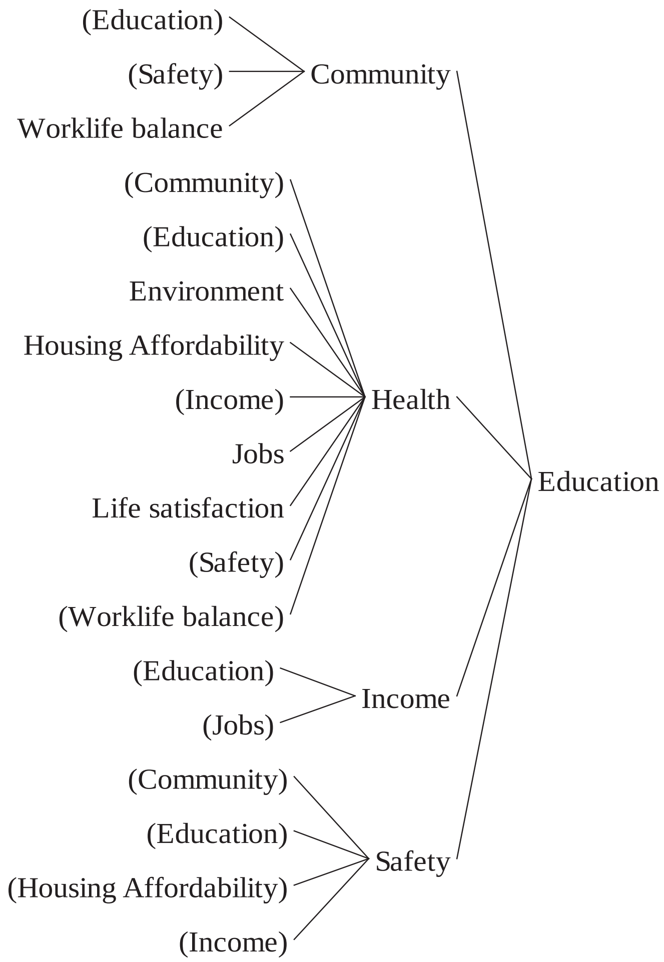


Figure 9-6: Backward links to Education in the OECD Better Life system.

9.3.3 Determine the roles of indicators in the system (Step 3)

The results of the analysis of the OECD links using the algorithm are in Table 9-3.

Table 9-3: OECD Indicator analysis

Indicator	Loops	Passive	Active	Active/Passive	Critical/ *Buffer*
Health	122	**9**	3	0. 33	**27**
Income	116	2	**8**	**4. 00**	**16**
Education	113	4	**6**	1. 50	**24**
Jobs	96	3	4	1. 33	12
Community	81	3	5	**1. 67**	15
Safety	78	4	3	0. 75	12
Life satisfaction	57	**8**	2	0. 25	**16**
Worklife balance	49	2	3	1. 50	*6*
Housing affordability	33	1	3	**3. 00**	*3*
Environment	14	2	3	1. 50	*6*
Civic engagement	12	3	1	0. 33	*3*
Total Loops	145				

The number of active and passive links for each indicator is shown in Figure 9-7. The bottom number of the bar shows that (i) Income (8), and (ii) Education (6) are the **active** indicators where a small change will have a strong impact on the OECD well-being system. The top number of the bar shows the **passive** indicators: (i) Health (9), and (ii) Life satisfaction (8) that react strongly in a positive or negative way to changes in the other indicators in the system.

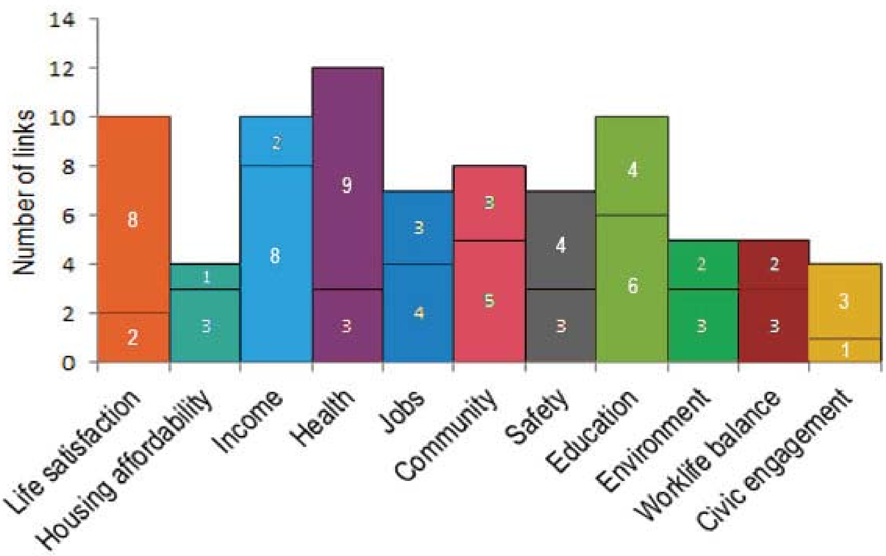


Figure 9-7: Links to and from well-being components.

Critical indicators that play a significant role in the system because they strongly influence the system, as well as being easily influenced themselves, are: (i) Health (27); (ii) Education (24); (iii) Income (16); and Life satisfaction (16).

The **buffers** in the system are (i) Housing affordability (3); (ii) Civic engagement (3); (iii) Environment (6); and Worklife balance (6).

9.3.4 Analyse feedback loops in the system (Step 4)

Table 9-3 shows that 'Health' is the most connected indicator in the system, as it is in 122 of the 145 loops. The system is dependent on 'Health', as when this is removed only 23 (15.8%) loops remain. This means that any austerity measures that reduce the level of health provision will have a significant consequence on well-being overall.

The OECD system is heavily orientated towards **reinforcing** loops with 110 of the total 145 reinforcing and only 35 **balancing** loops. Figure 9-8 shows the total number of feedback loops in the system for each of the well-being indicators and whether they are 'reinforcing loops' (bottom number) or 'balancing loops' (top number).

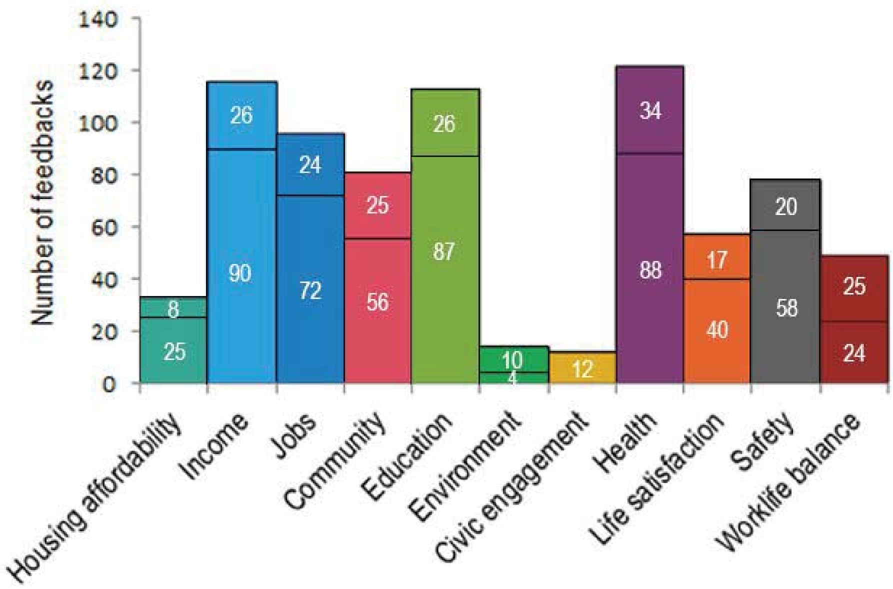


Figure 9-8: Feedback loops in the OECD well-being system.

Table 9-4 provides the **strong links** traversed most frequently in the OECD system (these are also marked by thick arrows in Figure 9-4). In the OECD model, the most important relationship in the system is that between 'Jobs' and 'Income'. The 'Health' links to 'Education' and to 'Jobs' are also important. If a change is needed in the system, these links will be useful targets, given the frequency they are traversed.

Table 9-4: OECD Strong links in the system

From indicator	To indicator	Total
Jobs	Income	85
Health	Education	62
Health	Jobs	59
Life satisfaction	Health	56
Safety	Community	42
Education	Jobs	33
Income	Housing affordability	33
Education	Income	31

Looking at the **time** factor, the longest reinforcing loop goes through 9 indicators. The longest balancing loop connects 8 different indicators.

9.3.5 Determine intervention points (Step 5)

Applying the Vester (2007) method shows that 'Income' (quotient = 4) is the best potential intervention indicator. This is a leverage point that can be manipulated to bring about change.

9.3.6 Run What-if (Step 6)

The OECD CLDs can be used to play out multiple what-ifs based on the 41 links. Following through the links of a CLD is an efficient way to test the logic and consistency of mental models. The stories told by the CLDs reflect generalised behaviour (for example, applies for a country or a region) rather than the behaviour of a specific individual. They can be told very quickly using interlinked thinking.

An issue raised in the *"OECD Society at a Glance 2014"* (OECD, 2014) report is worked through as examples using the linked indicators as in Figure 9-4. According to this report the "collapse in young people's employment opportunities is of particular concern because it leads to "scarring"– a term commonly used to describe how early working life difficulties can jeopardise long-term career paths and future earnings prospects" (p. 20).

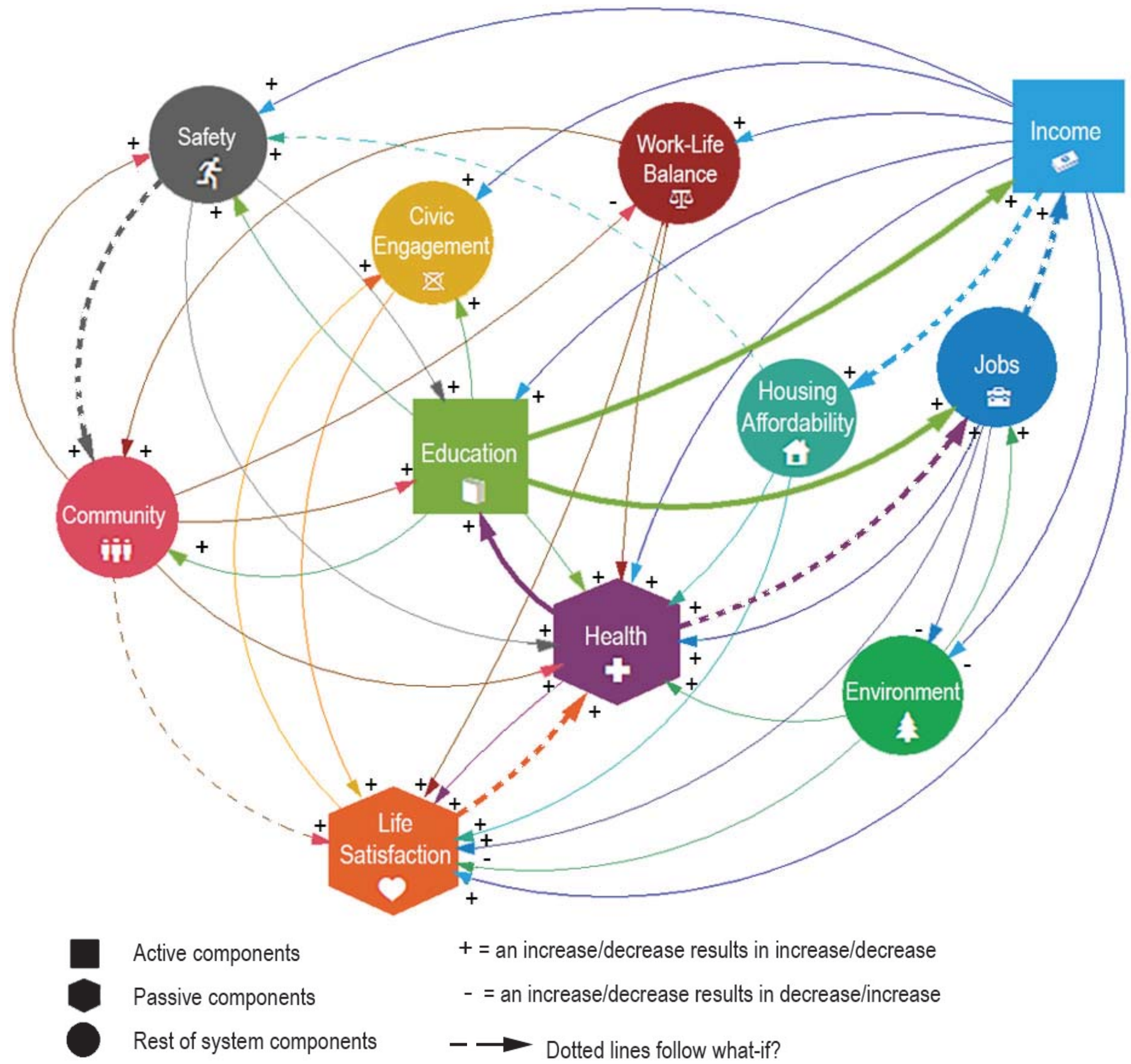


Figure 9-9: OECD linked what-if model.

Figure 9-9 shows the potential "scarring" effects are actually wider than the personal impacts referred to. These impacts can be followed through by looking at any or all of the 96 loops generated by the algorithm and listed in the spreadsheet output. 'Jobs' are part of 68 reinforcing and 28 balancing loops.

Starting at 'Jobs' and working through the what-if feedback loop marked by the dotted lines in Figure 9-9 we see how the decrease in jobs for young people results in diminished income earning potential, as referred to in OECD Society at a Glance 2014. A scenario is following from this effect, housing becomes less affordable. Young people cannot afford to leave home, despite being ready for this transition, and the consequence is overcrowding, tension, and conflict, which have a safety repercussion. Tension and conflict discourage community activity and interaction with friends and family, which negatively impact on life satisfaction and, in turn, on health. Unhealthy people are less equipped to learn, so there is less education and as a result jobs are harder to find. Balancing effects in the well-being system will at some stage come about as a result of less pressure on the environment due to less jobs and lower income. The ratio of reinforcing to balancing loops remains high, at 68:28. Therefore, there will still be strong drivers towards negative reinforcing cycles unless some form of intervention takes place.

9.4 OECD WEBSITE STATISTICS AND INTERLINKED THINKING OUTCOMES

As stakeholders were not involved in this case study, information provided on the OECD Better Life website was used for comparison purposes. The website provides data on how 615 respondents rank the eleven indicators according to their importance to New Zealand. These are compared with the interlinked analysis ranking of critical indicators in Table 9-5. The respondent sample is not representative of the New Zealand population as 60% are female and 52% of respondents in the 25–44 age cohort.

Table 9-5: Ranking of indicators by importance OECD website and interlinked OECD indicators

Rating of 615 respondents	Ranking of critical indicators in linked system analysis
1. Life satisfaction	1. Health
2. Health	2. Education
3. Education	3. Life satisfaction
4. Environment	4. Income
5. Worklife balance	5. Community
6. Safety	6. Safety
7. Jobs	7. Jobs
8. Housing	8. Environment
9. Income	9. Worklife balance
10. Community	10. Housing
11. Civic Engagement	11. Civic Engagement

http://www.oecdbetterlifeindex.org/responses/#NZL (615 responses downloaded 22 March 2015)

As Table 9-5 shows, the top three indicators are the same for both processes, though the order is different. ‘Civic Engagement’ rates last in both methods. ‘Environment’ and ‘Worklife balance’ are ranked more highly by the on-line respondents than the interlinked indicators predict. Income ranks as more important in the interlinked system than in the views of respondents. The reverse applies for 'Community'. As previously mentioned, the rationale for the links in the OECD model was based on information provided on the OECD Better Life website and other literature. The model constructed is therefore not specific to New Zealand.

The interlinked well-being model could also be an interactive on-line tool that allows people to change arrows connecting components. When completed, new information on: 1) feedback loops in the system and whether they are balancing or reinforcing, 2) strong links, 3) active components, 4) passive components, and, 5) critical components would be generated. These data could be collated over time and statistics generated on how people perceive the links in the well-being system. Additionally, insights into what policy change is needed to move away from income as the dominant active indicator and intervention point could be investigated.

9.5 SUMMARY

The OECD case study showed that the interlinked thinking method could be used without participants. The OECD system links were based on information derived by the researcher from the OECD website and general literature. However, it could be argued that when multiple participants are involved in determining links they are more robust as they are the product of a more diverse range of mental models. Regardless of whether links are based on the literature or participants mental models, the interlinked thinking method has the advantage of being flexible enough to quickly add or take away a link or indicator, to allow the resultant pattern change to be analysed and compared.

In the real world it is the relationships between the indicators that determine the level of well-being achieved. This is shown by the interlinked OECD indicators. With an interlinked system it is possible to follow the links to see the chain of reaction from any potential intervention point and move beyond short-term thinking and decision-making.

The OECD interlinked model identified 'Income' as a key active indicator in the system and a key place for intervention. This reflects the importance placed on material standards of living as a key driver of well-being. Individuals and society's need to be able to access to the goods and services required sustain their desired standard of living. This result can potentially explain why GDP is an ‘accepted’ proxy measure for well-being and the need to differentiate between income and GDP.

In the next chapter the results of the three case studies are discussed to draw out more general findings and conclusions from the analysis undertaken.

10 DISCUSSION

This chapter brings together the results of the three case studies and presents the responses from participants involved in the WR-GPI and Social Report workshops. The extent to which interlinked thinking can add more value than using individual indicators or indexed and aggregated indicators is then analysed. Whether a process to interlink indicators in a system helps progress sustainable well-being by supporting decision-making is examined. This information is used to determine how well the principal research question *“Does understanding the relationships between indicators add value and progress sustainable well-being?”* is answered.

A critique of the interlinked thinking method follows. The scope for improving future workshop facilitation is also addressed. An update on recent developments using a combination of CLDs and matrices is provided to acknowledge other work proceeding in this area. Last, the research methodology used in this research is assessed for appropriateness.

10.1 ACROSS-CASE-STUDIES COMPARISON

This section compares the results of the three well-being case studies that applied the interlinked thinking method set out in Chapter 6. Even though the indicator sets and links in each case study differed (the reduced WR-GPI had 59 indicators, the Social Report (SR) indicator set had 38 indicators, and the OCED had 11 indicators), these indicator sets were all developed to measure well-being. The across-case-studies comparison was undertaken to see if interlinking indicators revealed any similarities and differences in outcomes.

First, the roles allocated to indicators in the different well-being models constructed were compared. Table 10-1 lists the top scoring active indicators across the three case studies and shows that the indicators common to all are income related. ‘Living in deprivation’ is common to the WR-GPI and Social Report models, with the exception of SR Group 3. A measure of inequality was common to the SR Group 1 and the WR-GPI.

The OECD model, which has far less detail than the other models, ranked 'Income' the most active indicator in the system.

Table 10-1: Active indicators identified in the case studies

WR-GPI	(1) *P80/P20 ratio gross weekly household income (Inequality);(*2) Access to internet; (3) **Population living in deprivation**
SR Group 1	(1) **Living in deprivation;** (2=) Employment; (2=) *Income inequality;* (2=) Work/life balance
SR Group 2	(1) Perceived discrimination; (2) **Living in deprivation;** (3) Ability to express identity
SR Group 3	(1) Acceptance of diversity; (2) Trust in others; (3) Mental health
SR Combined	(1) Perceived discrimination; (2) **Living in deprivation;** (3) Acceptance of diversity; (4) Mental health
OECD	(1) Income; (2) Education; (3) Community

Key: **Bold** indicates common to all models. *Italics* indicates some commonality.

There was more consistency across the case studies with the 'passive' indicators. As can be seen from Table 10-2, in all the case studies 'Life satisfaction' and 'Health' were identified as the indicators that most react to change in the system. Both 'Life satisfaction' and 'Health' have a high number of links to them from other indicators so any change in the system filters quickly to these indicators. The degree of consistency in the roles allocated to indicators gives some confidence that these results are robust and would persist if the exercise was undertaken with a different group of participants working with a similar well-being indicator set.

Table 10-2: Passive indicators identified in the case studies

WR-GPI	(1) **Perception of health as good**; (2) *Employment*; (3) WR great place to live; (4) **Life satisfaction**
SR Group 1	(1) **Life satisfaction**; (2=) **Mental health**; (2=) **Physical health**; (3=) *Employment*; (3=) Loneliness
SR Group 2	(1) **Physical health;** (2) **Life satisfaction**; (3) **Mental health;** (4) *Employment*
SR Group 3	(1) **Life satisfaction**; (2) **Physical Health**; (3) **Mental health**
SR Combined	(1) **Mental health**; (2) **Life satisfaction**; (3) **Physical Health**
OECD	(1) **Health;** (2) **Life satisfaction**

Key: **Bold** indicates common to all models. *Italics* indicates some commonality.

Even though the models and indicators were different in the case studies, there was a similarity in the intervention indicators identified for the WR-GPI and Social Report systems using the Vester method. Based on the interlinked models constructed in the workshops, 'Inequality', 'Access to internet', 'Living in deprivation', 'Smoking and drinking', and 'Work/life balance' all rated highly in both systems as places to intervene. When the less detailed OECD model is included Table 10-3 shows the intervention indicators have a tendency to be income related.

Table 10-3: Intervention indicators identified in case studies

WR-GPI	(1) **P80/P20 ratio gross weekly household income (Inequality PC4);** (2) **Access to internet (CC9);** (3) **Population living in deprivation (QL1);** (4) *Purchasing power Hshld median weekly income (PC5);* (5) **Hazardous smoking/drinking (HC2,4);** (6) **Satisfied work/life balance (QL7).**
SR Combined	(1)Perceived discrimination; (2) **Work/life balance;** (3) **Phone and internet access;** (4) **Living in deprivation;** (5) **Income inequality;** (6) Perceived corruption; (7) **Smoking/drinking;** (8) Local content TV
OECD	(1) *Income*

Key: **Bold** indicates common to all models. *Italics* indicates some commonality.

The interlinked models all revealed a level of consistency when identifying the critical indicators in the well-being systems (see Table 10-4). 'Employment', 'Health' (physical and mental), and 'Living in deprivation' were rated highly in all models. 'Life satisfaction' was common to all but one model (SR Group 2). Again this gives some confidence that these roles would persist if the exercise was undertaken with a different group of participants working with similar well-being indicators.

Table 10-4: Critical indicators identified in the case studies

WR-GPI	(1) **Employment rate;** (2) Sense of local community; (3) **Perception of health as good;** (4=) **Pop living in deprivation;** (4=) Access to internet; (4=) P80/P20 ratio gross weekly Hshld income; (5) ***Life satisfaction;*** (6=) Participation in social activities; (6=) Participation in regular physical activity; (7) Contact with friends/family
SR Group 1	(1) **Mental health;** (2) **Employment;** (3) ***Life satisfaction;*** (4=) *Trust in others;* (4=) **Physical health;** (5) **Living in deprivation;** (6) *Loneliness;* (7) *Ability to express identity;* (8=) Language retention; (8=) *Acceptance of diversity;* (8=) *Participation culture & arts*
SR Group 2	(1=) **Mental health;** (1=) *Ability to express identity*; (2) **Living in deprivation**; (3=) **Physical health;** (3=) **Employment**; (4) Income purchasing power; (5) Voluntary work; (6=) *Loneliness;* (6=) High skilled workforce; (6=) School leavers>NCEA2; (6=) Income inequality
SR Group 3	(1) *Acceptance of diversity;* (2) **Mental health;** (3) **Physical health;** (4) Physical activity; (=5) *Loneliness;* (5=) Contact friends & family; (5=) *Trust in others;* (7) ***Life satisfaction;*** (8=) **Employment; (8=) Living in deprivation;** (8=) *Participation culture & arts;* (8=) Māori language speakers; (8=) Obesity
SR Combined	(1) **Mental health;** (2=) **Physical health;** (2=) **Employment;** (3) *Trust in others;* (4) *Acceptance of diversity;* (5) *Ability to express identity;* (6) ***Life satisfaction;*** (7) **Living in deprivation;** (8) *Participation culture & arts;* (9) Perceived discrimination
OECD	**(1) Health;** (2) Education; (3=) Income; (3=) ***Life satisfaction***; (4) Community; (5=) Jobs; (5=) Safety; (6=) Worklife balance; (6=) Environment; (7=) Housing affordability; (7=) Civic engagement

Key: **Bold** indicates common to all models. *Italics* indicates some commonality. Bold and italics indicate common to all but one model.

Table 10-5: Buffer indicators identified in the case studies

WR-GPI	(1=) Listed and registered heritage places (ST8) (0); Water allocation cf total resource (RF1) (0); People within 400m transport stop (CC6) (0); Avoidable deaths (HC11) (0); Soil quality outside target dairy/drystock farms (HE8,9) (0); Security of electricity (0); Value of household and community work (unpaid work PC6) (0); People within 400m transport stop (CC6) (0); People live and work same area, local employment (PC3) (0); (2=) Air quality PM10 days good/excellent (HE1) (1); Children attending Māori schools (ST12) (1); Visitor guest nights (QL13) (1); (3=) Access to local parks/green space (QL11) (2); GHG emissions /capita (HE16) (2); School leavers with> NCEA level 2 (EI4) (2); Perception can influence council d/m (ST4) (2); **Avg voter turnout local elections (ST2)** (2); **Spend >30% disposable income on housing (QL2).**
SR Combined	(1=)Work related injury (3); Adult literacy in English (3); (2=) Road causalities (4); Fear of crime (4); (3=) Crime (6); Household crowding (6); **Housing affordability (6);** (4=) Participation early childhood education (6) ; **Voter turnout (6)**
OECD	**(1=) Housing affordability** (3); Civic engagement (3); (2=) Environment (6); Worklife balance (6).

Key: **Bold** indicates common to all models. *Italics* indicate some commonality. Bold and italics indicate common to all but one model.

Buffer indicators (shown in Table 10-5) are those less connected in the system. Identifying buffer indicators is a potential way to reduce the number of indicators if this is desired. Before removal of a buffer indicator discussion is needed to determine if important links are missing in the system and the significance of the role played by the buffer indicator to well-being. If buffer indicators are removed new indicators assume the buffer role in the system.

Analysis of the strong links most commonly traversed in the different well-being models (Table 10-6) shows there are similarities. This analysis could not be done for the SR combined model due to the size limitation of the python algorithm. The link from 'Employment' to 'Income purchasing power' (yellow highlight in Table 10-6) appears as strong in two out of three SR groups. This link is also the first rated in the OECD model. While it is not in the top five for the WR-GPI model, it does show as having a high number of links (742) and is ranked 11th out of 189 links in this system. For SR Group 1 it ranks 6th in a system that has 123 links.

Another strong link common to the three case studies included 'Life-satisfaction' to 'Health'. This strong link is found in the WR-GPI, OECD, and SR Group 3 models (blue highlight in Table 10-6), emphasising the significance of these relationships in studies of well-being.

‘Health’ to ‘Employment’ was a strong link in the SR Group 1, SR Group 3, and the WR-GPI models (green highlight in Table 10-6). ‘Employment’ to ‘Income inequality’ ranks highly in both SR Group 1 and WR-GPI models (pink highlight in Table 10-6).

The case study comparisons show how perceived relationships and interdependencies determine the feedback loops and the behaviour of the well-being system. The interlinked thinking method provides a way to map feedback loops explicitly and provide information on the respective roles of indicators in the system. When considering the system of well-being, it is apparent that it is a complex system, where cause-and-effect links become less obvious the further they are from any initiating change. As a result of this distancing, humans become disconnected from the feedback loops that are fundamental to the systems in which they operate, and lose sight of potential control mechanism (Petersen et al., 2014).

The three Social Report models that linked the same set of indicators show the extent to which links in the system change the role of an indicator. SR Group 1 had far more links in their system than the other two SR groups. This was possibly a reflection of group personalities who approached the task of interlinking with enthusiasm, but potentially less mental model sharing. The other two groups were more considered in their link decision-making and intensely discussed each link made.

Experimenting with new links and generating different feedback loops provides a way to facilitate new thinking and behaviour (Petersen et al., 2014), and though not experimented with for this research, it is possible to intentionally change the role of an indicator by implementing a policy that removes or adds a particular link (Vester, 2007).

Table 10-6: Highly traversed links in the case study models

From indicator	To indicator	Total Links	From indicator	To indicator	Total Links
SR Group 1			**WR-GPI**		
Employment	Income inequality	1476	Perception of health as good (HC6)	Employment rate	2248
Life satisfaction	Trust in others	1441	Life sat (QL5)	Perception of health as good (HC6)	1185
Mental health	Employment	1281	Employment rate	P80/P20 ratio gross weekly household income (Inequality PC4)	1075
Trust in others	Acceptance of diversity	1247	Purchasing power Hshld median weekly income (PC5)	Access to internet (CC9)	1072
Obesity	Physical health	986	Pop living in deprivation (QL1)	Access to internet (CC9)	982
SR Group 2					
Mental health	Smoking/drinking	42	**OECD**		
Smoking/drinking	Living in deprivation	40	Jobs	Income	85
School leavers>NCEA2	High Skilled workforce	24	Health	Education	62
Loneliness	Mental health	23	Income	Jobs	59
Employment	Income purchasing power	20	Life satisfaction	Health	56
Living in deprivation	Infant immunisation	20	Safety	Community	42
Physical health	Mental health	20			
SR Group 3					
Physical health	Employment	27			
Employment	Income purchasing power	23			
Life satisfaction	Mental health	23			
Mental health	Physical activity	21			
Income purchasing power	Phone & internet access	18			
Mental health	Physical health	13			
Physical activity	Obesity	13			

10.2 RESPONSES FROM WORKSHOP PARTICIPANTS

Participants in the WR-GPI and Social Report workshops were surveyed at the start of workshop 1 and at the end of workshop 2 to learn their views on the value of the interlinked thinking/CLD[89] method. The questionnaires were a combination of Likert scale and open-ended questions. The questionnaires and full analysis of responses are provided in Appendices 6a–6g. For the Likert scale analysis, a positive response was classed as more than 50% of respondents, indicating 'agree' or 'strongly agree'.

The surveys at the start of the first workshops showed respondents had confidence in the reliability of the indicator sets currently used. All WR-GPI respondents and 71% of the Social Report respondents agreed the current individual indicators provided an accurate way to measure well-being.

WR-GPI respondents had less confidence in the accuracy of the WR-GPI indicators when aggregated and reported at the community outcomes level, or when a comparison was made with GDP trends. The WR-GPI was considered to be a more meaningful measure for well-being than GDP, but was not employed in policy discussions or decision-making or to bring important issues to the attention of decision-makers. Respondents were split 50/50 on whether the WR-GPI helps understanding of how well-being changes in the region, and whether it made relationships between indicators visible. Respondents were positive that the WR-GPI encouraged integrated thinking, and just over half agreed the WR-GPI communicates the complexity of well-being in a regional context.

The Social Report indicators were seen as an effective means to increase understanding of policy options and interventions to move towards sustained well-being. It was strongly felt that the Social Report indicators should be used to bring important issues to the attention of decision-makers. At the same time, the Social Report respondents did not believe the current Social Report indicators were sufficiently used in policy discussions in their workplace.

---

[89] When the workshops were undertaken the name 'interlinked thinking' was not used and the process was referred to as CLDs. To accurately report the responses from participants 'CLD' is used in Section 10.2.

The positive assessment of the current indicator sets gave the researcher the initial impression that there was little scope for improvement with the CLD method. However, the surveys undertaken at the end of the second workshop for each case study indicated the workshops had opened up a new way of thinking that most respondents had not had the opportunity to experience before.

There was unanimous agreement with WR-GPI respondents and no disagreement from Social Report respondents (3 neutral, 1 don't know) that their understanding and insight into the respective indicators had increased as a result of the CLD process. There was also majority agreement that CLDs help communicate relationships between indicators more effectively than the current methods used. This sentiment was stronger for WR-GPI respondents (83%) than the Social Report respondents (55%).

WR-GPI and Social Report respondents both considered CLDs useful for assessing which indicators are important for measuring well-being.

There was general agreement from both WR-GPI and Social Report respondents that using the matrix to identify potential intervention points in a system was useful. It was also agreed that using CLDs in a what-if context helps understand interactions in a complex system. Considering CLDs in a shared (group) context was seen by most WR-GPI and Social Report respondents to be a useful way to identify possible unintended consequences from intervention. Less certainty was expressed, however, regarding the benefit from considering CLDs in a shared (group) context to better identify the time delays between a change in one indicator, and a consequence in another.

That CLDs could provide *more insight* into well-being drivers was agreed by most WR-GPI respondents (one neutral response) but not by the Social Report respondents (only 3 agreed). Neither group thought that CLDs give insight *more quickly* than stand-alone indicators. That CLDs result in better communication between respondents was contested. The WR-GPI respondents tended to agree with this statement (1 neutral) whereas, Social Report respondents disagreed (6 were neutral).

That 'CLDs show the world is too complicated and best not go there' was not agreed on by any of the survey respondents, so the need for tools to work with complexity was definitely supported.

Seven of the WR-GPI pre and post survey questions were aligned to compare participant's views on the different capabilities of the WR-GPI and interlinked well-being systems i.e. CLDs (see Appendix 6b for analysis and graphs). The participants viewed CLDs as consistently more effective than the WR-GPI stand-alone indicators. In the few situations where CLD's scored lower so did the WR-GPI indicators.

Eight of the Social Report pre and post survey questions were aligned to compare participant's views on the different capabilities of the Social Report and interlinked well-being systems i.e. CLDs (see Appendix 6c for analysis and graphs). The participants viewed the Social Report stand-alone indicators as similar in effectiveness to CLDs in 5 of the 8 questions. CLDs were considered more effective in making relationships visible, encouraging integrated thinking and communicating complexity.

Table 10-7 summarises responses to questions that could be compared on a before-and-after basis across both case studies. It shows CLDs satisfied five more areas for the WR-GPI respondents than the existing indicators; whereas the benefits to the Social Report respondents were limited to two areas. The unique value that CLDs added for both case studies was making relationships between indicators visible.

Table 10-7: Respondents views on questions that were comparable

Questionnaire statement	**WR-GPI Indicators**	**WR-GPI CLD**	**SR Indicators**	**SR CLD**
Makes relationships between indicators visible		✓		✓
Assists understanding of policy discussions/ options		✓	✓	✓
Should be used to bring important issues to the attention of decision-makers		✓	✓	✓
Assists understanding of how well-being might change to assist being proactive		✓	✓	✓
Communicates the complexity of well-being		✓	✓	✓
Encourages integrated thinking	✓	✓		✓

The following responses (numbered R1 to R14) were provided by WR-GPI and Social Report respondents to the open-ended question asking what the best features of the workshops were:

R1 Ability to show complexity and critical elements all together.

R2 Insights into inter-relationships are really valuable to discussions around indicators.

R3 Overview of complex thinking, causal loops, feedbacks. Excellent working group sessions.

R4 Having a chance to assess the value of particular indicators and challenge each other on their relationships.

R5 Excellent discussion. Presentation examples very good.

R6 Highlights the challenges and complexity and helps bring the reality of a situation to the fore, and helps focus on what we can do in what otherwise may be overwhelming.

R7 Group work and discussion/debate.

R8 Discussing in a diverse group the linkages involved in well-being and in doing so gaining a better understanding.

R9 Group discussions about the causal loops and understanding other people's mental model.

R10 Group exercises.

R11 For me having results for three groups was very useful as it highlighted that even in a structured activity results can vary considerably. This does not reflect badly on the methodology but rather highlights that an empirical exercise can be strongly influenced by the process followed and the discipline from which participants come. This is highly relevant to discussion on composite measures and the importance of applying both qualitative and quantitative approaches to analysis of interventions and when setting priorities.

R12 To have participants from a range of agencies and an academic perspective (although this group already interacts regularly) was much appreciated.

R13 The discussion in groups and the overall analysis done with explanations was valuable.

R14 Getting a group of fairly tightly connected central government people together and seeing the diversity in the implicit world/system views alongside the common threads.

Two issues were mentioned in response to the question, "What were the most disappointing features or problems of the session?" A WR-GPI respondent was keen to have a 'final product' as an output. A Social Report workshop respondent expressed concern about comparing the Social Report indicator approach with the CLD approach without this being fully discussed at the outset.

In response to the question what new applications (numbered A1 to A9) could the CLD approach be used for the Social Report, respondents[90] made the following suggestions:

A1 Broader educational aspects with links to crime, etc., as a way to interconnect current service providers.

A2 Cross-agency exercises for policy intervention and other indicator work involving commonalities, crossovers and consistencies, e.g. Living Standards Framework Indicator selection, Social Policy Evaluation and Research Unit/Families Commission, Family/whanau report framework indicators, Harmonising Regional Monitoring.

A3 Has been useful but I need time to digest and think through further. Will definitely use this work to understand linkages in the future.

A4 Having a conversation and chatting to others about the links.

A5 Cross-government policy discussion. Integrated data explanation.

A6 It would be interesting to look at splitting groups by discipline, to assess the impact on outcomes. Understanding how different views influence how we prioritise activities and interventions would be beneficial to the policy process and could improve decision-making.

A7 I would suggest that this exercise benefits the analysis process more than the reporting end of social monitoring. We provided the indicators we are likely to include but adding those we have excluded would have helped in determining the legitimacy of these decisions.

[90] The WR-GPI participants were not asked this question, which was an oversight by the researcher.

A8 It would also be useful to use this exercise to look at how Government sets priorities. For example, how would the Better Public Service measures stand up under this analysis?

A9 Survey design and analysis, indicator suite development and appraisal, policy development and appraisal, learning and development.

10.3 ANSWER TO RESEARCH QUESTION

At the outset research questions were proposed, and this dissertation set out to answer them. Each of the previous chapters has addressed a specific question. The principal research question: *"Does understanding the relationships between indicators add value and progress sustainable well-being?"* is now considered.

First, to determine *if understanding of the relationships between indicators adds value,* Table 10-8 sets out the ways in which interlinked indicators are considered by the survey respondents to be more informative than stand-alone or aggregated indicators, and also highlights where there were reservations. The surveys ask about CLDs but the process used was as set out in Chapter 6 as was given the name of 'interlinked thinking'. The CLD/interlinked thinking method was considered to add value if more than 50% of respondents 'agreed' or 'strongly agreed' with the statement. 'Neutral' and 'don't know' responses were included in the 100%.

Table 10-8: Survey results on whether or not CLD/interlinked thinking adds value

ID	Survey statements	WR-GPI	SR
S1	My understanding of the indicators has increased due to the Causal Loop Diagram (CLD) process	Yes	Yes
S2	CLDs make the relationships between indicators more visible than the normal reporting format	Yes	Yes
S3	CLDs help communicate the relationships of indicators	Yes	Yes
S4	The Impact Matrix approach to identify potential intervention points in a system is useful	Yes	Yes
S5	Discussing intervention points through a CLD lens helped me understand interactions in a complex system (what-if example)	Yes	Yes
S6	CLDs are a useful to tool for assessing indicators important for measuring well-being	Yes	Yes
S7	CLDs could assist understanding of policy interventions to move towards sustained well-being	Yes	Yes
S8	CLDs could assist decision-making and understanding of policy options to move towards sustained well-being	Yes	Yes
S9	CLDs should be used to bring important well-being issues to the attention of decision-makers	Yes	Yes
S10	CLDs assist understanding of how well-being might change in NZ (i. e. enables us to be proactive)	Yes	Yes
S11	CLDs communicate the complexity of well-being	Yes	Yes
S12	CLDs encourage integrated thinking	Yes	Yes
S13	Considering CLDs in a shared (group) context is a useful way to identify possible unintended consequences from possible intervention	Yes	Yes
S14	Considering CLDs in a shared (group) context is a useful way to identify the time delays between a change in one indicator, and a consequence in another	Yes	Yes
S15	CLDs give more insight into well-being drivers than standard trends and indicators	No	No
S16	CLDs give insight more quickly, compared with the standard trends and indicators	Yes	No
S17	CLDs result in a better communication between participants than the standard trends and indicator graphs	Yes	No
S18	Complexity is an issue that needs to be addressed[91]	Yes	Yes

How interlinked thinking added or did not add value is summarised in Tables 10-8 and 10-9. This analysis is based on the responses to the above statements (supporting statement number listed) and the views expressed by respondents to the open ended questions (supporting response number listed).

[91] This is a rewording of the statement 'CLDs show the world is too complicated and best not go there'

Table 10-9: How interlinked thinking adds value based on survey results

Adds value by and ID:	Reason
Understanding of indicators increased S1,S5,S6 R2, R5, R7	Discussing the linkages involved in well-being, as part of a diverse group, enables participants to broaden their mental models and understanding of well-being indicators.
Helps make relationships more visible and helps communicate relationships and change S2, S3, S10 R1, R4, R8, R9, R10, R12	The links in the models represent the combined mental models of participants. They capture the many permutations between indicators that exist in the real-world well-being system. A different group of people would have different priorities and different sets of links. This reflects the real world, where what comprises well-being differs from individual to individual. The interlinked thinking method allows people to share and refine their mental models. This process provides a means of understanding the complexity of well-being, and increases awareness of the chain of reaction. The diversity among a relatively homogeneous socio-economic groups highlighted how results can vary considerably even when people complete the same structured activity. This was not deemed a reason not to use the interlinked thinking method but rather a justification to carry out a similar workshop process with people from different backgrounds.
Ability to work with complexity S 11,S18 R1, R3, R6	The interlinked thinking method provided participants with a way to work in the area of complexity without being overwhelmed.
Could assist decision-making and policy options to move towards sustainable well-being S7,S8, S13 R13	Respondents were positive that interlinked thinking provided a useful tool to assist decision-making and policy options to move towards sustainable well-being. This included bringing important well-being issues to the attention of decision-makers and exploring unintended consequences from possible intervention.
Allows consideration of intervention impacts S4, S9, S14	The usefulness of the interlinked method is that it can be used as a forward looking tool for: (1) exploring the impact of interventions on future well-being; (ii) considering the behaviours that result from the structure and processes of the system and its feedback loops; and (iii) presenting indicators in a way that can tell a story and can be used for what-if analysis. Having a complete list of the loops in the system and the loops of which each indicator is part provides a replicable process to follow policy interventions or policy options along various pathways to evaluate potential impacts. This is achieved at a high level, using a qualitative rather than quantitative approach.
Encourages integrated thinking S12 S11, S14	The interlinked thinking method provides a way to work with feedback loops within complex systems without specialist knowledge and move beyond immediate linear cause-and-effect relationships to consider the progression of impacts. The method provides a structured, replicable way to capture mental models and show the implications of relationships beyond the first point of impact in a transparent way. Becoming more able to document the chain of events that drive well-being enables a move from short-term fixes. Interlinked thinking makes the extensive network of connections between indicators visible and shows the multiple pathways by which feedback loops cycle back to influence their cause.

There were three areas where there was less certainty regarding the added value provided by interlinked thinking.

Table 10-10: Where interlinked thinking does not add value based on survey results

Did not add value and ID:	Reason
Does not give more insight into well-being drivers than standard trends and approaches S15	Interlinked thinking did provide insights, but the message here is that the standard approaches used also do and so interlinked thinking should be considered a complementary tool rather than a replacement.
Does not give insights more quickly than standard trends and indicators S16	The Social Report respondents did not agree that insights were easier to deduce than with the standard approach.
Does not result in better communication between participants S17	The Social Report respondents did not agree that interlinked thinking provided a better way for participants to communicate than standard trends and graphs. A possible reason is interlinked thinking was less familiar to work with.

Overall from Tables 10-8, 10-9 and 10-10 it can be concluded that understanding relationships between indicators and the interlinked thinking method do provide additional value. Aggregated and individual indicators also provide useful information (as shown in Table 10-10) but new insights can be gained from making relationships explicit. Further endorsements of this conclusion are: (1) the Social Report workshops were requested by a Statistics New Zealand employee who had attended the WR-GPI workshops; (2) the suggestions made for how interlinked thinking could be used in other work areas; and (3) the positive response and desire to revisit the workshops expressed by participants from the two case study workshops in an article they wrote for 'The Treasury Living Standard Newsletter' (reproduced as Figure 10-1).

The Living Standards Newsletter May 2015

http://www.treasury.govt.nz

1 The Terrace, Wellington 6011, New Zealand
PO Box 3724, Wellington 6140, New Zealand

MSD and the Greater Wellington Regional Council examine the links between indicators

The Wellington Region Genuine Progress Index (WR-GPI) working group and the Ministry of Social Development's Social Report team both hosted Causal Loop Analysis workshops with their stakeholder groups in recent months. The sessions were organised by Statistics NZ, facilitated by Vicky Forgie from Ecological Economics Research New Zealand at Massey University, and hosted by SUPERU and – whilst conducted separately – the insights the workshops provided were surprisingly similar.

What is Causal loop analysis?

Causal loop analysis is a progress in which stakeholders map out the relationships between indicators that they consider critical. Looking at the obvious causal loops in the context of an entire system (and from the differing perspectives of multiple stakeholders), enables participants to see where critical intervention points in a system might lie.

Specialised software was used to collate the workshop participant's responses and identify the number of links to any particular indicator, and which indicators are most critical to a system. "The workshop was really useful for us" says the WR-GPI's coordinator Richie Singleton, "as we are currently reviewing our framework and the indicators that comprise it. The results from the workshop can assist us in understanding the impact policy changes have had on different indicators - and on the system as a whole. Ultimately we are concerned with enhancing well-being - and tools like this help us understand how the region's 'path dependency' (the combined influence of governance policies, economic, social and environmental conditions and other factors) will affect those outcomes. "

An example…
There is clearly a link between levels of physical activity, obesity rates and people's perception of their general health status.

Considering those links in the context of an interconnected system – highlights the role that infrastructure which enables physical activity to occur as part of a commute (like walking and cycling as part of a public transport journey) can play in increasing physical activity while reducing traffic congestion and improving air quality.)

Both organisations will incorporate the results from the workshops into their monitoring activities, and will consider revisiting the exercise periodically in order to ensure it continued to inform the future development of their respective frameworks.

Figure 10-1: Article in the Treasury newsletter written by workshop participants.

The need for skilled decision-making is increasing in a world where decisions and their outcomes are not always closely related (Karakul & Qudrat-Ullah, 2008) and where cause-and-effect is not obviously linked in both time and space. The second part of the research question asks if interlinked thinking *progresses sustainable well-being.* Table 10-11 sets out the ways that interlinking indicators in a system provides new information for decision-makers and how this can be used to better pursue sustainable well-being. This analysis is based on evaluation of the semi-quantitative outputs generated by the interlinked thinking method.

Table 10-11: How interlinked indicators progresses sustainable well-being

Supports decision-making	**How**
Model diagram showing the structure of the well-being system and the feedback loops	The model generated helps to understand the concept of sustainable well-being from a systems perspective and makes feedback loops visible. A systems perspective requires analysing what we are trying to achieve when we refer to 'sustainable well-being'. When well-being is considered as a system, more attention is paid to the balancing and reinforcing feedback loops that make up the system and provide the checks and balances. Understanding reinforcing and balancing loops increases awareness that from a systems perspective, to avoid collapse, the growth pattern needs to be like a logistic S-curve rather than an exponential trend. Balancing loops are desirable in a system as they bring stability over time. Reinforcing loops move towards a vicious cycle of growth or decline. Current efforts to increase well-being focus on the reinforcing loops in the system without looking for places in the system where balancing loops can be effectively brought into play. Analysis of the case studies with an environmental component (WR-GPI and OECD) showed that the current balancing loops come about as a result of pressure on the environment. To avoid the cycle of boom/bust that has typified progress over time, well-being goals need to consider what components can continue to increase unimpeded, and where the breaking effects (balancing loops) are best introduced. Resolving this quandary is outside the scope of this research.
Excel spread sheet of the feedback loops in the well-being system	The Excel spreadsheet lists the feedback loops in the complex system and thereby provides a way to move beyond immediate linear cause-and-effect relationships. Analysis of feedback loops shows the progression of effects – the short feedback loops that give immediate impacts and the simultaneous longer feedback loops taking place in the system.

Role of indicators in the system	Analysis of the different roles indicators play in a system provides new information and understanding. Despite the diversity of the well-being models used in the case studies, there was some agreement on active and critical variables and a high level of agreement on passive indicators. The role of buffers is also made more apparent. When environment indicators were included (WR-GPI and OECD case studies) these had an important buffering role in the system.
Analysing ‘strong’ links in the well-being system	Information on the highly traversed links shows the strong relationships in the system. These links are important due to the number of times the system depends on them to function. These can be counterintuitive, for example, the Life satisfaction link to Health is strong in the system whereas it is normally the opposite relationship that is emphasised. A possible explanation is that from a systems perspective, for the majority of people Life satisfaction is an enabler to achieve health and many other outcomes. Better understanding of significant relationships can be used to progress sustainable well-being.
Insights into intervention points in the well-being system	Intervention places were identified in the case studies based on: (i) active variables with a high quotient - derived from dividing the active sum by the passive sum (as in Vester, 2007), and (ii) the Cross Impact Delay matrix (as in Hürlimann, 2009). The latter used the delays that participants placed on the links in the WR-GPI and Social Report case studies. Results showed both methods identified the same intervention points, but the time at which the intervention occurred was different when time delays were included. Time delays provide a means of introducing dynamics in the system. While the survey respondents saw the usefulness of considering time delays between a change in one indicator and a consequence in another, they had difficulty determining the likely delays involved. Ways to progress sustainable well-being can be informed when the impacts of delays in the well-being system are better understood.
The system and relationships are the focus rather than the independent indicators	The interlinked thinking method focuses on the relationships in the system and the networks that result. The system models allow participants to track and discuss potential impacts across a wider field.
Interlinked thinking can be used to explore complex systems and test what-ifs to better recognise potential unintended consequences	The interlinked thinking method helps inform decisions by providing information on the possible ramifications of making change at multiple points rather than relying on mono-causal “if-then” explanations.

The combined results provided in Section 10-3 evidence that understanding the relationships between indicators does add value and support decision-making to progress sustainable well-being.

However, while value has been shown to result from working from a systems perspective there are other factors that need to be taken into consideration when the interlinked thinking method is used, and these are discussed next.

10.4 CRITIQUE OF INTERLINKED THINKING

This section provides a critique of the research undertaken and its validity, as it is important to remain critical of one's own work to avoid biases (Maxwell, 2005).

10.4.1 Subjective versus objective analysis

The models created by participants are at the subjective as opposed to objective end of the spectrum. This does not necessarily detract from their value, as objectivity is not necessarily the determinant of usability (Vester, 2007). It does, however, need to be acknowledged that the output of the interlinked thinking method can be skewed by the extent of the knowledge of those involved, and that indicator selection can have a strong bias towards what can, or is currently, measured. Following the process for indicator selection using a systems approach, as outlined in Chapter 5, is one way to address this issue. As with any modelling, the outputs from interlinked thinking are the product of the people making the connections. It is possible key connections were not made as they were not part of the mental models of the participants. For example, there was no link in any of the models between Life satisfaction (the happiness measure) and income. However, recent research indicates a counterintuitive relationship may exist between happiness and income:

> For academics, these results reveal the strong possibility for reverse causality between income and happiness – a relationship that most have assumed unidirectional and causal. For policy-makers, it highlights the importance of promoting general well-being (GWB), not just because happiness is what the general population aspires to (instead of GDP) but also for its productive effects—i.e. it may pay off to focus policy on maximising happiness and minimising suffering. For the general public, and parents in particular, it means that the emotional well-being of children and adolescents is key to their future success and this research provides yet another reason for the need to create an emotionally healthy home

environment. (http://www.Oecdbetterlifeindex org/blog/ happiness-pays.htm)

While subjective in nature, the participants in the workshops actively engaged in a process of relevance to them and created combined models showing the complexity of the well-being system with which they work. All the print-out models from the workshops were taken by participants so they could refer to them. This evidenced interlinked thinking provided general insights that are not always apparent, and made visible connections that cut across artificial boundaries.

It can be argued that participants make the interlinked thinking method more rigorous, and that this is a way to overcome the lack of legitimacy associated with a model that is purely the construct of one researcher (as the OECD case study model).

10.4.2 Intervention points

With the interlinked thinking method, identifying potential intervention points is a means of generating discussion and considering flow-on implications from decisions. As stated by one respondent, it is important to apply both qualitative and quantitative approaches to any analysis of interventions. Intervention has to be carried out with caution as with a complex system it is important to allow for time lags and not over-steer or overreact (Dörner, 1997). It also needs to be recognised that in most situations the setting of priorities will be based on political, not analytical, considerations (Solomon, 2013). However, analysis, or lack of analysis, is usually the reason given for poor decision-making.

10.4.3 Indicator selection and labelling

The models developed to show the well-being systems are a function of the indicators selected to interconnect. The interlinked thinking method is flexible, and participants were encouraged to add indicators they considered important; however, this opportunity was not taken up by anyone. A possible reason for this was the high degree of focus required to connect the existing indicators.

To avoid misunderstanding, careful thought needs to be given to the name used for each indicator. A clear definition of the indicator also needs to be provided to participants. This is important as the indicators selected for inclusion determine the resultant model. For example, with the workshops undertaken it was decided that 'Employment' rather than 'Unemployment' be the indicator used. A different system of links would result if 'Unemployment' was used. Reasons for making the change from 'Unemployment' to 'Employment' included:

- Positive rather than negative variable names are preferable (Maani & Cavana, 2007)
- Some of the impacts in the system from unemployment were seen as being covered by 'Living in deprivation', whereas employment impacts were not considered covered
- The literature places importance on employment/jobs as a way to increase well-being. The connections with employment are greater than just income and also relate to health, self-esteem, the ability to be in a relationship, etc.

Out of interest an experiment was carried out replacing "Living in Deprivation" with "Wealth". This led to the polarity of the links 'to' and 'from' "Wealth" changing; however, the feedback loop designated as reinforcing and balancing remained the same.

10.4.4 Balancing and reinforcing loops

The case study systems were all dominated by reinforcing loops that amplify and bolster change (be it in a positive or negative direction). This is most likely a reflection of the prevalent pro-growth mental model. The interlinked thinking method makes it known that having balancing loops in a system is essential to bring it back to stability. However, with well-being, the goal is always understood as bringing into effect reinforcing feedback loops that can amplify positive effects in a system. As a consequence, the benefits of balancing loops and the need to take corrective/compensating actions are not promoted. The case studies indicated the balancing effects in well-being systems came about through less pressure on the environment. This links to natural capital as a limiting factor for well-being growth.

10.4.5 GDP

One of the issues identified at the outset of the research in Chapter 3 is that GDP is not a good measure of well-being. There is wide use of GDP as a proxy measure for well-being, despite the acknowledged fact that well-being consists of more than a monetary measure of the goods and services produced by the economy.

The interlinked thinking case studies all resulted in models where the 'active' and 'critical' roles were predominantly related to material living conditions. Active indicators identified included 'Living in Deprivation' and 'Income' and critical indicators identified included 'Employment' and 'Living in Deprivation'. This finding reflects that the mental models people have place great importance on material standards of living as it is a key driver of well-being. This is because fundamental to concepts of well-being is the ability for individuals to access the goods and services required to meet their needs. In general, a higher level of expenditure indicates a higher level of well-being, up to sufficiency bounds as at some point a saturation level is reached. With consumption diminishing marginal utility applies, so the benefits derived from an additional dollar of expenditure is greater for a poor family than for an affluent family (H. Daly & Cobb, 1994). Using a proxy measure such as GDP is obfuscating when no attempt is made to delineate between GDP per capita and how income and spending power is distributed throughout society. When GDP growth is associated with achieving well-being attempts to move 'beyond GDP' are working against the prevalent social and cultural norms concerning life style.

10.4.6 Weighting

The links between indicators placed in the system by workshop participants were all given equal weighting as the standard procedure. This approach is used elsewhere in the literature, for example, the Canadian Index of Wellbeing (Michalos et al., 2011, p. v) applies Laplace's *Principle of Nonsufficient Reason,* and argues the absence of a good rationale for assigning a particular weighting is justification for the equal treatment of all indicators. A similar logic is applied with Occam's razor, which states if agreement cannot be reached on what weighting to use the simplest and best response is to assign equal weights to all components (McGillivray & Noorbakhsh, 2007).

The Social Report case study was used to test the impact weighting had on the interlinked thinking models. This showed weighting did not make a significant difference to the indicators categorised as 'Active', 'Passive', and 'Critical', other than the order changing slightly.

Selecting appropriate weighting is problematic when there is a high correlation between component parts. If weighting is deemed necessary in a well-being measure, the interlinked thinking method could be applied to establish these. Weights could be generated based on the number of times a link is traversed in the system (i.e. strong links). This may provide an alternative to other approaches such as statistical methods that are criticised for their lack of conceptual or theoretical basis when applied to well-being measures (McGillivray & Noorbakhsh, 2007; Rijpma, 2014).

10.4.7 The qualitative versus quantitative approach to problem solving

The aim of the SP2 project is to provide multiple decision-support tools. CLDs as used in systems thinking are classed as a qualitative tool. The ability of CLDs to incorporate balancing and reinforcing loops is considered to be an effective way to show feedback structures and connections in a system (Lounsbury et al., 2014). Despite this, CLD use is criticised on many levels (Richardson, 1997; Lane 2008; Schaffernicht, 2010). The main issues are: (i) they are a qualitative tool; (ii) they do not take stocks into account; (iii) there is ambiguity of polarities; and (iv) they are not dynamic. These criticisms highlight the divide between qualitative systems thinking and quantitative systems dynamics.

Supporters of quantitative modelling argue that because CLDs are a qualitative rather than quantitative tool, behaviour can only be inferred and therefore CLDs lack precision (Lane, 2008; Sterman, 1994, 2002; Richardson, 1997). A simulation model is required for 'evidence' (Sterman, 2002). Sterman (1994, p. 321) advances that qualitative maps, "are simply too ambiguous and too difficult to simulate mentally to provide much useful information on the adequacy of the model structure or guidance about the future development of the system or the effects of policies." Proponents of quantitative models see the role of CLDs as limited to problem structuring and explaining outputs generated by simulation models. However, with a system as complex as well-being, even very sophisticated quantitative models would be of limited use.

Another criticism of CLDs is that they do not show accumulations in a system. As stocks are resources that need to be managed, how they change through flows in and out is important to the dynamics of a system (Richardson, 1997). It is contended that CLDs emphasise the role of feedback loops so much that the crucial and distinct role of the accumulation process is lost (Lane, 2008). It is, therefore, difficult to take into account the extent to which one variable influences another (Schaffernicht, 2010). Added to this, CLDs do not distinguish between links that increase stocks, and links that are purely information flows (Richardson, 1997; Lane, 2008).

The way polarity is defined and used is also an issue (Richardson, 1997; Lane, 2008; Schaffernicht, 2010). The standard characterisation of polarities (which is to use '+' or '-' to indicate how one variable impacts on another) works for information links, but not for showing the accumulation of a rate of flow. Without this information it is not possible to show if the influence is a positive or negative one (Richardson, 1997). A resultant mislabelling of loop polarities can lead to false loop understanding (Lane, 2008).

Schaffernicht (2010), Moxnes (2000), and others, make the point that systems dynamics is concerned with continuous behaviour as opposed to event-oriented, static thinking. The use of CLDs obscures this, as CLDs are 'structure' rather than 'behaviour' driven. Drawing valid inferences when two or more causes interact is difficult (Dörner, 1997; Hovmand, 2014; Sterman, 2000). The fact that systems are continually evolving and changing (Holling et al., 2002) can be overlooked, as CLDs are a snapshot of a given time and context.

While these points are all relevant there are also arguments in favour of qualitative modelling: (i) the difficulties associated with quantification especially if soft variables are to be included (R. G. Coyle, 2000); (ii) they draw attention to feedback loops (Lane, 2008); (iii) qualitative methods are more suited for managers and people working in policy as they are easier to understand (Dhawan, O'Connor, & Borman, 2011), help to think holistically, and work well for communication purposes (Beck et al., 2012); (iv) both approaches (qualitative and quantitative) provide ways to communicate assumptions and shared mental models, and feed into decision-making by contributing to understanding (Doyle & Ford, 1998); (v) CLDs and qualitative methods are appropriate to use when time and resources are not available to construct a mathematical model (Beck et al., 2012); (vi) CLDs can be used in a pragmatic way (Schaffernicht, 2010); and (vii) it is possible to integrate dynamics with scenarios (Sedlacko et al., 2014).

The interlinked thinking method does not negate the value of a good simulation model. However, as simulation models are not accessible for many people alternatives are required (Mirchi et al., 2012). Interlinked thinking provides insight into the complexity that drives systems and is a method to understand causality between key system components. The "keep it simple" paradigm is prevalent with interlinked thinking. It is acknowledged that this paradigm, and hence interlinked thinking, will not be acceptable to those who believe complex real world problems require complex solutions. However, as understanding and influencing well-being involves the consideration of a large number of highly interlinked variables there is a risk the system is so complex it cannot be manage using quantitative approaches. The dilemma is not an either/or choice between qualitative and quantitative modelling, but rather how to best facilitate a progressive modelling process that is 'fit for purpose' and meets end-user needs.

Interlinked thinking progresses from being purely qualitative. The use of matrices provides an analytical capability and semi-quantitative element in the method thereby bridging the qualitative/quantitative divide.

10.4.8 What-ifs

There are a number limitations associated with what-ifs. As with scenario planning what-ifs are run purely for understanding and not to predict what is going to happen. Scenario planning is a major exercise that requires time to plan, design and research properly (Moyer, 1996). The scenarios, and the assumptions behind them, are laid out in advance to show decision-makers the possible impacts of different courses of action. The scenario technique is of greatest value when there is a high level of uncertainty, and when the future is anticipated as being affected by events without historical precedents (Maani & Cavana, 2007). Scenario analysis can deal with the tweaking of multiple variables at the same time which requires the use of system dynamics modelling.

What-if analysis is interpreted in this dissertation as a less ambitious procedure. What-ifs involve the tweaking of one link or polarity at a time and manually following through the logic of the resultant change. This can be done without prior preparation and the value generated comes from participant discussion of the potential flow-on effects. The what-if process is manual (rather than computer simulated) so there are limits to the extent to which outcomes of a partial system can be tested under alternative sets of assumptions. As some indicators can have a large number of feedback loops this can make manual analysis challenging. What-if are not dynamic therefore only take into account the first 'cause-and-effect' stage. What-ifs emphasise the role of feedback loops. This can lead to the important role of accumulations in a system being overlooked (Richardson, 1997; Lane, 2008). With what-ifs, as with other forms of modelling, there is always the risk of drawing the wrong conclusion.

10.4.9 Model size limit

While the matrix analysis can be studied to include any number of links, the algorithm used to generate the information on the loops in the system and to determine the links most frequently traversed has a size constraint. Therefore, the number of indicators to be linked, and the number of direct links to be made in the system, should be considered carefully. It is not so much the number of links but the extent of interconnectedness in the system that prevents the algorithm from running. For this reason it is recommended that the number of indicators be limited to between 20 and 40, as in the recommendations for selecting indicators from a systems perspective.

10.4.10 Delays in systems

Delays take place in all systems. The interlinked thinking method endeavours to get people to consider whether relationships in the system have a quick effect or delayed effect. Participants in the workshops struggled with placing an estimate on the time an impact would need to take effect, and this was not done as comprehensively as the placing of links between indicators. There is a tendency to underestimate the significance of delays between cause-and-effect in linear processes and this was also apparent when working at a systems level.

The dynamics of systems comes from the time component. The interlinked thinking method attempted to allow this by incorporating a time dimension (delays) in the calculation of intervention points. The response from participants was they were less convinced about the value this provided.

As using CLDs does not try to estimate how stocks change, delay length cannot be measured relative to the rate of change in a stock that the feedback loop is trying to control (Meadows, 2008). The ability to show such change is one of the advantages of using a simulation model. However, it must be noted that none of the interlinked systems in the case studies take into account stocks, which is a prerequisite for a strong well-being measure.

10.4.11 Improved workshop process

Each workshop experience gave new insights on how the interlinked thinking method could be further refined to improve the process. From the researcher's perspective, areas include:

1. Participants did not take up the opportunity to add/delete indicators, which may signal the need for a phased approach where indicators are introduced and discussed in advance of making links. Discussing indicators at the start of the first workshop would ensure that participants agree with the set of indicators chosen to be interlinked and understand the rationale for their selection. Participants could identify factors that influence the system being studied, and roughly define key aspects of the system, boundary issues, and the environment in which the system operates. The requirements for indicator selection from a systems perspective would also need to be presented (as discussed in Chapter 5). Presenting the selected indicators using a 'bulls eye' diagram (Meadows & Robinson, 1985) to show what is included and excluded, is a potential way to introduce the indicators and initiate discussion.

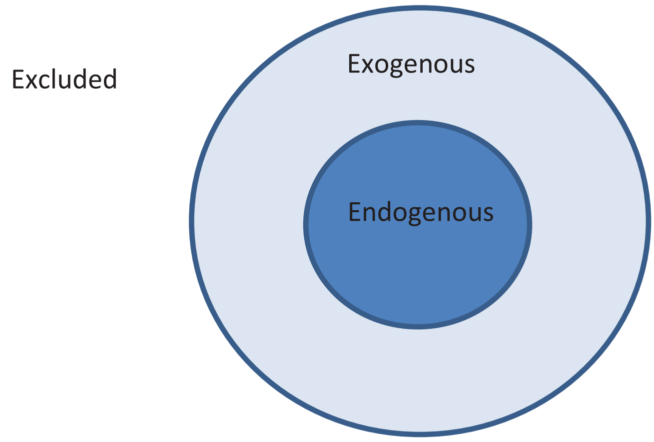


Figure 10-2: Bulls eye diagram to show what is included and excluded in the system. (Source: Meadows & Robinson, 1985).

2. Starting all groups at the same point to remove biasing links towards the start point chosen. The start point indicator can be randomly selected. This change is suggested because the models produced showed a denser number of links at the start point due to participants immediately going to the point they were most familiar with.
3. Participants need to spend time towards the end of the first workshop considering whether any of their links are indirect, given only direct links should be included.
4. Time should be allowed in the second workshop for participants to work through some of the balancing and reinforcing CLDs generated. The advantage of doing this is an increased understanding of flow-on effects and more scope to examine what-ifs. It is also a mechanism to reconsider the legitimacy of the links and whether or not polarities have been correctly labelled.
5. From the researcher's perspective it would be an interesting exercise for participants to explore retrospectively why their model resulted in the specific roles being assigned to the various indicators.
6. Placing a limit to the number of links allowed so that people put more effort and thought into prioritising the links in their system could be experimented with. This would encourage people to put more consideration into the links of major importance.

Participants at both workshops had the opportunity to provide suggestions for how the CLD/interlinked thinking method could be improved for future use. From the WR-GPI respondents suggestions for improvement were:

- From a council perspective politicians should test how useful the CLD approach is for decision-making, reporting, evaluation, etc.
- More diverse representation is needed.
- Start to explore Council mechanisms – what are the levers? Are these different for different Territorial Authorities? What is the extent of Council contribution/influence on these levers?
- Provide data/knowledge/information above what is known (evidence-based) about associations as this can sometimes be counterintuitive.
- Systems links may be different by distributional group, for example, Pacifica/Māori, older or younger, etc. It would be a good exercise to explore this.
- Longer sessions would be beneficial.
- Starting with a high level analysis or common system belief could give a more consistent CLD.
- The indicators on the A1 sheet need to have accurate titles to ensure they are not misinterpreted.
- Use a logic intervention model to structure the intervention process.

The Social Report workshop participants provided the following ideas:

- In the model it would have been good to highlight the lines showing the differences between the three groups.
- The start point may influence the links drawn in, so the methodology should stipulate different groups start in the same place.
- A wider cross-section of organisations participating will achieve a greater understanding of interlinkages between indicators and hence policy interventions.
- We would like to repeat the exercise at a domain, or sub-domain level

These suggestions will be incorporated into future interlinked thinking sessions where feasible. A disappointment expressed by one participant that there was no 'final product' could be addressed with a report if demand warranted it.

10.4.12 Interactive WR-GPI model

At the outset of this research, the view was expressed by a Wellington Regional Council staff member that an interactive web-based tool for the WR-GPI website would be a 'nice-to-have' extra. From this research a simple tool could be developed that allows people to show the links between indicators they considered most important. This could be done with the following steps:

1. Select a reduced set of approximately 20 indicators. It would not be desirable to use the number of indicators currently used as this would be too confusing.
2. Allow people to click between indicators to determine the direction of the link and whether in their opinion it results in change that is an increase or decrease.
3. Capture the links in a matrix so the python algorithm can be run.
4. Based on the outputs from the algorithm, give on-line information to the person on:
    a. The active and passive indicators in the well-being model they had constructed with their links
    b. The links most traversed or 'strong' links
    c. Accumulate the data to provide a comparison of the mental model of the person undertaking the interactive activity with the aggregated mental model of all previous players.

The actual process of setting up the on-line interactive tool is not part of this research. It would, however, be possible, and if done would provide a means for people to better appreciate how their well-being, and that of the region, is influenced in multiple ways.

10.5 COMPARATIVE RESEARCH

The combined use of CLDs and matrices was not in common use when this PhD research commenced. The development of the interlinked thinking method built on the research of Vester (2007), Hurlimann (2009) and Beck et al. (2012). While Group Model Building (Rouwette, Vennix, & Felling, 2009; Rouwette et al., 2002; Vennix & Rouwette, 2000) and other similar approaches have firmly established the value of qualitative systems modelling, new developments occurring in the semi-quantitative modelling have not yet achieved the same level of recognition. Two 2014 publications signify progress in this regard. Schoenenberger et al., (2014) combine CLDs and matrices to analyse terrorism from a systems thinking perspective. Emphasis is on how CLDs and matrices, when combined, provide a new framework for reasoning. The application uses fictional data. Videira et al., (2014) use Causal Loop Diagramming in a collaborative setting working with researchers and activists looking at the issue of degrowth. They then use matrices to identify synergies and possible intervention points. Analysis is further extended with 'what if' applications across different time frames.

This concurrent research trajectory using a combination of systems thinking and matrices when working with non-modellers corroborates the validity of the research approach undertaken as part of this dissertation. Table 10-12 identifies the key similarities and differences between interlinked thinking and the other approaches that combine CLDs and matrices.

The main differences with interlinked thinking are: (1) it has been applied to the multi-dimensional well-being which is an area international research highlights there is a lack of understanding of relationships; (2) a large number of relationships can be handled; and (3) strong links in the system are calculated.

Table 10-12: Where interlinked thinking differs from other approaches that combine CLDs and matrices

	Hurlimann (2009)	Vester (2007)	Schoenenberger et al. (2014)	Beck et al. (2012)	Videria et al. (2014)	Interlinked thinking
Participatory to share/connect mental models	✓	✓	x	✓	✓	✓
Models are participants perspectives (picture) on how they see the system	✓	✓	x[a]	✓	x in part	✓
Applied to well-being	x	x	x	x	x	✓
Intervention places/Leverage points	✓	✓	✓	✓	✓	✓
What if / scenario applications	✓	✓	✓[b]	x	✓	✓
Feedback loops analysed using an algorithm	✓	✓	✓	✓	x	✓
Large number of links handled (non-reductionist)	x	x	x	x	x	✓
Does not require large investments of time and resources	x	x	✓	✓	✓	✓
Transparent and easily communicated	✓in part	✓	✓	✓	✓	✓
Systems application/systemic understanding of issue	✓	✓	✓	✓	✓	✓
Strong links calculated	x	x	x	x	x	✓
Systems expertise not required by participants	✓	✓	✓	✓	✓	✓
Applicable for multiple indicator set use (i.e. topic neutral)	✓	✓	✓	✓	✓	✓
User friendly	x	✓	✓	✓	✓	✓
Semi-quantitative systems thinking	✓	✓	✓	✓	✓	✓
Roles of indicators (relationship between variable and system)	✓	✓	✓	✓	✓	✓
Time dimension	✓	x	✓	✓	✓	✓
Tested in policy application	✓	✓	x	✓	x	✓
Communication tool. CLDs used to encourage dialogue and common understanding	✓	✓	✓	✓	✓	✓
Analyse feedbacks (Reinforcing & Balancing). Closed loop thinking	✓	✓	✓	✓	✓	✓
Session length with participants 80-180 mins	not given	✓	✓	not given	✓	✓
Problem focused	✓	✓	✓	x	✓	x
Instrument for coping with complexity	✓	✓	✓	✓	✓	✓
Specialised software required	✓	✓	x	x	x	x
Extends to quantitative dynamic modelling	✓	✓	x	x	x	x

a) Analytical framework was the important aspect of this paper; b) Done by removing variable. ✓= Yes. X = No.

The 'Participatory Systems Mapping' (PSM) of Sedlacko et al., (2014) uses a similar workshop structure to interlinked thinking and confirmed many of the outcomes of 'interlinked thinking' method.

A feature in common with interlinked thinking and PSM is that they both combine participatory interaction with CLDs to obtain insights and enable reflection and sharing of knowledge. Neither approach is tied to a specific decision-making process.

The structure of the workshops was similar in that both familiarised the participants with the CLD syntax. Then participants discussed linkages and shared knowledge. The facilitator's role was to inform about the CLD process but to be impartial.

Both methods: (1) provide instruments for coping with complexity; (2) use CLDs to initiate discussion on the importance of individual feedback loops (though this took place at different stages of the process); (3) help explore structural causes, unintended consequences, and potential leverage points; (4) found closed loops encourage thinking about relationships between feedback loops, which is useful to understand and infer behaviour over time; and (5) provide learning outcomes at the implicit knowledge level (i.e. changed mental models) rather than at the direct policy level.

Other common points were both Sedlacko et al., (2014) and interlinked thinking found that homogeneity among group members speeds up the process but does not provide the diversity of underlying paradigms. Also, in both applications, the CLDs produced in workshops contained inconsistencies, duplicities, and under-developed structures that were addressed after the event.

The main difference between the interlinked thinking method and PSM was how CLDs were constructed and matrices not being used. With PSM, a facilitator starts with a 'problem variable' and participants are "tasked with establishing causal pathways between the starting cause-and-effect variables, followed by attempting to link effects back to causes (i.e. establishing feedback loops)" (Sedlacko et al., 2014, p. 37). Having a problem issue was seen as necessary to focus participants and provide boundaries. Without these conditions the PSM process was considered to be at risk of being paralysed by detail.

In contrast, the interlinked thinking method starts with large sheets of paper (number depends on the number of groups) on which the variable names are printed. Before the workshop, the key components of the system being studied were identified by the researcher and other vital individuals. During the workshop, participants work in small groups to make the links between variables and assign polarity. Participants have the freedom to add or delete variables. From the resulting links made between indicators, CLDs are produced and reported on using matrices.

The PSM workshops were two facilitated 90-minute sessions. This study learned that a viable duration seemed to be between 80 and 120 minutes. After this time span attention levels dropped. Participant numbers ranged from 8 to 18 per session and the ideal number of participants was considered to be 10–12. The PSM approach found larger groups provided more plurality of perspective and the potential for greater knowledge exchange and learning, but large numbers limited the time available per participant and consensus on links was more difficult to obtain.

With the interlinked thinking workshops, sessions were longer (approximately 180 minutes each). This was not seen as a problem because the people involved were engaged in a process they considered relevant to their work goals. The total number of participants was similar to that of the PSM, but as people were divided into smaller work groups each person had time to express their views and consensus was reached fairly quickly. While smaller groups provide each participant with more time to express their viewpoint, this did limit the plurality of perspective and the potential for greater knowledge exchange and learning.

10.6 RESEARCH METHODOLOGY

The methodology for this research involved a range of techniques. These were employed to determine whether understanding relationships between indicators adds value and can progress sustainable well-being goals. Case studies were used so interlinked thinking could be tested in a real world situation. These case studies implemented qualitative systems thinking approaches, and a semi-quantitative analysis using matrices. Two of the case studies involved participants; the third was a desk top exercise. Evaluation was done using both qualitative and quantitative assessment tools. The following discussion explains the methodology used to conduct the research, provides the justification for the techniques selected, and appraises the extent to which findings based on the use of these techniques can be considered credible and trustworthy.

10.6.1 Case Studies

The case study approach is a widely recognised research technique (Gerring, 2007; Kumar, 2014; O'Dwyer & Bernauer, 2014; Woodside, 2010). It can be used for exploring and understanding an issue as well as confirming and quantifying (O'Dwyer & Bernauer, 2014). "The case study design is based upon the assumption that the case being studies is typical of cases of a certain type and therefore a single case can provide insight into the events and situations prevalent in a group from where the case has been drawn" (Kumar, 2014, p. 365).

As the case study approach is flexible and experimental by design there are no fixed rules for how it is carried out. The evidentiary basis on which case studies rely is plural, not singular, so it is legitimate to employ a range of quantitative and qualitative techniques for gathering and analysis of evidence (Gerring, 2007; Kumar, 2014; O'Dwyer & Bernauer, 2014; Woodside, 2010). While case study research is characterised by flexibility and open-ended techniques of data collection and analysis (Gerring, 2007; O'Dwyer & Bernauer, 2014) there are general requirements that need to be met to ensure outcomes are credible and defendable (Gerring, 2007; Kumar, 2014; O'Dwyer & Bernauer, 2014; Woodside, 2010).

To enable findings to be generalised to a wider population quantitative studies need to meet some form of internal and external validity criteria. As it is numerically based quantitative analysis is often considered 'objective' and 'value free' which is not correct (O'Dwyer & Bernauer, 2014). As O'Dwyer & Bernauer (2014, p. 64) note "empirical evidence tends to be more credible for individuals in power; it can be summarised and presented for a quick snapshot of reality, and unfortunately, it can be easily misused, either unintentionally or intentionally". The level of reliability achieved and the degree of impartiality is influenced by the assumptions made at the outset and the way data is collected and analysed.

For qualitative research transferability of findings is less important than achieving an accurate and valid understanding of phenomena that can be generalised as a theory (O'Dwyer & Bernauer, 2014). Qualitative methods recognise the importance of tacit knowledge and acknowledge that the social world is an interpreted world, not a literal world, always under symbolic construction and deconstruction (Altheide & Johnson, 2011). With qualitative research usefulness is tied to practical outcomes as opposed to the type of validity sought for bureaucratic, rational and organisational purposes (Altheide & Johnson, 2011). Rather than controlling and simplifying data to make sense of it qualitative researchers identifying patterns that exist in their data (O'Dwyer & Bernauer, 2014); be that 'hard' (e.g. numbers), or 'soft' (e.g. feelings) data.

Criticism of the case study approach include subjectivity in implementation, evaluation and presentation of results (B. Becker et al., 1994-2012). The case study research for this dissertation endeavoured to minimise subjectivity and evaluated the outcomes with a combination of both of qualitative and quantitative techniques. No method, however, can claim to be completely objective (Myrdal, 1969; Pangaro, 1991; Bossel, 1998). The case study approach was considered appropriate as the interlinked thinking method developed was innovative and needed to be tested in real world applications. How case studies are best structured depends on the interests of the researcher and the nature of the process being examined (Woodside, 2010). Using case studies had the added advantage of being able to describe the interlinked thinking method in sufficient detail for readers to replicate elsewhere if desired (see the workshop process set out in Appendix 5).

The case studies were undertaken from an experimental perspective which requires satisfying the methodological criteria that define a well-designed experiment for internal validity (Gerring, 2007). With respect to the interlinked thinking case studies this was achieved by the following:

- The structure of case study 2 was designed to closely follow case study 1.
- Case study 2 was undertaken within 2 months of case study 1
- The participants were similar (local and central government officials)
- Temporal effects were estimated with before and after questions that lined up for each case study. There was no control group to measure change against.

Here the control was the pre-intervention state which was assumed to remain the same without intervention.

- The questionnaires were structured as closely as possible to enable comparisons between the two case studies and for similarities and differences to be identified. [A note of importance is that the term 'interlinked thinking' was not used at the workshops as this had not been coined at this stage. Instead the questionnaires refer to CLDs but the method used was the same.]
- For each case study the two workshops were held close together (one week in each case). It is therefore unlikely that other confounding causal factors impacted the results (i.e. *ceteris paribus* conditions were maintained).

Combining several cases into a single study is referred to as the comparative method[92] (Gerring, 2007). "Properly constituted, there is no reason that case study results cannot be synthesized with results gained from cross-case analysis, and vice versa." (Gerring, 2007, p. 13). While it is acknowledged that comparative assessments between studies, over time and between diverse settings increases research reliability the undertaking of comparative studies is not straightforward and evaluations across interventions challenging (Gerring, 2007; Midgley et al., 2013). It is generally very difficult to replicate the studied situation with similar contexts and participants. With the two case studies that involved participants the interlinked thinking method was tested under very similar circumstances (though the indicators used were not the same).

External validity refers to the extent to which a study's results are applicable to a wider population. The case study approach is not intended to generalise findings but rather as a way to probe theory (Woodside, 2010). With the case study method the total study population is treated as one entity that is either representative or extremely atypical. There is no expectation of homogeneity across the sample and the population (Gerring, 2007) so no need for participants to be randomly selected. If there is a need

[92] The interlinked thinking case studies could be termed 'comparative-historical' as there was both spatial and temporal variation. Temporal (across 2 workshops) and spatial (across 2 different groups).

to generalise case study findings can only be extended to situations similar to the cases studied (O'Dwyer & Bernauer, 2014).

The participants involved were selected by the workshop organisers for their interest and working involvement with the indicator sets being linked. The objective was to demonstrate there a new way to make mental models explicit, and for participants to get a better understanding of the mental models of others. Both case studies involved participants from local and central government so it could be theorised that the interlinked thinking findings (that mental models are diverse but the roles assigned to key indicators have some similarity) would apply to other participants from local and central government. This similarity also makes it legitimate to compare case study findings.

The interlinked thinking method was tested with participants in two different case studies. The sessions mirrored each other as closely as possible in approach, presentation, and tasks. Participants received the same briefing on systems thinking and causal loop diagrams. The links made in each workshop reflected the mental models of the participants who came to the workshops. The data interpretation was generated between workshops using the same replicable method, and the process of reporting back the results to participants was similar.

The OECD desk-top study did not involve participants. Here links were made in the system based on the literature read, and the researcher’s understanding of well-being drivers. To be as objective as possible there was no re-working after the initial links were made to change outcomes.

10.6.2 Systems thinking and the use of matrices

The systems models constructed by participants were qualitative. Systemic problem solving methods have been derived explicitly to enhance understanding between stakeholders as well as provide a big picture analyses to broaden the perspectives of participants and facilitate the emergence of new framings, strategies and actions (Midgley et al., 2013). As such systems thinking and system dynamics are valid and fitting methods of undertaking case study research (Woodside, 2010) and legitimately incorporate both qualitative and quantitative analysis (Wolstenholme, 1999).

Answering the research question set at the beginning required using an approach that could link indicators. With systems approaches much wider boundaries are generally set compared with non-systems studies. This was essential for the well-being case studies. It can be argued that qualitative models that are structured at workshops provide transitional objects to structure stakeholder engagement (Eden & Ackermann, 2006; Midgley et al., 2013). They can play a key role in developing common understanding without requiring large amounts of data. With the interlinked thinking method the models generated reflected the mental models of participants as was the objective. The sheet detailing the rationale for each link clarified the logic of the thinking and was a good resource to refer to when doing the analysis. A very small number of links were difficult to understand and needed interpretation by the researcher to enable the analysis to be undertaken and reported back at Workshop 2. This interpretation was discussed with participants and agreed with. However, if this had not been the situation the analysis as done would not have been correct.

The objective with systems thinking and system dynamics is not to predict into the future as this is impossible (Taleb, 2007) but to aim at achieving broader understanding. When interlinked thinking was used the diversity of links in the well-being models constructed showed the limited common understanding. It was not until links were made explicit and shared that the extent to which mental models differed was comprehended.

No attempt was made to use system dynamics models to run multiple simulations and carry out sensitivity tests. These can help avoid misinterpretation (Forrester, 1994; Sterman, 2000; Woodside, 2010). While this is a strength of system dynamics and could potentially have increased the rigor of the research the disadvantages when this was investigated were considerable and included: (1) the large amount data required; (2) lack of appropriate data; (3) the questionability of the assumptions needed to be made; (4) the amount of time required; and (5) the black box nature of large scale model building.

Matrices analysis was used to communicate findings and insights so patterns could be described and explained in a way that is comprehensible. This quantitative analysis allowed participants to appreciate the degree of complexity in a well-being system. A large number of feedback loop were quickly generated to reflect how the real world well-being system operates. The process of calculating links and roles in a well-being system is very transparent. In terms of validity the outcomes generated by the algorithm can be manually checked if desired (though this is time consuming). An internal validity check that can be done to ensure all the links are transcribed correctly (between the model and the matrix) is checking against the Vensim outputs for random indicators.

A comparison of the effectiveness of interlinked thinking compared to other approaches (see Table 10-12) would have been informative. This is difficult due to problems of replicability (Midgley et al., 2013) and was not considered for this research.

10.6.3 Questionnaires

When undertaking research some form of before and after intervention measurement is required. Rather than relying on the personal reflections of the researcher to measure the outcomes questionnaires were used for evaluating IT. The survey process is a theoretically driven deductive framework for generating data for analysis (Tolich & Davidson, 2011) and extensively used to gather feedback from participants (Midgley et al., 2013; Rouwette, 2011; Sykes & Goodwin, 2007). As a result questionnaires are commonly used for evaluation studies and considered a reliable way of measuring the impact or effectiveness of a project (Kumar, 2014).

A strength of questionnaires is they provide a voice for participants, and a way to get their viewpoints on process and short term outcomes immediately after their involvement. With the interlinked thinking research the two case studies that involved questionnaires were run in quick succession. All participants were asked to fill in the questionnaire to evaluate their own recent experiences using a mix of open-ended and closed questions. The purpose of the questionnaires was explained at the first workshop session. Questionnaires do not give reliable data if the questions are not well framed and/or they are not operationalised correctly for measurements to be valid. Therefore the questionnaires used were designed to follow recommended survey practice (i.e. short, clear, not ambiguous, reliable) (Tolich & Davidson, 2011) and were piloted with a GWRC staff member on the SP2 team who was not a workshop participant. The questionnaire for the second case study was kept as similar as feasible to the first case study for analysis and comparison purposes. However, the process was not rigid and improvements were made. According to Eden (1995) this is legitimate as interventions are complex and researchers need to respond to the unexpected.

The usability of the questionnaires was proven by participants completing them in a sensible way with no problems understanding the questions. According to Midgley et al., (2013) the more data you collect the more important this prerequisite for validity and reliability becomes. The questionnaire had a reverse question at the end to detect if people were actually considering each question individually rather than engaging in a box ticking exercise. No counterintuitive answers were given and corresponding questions generated similar answers. These are also checks for the usability of a questionnaire (Midgley et al., 2013). Respondents did not have to identify themselves and the responses were treated as confidential to encourage honest feedback. All answers provided by participants were considered to be correct as responses are subjective and there is no right or wrong. Filling out the questionnaires was voluntary.

A questionnaire should be tested for validity to ensure it measures what it is designed to measure, and reliability in terms of does it provide consistent results and accuracy (Cavana, Delahaye, & Sekaran, 2001; Kumar, 2014). The face validity of the questionnaires was satisfactory in that the questions included were justified based on the research objectives. As the questionnaires were short no attempt was made to replicate questions as a reliability test. This is another potential check for the validity and reliability (Tolich & Davidson, 2011) but difficult to apply with short questionnaires as participants are reluctant to answer the same question repeatedly.

A weakness of the questionnaire use in this research was not being able to capture data on longer term mental model change. This was not possible within the research timeframe. It would have been useful to establish if there had been longer term benefits from the intervention using interlinked thinking by interviewing participants and using reflective questions after a certain time period. This could, for example, have determined if having a better understanding of feedback loops shifted participants from linear thinking to system thinking in their routine working day. Also this would have allowed triangulation across two or more evaluation methods, an accepted means of strengthening findings (Midgley et al., 2013; Woodside, 2010). With the questionnaires statistical analysis could have been done but this was not considered necessary as the results were not being extrapolated to a broader population.

10.6.4 Research methodology conclusion

Research can be understood to be "a systematic process to make things known that are currently unknown by examining phenomena multiple times and in multiple ways" (O'Dwyer & Bernauer, 2014, p. 65). Having an appropriate research methodology contributes to the validity of the research undertaken (Kumar, 2014) and with this research it is claimed the processes followed and implemented were fitting. How the case studies were undertaken, the use of questionnaires, and the combination of quality and quantitative analysis, incrementally and interactively, contributed to building reliability and validity. What matters most in an evaluation is what is achieved by the method in a given context, judged from the perspectives of stakeholders (Eden, 1995; Eden & Ackermann, 2006; Gerring, 2007; Midgley et al., 2013). That value was added for participants can be concluded from the questionnaire response, the Treasury newsletter article, the keenness to undertake the second case study and the demand for the printed models.

10.7 SUMMARY

The focus of this chapter was answering the principal research question established at the outset: *"Does understanding the relationships between indicators add value and progress sustainable well-being?"* Findings from the three case studies and survey data were used to confirm that understanding the relationships between indicators adds value and can support decision-making to achieve sustainable well-being.

Comparing and contrasting the outcomes from the three case studies determined that different models constructed for well-being exhibit similarities. These concordances existed despite the indicator sets and models that linked the indicators having a high degree of variability. The workshops demonstrated that how people perceive the relationships that impact on well-being can vary considerably, but there is consistency in role allocation when a systems perspective is applied.

The interlinked thinking method was tested and approved for its ability to make relationships between indicators visible. The survey responses from participants in the WR-GPI and Social Report case studies confirmed there were many aspects of interlinked thinking that they considered added value and supported decision-making. Having a structured process to allow the sharing of mental models was one of the significant benefits gained.

The value of the interlinked thinking was affirmed by how readily participants suggested specific applications to use the method. Participants also contributed valuable comments on how the workshop process could be improved. These included highlighting on combined models links that all groups agree on, and ensuring all groups commence at the same place to avoid different starting places influencing the outcome. This advice will be followed in future workshops.

It was not, however, concluded that interlinked thinking should be used instead of the standalone/aggregated indicators currently used to measure well-being. Interlinked thinking, therefore, is an investment that adds value but as an addition to, rather than replacement for, the current indicator reporting approaches.

A critique of the research has been provided. Users need to be aware that there are multiple factors that can influence the implementation and outcomes from interlinked thinking and take this into account. Recent research along similar lines to interlinked thinking was briefly introduced for completeness. This presents current research trajectories being explored internationally. Last, the methodology used to conduct the research and how it was applied was reviewed.

The last chapter of this dissertation draws some final conclusions on tackling sustainable well-being complexity using interlinked thinking.

11 CONCLUSION: TACKLING COMPLEXITY USING INTERLINKED THINKING

This final chapter discusses the success of the research undertaken to achieve the goals outlined in the introduction of this dissertation. The principal question addressed was: "*Does understanding the relationships between indicators add value and progress sustainable well-being*?"

The chapter first summarises the findings from this research based on the discussion in Chapter 10. The original contribution to knowledge as an outcome of the research undertaken is then outlined. Next the implications of the research are discussed. Within the context of the SP2 research project there was the added requirement that any new tool developed complement the other research streams. Therefore, the method developed specifically worked towards understanding relationships between indicators in a way that:

- adds/demonstrates value to users over and above unconnected indicators
- is manageable and low cost
- facilitates policy-making by making mental models and relationships explicit
- is transparent
- enhances understanding of the impacts of intervention/change
- increases understanding of complexity

This chapter revisits these requirements and discusses how well they have been met. This is followed by a reflection on the research limitations, further research possibilities and a concluding statement.

11.1 RESEARCH FINDINGS

Based on the case studies and participant responses the research finding is that understanding relationships between indicators does add value and progress sustainable well-being. People are aware of the interconnectedness of issues and this research demonstrated a demand for tools that allow working in a broad, rather than narrow, context. Interlinked thinking is orientated to the real world and can be used in multiple contexts. That interlinked thinking meets a need was shown by the second case study being requested by a participant who had been involved in the first case study. Participants gained new knowledge through discussing and rationalising relationships and have independently stated they would like to have more workshops. Their experience confirmed the findings of Videria et al., (2014) that CLDs can be used in a participatory setting to: (1) provide an open learning platform; (2) structure the deliberative process; and (3) promote the co-production of knowledge in line with the post-normal science mode of Funtowicz & Ravetz (1993).

Having a process that allows participants to communicate their *a priori* mental models and show the complexity and critical elements of the well-being system without being overwhelmed was valued. More simplistic ways are needed to encourage integrated decision-making as most end-users (such as those involved in the case study workshops) have time and budget constraints that prevent them from acquiring the technical skills to become competent system dynamics modellers. Participants readily shared their mental models of how they depict well-being relationships. The mental models were varied and the interlinked thinking method could handle this diversity. Interlinked thinking also provided a way for the outputs of different groups of participants to be compared.

Understanding of interrelationships continues to be an area underestimated in policy (UNU-IHDP and UNEP, 2014). Not taking into account relationships between the components and isolating indicators from their systems context is short-sighted. There are many instances where not taking an holistic approach to societal problems have resulted in worse outcomes and new problems (Dörner, 1997; Hovmand, 2014; Vester, 2007).

Analysing feedback loops adds value by enabling participants to better understand the connections between what they do and other critical factors within the wider system in which they operate. This helps overcome the silos that develop when day-to-day work routines become institutionalised and inflexible. As pointed out by Bateson (1972), habitual use means an accepted way of working is not questioned, and as a result, becomes hard-wired and difficult to change. However, frequency of use is not proof an idea is either true or pragmatically useful over a long period of time (Bateson, 1972). Having accessible ways (such as interlinked thinking) to see the bigger picture and question general theories from a wider systems perspective can only improve policy outcomes.

Making relationships more visible can progress sustainable well-being when cause-and-effect information is used to inform decisions and policy. Being aware of potential down-stream impacts enables proactive rather than reactive responses. Agreement or disagreement with the results from the analysis of feedback loops provides opportunities to discuss whether the system is as presented, and if any major issues are being overlooked. Working with cause-and-effect and potential impacts on the rest of the system broadens spheres of interest beyond immediate effects. In an ideal world this would provide sufficient insight to prevent unintended consequences thwarting policy action.

Working with relationships and using a systems approach introduces the concept of system limits and that all system components must be viable and contribute to well-being. The interlinked thinking method works with relationships rather than numbers with the emphasis on maintaining a healthy and viable system. From a systems perspective, the goal should be gains that keep the system (each of the four capitals in the case of well-being) healthy and able to function without uncontrollable volatility, rather than aim for the greatest possible growth – as with GDP ambitions.

11.2 CONTRIBUTION AND SIGNIFICANCE OF THE RESEARCH

This dissertation developed and tested the interlinked thinking method in both participatory and non-participatory contexts. Interlinked thinking draws on concepts used in systems thinking (Hürlimann, 2009; Maani & Cavana, 2007, 2009; Meadows, 2008, 2009; Senge, 2006) and systems theory (Lane, 2008; Richardson, 2011; Sterman, 2000), and combines CLDs and matrices as in the work of Vester (2007) and Hürlimann (2009). The key ways in which interlinked thinking makes a significant contribution are summarised below.

11.2.1 How CLDs are derived

The process of constructing CLDs is different in that participants (or the researcher/s when a desk exercise is undertaken) first identify direct links between the indicators that are selected to represent the system. These links combine to make the system. The orthodox approach to constructing CLDs is to draw each feedback loop individually to tell a specific story.

The links are transcribed into a matrix that is the input for an algorithm used to generate the CLDs in the system. The algorithm provides new information on: 1) feedback loops in the system and whether they are balancing or reinforcing; 2) strong links; 3) active components; 4) passive components; 5) critical components; and (6) buffer components.

The links in the system provide a way to explore what-ifs by following the potential cause-and-effect impacts from a change that takes place – whether it is a planned intervention, or occurs as a result of an exogenous impact on the system.

11.2.2 A large number of links can be included

With the interlinked thinking method the boundaries and the number of links are not pared down to a bare minimum. This is an advantage as boundaries work to conceal unintended consequences (Wolstenholme, 2003).

The multi-dimensional nature of well-being and the large number of links in any well-being system makes it difficult to consider what constitutes well-being and how indicators interconnect. The interlinked thinking method was able to incorporate a large number of links and reflect this complexity. A quantitative dynamic mathematical model of well-being, conversely, would have limits imposed by the formulation and validation requirements to become operational.

While the interlinked thinking method has the ability to include more relationships than most modelling, the workshop process revealed there are limits to the number of links that can be handled. This was shown with the combined Social Report model where the number of loops generated was so great that the algorithm could not cope with the size. However, despite these limits, any model constructed can include many more relationships than other current models, so is therefore more true to reality.

11.2.3 Easily communicated

There is no 'black box' associated with interlinked thinking. It is a method that is both simple to use and simple to explain. The outputs, though generated by an algorithm for speed of production, could also be produced manually if desired. Using the spreadsheet output it is possible to identify both tight feedback loops where cause-and-effect happen quickly and also concurrent longer feedback loops where the implications of decision-making become less obvious and harder to control. Important relationships can be easily identified using the spreadsheet output.

11.2.4 Understanding the ways indicators interlink

The purpose of the interlinked thinking method is to provide an accessible and formalised procedure for people to share how they believe drivers of well-being interact across a complex system. Every person has a unique mental model based on their experiences and knowledge. It is widely accepted that understanding is improved if you can combine different approaches and integrate different perspectives. Use of quantitative system dynamics models (Sterman, 2000, 2002) requires specialised and technical knowledge, which the majority of people do not have. Interlinked thinking provides both an opening for these people to interact with complexity, as well as some quantitative analysis. It thereby partially overcomes a common criticism that CLDs are limited by being a purely qualitative tool.

The emergent behaviour of parts interacting as a system makes complex problems hard to understand (Hovmand, 2014; Hürlimann, 2009; Meadows, 2008; Senge, 2006; Sterman, 2000; Vester, 2007). Having a new pragmatic tool to work with complexity is significant, given the greater connectivity of the world in which we live. While there is increased awareness of the importance of not compartmentalising problems and solutions tools to assist that are not highly specialized and technical are not readily available. Ways to deal with interconnectivity are limited, as are ways for diverse groups to come together to use the same language and share the same big picture. This is despite the fact that a common conceptual understanding is essential for research and policy to back each other up. As most people do not have the necessary skills or time to develop and use highly technical quantitative models, alternatives are needed that can fill this gap. In the absence of such tools, the standard approach is to reduce a complex problem into smaller components and explore each in detail. The downside of this is reductionist thinking and isolating problems from their wider context. The interlinked thinking method encourages people to move away from this way of problem solving, and instead place an issue or problem in the system of which it is part.

Interlinked thinking is based on relationships rather than being problem-based. This allows links to be explored independent of a problem in need of solution. This differs from system dynamics models that are constructed to solve a problem and are intentionally designed to replicate undesired behaviour.

11.2.5 Strong links in the system are calculated

The strong links in a system are determined by the number of feedback loops that depend on that link. This feature of interlinked thinking is not, as far as the author is aware, used in any other systems applications. It is expected that a policy action that influences a strong link will have a significant impact on the overall system due to the high number of feedback loops that are dependent on this link. When analysing the system as a whole, the strong links revealed can vary from what would be intuitively expected. Using interlinked thinking allows policy to take identified strong links into account.

11.2.6 Does not require experts, or specialist software to run

While complexity was the motivation for the research, simplicity and clarity are the products. The models were generated by a process that required only a short explanation of how to construct a CLD relationship. The outputs can be explained very easily, which means they can be understood and are transparent. The process itself is quick. Workshops can be completed in two, half day sessions run a few days apart. Analysis is done using a spreadsheet and the algorithm, which is freely available. Vensim™ is not essential for analysis, but the visual outputs are appealing (as the requests to take the models printed for the workshops proved) and easy to generate with free software. The interlinked thinking method as tested was found to be accessible to the participants involved. It facilitated quick understanding in a real world driven by deadlines, pressure, and budget restrictions.

Ease of use and a comprehensive understanding of the interlinked thinking process opens up the world of complexity to non-modellers. Ways to better understand the system within which people operate increases the ability to find and implement solutions (Hovmand et al., 2012). Applying the interlinked thinking method proved to be an enjoyable and accessible process for participants in the workshops. In addition, it bridged the gap highlighted in post-normal science between academia and the needs of people working at the front-line.

The interlinked thinking process makes it possible to acquire an understanding of a system and its complexity without having to accumulate large amounts of data. It moves from focusing on detailed information gathering to understanding system structure. This differs from most other systems approaches. For example, system dynamics modelling primarily operationalises historic data trends for validation (Ford, 2010; Morecroft, 2007; Sterman, 2000) and network-analysis researchers are required to undertake in-depth stakeholder interviews to elicit system knowledge, which involves a large amount of energy and time (Bezuidenhout et al., 2012).

Well-being is a highly uncertain and complex system where economic-social-environmental indicators interact in ways that are indirect, non-linear, cumulative, and synergistic (Coleman, 1998). If the interlinked thinking method can be used with well-being it will be transferable to many other contexts where people seek a better understanding of how indicators in a system interact. Evidence of this was the number of different applications where the Social Report workshop participants considered interlinked thinking would be of value, and the expressed interest in using interlinked thinking in the future.

The interlinked thinking method also has scope to be used as a first step in the process of quantitative modelling, where it would help modellers and end-users to better understand the structure of the system they are working with. It can also help develop the necessary mind-set to run and engage with highly technical quantitative models.

11.2.7 Progresses sustainable well-being

Interlinked thinking both strengthens and supports the cognitive functions of decision-making. It does this by making the connections in the system more visible so potential unintended consequences can be anticipated and counterintuitive insights revealed.

Humans are prone to rely on intuition (Kahneman, 2011) and to selectively monitor some events while downplay or ignoring others (Klein, Snowden, & Lock Pin, 2011). Interlinked thinking helps people overcome these subconscious traits. It provides a method to reframe and support the growth of shared understanding. The workshop process allows people to consider future events in a way not based on predicting from past trends. Instead the broad scope of the system is revealed which allows connections that cut across accepted boundaries to be exposed.

Guidelines for indicator selection are an additional output from this research. Currently, limited material is available on how to select indicators from a systems perspective. The production of these guidelines will reduce the time and resources required to identify appropriate indicators.

11.3 MEETING SP2 REQUIREMENTS

This research was undertaken as part of the SP2 research project and to add to the SP2 toolkit. How successfully the interlinked thinking method has met the following requirements is now reviewed.

Aim 1: Adds/demonstrates value to users over and above unconnected indicators

Making relationships visible was identified as an area where the interlinked thinking method adds value over and above the individual and aggregated indicator reporting. The provision of information on the nature of the relationships in a system is an enhancement that is an additional benefit. The current reporting formats (used for the WR-GPI and Social Report) were also valued.

Aim 2: Is manageable and low cost

This was achieved. The two workshops take a half-day each and analysis can be completed in a week, so momentum is not lost. The tools required are large sheets of paper, Excel, and the algorithm available free on request. The Vensim™ software used in this research for the visualisation is available free on-line. A major advantage of the method is the limited input of time and costs required by both participants and the person carrying out the analysis.

Aim 3: Facilitates policy-making by making mental models and relationships explicit

The workshop process allows participants to determine and highlight the links and impacts they consider important, arrive at a level of consensus, and document the rationale for the decision, thereby making a relationship explicit. The researcher observed variance in mental models, both within and between groups, despite group members having similar educational and economic status.

Workshop surveys revealed that participants found the process of deciding on links valuable, as they tended to look at the system from the perspective of their own field of expertise and the discourse with others required assimilating different knowledge. For some links there was a lively debate before a decision on the link and its polarity.

Once links are documented, they become explicit rather than implicit, which facilitates policy-making as it contributes understanding of how indicators impact each other. All the large charts that were drawn for the workshops were taken by participants as they considered these useful resources in the workplace.

Aim 4: Is transparent

The method is entirely based on the linkages that participants consider important for the system they are interested in. Inputs are very transparent as they are their own ideas and concepts; outputs are easy to understand and interpret once explained to the users.

Experts are not required for analysis as it is very logic-based and done using spreadsheet software with which most people are familiar and competent at using. The steps are straight-forward, as described in this dissertation. The one time-consuming element involved is the transferring of the hand-drawn links from charts to the spreadsheet matrix and diagramming software. If Vensim™ is used the loop count function provides a useful check procedure to ensure the transcribing is correct.

Responses to the questionnaires indicate that participants increased their knowledge of the wider system in which they operated. The vast amount of information that exists in a digital world results in information overload, which forces people to specialise simply to keep abreast of current thinking. The interlinked thinking method devised, provides a way to reverse this trend and instead work at the level of emerging patterns to inform understanding. It moves participants away from the trap of silo thinking. Basic what-ifs, generated using the interlinked model, allow cause-and-effect to be considered in more detail.

Aim 5: Enhances the understanding of the impacts of intervention/change

The interlinked thinking method makes relationships between indicators visible and provides a way for potential intervention points to be identified. The spreadsheet printout of the CLDs for each indicator lets participants track the impact of change. The extensive list of linkages allows looking further into the future than would be possible with the usual linear cause-and-effect approach. Tracking impacts in an interconnected way encourages discussion and enhances understanding. It is straight-forward to revisit interlinkages made at the outset, as sometimes the outcomes are counterintuitive and need further exploration and justification.

Aim 6: Increases understanding of complexity

The method allows users to consider interlinkages in a system in a structured way. Interlinked thinking encourages participants to approach the challenge of complexity and voice their logic and argument for why a specific link is important. When combined into one system, participants can acquire a useful overview of how the indicators they work with interrelate and impact on other areas outside their sphere of responsibility. Comparing the different models constructed is a way to demonstrate to participants how different world views impact outcomes. Interlinked thinking is a first step into the world of complexity and provides pathways to introduce participants to the functions of the more sophisticated dynamic tools such as those produced by the SP2 project.

11.4 RESEARCH LIMITATIONS

Interlinked thinking is a tool to assist people deal with complexity in a manageable way, and gain new information to improve policy design and working together. In the words of a participant: “I think [the interlinked thinking method] highlights challenges and complexity and helps bring the reality of a situation to the fore and helps focus on what we can do in what otherwise may be overwhelming.” While successful in adding value the following research limitations have been identified and need to be taken into consideration when applying the interlinked thinking method.

11.4.1 Long term benefits not established

The questionnaire results indicated that the interlinked thinking method had short term benefits helping people to think in systems. The extent to which this is a long term effect was not analysed as only immediate short term responses were collected. It is difficult to evaluate change over the long term due to the many factors that impact knowledge accumulation and the measurement challenges when there is no control group not subject to continuous change (Checkland, 1993; Midgley et al., 2013). People easily assimilate learning without attributing it to a specific event. Nevertheless there is research, such as that undertaken by Scott et al., (2013), that does indicate that mental model changes are durable and likely to impact the decision-making processes of those involved in the future.

11.4.2 Dynamics

With the interlinked thinking method it can be argued there is a lack of dynamics in the feedback process as the qualitative models constructed are snapshots for a given timeframe and only consider the first contact between two indicators. It is therefore hard to tell what behaviour will eventuate in the longer term. To generate trends in behaviour over time system dynamics models are used. However, incorporating the complexity of well-being in a system dynamics model would be near impossible. With well-being there are multiple non-linear relationships that exist but little attempt has been made to quantify these relationships. Additional barriers to the use of system dynamics modelling with well-being include peoples’ reluctance to engage when tools are unfamiliar and complicated to use, the required data is hard or impossible to get, and outputs become meaningless when there is more than one soft variable (Hürlimann, 2009).

11.4.3 The mental models explored

The interlinked thinking method provides a structured means for the people who attend the interlinked thinking workshops to share their mental models. Each person has their own personal conceptualisation of reality, (i.e. a mental model) and communicating these to others increases deep understanding (Senge, 2006; Woodside, 2010). The interlinked thinking method transfers the perceptions and mental models of individuals and groups into shared causal and feedback structures which are the object of analysis and shared in two different ways. The first workshop allows groups of three to four participants to discuss and share their mental models and come up with a model they agree on. The second workshop shares the separate group mental models and the combined mental model of all participants.

With this research the mental models shared were those of central and local government officials. The question of interest was how they visualise well-being relationships as this influences policy outcomes. The diversity in mental models was shown by the analysis. The combined WR-GPI model had only 14% of the links the same for all three groups and the Social Report combined model had only 20% the same across the three groups. The different models created allow a comparison of mental models, and presented the opportunity to see how they differed. Analysis of how the different systems models would impact on policy outcomes was not undertaken. Instead how this could be done was demonstrated with a what-if example using a partial model.

Interlinked thinking was tested with a fairly homogenous group of participants working in small groups. It can be argued that the pace of progress is faster with homogeneous groups and constructing a model may take much longer if there were strongly opposing views among participants. The impact of working with a larger diverse group was not experienced. It would be expected that this would allow greater exchange and learning but also limit the amount of time each participant would get to contribute. Small groups have the advantage of reducing the scope for individual/individuals to dominant the process.

11.4.4 Role allocation

The objective of interlinked thinking is to share the different mental models people use to conceptualise well-being. It was therefore interesting to find that the multiple representations of well-being exhibited some consistent features in terms of the role allocations given to specific indicators. This gives some confidence that these roles are common to well-being systems and would persist if the interlinked thinking method was undertaken with a different group of participants working with well-being indicators. A theory that would be good to further test is whether the consistent 'active' role of 'Income' and 'Living in Deprivation', explains in part why GDP is so dominant in well-being thinking.

With the well-being studies there was interest expressed (see Appendix 5a) in testing the interlinked thinking method with different stakeholder groups to see if the well-being system depicted was very different and if the roles identified varied. Further case study applications using the interlinked thinking method are essential to allow refinement of the method and extension of the analysis.

11.4.5 The large number of loops

There is scope for the large number of loops generated and listed in the spreadsheet to be presented in a more user-friendly and visually appealing way. While the large number of feedback loops represents the reality of well-being and the multi-dimensional interconnectedness more research is needed into how to better package this information.

11.4.6 Assumption of causality

The interlinked thinking method is based on the assumption that causality exists and CLDs are proficient to show the resultant cause-and-effect. With interlinked thinking CLDs are utilised for knowledge brokering and capturing complex systems in a holistic way. CLDs are considered to be best suited to knowledge sharing rather than new knowledge generation (Sedlacko et al., 2014). Data gathering and the implementation of action is not the intended purpose. The idea is to gain information as a basis for policy design and working together by expanding the mental models on which policy solutions are based (Sedlacko et al., 2014). However, this may be insufficient to satisfy those people who prefer definite outputs.

11.4.7 Transferability of findings

The extent to which results from case study analysis are transferable to other participants, conditions, times and places is a measure of external validity. Table 11-1 sets out the transferable findings generated by the research undertaken.

Table 11-1: Transferable workshop findings

Interlinked thinking workshop findings:	Transferable
Interlinked thinking makes relationships between indicators visible	Yes
The interlinked thinking method can be easily replicated with different indicators and participants	Yes
Helps people think in an integrated/systems way	Yes
Models of well-being as a system. These models are idiosyncratic to the participants involved in the workshops.	No
Leverage points. These are relative to the models constructed in each workshop and are not absolute.	No
People have very different mental models of the well-being system and how it is linked.	Yes
Well-being is not a dependent variable determined by independent variables, but a system of interconnected variables.	Yes
The roles of key indicators were fairly consistent even when people have different mental models of the well-being system and how it is linked. A theory is that all well-being systems have similar active, passive and critical indicators (though the names used may vary).	More well-being case studies using interlinked thinking with a broader range of participants would be necessary to substantiate this theory.

As Table 11-1 shows the interlinked thinking method is the transferable aspect rather than the analysis of the well-being systems. As complex systems are complex generalising about them can be dangerous (Meadows, 2008).

11.5 FURTHER RESEARCH

Further research to investigate how to best manage down-stream effects to improve well-being in a region is required. More empirical evaluation of the success of working at the proposed intervention points would be a worthwhile exercise, as this would build more confidence in the interlinked thinking method. This, however, like all interventions in the real world, would be hampered by lack of a control to measure against, as in complex systems change is always occurring.

The real value of interlinked thinking, as with other modelling, is enabling people to consider alternatives, increase their awareness of interrelationships and see the system as a whole. Nonetheless, it would be interesting to stress test the interlinked thinking method in a real decision-making process to see how effective it is in bringing people together and resolving controversial issues.

Another research area of interest is to use the interlinked thinking method to further explore how links reinforce the importance of income for well-being. If this dependency persists GDP will remain the dominant policy focus, and the disadvantages of using this yardstick as a measure of well-being will continue to be ignored.

Interlinked thinking was trialed on case studies that all related to well-being. Further research to test the method with other issues would confirm the usability and usefulness of interlinked thinking in other areas.

There is also scope to trial different workshop strategies. It would be interesting to look at splitting groups by discipline to assess the impact on outcomes and better understand how different world views influence how we prioritise activities and interventions. Different approaches, such as limiting the number of links participants can make and experimenting with alternative starting points from which to make links, are also areas where further research would add to the robustness of interlinked thinking method.

11.6 CONCLUSION

The research objective in this dissertation was to determine whether better understanding of the relationships between indicators could add value and progress sustainable well-being. This was motivated by the desire of the stakeholders involved in the Greater Wellington SP2 Mediated Modelling workshops to gain a better understanding of how the indicators used to measure well-being in the region interrelate. The stakeholders were cognisant of the fact that the relationships existed and that these were not explicitly taken into account in the monitoring of well-being or in policy making.

Economic thinkers since the time of Marshall have advocated that economic science provides a tool for breaking down complex problems into simpler parts that can be analysed one at a time (Nasar, 2011). The purpose of this research was the opposite. The goal was, instead, to find a method that enabled interpretation of relationships in a system with more ease, and thereby provide an increased understanding of the interactions of a complex system.

The research process undertaken first conceptualised what is meant by 'progress' and 'well-being'. As progressing sustainable well-being was the motivation for understanding the relationships between indicators, this discussion was a necessary precursor to the work undertaken. The next step involved finding a way to interlink indicators so a comparison could be made between the current methods used to consider indicators and the new approach where relationships between indicators were more visible.

Once a method was devised which was named 'interlinked thinking' this was tested to determine if it provided added value and could support decision-making. Two case studies were undertaken with participants that confirmed interlinked thinking did add value and that the process was useful because it: (1) increased understanding of the indicators in the system; (2) made relationships more visible; (3) expanded the available toolkit to work with complexity; (4) increased ability to bring important issues to the attention of decision-makers; (5) allowed consideration of intervention impacts; and (6) encouraged integrated thinking. What was learned is there are many diverse views on well-being and interlinked thinking provides one way to bring these together.

A motivation for this research was to bridge the significant gap between the people proficient in the use of systems modelling and those with no previous experience. When operating in a connected world and meeting the needs of a diverse society, decision-makers are faced with the challenge of taking into account multiple factors that are highly interconnected. In an environment where there is more information than ever and the pace of decision-making is occurring at a much faster rate, these decision-makers need to be able to take diverse factors into consideration before moving forward.

A personal objective of the researcher was to provide a tool that had practical value and was accessible to a wide range of end-users – which, I believe, has been achieved. Our decisions are affected by biases of which we are not consciously aware, and these influence the outcomes we achieve. We need more tools to capitalise on diversity of thought, and connect this information in structured ways. The interlinked thinking method provides a new way to work with complexity that can be used by any group wanting to explore how different variables interrelate and impact on each other.

Interlinked thinking is an accessible tool to help understand well-being as a system. This is a prerequisite to making the necessary social, environmental and economic changes to progress sustainable well-being. 7

12 REFERENCES

ACNielson. (2013). Quality of Life Survey 2012 Six Councils Report. Retrieved from www.qualityoflife.govt.nz

Adamson, P. (2013). A measure of progress. *New Internationalist, 460*, 12-15.

Advisory Committee on Official Statistics. (2009). Good practice guidelines for the development and reporting of indicators. Retrieved from http://www.statisphere.govt.nz/further-resources-and-info/good-practice-guidelines.aspx

Alkire, S. (2002). Dimensions of Human Development. *World Development, 30*(2), 181-205. doi:http://dx.doi.org/10.1016/S0305-750X(01)00109-7

Allen, W. (n.d.). Complicated or complex - knowing the difference is important. Retrieved from http://learningforsustainability.net/sparksforchange/complicated-or-complex-knowing-the-difference-is-important-for-the-management-of-adaptive-systems/

Altheide, D., & Johnson, J. (2011). Reflections on interpretive adequacy in qualitative research. In N. Denzin & Y. Lincoln (Eds.), *The SAGE Handbook of Qualitative Research*. Thousand Oaks, CA, USA: SAGE.

Andrew, R., & Forgie, V. (2008). A three-perspective view of greenhouse gas emission responsibilities in New Zealand. *Ecological Economics, 68*, 194–204.

Andrew, R., & Forgie, V. (2011). *An analysis of New Zealand's Ecological Footprint as estimated by the Global Footprint Network: An update*. http://www.footprintnetwork.org/en/index.php/GFN/page/publications/

Angner, E. (2010). Subjective well-being. *The Journal of Socio-Economics, 39*(3), 361-368. doi:http://dx.doi.org/10.1016/j.socec.2009.12.001

Anielski, M., Griffiths, M., Pollock, D., Taylor, A., Wilson, J., & Wilson, S. (2001). Alberta Sustainability Trends 2000: The Genuine Progress Indicators Report 1961–1999. Retrieved from http://www.anielski.com/wp-content/uploads/2011/11/Alberta-Sustainability-2000.pdf

Anthony, J. (2015, Monday, July 27, 2015). Repetitive jobs at risk, warns futurist. *Manawatu Standard,* p. 8.

Argyle, M. (1987). *The Psychology of Happiness*. London: Routledge.

Aronson, J., Milton, S. J., & Blignaut, J. N. (2007). Restoring Natural Capital: Definitions and Rationale. In S. J. M. James Aronson, and James N. Blignaut (Ed.), *The Science and Practice of Ecological Restoration*. Washington DC: Island Press.

Arrow, K. (2000). Observations on social capital. In P. Dasgupta & I. Serageldin (Eds.), *Social capital: A multi-faceted perspective* (pp. 3-5). Washington, D.C.: World Bank.

Ashby, W. (1958). General systems theory as a new discipline. *General systems, 3*(1).

Atkinson, A. (1970). On the Measurement of Inequality. *Journal of Economic Theory, 2*, 244-263.

Atkinson, G. (2008). Sustainability, the capital approach and the built environment. *Building Research & Information, 36*(3), 241-247. doi:10.1080/09613210801900734

Barbier, E. B., & Markandya, A. (2013). *A new blueprint for a green economy*. Abingdon, Oxon; New York, NY: Routledge.

Barnett, H. J., & Morse, C. (1963). *Scarcity and Growth: The Economics of Natural Resource Availability*. Baltimore MD and London: Johns Hopkins University Press.

Bartelmus, P. (2009). Sustainable Development -Has It Run Its Course? Retrieved from http://www.researchgate.net/publication/46473343_Sustainable_Development_-_Has_It_Run_Its_Course

Bateson, G. (1972). *Steps to an ecology of mind* (2000 ed.). Chicago: University of Chicago Press.

Bauer, R. (1966). *Social Indicators*. Cambridge, Mass.: M.I.T. Press.

Beaumont, J. (2011). Measuring National Well-being: A discussion paper on domains and measures. Retrieved from http://www.ons.gov.uk/ons/dcp171766_240726.pdf

Beck, M., Schoenenberger, L., & Schenker-Wicki, A. (2012). How Managers Can Deal with Complex Issues: A Semi-Quantitative Analysis Method of Causal Loop Diagrams Based on Matrices. *UZH Business Working Paper Series.* Retrieved from http://ssrn.com/abstract=2573718 or http://dx.doi.org/10.2139/ssrn.2573718

Becker, B., Dawson, P., Devine, K., Hannum, C., Hill, S., Leydens, J., . . . Palmquist, M. (Producer). (1994-2012, 29 April, 2015). Case Studies. Writing@CSU. Retrieved from http://writing.colostate.edu/guides/guide.cfm?guideid=60.

Becker, J. (2010). Use of backcasting to integrate indicators with principles of sustainability. *International Journal of Sustainable Development and World Ecology, 17*(3), 189-197. doi:10.1080/13504501003726974

Beckerman, W. (1994). "Sustainable devlopment": is it a useful concept? *Environmental Values, 3*(3), 191-209.

Bezuidenhout, C., Bodhanya, S., Sanjika, T., Sibomana, M., & Boote, G. (2012). Network-analysis approaches to deal with causal complexity in a supply network. *International Journal of production Research, 50*(7), 1840-1849.

Bina, O. (2013). The green economy and sustainable development: an uneasy balance? *Environment and Planning C: Government and Policy, 31*, 1023-1047.

Bleys, B. (2008). Proposed changes to the Index of Sustainable Economic Welfare: An application to Belgium. *Ecological Economics, 64*(4), 741-751. doi:http://dx.doi.org/10.1016/j.ecolecon.2007.10.013

Bossel, H. (1998). *Earth at a Crossroads*. Cambridge, UK: Cambridge University Press.

Bossel, H. (1999). *Indicators for Sustainable Development: Theory, Method, Applications. A Report to the Balaton Group*. Retrieved from https://www.iisd.org/library/indicators-sustainable-development-theory-method-applications

Bossel, H. (2000). Policy assessment and simulation of actor orientation for sustainable development. *Ecological Economics, 35*(3), 337-355. doi:http://dx.doi.org/10.1016/S0921-8009(00)00218-4

Bossel, H. (2001). Assessing viability and sustainability: a systems-based approach for deriving comprehensive indicator sets *Conservation Ecology, 5(2)*(12 [online]).

Boulding, K. (1966). The Economics of the Coming Spaceship Earth. In H. Jarrett (Ed.), *Environmental Quality in a Growing Economy*. Baltimore, MD: Resources for the Future/Johns Hopkins University Press.

Boyle, D., & Simms, A. (2009). *The New Economics. A Bigger Picture*. London: Earthscan.

Briggs, X. (2008). On half blind men and elephants: Understanding greater ethnic diversity and responding to “good enough” evidence. *Housing Policy Debate, 19*(1), 218-229. doi:DOI:10.1080/10511482.2008.9521632

Brinsden, C. (2015, Wed, June 17, 2015). 5m Oz jobs may go in next 15 years: research. *The New Zealand Herald*.

Bromley, D. (1990). The Ideology of Efficiency: Searching for a Theory of Policy Analysis. *Journal of Environmental Economics and Management, 19*, 86-107.

Browning, C. R. (2009). Illuminating the Downside of Social Capital: Negotiated Coexistence, Property Crime, and Disorder in Urban Neighborhoods. *American Behavioral Scientist, 52*(11), 1556-1578.

Brue, S., & Grant, R. (2013). *The Evolution of Economic Thought* (8th Ed.). USA: South-Western, Cengage Learning.

Bryson, L., & Mowbray, M. (2005). More spray on solution: community, social capital and evidence based policy. *Australian Journal of Social Issues*(1), 91.

Buchanan, M. (2002). *Nexus. Small Worlds and the Groundbreaking Science of Networks*. New York, London: W.W. Norton & Company.

Buettner, D. (2009). The Blue Zones. Retrieved from https://www.bluezones.com/about-blue-zones/

Canterbery, E. R. (2011). *A Brief History of Economics. Artful Approaches to the Dismal Science* (2nd ed.). Singapore: World Scientific.

Capra, F. (1996). *The Web of Life: A New Synthesis of Mind and Matter*. London: HarperCollins.

Capra, F. (2005). Complexity and Life. *Theory, Culture & Society, 22*(5), 33.

Cavana, R., Delahaye, B., & Sekaran, U. (2001). *Applied Business Research: Qualitative and Quantitative Methods*. Brisbane: Wiley.

Centre for the Study of Existential Risk. (n.d.). Systemic Risks and Fragile Networks. Retrieved from http://cser.org/emerging-risks-from-technology/systemic-risks-and-fragile-networks/

Checkland, P. (1993). *Systems Thinking, Systems Practice*. Chichester, UK: John Wiley & Sons.

Churchman, C. (1974). Perspectives of the Systems Approach. *Interfaces, 4*(4), 6-11.

Churchman, C., Ackoff, R., & Arnoff, E. (1957). *Introduction to Operations Research*: John Wiley.

Chusseau, N., & Dumont, M. (2013). Growing Income Inequalities in Advanced Countries. In J. Hellier & N. Chusseau (Eds.), *Growing Income Inequalities* (pp. 13-40): Palgrave Macmillan.

Cinquin, O., & Demongeot, J. (2002). Roles of positive and negative feedback in biological systems. *Biologies, 325*, 1085-1095.

Cobb, C., Halstead, T., & Rowe, J. (1995). *The genuine progress indicator: summary of data and methodology*. San Francisco: Redefining Progress.

Cohen, A. J., & Harcourt, G. C. (2003). Whatever Happened to the Cambridge Capital Theory Controversies? *Journal of Economic Perspectives, 17*(1), 199-214.

Cole, A., & Patterson, M. (2013). *A Dynamic GPI Accounting Model for the Nelson Tasman Regions and Motueka Catchment of New Zealand*. Palmerston North: Massey University.

Coleman, R. (1998). Measuring Sustainable Development: Application Of The Genuine Progress Index To Nova Scotia. Retrieved from http://www.gpiatlantic.org/pdf/general/framework.pdf

Cook, D. (2004). *The Natural Step. Towards A Sustainable Society*. Darlington, UK: Green Books Ltd.

Costanza, R. (1999). Four visions of the century ahead: will it be Star Treck, Ecotopia, Big Government, or Mad Max? *Futurist, 33*(23-28).

Costanza, R. (2000). The dynamics of the ecological footprint concept. *Ecological Economics, 32*, 341-345.

Costanza, R., Alperovitz, G., Daly, H., Farley, J., Franco, C., Jackson, T., . . . Victor, P. (2012). Building a sustainable and desirable economy-in-society-in-nature: United Nations Division for Sustainable Development 2012-11-19T23:23:41Z 2012-11-19T23:23:41Z 2012.

Costanza, R., Cumberland, J., Daly, H., Goodland, R., & Norgaard, R. (1997). *An Introduction to Ecological Economics*. Boca Raton: St. Lucie Press.

Costanza, R., Cumberland, J., Daly, H., Goodland, R. t., Norgaard, R., Kubiszewski, I., & Franco, C. (2015). *An Introduction to Ecological Economics*. Baca Raton: CRC Press.

Costanza, R., d'Arge, R., deGroot, R., Farber, S., Grasso, M., Hannon, B., . . . van den Belt, M. (1997). The value of the world's ecosystem services and natural capital. *Nature, 387*, 253-260.

Costanza, R., & Daly, H. (1992). Natural capital and sustainable development. *Conservation Biology, 6*, 37-46.

Costanza, R., Erickson, J., Fligger, K., Adams, A., Adams, C., Altschuler, B., . . . Williams, L. (2004). Estimates of the Genuine Progress Indicator (GPI) for Vermont, Chittenden County and Burlington, from 1950 to 2000. *Ecological Economics, 51*(1–2), 139-155. doi:http://dx.doi.org/10.1016/j.ecolecon.2004.04.009

Costanza, R., & Faber, S. (2002). Introduction to the special issue on the dynamics and value of ecosystem services: integrating economic and ecological perspectives. *Ecological Economics, 41*, 367-373.

Costanza, R., Fisher, B., Ali, S., Beer, C., Bond, L., Boumans, R., . . . Snapp, R. (2007). Quality of life: An approach integrating opportunities, human needs, and subjective well-being. *Ecological Economics, 61*(2–3), 267-276. doi:http://dx.doi.org/10.1016/j.ecolecon.2006.02.023

Costanza, R., Hart, M., Talberth, J., & Posner, S. (2012). Beyond GDP: The Need for New Measures of Progress. Boston: Boston University - The Frederick S. Pardee Center for the Study of the Longer-Range Future

Costanza, R., Kubiszewski, I., Giovannini, E., Lovins, H., McGlade, J., Pickett, K. E., . . . Wilkinson, R. (2014). Time to leave GDP behind. *Nature, 505*, 283-285.

Coyle, D. (2014). *GDP : A Brief but Affectionate History*. Princeton: Princeton University Press.

Coyle, R. G. (2000). Qualitative and quantitative modelling in system dynamics research:some research questions. *System Dynamics Review, 16*(3), 225-244.

Craik, K. J. W. (1943). *The nature of explanation*. Cambridge: Cambridge University Press.

Dale, V., & Beyeler, S. (2001). Challenges in the development and use of ecological indicators. *Ecological Indicators, 1*, 3-10.

Daly, H. (1996). *Beyond Growth*. Boston: Beacon Press.

Daly, H. (2003). *Ecological Economics: The Concept of Scale and Its Relation to Allocation, Distribution, and Uneconomic Growth*. Paper presented at the CANSEE, Jasper, Alberta Canada.

Daly, H. (2005). Economics in a Full World. *Scientific American, 293*(3), 100–107.

Daly, H. (2010). How a Green Economy Grows: Remarks by Herman Daly. *National Council for Science and the Environment.* Retrieved from http://newsdesk.umd.edu/sociss/release.cfm?ArticleID=2065

Daly, H. (2013). A further critique of growth economics. *Ecological Economics, 88*, 20-24.

Daly, H., & Cobb, J. (1994). *For the Common Good: Redirecting the Economy toward Community, the Environment, and a Sustainable Future* (2nd ed.). Boston: Beacon Press.

Daly, H., & Farley, J. (2004). *Ecological economics. Principles and applications*. Washington, Covelo, London: Island Press.

Daly, L., & Posner, S. (2011). Beyond GDP. New measures for a new economy. Retrieved from http://www.demos.org/publication/beyond-gdp-new-measures-new-economy

Dalziel, P., & Saunders, C. (2014). *Wellbeing Economics. Future Directions for New Zealand*. Wellington: BWB Texts.

Dasgupta, P. (1995). *An inquiry into well-being and destitution*. Oxford, UK: Oxford University Press.

Dasgupta, P. (2001). *Human Well-being and the Natural Environment*. Oxford: Oxford University Press.

de Nooy, W., Mrvar, A., & Batagelj, V. (2011). *Exploratory Social Network Analysis with Pajek* (2nd Ed.). New York: Cambridge University Press.

Deming, W. E. (1997). *The New Economics. For industry, government, education* (4th ed.). Cambridge, MA: Massachusetts Institute of Technology.

Department of Labour. (2007). Annual in-depth regional report. Wellington region. Retrieved from http://dol.govt.nz/PDFs/aidr-wellington.pdf

Deutsch, L., Folke, C., & Skånberg, K. (2003). The critical natural capital of ecosystem performance as insurance for human well-being. *Ecological Economics, 44*(2–3), 205-217. doi:http://dx.doi.org/10.1016/S0921-8009(02)00274-4

Dhawan, R., O'Connor, M., & Borman, M. (2011). The effect of qualitative and quantitative systems dynamics training: an experimental investigation. *System Dynamics Review, 27*(3), 313-327.

Diamond, J. (2005). *Collapse. How societies choose to fail or succeed*. New York: Viking.

Diener, E. (1984). Subjective Well-being. *Psychological Bulletin, 95*, 542-575.

Diener, E. (1994). Assessing subjective well-being. Progress and opportunities. *Social Indicators Research, 31*, 103-157.

Diener, E. (1995). A value based index for measuring national quality of life. *Social Indicators Research, 36*(2), 107-127. doi:10.1007/BF01079721

Diener, E., Diener, M., & Diener, C. (1995). Factors predicting the subjective well-being of nations. *J. Pers. Soc. Psychol, 69*(5), 851-864.

Dietz, S., & Neumayer, E. (2006). Some constructive criticisms of the Index of Sustainable Economic Welfare. In P. A. Lawn (Ed.), *Sustainable development indicators and public policy: assessing the policy-guiding value of sustainable development indicators* (pp. 186–206). Northampton, USA: Edward Elgar Publishing.

Donahue, M., & Benson, P. (1995). Religion and the well-being of adolescents. *Journal of Social Issues, 51*(2), 145-160.

Dörner, D. (1997). *The Logic of Failure: Recognizing and Avoiding Error in Complex Situations*. New York: Basic Books.

Doyle, J. K., & Ford, D. N. (1998). Mental models concepts for system dynamics research. *System Dynamics Review (Wiley), 14*(1), 3-29.

Doyle, J. K., & Ford, D. N. (1999). Mental models concepts revisited: some clarifications and a reply to Lane. *System Dynamics Review (Wiley), 15*(4), 411-415.

Druskat, V. U., & Pescosolido, A. T. (2002). The Content of Effective Teamwork Mental Models in Self-Managing Teams: Ownership, Learning and Heedful Interrelating. *Human Relations, 55*(3), 283-314.

Dryzek, J. S. (2005). *The Politics of the Earth: Environmental Discourses* (2nd Ed.). Oxford: Oxford University Press.

Duncan, O. (1974). Developing Social Indicators. *Proc. Nat. Acad. Sci., 71*(12), 5096-5102.

Durand, M. (2012). 4th OECD World Forum Provisional Key Messages and Future Directions. Retrieved from http://www.oecd.org/site/worldforumindia/Martine%20Durand%20Concluding%20presentation.pdf

Durling, N. (2011). The Approach to the Wellington Region Genuine Progress Index (WR-GPI) 2001-2010 Retrieved from http://www.gpiwellingtonregion.govt.nz/publications/

Easterlin, R. (1974). Does Economic Growth Improve the Human Lot? In P. A. David & M. W. Reder (Eds.), *Nations and Households in Economic Growth: Essays in Honor of Moses Abramovitz*. New York: Academic Press.

Easterlin, R. (2001). Income and Happiness: Towards a Unified Theory. *Economic Journal, 111*(July), 465-484.

Easterlin, R. (2003). Explaining happiness. *Proceedings of the National Academy of Sciences, 100*(19), 11176–11183.

Easterlin, R., & Angelescu, L. (2009). Happiness and growth the world over: Time series evidence on the happiness-income paradox. Retrieved from http://ftp.iza.org/dp4060.pdf

Eden, C. (1995). On evaluating the performance of 'wide-band' GDSS. *European Journal of Operational Research, 81*, 302-311.

Eden, C., & Ackermann, F. (2006). Where next for problem structuring methods. *Journal of the Operational Research Society, 57*, 766-768.

Ehrlich, P. (1968). *Population Bomb*. New York: Ballantine.

Eid, M., & Diener, E. (2003). Global Judgements of Subjective Well-being: Situational Variability and Long-term Stability. *Social Indicators Research, 65*, 245-277.

Ekins, P. (1992). The four capital model for wealth creation. In P. Ekins & M. Max-Neef (Eds.), *Real life economics. Understanding wealth creation* (pp. 414-455). London: Rutledge.

Ekins, P., Simon, S., Deutsch, L., Folke, C., & De Groot, R. (2003). A framework for the practical application of the concepts of critical natural capital and strong sustainability. *Ecological Economics, 44*(2–3), 165-185. doi:http://dx.doi.org/10.1016/S0921-8009(02)00272-0

Engelbrecht, H.-J. (2009). Natural capital, subjective well-being, and the new welfare economics of sustainability: Some evidence from cross-country regressions.

Ecological Economics, 69(2), 380-388. doi:http://dx.doi.org/10.1016/j.ecolecon.2009.08.011

European Commission. (2009). Beyond GDP Initiative. Retrieved from http://ec.europa.eu/environment/index_en.htm

Ferrer-i-Carbonella, A., & Gowdy, J. M. (2007). Environmental degradation and happiness. *Ecological Economics, 60*, 509-516.

Flannery, T. (2005). *The Weather Makers: How Man Is Changing the Climate and What It Means for Life on Earth*. New York: Grove Press.

Flenley, J., & Bahn, P. G. (2003). *The enigmas of Easter Island : island on the edge*: Oxford : Oxford University Press.

Florida, R. L. (2008). *Who's your city? How the creative economy is making where to live the most important decision of your life*. New York: Basic Books.

Folke, C., Hahn, T., Olsson, P., & Norberg, J. (2005). Adaptive Governance of Social-Ecological Systems. *Annual Review of Environment & Resources, 30*(1), 441-473. doi:10.1146/annurev.energy.30.050504.144511

Ford, A. (2010). *Modeling the Environment*. Washington, DC: Island Press.

Forgie, V. (2007). The need for convention in environmental valuation. *The International Journal of Environment, Workplace and Employment, 3*(2), 72-90.

Forgie, V., Cheyne, C., & McDermott, P. (1999) Democracy in New Zealand Local Government: Purpose and Practice. *Occasional Paper 2*. Palmerston North: Massey University.

Forgie, V., & McDonald, G. (2013). Towards a genuine progress indicator for New Zealand. In J. Dymond (Ed.), *Ecosystem services in New Zealand - conditions and trends* (pp. 474-495). Lincoln, New Zealand: Manaaki Press.

Forrester, J. (1961). *Industrial Dynamics*. Cambridge, Mass.: M.I.T. Press.

Forrester, J. (1971). Counterintuitive behaviour of social systems. *Technology Review, 73*(3), 52-68.

Forrester, J. (1973). *World Dynamics* (2nd ed.). Cambridge, Massachusetts: Wright-Allen Press, Inc.

Forrester, J. (1975). *Collected Papers of Jay W. Forrester*. Waltham, MA: Pegasus Communications.

Forrester, J. (1985). "The model" versus a modeling "process". *System Dynamics Review, 1*(1), 133-134.

Forrester, J. (1994). System dynamics, systems thinking, and soft OR. *System Dynamics Review (Wiley), 10*(2/3), 245-256.

Frashure, K. M., Bowen, R. E., & Chen, R. F. (2012). An integrative management protocol for connecting human priorities with ecosystem health in the Neponset River Estuary. *Ocean and Coastal Management, 69*, 255-264. doi:10.1016/j.ocecoaman.2012.08.014

Frey, B., & Stutzer, A. (2002a). The Economics of Happiness. *World Economics, 3*(1).

Frey, B., & Stutzer, A. (2002b). What can Economists Learn from Happiness Research. *Journal of Economic Literature, 40*(2), 402-435.

Fricker, A. (1998). Measuring up to Sustainability. *Futures, 30*.

Friedman, T. (2007). *The world is flat: a brief history of the twenty-first century* (2nd ed.). New York: Farrar, Straus and Giroux.

Frisch, M., Clark, M., Rouse, S., Rudd, M., Paweleck, J., Greenstone, A., & Kopplin, D. (2005). Predictive and treatment validity of life satisfaction and the quality of life inventory. *Assessment, 12*(1), 66-78.

Funtowicz, S., & Ravetz, G. (1993). Science for the post-normal age. *Futures, 25*, 739-755.

Galbraith, J. K. (1987). *A History of Economics. The Past as the Present*. London, U.K.: Hamish Hamilton Ltd.

Galbraith, J. K. (1999). *The affluent society* (3rd ed.). London: Penguin Economics.

Gasper, D. (2007). Human Well-being: Concepts and Conceptualizations. In M. McGillivray (Ed.), *Human well-being. Concept and Measurement* (pp. 23-64). Basingstoke, Hampshire: Palgrave Macmillan.

Georgescu-Roegen, N. (1971). *The Entropy Law and the Economic Process* Cambridge: Harvard University Press.

Gerring, J. (2007). *Case study research. [electronic resource] : principles and practices*: New York : Cambridge University Press, 2007.

Giddens, A. (1984). *The Constitution of Society. Outline of the Theory of Structuration*. Cambridge, UK: Polity Press.

Giddens, A. (1991). *Modernity and Self-Identity: Self and society in the late modern age*. Cambridge, UK: Polity Press.

Gijsberts, M. (2002). The Legitimation of Income Inequality in State-socialist and Market Societies. *ACTA SOCIOLOGICA, 45*.

Ginsberg, M. (1973). Progress in the Modern Era. In P. P. Wiener (Ed.), *Dictionary of the History of Ideas: Studies of Selected Pivotal Ideas* (Vol. 3, pp. 633-650). New York: Charles Scribner's Sons.

Gleeson-White, J. (2014). *Six Capitals. The revolution capitalism has to have - or can accountants save the planet?* Sydney: Allen & Unwin.

Gravitas Research and Strategy Limited. (2005). *Quality of life in New Zealand's largest cities: Residents' survey*. Retrieved from http://www.bigcities.govt.nz/pdf2004/Quality_of_Life_2004_full_report.pdf

Gray, W., & Rizzo, N. (1969). History and Development of General Systems Theory. In W. Gray, F. Duhl, & N. Rizzo (Eds.), *Theory and Psychiatry* (pp. 7-32). Boston: Little, Brown and Company.

Griffin, J., Crisp, R., & Hooker, B. (2000). *Well-being and Morality: Essays in Honour of James Griffin*. Oxford, UK: Oxford University Press.

Grisez, G., Boyle, J., & Finnis, J. (1987). Practical principles, moral truth and ultimate ends. *American Journal of Jurisprudence, 32*, 99-151.

Groesser, S. N., & Schaffernicht, M. (2012). Mental models of dynamic systems: Taking stock and looking ahead. *System Dynamics Review, 28*(1), 46-68. doi:10.1002/sdr.476

Grosskurth, J. (2007). Ambition and reality in modeling: a case study on public planning for regional sustainability. *Sustainability: Science, Practice, & Policy, 3*(1).

Haas, B. (1999). A multidisciplinary concept analysis of quality of life. *Western Journal of Nursing Research, 21*, 728-742.

Haken, H. (2004). *Synergetics: Introduction and Advanced Topics*. Berlin, Heidelberg: Springer - Verlag.

Hall, J., Giovannini, E., Morrone, A., & Ranuzzi, G. (2010). *A Framework to Measure the Progress of Societies*. Retrieved from OECD Publishing: http://dx.doi.org/10.1787/5km4k7mnrkzw-en

Hamilton, C. (1999). The Genuine Progress Indicator methodological developments and results from Australia. *Ecological Economics, 30*, 13–28.

Hammond, A., Adriaanse, A., Rodenburg, E., Bryant, D., & Woodward, R. (1995). *Environmental Indicators: A systematic Approach to Measuring and Reporting on Environmental Policy Performance in the Context of Sustainable Development*. Retrieved from http://pdf.wri.org/environmentalindicators_bw.pdf

Hanneman, R. (1988). *Computer-assisted theory building*. Thousand Oakes, CA: Sage Publications.

Harkness, S. (2007). Social and Political Indicators of Human Well-being. In M. McGillivray (Ed.), *Human well-being. Concept and Measurement* (pp. 88-112). Basingstoke, Hampshire: Palgrave Macmillan.

Harman, J. (2013). *The Shark's Paintbrush*. London, UK; Boston, USA: Nicholas Brealey Publishing.

Harshaw, H. W., Sheppard, S. R. J., & Lewis, J. L. (2007). A review and synthesis of social indicators for sustainable forest management. *BC Journal of Ecosystems and Management, 8*(2), 17-36.

Hartwick, J. M. (1977). Intergenerational Equity and the Investing of Rents from Exhaustible Resources. *American Economic Review, 67*(5), 972-974.

Hatfield-Dodds, S. (2005). *Decision support for highly contested choices: The role of monetised values and other metrics in the pursuit of sustainability*. Paper presented at the Australia New Zealand Society for Ecological Economics, Palmerston North, New Zealand.

Headey, B., Muffels, R., & Wagner, G. (2010). Long-running German panel survey shows that personal and economic choices, not just genes, matter for happiness. *PNAS, 107*(42), 17922-17926.

Hector, D., Christensen, C., & Petrie, J. (2014). Sustainability and Sustainable Development: Philosophical Distinctions and Practical Implications. *Environmental Values, 23*, 7-28.

Hellier, J., & Lambrecht, S. (2013). Inequality, Growth and Welfare: The Main Links. In J. Hellier & N. Chusseau (Eds.), *Growing Income Inequalities* (pp. 274-305): Palgrave Macmillan.

Helliwell, J. (2003). How's life? Combining individual and national variations to explain subjective well-being. *Economic Modelling, 20*, 331-360. doi:http://dx.doi.org/10.1016/S0264-9993(02)00057-3

Helliwell, J., Layard, R., & Sachs, J. (Eds.). (2012). *World Happiness Report*. New York: Earth Institute.

Henderson, H. (1994). Paths to sustainable development: The role of social indicators. *Futures, 26*(2), 125-137. doi:10.1016/0016-3287(94)90102-3

Hicks, J. (1939). The Foundations of Welfare Economics. *The Economic Journal, 49*, 696-712.

Hicks, J. (1946). *Value and Capital* (2nd ed.). Oxford: Oxford University Press.

Hjorth, P., & Bagheri, A. (2006). Navigating towards sustainable development: A system dynamics approach. *Futures, 38*(1), 74-92. doi:http://dx.doi.org/10.1016/j.futures.2005.04.005

Hodgkinson, G. P., & Healey, M. P. (2008). Cognition in organizations. *Annual Review of Psychology, 59*, 387-417. doi:10.1146/annurev.psych.59.103006.093612

Holling, C. S. (2000). Theories for sustainable futures. *Conservation Ecology, 4*(2), 7 [online].

Holling, C. S., & Gunderson, L. (2002). Resilience and Adaptive Cycles. In L. H. Gunderson & C. S. Holling (Eds.), *Panarchy: Understanding Transformations in Human and Natural Systems*. Washington, D.C.: Island Press,.

Holling, C. S., Gunderson, L., & Ludwig, D. (2002). In Quest of a Theory of Adaptive Change. In L. H. Gunderson & C. S. Holling (Eds.), *Panarchy: Understanding Transformations in Human and Natural Systems*. Washington, D.C.: Island Press,.

Homer, J., & Oliva, R. (2001). Maps and models in system dynamics: a response to Coyle. *System Dynamics Review (Wiley), 17*(4), 347-355. doi:10.1002/sdr.224

Hovmand, P. S. (2014). *Community Based System Dynamics*. New York: Springer Science+Business Media.

Hubbert, M. K. (1962). Energy Resources. *National Academy of Sciences, 1000-D*, 73-75.

Hunt, E. K., & Lautzenheiser, M. (2011). *History of Economic Thought. A Critical Perspective* (3rd ed.). Armonk, New York: London, England: M.E. Sharpe.

Hunt, L., MacLeod, C., Moller, H., Reid, J., & Rosin, C. (2014). *Framework and KPIs for 'The New Zealand Sustainability Dashboard': reflecting New Zealand's economic, social, environmental and management values*. Retrieved from www.nzdashboard.org.nz

Hürlimann, M. (2009). *Dealing with Real-World Complexity. Limits, Enhancements and New Approaches for Policy Makers*. Wiesbaden: Gabler.

Hutchins, C. (1996). *Systemic Thinking: Solving Complex Problems*: CO:PDS. 1-888017-51-1.

Hyunjung, K. (2009). In search of a mental model-like concept for group-level modeling. *System Dynamics Review, 25*(3), 207-223. doi:10.1002/sdr.422

Inglehart, R., Foa, R., Peterson, C., & Welzel, C. (2008). Development, Freedom, and Rising Happiness: A Global Perspective (1981-2007). (4), 264-285.

International Integrated Reporting Council. (2013). *The International <IR> Framework*. Retrieved from www.theiirc.org: www.theiirc.org

IPCC. (2013). *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* Retrieved from http://www.ipcc.ch/report/ar5/wg1/

Jackson, T. (2009). *Prosperity without growth*. London: Earthscan.

Jacobs, J. (2002). *The death and life of great American cities*: New York : Random House, 2002 ed.

Jevons, W. S. (1909). *The Coal Question: An Inquiry Concerning the Progress of the Nation and the Probable Exhaustion of Our Coal-Mines*. London: MacMillan.

Johnson-Laird, P. N. (1983). *Mental models: towards a cognitive science of language, inference and consciousness*. Cambridge: Cambridge University Press.

Johnson-Laird, P. N. (2001). Mental models and deduction. *Trends in Cognitive Sciences, 5*(10), 434-442. doi:10.1016/S1364-6613(00)01751-4

Joint UNECE/OECD/Eurostat Working Group on Statistics for Sustainable Development. (2008). *Measuring Sustainable Development*. Retrieved from http://www.oecd.org/greengrowth/41414440.pdf

Jollands, N. (2003). *An ecological economics of eco-efficiency - theory, interpreations and applications.* (PhD), Massey University, Palmerston North, New Zealand.

Jones, C. I. (2002). Sources of U.S. Economic Growth in a World of Ideas. *The American Economic Review, 92*(1).

Jones, C. I. (2015). The Facts of Economic Growth. Retrieved from http://www.hoover.org/sites/default/files/jones-facts040.pdf

Kagen, S. (1994). Me and My Life. Summary. In F. Ackerman, D. Kiron, N. Goodwin, J. Harris, & K. Gallagher (Eds.), *Human Well-being and Economic Goals* (pp. 194-196). Washington, D.C.: Island Press.

Kahneman, D. (2011). *Thinking, fast and slow*. London, UK: Allen Lane.

Kahneman, D., Krueger, A. B., Schkade, D., Schwarz, N., & Stone, A. (2004). Toward national well-being accounts. *The American Economic Review, 94*(2), 429–434.

Kahneman, D., & Sugden, R. (2005). Experienced utility as a standard of policy evaluation. *Environmental and Resource Economics, 32*, 161-181.

Kaldaru, H., & Parts, E. (2008). Social and institutional factors of economic development: evidence from Europe. *Baltic Journal of Economics, 8*(1), 29-51.

Kao, Y.-F., & Velupillai, K. V. (2015). Behavioural Economics: Classical and Modern. *European Journal of the History of Economic Thought, 22*(2), 236-271. doi:http://www.tandfonline.com/loi/rejh20

Karakul, M., & Qudrat-Ullah, H. (2008). How to Improve Dynamic Decision Making? Practice and Promise. In H. Qudrat-Ullah, M. Spector, & P. Davidsen (Eds.), *Complex Decision Making: Theory and Practice* (pp. 3-24). New York: Springer-Verlag.

Kates, R., Parris, T., & Leiserowitz, A. (2005). What is sustainable development? Goals, Indicators, Values, and Practice. *Environment: Science and Policy for Sustainable Development, 47*(3), 8-21. doi:10.1080/00139157.2005.10524444

Keeley, B. (2009). *Human Capital: How what you know shapes your life*. Paris: Organisation for Economic Co-operation and Development.

Kennedy, R. (1968). Address to the University of Kansas. Lawrence, Kansas, USA.

Kettle, D. (2006). *An Urban 3-Waters Infrastructure Sustainability Decision-making Process.* (Doctor of Philosophy in Architecture and Planning), The University of Auckland, Auckland.

Keynes, J. M. (1930). Economic Possibilities for our Grandchildren. *Essays in Persuasion* (1963 ed., pp. 358-373). New York: W.W.Norton & Co.

Kim, D. H. (1999). *Introduction to Systems Thinking* (Vol. IMS0013E): Pegasus Communications, Inc.

Klaassen, H., Ooms, G., & Paelinck, J. (1978). *A Study of the Formal Structure of J.W. Forrester's World Dynamics Model*. Rotterdam: Erasmus University, Faculty of Economics, Department of Spatial Economics.

Klein, G., Snowden, D., & Lock Pin, C. (2011). Anticipatory Thinking. Retrieved from http://media.wix.com/ugd/2360d8_36f32b754041434391cba7122af5cd2a.pdf

Kroll, C. (2008). *Social Capital and the Happiness of Nations*. Frankfurt am Main: P. Lang.

Kubiszewski, I., Costanza, R., Franco, C., Lawn, P., Talberth, J., Jackson, T., & Aylmer, C. (2013). Beyond GDP: Measuring and achieving global genuine progress. *Ecological Economics, 93*, 57-68.

Kulig, A., Kolfoort, H., & Hoekstra, R. (2010). The case for the hybrid capital approach for the measurement of the welfare and sustainability. *Ecological Indicators, 10*(2), 118-128. doi:http://dx.doi.org/10.1016/j.ecolind.2009.07.014

Kumar, R. (2014). *Research methodology : a step-by-step guide for beginners*: Fourth edition.

Kunstler, J. (2005). *The Long Emergency*. New York: Grove Press.

Kuznets, S. (1962). How to judge quality. *The New Republic*, 29–32.

Lancker, E., & Nijkamp, P. (1999). *A policy scenario analysis of sustainable agricultural development options. A case study for Nepal*. Retrieved from Amsterdam: http://dare.ubvu.vu.nl/bitstream/handle/1871/3382/11683.pdf?sequence=1

Lane, D. C. (2008). The Emergence and use of diagramming in system dynamics: a critical account. *Research and Behavioral Science Systems, 25*, 3-23.

Lawn, P. (2003). A theoretical foundation to support the Index of Sustainable Economic Welfare (ISEW), Genuine Progress Indicator (GPI), and other related indexes. *Ecological Economics, 44*(1), 105-118.

Lawn, P. (2005). An Assessment of the Valuation Methods Used to Calculate the Index of Sustainable Economic Welfare (ISEW), Genuine Progress Indicator (GPI), and Sustainable Net Benefit Index (SNBI). *Environment, Development and Sustainability, 7*, 185-208.

Lawn, P. (2006). Sustainable development: concept and indicators. In P. Lawn (Ed.), *Sustainable Development Indicators in Ecological Economics*. Cheltenham, UK: Edward Elgar.

Lawn, P. (2007). A Stock-Take of Green National Accounting Initiatives. *Social Indicators Research, 80*(2), 427-460. doi:10.1007/s11205-006-0003-1

Lawn, P., & Clarke, M. (2006). *Measuring genuine progress: an application of the genuine progress indicator*. New York: Nova Scince Publishers.

Lawn, P., & Clarke, M. (2008). In defence of the Genuine Progress Indicator. In P. Lawn & M. Clarke (Eds.), *Sustainable Welfare in the Asia-Pacific*. Cheltenham, UK; Northamption, MA, USA: Edward Elgar.

Lee, D. R. (1992). The Perpetual Assault on Progress. *Society, 29*(3), 50.

Leipert, C. (1989). National Income and Economic Growth: The Conceptual Side of Defensive Expenditures *Journal of Economic Issues, 23*(3), 843-856.

Lounsbury, D. W., Hirsch, G. B., Vega, C., & Schwartz, C. E. (2014). Understanding social forces involved in diabetes outcomes: a systems science approach to quality-of-life research. *Qual Life Res, 23*, 959-969. doi:DOI 10.1007/s11136-013-0532-4

Lovejoy, A. O., & Boas, G. (1935). *Primitivism and Related Ideas in Antiquity*. Baltimore: The Johns Hopkins Press.

Maani, K., & Cavana, R. (2007). *Systems Thinking, Systems Dynamics. Managing Change and Complexity* (2nd Ed.). New Zealand: Pearson Education.

Maani, K., & Cavana, R. (2009). *Introduction to Systems Thinking*. New Zealand: Pearson Education.

Malthus, T. R. (1826). An Essay on the Principle of Population. Retrieved from http://www.econlib.org/library/Malthus/malPlong40.html

Manderson, A. (2006). A systems based framework to examine the multi-contextual application of the sustainability concept. *Environment, Development and Sustainability, 8*, 85-97. doi:DOI 10.1007/s10668-005-2787-6

Maslow, A. (1943). A Theory of Human Motivation. *Psychological Review, 50*(370-396).

Maslow, A. (1968). *Towards a psychology of being* (2nd Ed.). New York: Van Nostrand.

Mathieu, J. E., Heffner, T. S., Goodwin, G. F., Salas, E., & Cannon-Bowers, J. A. (2000). The influence of shared mental models on team process and performance. *Journal of Applied Psychology, 85*, 273-283.

Max-Neef, M. (1995). Economic Growth and Quality of Life: A Threshold Hypothesis. *Ecological Economics, 15*(2), 115-118. doi:http://www.sciencedirect.com/science/journal/09218009

Max-Neef, M., Elizalde, A., & Hopenhayn, M. (1991). *Human Scale Development. Conception, application and further reflection*. New York: The Apex Press.

Maxwell, J. (2005). *Qualitiative research design: An interactive approach*. Thousand Oaks, California: Sage Publications, Inc.

McDonald, G. (2006). *Integrating Economics and Ecology: A Systems Approach to Sustainability in the Auckland Region.* (PhD), Massey University, Palmerston North, New Zealand.

McGillivray, M. (2007). Human Well-being: Issues, Concepts and Measures. In M. McGillivray (Ed.), *Human well-being: Concept and Measurement* (pp. 1-22). Houndmills, Basingstoke, Hampshire; New York Palgrave Macmillan in association with the United Nations University-World Institute for Development Economics Research.

McGillivray, M., & Noorbakhsh, F. (2007). Composite Indexes of Human Well-being: Past, Present and Future. In M. McGillivray (Ed.), *Human well-being : concept and measurement*: Houndmills, Basingstoke, Hampshire ; New York : Palgrave Macmillan in association with the United Nations University-World Institute for Development Economics Research.

McGuire, S., Posner, S., & Haake, H. (2012). Measuring Prosperity: Maryland's Genuine Progress Indicator. *Solutions, 3*(2), 50-58.

McKenzie, B. (2008). Reconsidering the Effects of Bonding Social Capital: A Closer Look at Black Civil Society Institutions in America. *Polit Behav, 30*, 25-45. doi:DOI 10.1007/s11109-007-9038-5

McLanahan, S., & Adams, J. (1987). Parenthood and psychololological well-being. *Annual review of sociology, 13*, 237-257.

Meadows, D. (1982). Whole earth models and systems. *CoEvolutionary Quarterly, Summer*, 98-108.

Meadows, D. (1989). System dynamics meets the press. *System Dynamics Review, 5*(1), 68-80.

Meadows, D. (2008). *Thinking in systems: a primer*. White River Junction: Chelsea Green Publishing Company.

Meadows, D. (2009). Leverage Points. Places to Intervene in a System. *Solutions, 1*(1), 41-49.

Meadows, D., Meadows, D. L., Randers, J., & Behrens, W. (1972). *The Limits to Growth*. London: Earth Island.

Meadows, D., & Robinson, J. (1985). *The electronic oracle: computer models and social decisions*. Wiley: Chichester; New York.

Meijboom, F., Visak, T., & Brom, F. (2006). From Trust To Trustworthiness: Why Information Is Not Enough In The Food Sector. *Journal of Agricultural and Environmental Ethics, 19*, 427-442.

Michalos, A. C., Smale, B., Labonté, R., Muharjarine, N., Scott, K., Moore, K., . . . Hyman, I. (2011). *The Canadian Index of Wellbeing. Technical Report 1.0*. Waterloo, ON: Canadian Index of Wellbeing and University of Waterloo.

Midgley, G., Cavana, R. Y., Brocklesby, J., Foote, J. L., Wood, D. R. R., & Ahuriri-Driscoll, A. (2013). Decision Support: Towards a new framework for evaluating systemic problem structuring methods. *European Journal of Operational Research, 229*, 143-154. doi:10.1016/j.ejor.2013.01.047

Millennium Ecosystem Assessment. (2003). *Ecosystems and Human Well-being: A framework for assessment*. Washington D.C.: Island Press.

Millennium Ecosystem Assessment. (2005). *Ecosystems and Human Wellbeing: Synthesis*. Washington, DC: Island Presss.

Mills, J. S. (1848/1909). *On Liberty*. London: Longmans, Green and Co.

Mills, J. S. (1866). *Auguste Comte and Positivism*. London: N. Trübner & Co.

Ministry of Social Development. (2010). *The Social Report*. Retrieved from http://socialreport.msd.govt.nz/

Mirchi, A., Madani, K., Watkins, D., & Ahmad, S. (2012). Synthesis of System Dynamics Tools for Holistic Conceptualization of Water Resources Problems. *Water Resource Management, 26*, 2421-2442. doi:DOI 10.1007/s11269-012-0024-2

Miser, H., & Quade, E. (1985). *Handbook of Systems Analysis*. New York, Amsterdam, Oxford: North-Holland.

Missimer, M. (2013). *The Social Dimension of Strategic Sustainable Development.* (licentiate dissertation series No 2013:03), School of Engineering, Blekinge Institute of Technology, Karlskrona, Sweden.

Monbiot, G. (2014, 24 July). Put a price on nature? We must stop this neoliberal road to ruin. *The Guardian*. Retrieved from http://www.theguardian.com/environment/georgemonbiot/2014/jul/24/price-nature-neoliberal-capital-road-ruin

Morecroft, J. (2007). *Strategic Modelling and Business Dynamics*. Chichester: John Wiley & Sons, Ltd.

Morris, M. (1979). *Measuring the Conditions of the World's Poor: The Physical Quality of Life Index*. New York: Pergamon.

Moxnes, E. (2000). Not only the tragedy of the commons: misperceptions of feedback and policies for sustainable development. *System Dynamics Review, 16*, 325-348.

Moxnes, E. (2004). Misperceptions of basic dynamics: the case of renewable resource management. *System Dynamics Review (Wiley), 20*(2), 139-162.

Moyer, K. (1996). Scenario Planning at British Airways - A case study. *Long Range Planning, 20*(2), 180-181.

Muhajarine, N., Labonte, R., & Winquist, B. D. (2012). The Canadian Index of Wellbeing: Key Findings From the Healthy Populations Domain. *Canadian Journal of Public Health-Revue Canadienne De Sante Publique, 103*(5), E342-E347.

Munasinghe, M., & McNeely, J. (1995). Key concepts and terminology of sustainable development. In M. Munasinghe & W. Shearer (Eds.), *Defining and Measuring Sustainability* (pp. 19-56). Washington, D.C.: The Biogeophysical Foundations.

Myrdal, G. (1969). *Objectivity in Social Research*. New York: Pantheon.

Nasar, S. (2011). *Grand Pursuit: The Story of Economic Genius*. New York: Simon and Schuster.

National Sustainability Council. (2013). *Sustainable Australia Report 2013, Conversations with the future*. Retrieved from https://www.environment.gov.au/sustainability/publications/sustainable-australia-report-2013-conversations-future

Neumayer, E. (2000). On the Methodology of ISEW, GPI and Related Measures: Some Constructive Suggestions and Some Doubt on the 'Threshold' Hypothesis. *Ecological Economics, 34*(3), 347-361. doi:http://www.sciencedirect.com/science/journal/09218009

Neumayer, E. (2003). *Weak versus Strong Sustainability* (2nd ed.). Cheltenham: Edward Elgar.

Neumayer, E. (2004). *Sustainability and well-being indicators*. Retrieved from http://www.lse.ac.uk/geographyAndEnvironment/whosWho/profiles/neumayer/pdf/Sustainabilitywellbeingarticle.pdf

Neumayer, E. (2007). Sustainability and Well-being Indicators. In M. McGillivray (Ed.), *Human well-being: concept and measurement*. Houndmills, Basingstoke, Hampshire; New York: Palgrave Macmillan in association with the United Nations University-World Institute for Development Economics Research.

Newman, M. (2003). The structure and function of complex networks. *SIAM Reviews, 45*(2), 167-256.

Niemeijer, D., & de Groot, R. (2008). A conceptual framework for selecting environmental indicator sets. *Ecological Indicators, 8*, 14-25.

Niemi, G., & McDonald, M. (2004). Application of ecological indicators. *Annual Review of Ecology, Evolution and Systematics, 35*, 89-111.

Noll, H. H. (2002). Towards of European system of social indicators: Theoretical framework and system architecture. *Social Indicators Research, 58*(1-3), 47-87. doi:10.1023/A:1015775631413

Norgaard, R. (1989). The case for methodological pluralism. *Ecological Economics, 1*, 37-57.

Norman, D. A. (1983). Some Observations on Mental Models. In D. Gentner & A. L. Stevens (Eds.), *Mental Models* (pp. 7-14). Hillsdale: Laurence Erlbaum Associates.

Northrop, R. (2011). *Introduction to Complexity and Complex Systems*. Boca Raton, FL: CRC Press.

Northrop, R., & Connor, A. (2013). *Ecological sustainability: understanding complex issues*. Boca Raton, FL, USA: CRC Press, Taylor & Francis Group.

Norton, B. (2007). Ethics and sustainable development: an adaptive approach to environmental choice. In G. Atkinson, S. Dietz, & E. Neumayer (Eds.), *Handbook of Sustainable Development*. Cheltenham: Edward Elgar.

Nussbaum, M., & Glover, J. (1995). *Women, Culture and Development: A study of Human Capabilities*. Oxford: Oxford University Press.

Ny, H., MacDonald, J. P., Broman, G., Yamamoto, R., & Robért, K.-H. (2006). Sustainability Constraints as System Boundaries: An Approach to Making Life-Cycle Management Strategic. *Journal of Industrial Ecology, 10*(1/2), 61-77. doi:10.1162/108819806775545349

O'Dwyer, L. M., & Bernauer, J. A. (2014). *Quantitative research for the qualitative researcher*: Thousand Oaks, California : SAGE, [2014].

OECD. (1973). List of Social Concerns Common to Most OECD Countries. The OECD Social Indicator Development Programme. Retrieved from http://eric.ed.gov/?id=ED081702

OECD. (2001). *The well-being of nations: The role of human and social capital*. Retrieved from http://www.oecd.org/site/worldforum/33703702.pdf

OECD. (2005). *Education at a Glance*. Paris: OECD.

OECD. (2008). Handbook on Constructing Composite Indicators: Methodology and User Guide. Retrieved from http://www.oecd.org/std/42495745.pdf

OECD. (2013a). *How's Life? 2013: Measuring Well-being*. Retrieved from http://www.oecd-ilibrary.org/economics/how-s-life-2013_9789264201392-en

OECD. (2013b). OECD Better Life Index 2013. Retrieved from http://www.oecdbetterlifeindex.org/

OECD. (2014). *Society at a Glance 2014: OECD Social Indicators*. Retrieved from http://dx.doi.org/10.1787/soc_glance-2014-en

OECD. (2015). In It Together. Why Less Inequality Benefits All. Retrieved from http://dx.doi.org/10.1787/9789264235120-en

Office for National Statistics. (2014). *Measuring National Well-being*. Retrieved from http://www.ons.gov.uk/ons/guide-method/user-guidance/well-being/index.html

Olaya, C. (2012). *Models that Include Cows: The Significance of Operational Thinking*. Paper presented at the 30th International Conference of the System Dynamics Society, St Galliens.

Oliva, R. (2004). Model structure analysis through graph theory: partition heuristics and feedback structure decomposition. *System Dynamics Review, 20*(4), 313-336.

Ostrom, E. (1992). *Crafting institutions for self-governing irrigation systems*. San Francisco: ICS Press.

Ostrom, E., & Walker, J. (2003). *Trust and reciprocity: interdisciplinary lessons from experimental research*. New York: Russell Sage.

Ostrum, E., & Ahn, T. (2009). The meaning of social capital and its link to collective action. In G. Svendsen & G. Svendsen (Eds.), *Handbook of social capital* (pp. 17-35). Cheltenham: Edward Elgar.

Packard, A. (2009). *Rethinking 'Progress'; An Evaluation Of The Wellington Region Genuine Progress Index.* (Master of Environmental Studies), Victoria University of Wellington, Wellington.

Pangaro, P. (1991). Cybernetics - A definition *Encyclopedia of Computers*: Macmillan.

Parris, T., & Kates, R. (2003). Characterizing and Measuring Sustainable Development. *Annual Review of Environmental Resources, 28*, 559-586.

Patterson, M., & Jolland, N. (2004). The power of one: developing a headline indicator for tracking progress to sustainability in New Zealand. *Int. J. Environment and Sustainable Development, 3*(3/4), 316-338.

Pearce, D., & Atkinson, G. (1993). Capital theory and the measurement of sustainable development: an indicator of "weak" sustainability. *Ecological Economics, 8*(2), 103-108. doi:http://dx.doi.org/10.1016/0921-8009(93)90039-9

Pearce, D., Markandya, A., & Barbier, E. (1989). *Blueprint for a Green Economy*. London: Earthscan.

Petersen, J., Frantz, C. M., & Shammin, R. (2014). Using Sociotechnical Feedback to Engage, Educate, Motivate, & Empower Environmental Thought and Action. *Solutions, 5*(1), 79-87.

Pezzoli, K. (1997). Sustainable development literature: a transdisciplinary bibliography. *Journal of Environmental Planning & Management, 40*(5), 575-601.

Piketty, T. (2014). *Capital in the twenty-first century*: Cambridge Massachusetts : The Belknap Press of Harvard University Press, 2014.

Piketty, T., & Zucman, G. (2014). Capital is back: wealth-income ratios in rich countries 1700-2010. *Quarterly Journal of Economics*(3), 1255.

Porter, M. (1998). *The Competitive Advantage of Nations* (2nd Ed.). Basingstoke: Palgrave.

Porter, M., & Stern, S. (2014). *Social Progress Index 2014*. Retrieved from http://www.socialprogressimperative.org/system/resources/W1siZiIsIjIwMTQvMDUvMjYvMTYvMzQvNTQvNzk5L1NvY2lhbF9Qcm9ncmVzc19JbmRleF8yMDE0X1JlcG9ydF9lXy5wZGYiXV0/Social%20Progress%20Index%202014%20Report%20e%20.pdf

Posner, S. M., & Costanza, R. (2011). A summary of ISEW and GPI studies at multiple scales and new estimates for Baltimore City, Baltimore County, and the State of Maryland. *Ecological Economics, 70*(11), 1972-1980. doi:10.1016/j.ecolecon.2011.05.004

Prescott-Allen, R. (2001). *The well-being of nations: A country-by-country index of quality of life and the environment*. Washington, D.C.: Island Press.

Przeworski, A., Alvarez, M., Cheibub, J., & Limongi, F. (2000). *Democracy and development: political institutions and well-being in the world, 1950-1990* Cambridge, UK: Cambridge University Press.

Putnam, R. (2000). *Bowling Alone*. New York: Simon & Schuster.

Ragnarsdottir, K. V., Costanza, R., Giovannini, E., Kubiszewski, I., Lovins, H., McGlade, J., . . . Wilkinson, R. (2014). Beyond GDP. *Geoscientist Online.* Retrieved from http://www.geolsoc.org.uk/Geoscientist/Archive/October-2014/Beyond-GDP

Rawls, J. (1999). *A Theory of Justice* (Revised Ed.). Cambridge, MA: Harvard University Press.

Richardson, G. P. (1995). Loop polarity, loop dominance, and the concept of dominant polarity. *System Dynamics Review, 11*(1), 67-88.

Richardson, G. P. (1997). Problems in causal loop diagrams revisited. *System Dynamics Review (Wiley), 13*(3), 247-252.

Richardson, G. P. (2011). Reflections on the foundations of system dynamics. *Systems Dynamics Review, 8*(3), 219-243.

Richmond, B. (1993). Systems thinking: critical thinking skills for the 1990s and beyond. *System Dynamics Review, 9*(2), 113-133.

Richmond, B. (1994). *System Dynamics/Systems Thinking: Let's Just Get On With It.* Paper presented at the International Systems Dynamics Conference, Sterling, Scotland.

Rijpma, A. (2014). A composite view of well-being since 1820. In Jan Luiten van Zanden et al. (Ed.), *How was Life? Global Well-being Since 1820*. Paris: OECD.

Robèrt, K.-H. (2000). Tools and Concepts for Sustainable Development: How Do They Relate to a General Framework for Sustainable Development and to Each Other? *The Journal of Cleaner Production, 8*(3), 243-254.

Robèrt, K.-H. (2002). *The Natural Step Story: Seeding a Quiet Revolution*. Gabriola Island, BC.: New Catalyst Books.

Roberts, P. (2004). *The End of Oil*. London: Bloomsbury Publishing.

Robertson, J. M. (1912). *The Evolution of States. An Introduction to English Politics*. London: Watts & Co.

Robinson, J. (2004). Squaring the circle? Some thoughts on the idea of sustainable development. *Ecological Economics, 48*(4), 369-384.

Robinson, S. (2011). *Choosing the right model: Conceptual modeling for simulation.* Paper presented at the 2011 Winter Simulation Conference, Phoenix, AZ.

Rockstrom, J., Steffen, W., Noone, K., Persson, A., Chapin, F. S., III, Lambin, E. F., . . . Foley, J. A. (2009). A safe operating space for humanity. *Nature*(7263), 472.

Rook, L. (2013). Mental models: a robust definition. *Learning Organization, 20*(1), 38-47. doi:10.1108/09696471311288519

Rothman, D., Robinson, J., & Briggs, D. (2002). Signs of life: linking indicators and models in the context of QUEST. In H. Abaza & A. Baranzini (Eds.), *Implementing Sustainable Development*. Cheltenham, UK: Edward Elgar Publishing.

Rouwette, E. (2011). Facilitated modelling in strategy development: measuring the impact on communication, consensus and commitment. *Journal of the Operational Research Society, 62*, 879-887.

Rouwette, E., Vennix, J. A. M., & Felling, A. (2009). On Evaluating the Performance of Problem Structuring Methods: An Attempt at Formulating a Conceptual Model. *Group Decision and Negotiation, 18*, 567-587. doi:10.1007/s10726-007-9100-z

Rouwette, E., Vennix, J. A. M., & van Mullekom, T. (2002). Group model building effectiveness: a review of assessment studies. *System Dynamics Review, 18*(1), 5-45. doi:10.1002/sdr.229

Sandelin, B., Trautwein, H.-M., & Wundrak, R. (2008). *A Short History of Economic Thought* (2nd Ed.). London and New York: Routledge.

Savelsberg, E. (2008). *Innovation in European Freight Transportation. Basics, Methodology and Case Studies for the European Markets*. Verlag Berlin Heidelberg: Springer.

Schaffernicht, M. (2006). Detecting and monitoring change in models. *System Dynamics Review (Wiley), 22*(1), 73-88.

Schaffernicht, M. (2010). Causal loop diagrams between structure and behaviour: a critical analysis of the relationship between polarity, behaviour and events. *Systems Research and Behavioral Science*(6), 653.

Schepelmann, P., Goossens, Y., Makipaa, A., Herrndorf, M., Klees, V., Kuhndt, M., & Sand, I. v. d. (2010). Towards Sustainable Development Alternatives to GDP for measuring progress. Retrieved from http://epub.wupperinst.org/frontdoor/index/index/docId/3486

Schianetz, K., & Kavanagh, L. (2008). Sustainability Indicators for Tourism Destinations: A Complex Adaptive Systems Approach Using Systemic Indicator Systems. *Journal of Sustainable Tourism, 16*(6), 601-628.

Schoenenberger, L., Schenker-Wicki, A., & Beck, M. (2014). Analysing Terrorism from a Systems Thinking Perspective. *Perspectives on Terrorism, 8*(1).

Schumpeter, J. (1961). *The Theory of Economic Development*. Oxford: Oxford University Press.

Schwarz, N., & Strack, F. (1999). Reports of subjective well-being: judgmental processes and their methodological implications. In D. Kahneman, E. Diener, & N. Schwarz (Eds.), *Well-Being: The Foundations of Hedonic Psychology* (pp. 61-84). New York: Russell Sage Foundation.

Scott, R. J., Cavana, R. Y., & Cameron, D. (2013). Evaluating immediate and long-term impacts of qualitative group model building workshops on participants' mental models. *System Dynamics Review (Wiley), 29*(4), 216-236. doi:10.1002/sdr.1505

Scott, R. J., Cavana, R. Y., & Cameron, D. (2015). Client Perceptions of Reported Outcomes of Group Model Building in the New Zealand Public Sector. *Group Decis Negot*. doi:10.1007/s10726-015-9433-y

Seaford, C. (2013). *Report on results on action research: barriers to the use of alternative ('beyond GDP') indicators in policy making and how they are being overcome and can be overcome. BRAINPOoL deliverable 3.1 (nef)*. Retrieved from http://www.brainpoolproject.eu/wp-content/uploads/2014/01/WP3-synthesis-draft-FINAL.pdf

Sedlacko, M., Martinuzzi, A., Røpke, I., Videira, N., & Antunes, P. (2014). Participatory systems mapping for sustainable consumption: Discussion of a method promoting systemic insights. *Ecological Economics, 106*(0), 33-43. doi:http://dx.doi.org/10.1016/j.ecolecon.2014.07.002

Seel, N. M. (2001). Epistemology, situated cognition, and mental models: 'Like a bridge over troubled water'. *Instructional Science, 29*(4/5), 403-427.

Self, A., Thomas, J., & Randall, C. (2012). *Measuring National Well-being: Life in the UK, 2012*. Retrieved from London, UK: http://www.ons.gov.uk/ons/dcp171766_287415.pdf

Sen, A. (1992). *Inequality reexamined*. Oxford: Clarence Press.

Sen, A. (1999). *Development as Freedom*. New York: Knopf.

Sen, A. (2008). Capability and Well-being. In D. Hausman (Ed.), *The Philosphy of Economics. An Anthology* (Vol. Third Edition, pp. 270-294). Cambridge: Cambridge University Press.

Senge, P. M. (2006). *The Fifth Discipline* (2nd . First published 1990. ed.). London: Random House Business Books.

Senge, P. M., Smith, B., Kruschwitz, N., Laur, J., & Schley, S. (2008). *The necessary revolution: how individuals and organizations are working together to create a sustainable world*. New York Doubleday.

Serafy, S. E. (1989). The proper calculation of income from depletable natural resources. In Y. Ahmad, S. E. Serafy, & E. Lutz (Eds.), *Environmental Accounting for Sustainable Development* (pp. 10-18). Washington, D.C: World Bank.

Shmelev, S. E. (2011). Dynamic sustainability assessment: The case of Russia in the period of transition (1985–2008). *Ecological Economics, 70*(11), 2039-2049. doi:10.1016/j.ecolecon.2011.06.003

Simon, H. (1972). Theories of Bounded Rationality. In C. McGuire & R. Radner (Eds.), *Decision and Organization*. Amsterdam: North-Holland Publishing Company.

Simon, H., & Cilliers, P. (2005). The architecture of complexity. *Emergence: Complexity & Organization, 7*(3/4), 138-154.

Simon, J. (1996). *The Ultimate Resource 2* (2nd ed.). Princton, New Jersey: Princton University Press.

Simpson, G. G. (1944). *Tempo and Mode in Evolution*. New York: Columbia University Press.

Smith, A. (1776). *An Inquiry into the Nature and Causes of the Wealth of Nations* (1937 ed.). New York: The Modern Library.

Smith, D. J. (2010). Systems thinking: The knowledge structures and the cognitive process. Retrieved from http://www.smithsrisca.co.uk/systems-thinking.html

Smith, N. J., McDonald, G. W., & Patterson, M. G. (2014). Is there overshoot of planetary limits? New indicators of human appropriation of the global biogeochemical cycles relative to their regenerative capacity based on ‘ecotime’ analysis. *Ecological Economics, 104*, 80-92. doi:http://dx.doi.org/10.1016/j.ecolecon.2014.04.023

Solomon, R. (2013). *Modelling as alchemy? Reflections from a PSS developer on the politics of land-use models*. Paper presented at the State of Australian Cities National Conference Sydney, NSW.

Solow, R. (1974). Intergenerational equity and exhaustible resources. *Review of Economic Studies, 29-45*.

Spiegel, H. (1991). *The Growth of Economic Thought* (3rd ed.). Durham & London: Duke University Press.

Spradley, J. (1979). *The ethnographic interview*. New York: Holt, Rinehart and Winston.

Staley, C. (1989). *A History of Economic Thought. From Aristotle to Arrow*. Cambridge MA & Oxford UK: Blackwell.

Statistics New Zealand. (2011). *Key findings on New Zealand's progress using a sustainable development approach: 2010*. Retrieved from http://www.stats.govt.nz/browse_for_stats/snapshots-of-nz/Measuring-NZ-progress-sustainable-dev-%20approach/key-findings-2010.aspx

Statistics New Zealand. (n.d.). Indicator Guidelines. Retrieved from https://www.google.co.nz/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0ahUKEwjXoM-7orzJAhVjLqYKHbkQCcoQFggbMAA&url=http%3A%2F%2Fwww.stats.govt.nz%2F~%2Fmedia%2FStatistics%2Fsurveys-and-methods%2Fmethods%2Findicator-guidelines%2Findicator-guidelines.pdf&usg=AFQjCNHHNqRCvmldpk1AjQfq8sin3TOuvA&sig2=Z-y4ARa8ileRI7pYM_casw

Steptoe, A., Deaton, A., & Stone, A. (2015). Subjective well-being, health and ageing. *The Lancet, 385*(9968), 640-648.

Sterman, J. D. (1994). Learning in and about complex systems. *System Dynamics Review, 10*(2-3), 291-330.

Sterman, J. D. (2000). *Business Dynamics. Systems Thinking and Modeling for a Complex World*. Boston: Irwin McGraw-Hill.

Sterman, J. D. (2002). All models are wrong: reflections on becoming a systems scientist. *System Dynamics Review, 18*(4), 501–531.

Stern, N. (2006). *Stern Review: The Economics of Climate Change*. Retrieved from http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/stern_review_report.cfm

Stern, S., Wares, A., Orzell, S., & O'Sullivan, P. (2014). *2014 Social Progress Index Methodological Report*. Retrieved from http://www.socialprogressimperative.org/system/resources/W1siZiIsIjIwMTQvMDQvMDIvMjAvMTkvNDQvMjcyL1NvY2lhbF9Qcm9ncmVzc19JbmRleF8yMDE0X01ldGhvZG9sb2dpY2FsX1JlcG9ydC5wZGYiXV0/Social+Progress+Index+2014+Methodological+Report.pdf

Stiglitz, J. E. (2002). *Globalization and its discontent*. London: Penguin Books.

Stiglitz, J. E., Sen, A., & Fitoussi, J.-P. (2009). Report by the Commission on the Measurement of Economic Performance and Social Progress. Retrieved from http://www.insee.fr/fr/publications-et-services/dossiers_web/stiglitz/doc-commission/RAPPORT_anglais.pdf

Stone, C. (2010). *Should Trees Have Standing? Law, morality and the environment*. Oxford: Oxford University Press.

Stordeur, S., Vrijens, F., Devriese, S., Beirens, K., Van Eycken, E., & Vlayen, J. (2012). Developing and measuring a set of process and outcome indicators for breast cancer. *Breast, 21*(3), 253-260. doi:10.1016/j.breast.2011.10.003

Sykes, C., & Goodwin, W. (2007). Assessing patient, carer and public involvement in health care. *Quality in Primary Care, 15*, 45-52.

Talberth, J., & Cobb, C. (2010). Sustainable Development and the Genuine Progress Indicator: An Updated Methodology and Application in Policy Settings. In Ukaga Okechukwu, Maser Chris, & Reichenbach Mike (Eds.), *Sustainable Development. Principles, Frameworks, and Case Studies*. Boca Raton: CRC Press, Taylor & Francis Group.

Talberth, J., Cobb, C., & Slattery, N. (2007). *The genuine progress indicator 2006: A tool for sustainable development*. Washington, DC: Redefining Progress.

The Economist. (2014). Coming to an office near you. *The Economist, Jan 18 2014*.

The Encylopedia of Earth. (2007). Earth, Inc. Shareholder Report: Natural Capital. Retrieved from http://www.eoearth.org/view/article/151837/

The Encylopedia of Earth. (2008). Earth, Inc. Shareholder Report: Built Capital. Retrieved from http://www.eoearth.org/view/article/151833/

The European Commission, European Parliament, Club of Rome, OECD, & WWF. (2007). Beyond GDP: measuring progress, true wealth and the well-being of nations. Retrieved from http://www.beyond-gdp.eu/index.html

The New Zealand Institute. (2010). *NZahead Report Card*. Wellington: The New Zealand Institute.

The Treasury. (2011). *Working Towards Higher Living Standards for New Zealanders* (Vol. New Zealand Treasury Paper 11/02). Wellington: New Zealand Government.

The World Bank. (2007). World Development Indicators. Retrieved from http://siteresources.worldbank.org/DATASTATISTICS/Resources/WDI07frontmatter.pdf

Tolich, M., & Davidson, C. (2011). *Getting started : an introduction to research methods*: Melbourne, Vic. : Pearson, 2011.

Tversky, A., & Kahneman, D. (1973). Availability: A heuristic for judging frequency and probability. *Cognitive Psychology, 5*(2), 207-232.

Ulrich, W. (1987). Critical heuristics of social systems design. *European Journal of Operational Research, 31*(3), 276-283. doi:http://dx.doi.org/10.1016/0377-2217(87)90036-1

Ulrich, W. (2000). Reflective Practice in the Civil Society: The contribution of critically systemic thinking. *Reflective Practice, 1*(2), 247-268. doi:10.1080/713693151

Ulrich, W. (2005). Review: Can Nature Teach us Good Research Practice? A Critical Look at Frederic Vester's Bio-cybernetic Approach. *Journal of Research Practice, 1*(1).

UNDP. (2007). *Measuring Human Development: A Primer*. Retrieved from http://hdr.undp.org/en/media/primer_intro.pdf

UNDP. (2010). *Human Development Report 2010-20th Anniversary Edition. The Real Wealth of Nations: Pathways to Human Development*. Retrieved from http://hdr.undp.org/sites/default/files/reports/270/hdr_2010_en_complete_reprint.pdf

United Nations. (1993). *System of National Accounts*. New York: United Nations.

United Nations. (2012). *The future we want. Rio +20 - United Nations Conference on Sustainable Development*. Retrieved from Rio de Janeiro:

United Nations. (2015). Transforming our world: the 2030 Agenda for Sustainable Development. Retrieved from http://www.un.org/ga/search/view_doc.asp?symbol=A/70/L.1&Lang=E

United Nations Secretary-General's High-Level Panel on Global Sustainability. (2012). Resilient people, resilient planet: A future worth choosing, Overview. Retrieved from http://uscib.org/docs/GSPReportOverview_A4%20size.pdf

UNU-IHDP and UNEP. (2012). *Inclusive Wealth Report 2012. Measuring progress toward sustainability*. Cambridge Cambridge University Press.

UNU-IHDP and UNEP. (2014). *Inclusive Wealth Report 2014. Measuring progress towards sustainability*. Cambridge: Cambridge University Press.

van den Belt, M. (2000). *Mediated Modeling: A collaborative approach for the development of shared understanding and evaluation of environmental policy scenarios, with case* *studies in the Fox River Basin, Wisconsin and the Ria Formosa, Portugal.* (Doctor of Philosophy), University of Maryland.

van den Belt, M. (2004). *Mediated Modeling - a system dynamics approach to environmental consensus building*. Washington: Island Press.

van den Belt, M., & Forgie, V. (2015). *Applied Systems Thinking: Freshwater Management Unit*. Retrieved from http://www.massey.ac.nz/massey/fms/Colleges/College%20of%20Humanities%20and%20Social%20Sciences/EERNZ/Sustainable%20Pathways%202/Publications%20available/Freshwater-Management-report-print-version-1.pdf?0FCECBF09E2DCE852A3204EDCA7DCFED

van den Belt, M., Forgie, V., Bremer, S., McDonald, G., Montes de Oca, O., & Joy, M. (2010). *Modelling tools for integrated, adaptive management: a case study of New Zealand Regional Authorities*. Palmerston North: Ecological Economics Research New Zealand.

van den Belt, M., Forgie, V., Stouten, H., & Solomon, R. (2012). *Sustainable Pathways 2: Auckland region mediated modelling: Post-report supporting action research and integrated assessment*. Retrieved from http://www.sp2.org.nz/assets/Uploads/Post-report-Auckland-22-June-2012-Final-1.pdf

van den Belt, M., Forgie, V., Stouten, H., Thornton, M., & McDonald, G. (2012). *Sustainable Pathways 2: Wellington region mediated modelling: Post-report supporting action research and integrated assessment*. Retrieved from http://www.sp2.org.nz/assets/Documents/Post-Report-Wellington-FINAL-15-May-2012.pdf

van den Belt, M., Krueger, E., Maynard, A., Roy, M. G., & Raphael, I. (2010). Public Sector Administration of Ecological Economics Systems Using Mediated Modeling. *Ecological Economics Reviews, 1185*, 196-210.

van den Bergh, J. (2009). The GDP paradox. *Journal of Economic Psychology, 30*(2), 117-135. doi:http://dx.doi.org/10.1016/j.joep.2008.12.001

Vazquez, M., Liz , M., & Aracil, J. (1996). Knowledge and reality: Some conceptual issues in system dynamics modeling. *System Dynamics Review, 12*(1), 21-37.

Veenhoven, R. (1996). Happy Life Expectancy: A Comprehensive Measure of the Quality-of-LIfe of Nations. *Social Indicators Research, 39*, 1-58.

Veenhoven, R. (2010). Life is Getting Better: Societal Evolution and Fit with Human Nature. *Social Indicators Research, 97*(1), 105-122. doi:10.1007/s11205-009-9556-0

Vemuri, A., & Costanza, R. (2006). The role of human, social, built, and natural capital in explaining life satisfaction at the country level: Toward a National Well-Being Index (NWI). *Ecological Economics, 58*, 119-133.

Vennix, J. A. M., & Rouwette, E. (2000). *Group model building: What does the client think now?* Paper presented at the 18th International Conference of the Systems Dynamics Society, Bergen, Norway.

Vester, F. (1988). The Biocybernetic Approach as a Basis for Planning Our Environment. *Systems Practice, 1*(4), 399-413.

Vester, F. (2004). *Sensitivity Model Prof. Vester*. [Commercial software package]. The Basis-and Professional Software SYSTEMTOOLS 9.1 for Windows XP, Vista, Windows 7, Windows 8 exists as trilingual software (German, English, Spanish). Retrieved from http://www.frederic-vester.de/eng/sensitivity-model/

Vester, F. (2007). *The art of interconnected thinking*. Munchen, Germany: MCB Publishing House.

Vester, F., & Hestler, A. (1980). *The Sensitivity Model [Computer software]. Regionale Planungsgemeinschaft Untermain*. Frankfurt.

Victor, P. (1991). Indicators of sustainable development: some lessons from capital theory. *Ecological Economics, 4*(3), 191-213. doi:http://dx.doi.org/10.1016/0921-8009(91)90051-F

Victor, P. (2008). *Managing without growth. Slower by Design, Not Disaster*. Cheltenham, UK, Mass., USA: Edward Elgar.

Vidal-Abarca, M. R., Suárez-Alonso, M. L., Santos-Martín, F., Martín-López, B., Benayas, J., & Montes, C. (2014). Understanding complex links between fluvial ecosystems and social indicators in Spain: An ecosystem services approach. *Ecological Complexity, 20*, 1-10. doi:10.1016/j.ecocom.2014.07.002

Videira, N., Schneider, F., Sekulova, F., & Kallis, G. (2014). Improving understanding on degrowth pathways: An exploratory study using collaborative causal models. *Futures, 55*, 58-77. doi:10.1016/j.futures.2013.11.001

Viedermans, S. (1995). Knowledge for sustainable devlopment: what do we need to know? In T. Trzyna (Ed.), *A Sustainable World: Defining and Measuring Sustainability*: IUCN.

von Bertalanffy, L. (1945). Zu einer allgemeinen Systemlehre. *Blatter fur Deutsche Philosophie, 18*.

Waikato Regional Council. (2012). Waikato Regional Community Outcomes MARCO Indicators. Data Analysis Report Update 2012. Retrieved from http://www.waikatoregion.govt.nz/PageFiles/36757/2012/2012/Waikato_Regional_Community_Outcomes_MARCO_Data_Analysis_Report_2012.pdf

Walsh, P. (2005). *The Oxford Companion to Philosophy*. Oxford, UK: Oxford University Press.

WCED. (1987). *Our Common Future*. London: World Commission on Environment and Development.

Wellington Regional Strategy Office. (2011). Wellington Region Genuine Progress Index (GPI) 2001-2010. Retrieved from http://www.wrs.govt.nz/assets/WRS/Publications/Wellington-Region-Genuine-Progress-Index-GPI-2001-2010.pdf

Wellington Regional Strategy Office. (2014). Wellington Region Genuine Progress Index (WR-GPI) 2001-2013. Retrieved from http://www.gpiwellingtonregion.govt.nz/assets/WR-GPI2001-2013.pdf

Wenger, R. B., Harris, H. J., Sivanpillai, R., & DeVault, D. S. (1999). A graph-theoretic analysis of relationships among ecosystem stressors. *Journal of Environmental Management, 57*(2), 109-122. doi:http://dx.doi.org/10.1006/jema.1999.0294

Wilkinson, R., & Pickett, K. (2009). *The Spirit Level: Why More Equal Societies Almost Always Do Better*. London: Allen Lane.

Wilson, J., Anielski, M., & Seidel, C. (2007). *Genuine Wealth Assessment of Alberta's Stewardship Programs*. Retrieved from http://esrd.alberta.ca/waste/waste-management/documents/WealthAssessmentStewardship-Jul31-2007.pdf

Wilson, J., & Tyedmers, P. (2013). Rethinking what counts. Perspectives on Wellbeing and Genuine Progress Indicator Metrics from a Canadian Viewpoint. *Sustainability: Science, Practice, & Policy, 5*, 187-202. doi:doi:10.3390/su5010187

Wolstenholme, E. F. (1999). Qualitative v. quantitative modelling: the evolving balance. *Journal of the Operational Research Society, 50*, 422-428.

Wolstenholme, E. F. (2003). Towards the definition and use of a core set of archetypal structures in system dynamics. *System Dynamics Review, 19*(1), 7-26. doi:10.1002/sdr.259

Wolstenholme, E. F. (2004). Using generic system archetypes to support thinking and modelling. *System Dynamics Review, 20*(4), 341-356.

Woodside, A. G. (2010). *Case study research : theory, methods, practice*: Bingley: Emerald, 2010.

Woolcock, M. (2001). The Place of Social Capital in Understanding Social and Economic Outcomes. *Canadian Journal of Policy Research, 2*(1), 11-17.

World Bank. (1997). *Expanding the measure of wealth: Indicators of environmental sustainable development*. Washington, D.C.

Zadeh, L. (1965). Fuzzy Sets. *Information and control, 8*.

13 APPENDICES

Appendix 1: Dimensions of human development (from Alkire, 2002)

Grisez et al. (1987) Basic human values	Nussbaum (2000) Central human capabilities	Max-Neef (1993) Axiological categories	Narayan et al. (2000) Dimensions of well-being	Schwartz (1994) Human values	Cummins (1996) Domains of life satisfaction	Ramsay (1992) Human needs	Doyal and Gough(1993) Intermediate needs
Life Knowledge and appreciation of beauty Some degree of excellence in work and play Friendship Self-integration Coherent self-determination, or practical reason Religion, or harmony with some greater than-human source of meaning and value	Life Bodily health Bodily integrity Senses, thought, imagination Emotions Practical reason Affiliation Other species Play Control over one's environment	Subsistence Protection Affection Understanding Participation Leisure Creation Identity Freedom	Material well-being Bodily well-being Social well-being Security Freedom of choice and action Psychological well-being	Power Achievement Hedonism Stimulation Self-direction Universalism Benevolence Tradition Conformity Security	Material well-being Health Productivity Intimacy/friendship Safety Community Emotional well-being	Physical survival Sexual needs Security Love and relatedness Esteem and identity Self-realization	Nutritional food/water Protective housing Work Physical environment Health care Security in childhood Significant primary relationships Physical security Economic security Safe birth control/ childbearing Basic education
Rawls (1993) Political liberalism	Galtung (1994) HR in another key	Allardt (1993) Comparative Scandinavian welfare study	Andrews and Withey (1976) Concern clusters	Lasswell (1992) Human values	Diener and Biwas(2000) 12 life domains	Qizilbash(1996a,b) Prudential values for development	
The basic liberties Freedom of movement, freedom of association and freedom of occupational choice against a background of diverse opportunities Powers and prerogatives of office and positions of responsibility in political and economic institutions Income and wealth The social bases of self-respect	1. *Survival needs: to avoid violence* Individual and collective 2. *Well-being needs: to avoid misery* Nutrition, water, air, movement, excretion, sleep, sex, protection against climate, against diseases, against heavy degrading boring work, self-expression, dialogue, education 3. *Identity needs: to avoid alienation* Creativity, praxis, work, self-actuation, realising potentials, well-being, happiness, joy being active subject, not passive client/object, challenge and new experiences, affection, love, sex; friends, offspring, spouse, roots, belongingness, networks, support, esteem, understanding social forces, social transparency, partnership with nature, a sense of purpose, of meaning, closeness to the transcendental, transpersonal 4. *Freedom needs: choice* In receiving/expressing information and opinion, of people/ places to visit and be visited in, consciousness formation, in mobilization, confrontation, occupation, job, spouse, goods/services, way of life	*Having* Econ resources Housing Employment Working conditions Health Education *Loving* Attachments/ contacts with local community, family and kin, friends, associations, work-mates *Being* Self-determination Political activities Leisure-time activities Opportunities to enjoy nature Meaningful work	Media Societal standards Weather Government Safety Community House Money Job Services Recreation facilities Traditions Marriage Children Family relations Treatment Imagination Acceptance Self-adjustment Virtues Accomplishment Friends Religion Health Own education Beneficence Independence Mobility Beauty	Skill Affection Respect Rectitude Power Enlightenment Wealth Well-being	Morality Food Family Friendship Material resources Intelligence Romantic relationship Physical appearance Self Income Housing Social life	Health/nutrition/ sanitation/rest/ shelter/security Literacy/basic intellectual and physical capacities Self-respect and Aspiration Positive freedom, autonomy or self-determination Negative freedom or liberty enjoyment Enjoyment Understanding or knowledge Significant relations with others and some participation in social life Accomplishment (sort that gives life point/weight)	

Source: Alkire (2002, pp 203–205)

Appendix 2: Algorithm code in Python

The code for the algorithm that generates the reporting spreadsheet (in Excel) was separately commissioned as part of this research. It was written in python by Tomas Burleigh Behrens (t.burleigh@gmail.com).

```
from openpyxl import Workbook, load_workbook
from openpyxl.exceptions import SheetTitleException
import md5
import argparse
import itertools

"""
Cross impact matrix on/off analysis

Requires openpyxl
"""

def dfs(graph,root):
	nodes_to_visit = [root]
	visited = []
	while len(nodes_to_visit) > 0:
		current = nodes_to_visit.pop()
		nodes_to_visit.extend(graph.neighbors(current))

def _simpleCycles4(adjMat, root):
	candidates = [(root,)]
	cycles = []
	while len(candidates):
		path = candidates.pop()
		end = path[-1]
		for (vertex,weight) in enumerate(adjMat[end]):
			if weight != 0:
				if vertex == root:
					cycles.append(path)
				elif vertex not in path:
					candidates.append(path + (vertex,))
	return map(list, cycles)


def _simpleCycles3(g, root):
	edges = g.asDict()
	candidates = [(root,)]
	cycles = []
	while len(candidates):
		path = candidates.pop()
		endOfPath = path[-1]
		nodesToVisit = g.getEdgesFromVertex(endOfPath)
		newCandidates = [ path + (v,) for (src, v, value) in 
nodesToVisit if v not in path or v == root]
		cycles.extend([c[:-1] for c in newCandidates if c[-1] 
== root])
		candidates.extend([c for c in newCandidates if c[-1] 
!= root])
	return map(list,cycles)
```

```
def _simpleCycles(graph,root, visited=[]):
    if visited == []:
        visited = [root]

    for e in graph[root]:
        if e == visited[0]:
            yield [v for v in visited]
        elif e not in visited:
            visited.append(e)
            for result in _simpleCycles(graph,e,visited):
                yield result
            visited.pop()

def _simpleCycles2(graph, root, visited=[]):
    mat = graph.adjMat
    if len(visited) == 0:
        visited = [root]

    for i,v in enumerate(mat[root]):
        if v == 0:
            continue

        if i == visited[0]:
            yield visited
        elif i not in visited:
            visited.append(v)
            for result in _simpleCycles2(graph,i,visited):
                yield result
            visited.pop()


class Graph(object):
    def __init__(self, adjMat, titles=None):
        self.adjMat = adjMat
        self.cycleLookUp = {}
        self.titles = titles

    def getVertexName(self,vIndex):
        if self.titles is None:
            return vIndex
        return self.titles[vIndex]


    def neighbors(self, vIndex):
        for i,value in enumerate(self.adjMat[vIndex]):
            if value != 0:
                yield i

    @property
    def size(self):
        return len(self.adjMat)


    def withoutVertex(self,vertex):
```

```
        newAdjMat = [ r[:vertex] + r[vertex+1:] for r in
self.adjMat[:vertex] + self.adjMat[vertex+1:]]
        return Graph(newAdjMat)


    def asDict(self):
        mat = self.adjMat
        tfed = map(lambda r:[i for i in range(len(r)) if r[i]
!= 0], mat)
        pairs = zip(range(len(mat)),tfed)
        return dict(pairs)


    def simpleCycles(self,root):
        cycles = self.cycleLookUp.get(root,None)
        if cycles is None:
            #cycles = _simpleCycles(self.asDict(),root)
            #cycles = _simpleCycles2(self,root)
            cycles = _simpleCycles3(self,root)
            self.cycleLookUp[root] = cycles
        return cycles


    def uniqueCycles(self):
        if hasattr(self,"_uniqueCycles"):
            return self._uniqueCycles

        lookup = self._uniqueCycles = {}
        def hashCycle(cycle):
            y = min(cycle)
            yIndex = cycle.index(y)
            return    ",".join(map(str,cycle[yIndex:]    +
cycle[:yIndex]))
        for v in self.vertices:
            for cycle in self.simpleCycles(v):
                hashed = hashCycle(cycle)
                if hashed not in lookup:
                    lookup[hashed] = [c for c in cycle]
        return lookup


    def cyclesContaining(self, vertex):
        for cycle in self.uniqueCycles().itervalues():
            if vertex in cycle:
                yield cycle

    def getEdge(fromV, toV):
        value = self.adjMat[fromV][toV]
        if value is not 0 and value is not None:
            return (fromV, toV, value)
        return None


    @property
    def weightedEdges(self):
        for i,row in enumerate(self.adjMat):
```

```
            for j,v in enumerate(row):
                if v != 0:
                    yield (i,j,v)


    def getEdgesFromVertex(self,vertex):
        for i in range(len(self.adjMat[vertex])):
            value = self.adjMat[vertex][i]
            if value != 0 and value is not None:
                yield (vertex, i, value)


    def getEdgesToVertex(self,vertex):
        for u,row in enumerate(self.adjMat):
            value = row[vertex]
            if value != 0 and value is not None:
                yield (u, vertex, value)


    @property
    def edges(self):
       for v,row in enumerate(self.adjMat):
        for u,value in enumerate(row):
            if value != 0 and value is not None:
                yield (v,u,value)


    def getSourceVertices(self):
        for v in self.vertices:
            outbound = list(self.getEdgesFromVertex(v))
            inboud = list(self.getEdgesToVertex(v))
            if len(outbound) > 0 and len(inboud) == 0:
                yield v


    def getDrainVertices(self):
        for v in self.vertices:
            outbound = list(self.getEdgesFromVertex(v))
            inboud = list(self.getEdgesToVertex(v))
            if len(outbound) == 0 and len(inboud) > 0:
                yield v


    @property
    def balancingCycles(self):
        bal,rein = self.categorisedCycles()
        return bal


    @property
    def reinforcingCycles(self):
        bal, rein = self.categorisedCycles()
        return rein


    def categorisedCycles(self):
```

```
        if   hasattr(self,"_balancing")   and   hasattr(self,
"_reinforcing"):
            return (self._balancing, self._reinforcing)
        cycles = self.uniqueCycles()
        balancing = []
        reinforcing = []
        for cycle in cycles.itervalues():
            if self.cycleIsBalancing(cycle):
                balancing.append(cycle)
            else:
                reinforcing.append(cycle)

        self._balancing = balancing
        self._reinforcing = reinforcing
        return (balancing, reinforcing)


    def cycleIsBalancing(self,cycle):
        edges = zip(cycle, cycle[1:] + cycle[:1])
        weights = [ self.adjMat[a][b] for (a,b) in edges ]
        return len(filter(lambda x : x < 0,weights)) % 2 != 0


    @property
    def vertices(self):
        return xrange(len(self.adjMat))


    def stronglyConnectedComponents(self):
        """ Find the strongly connected components in a graph
using
            Tarjan's algorithm.
            """
        graph = self.asDict()

        result = [ ]
        stack = [ ]
        low = { }

        def visit(node):
            if node in low:
                return
            num = len(low)
            low[node] = num
            stack_pos = len(stack)
            stack.append(node)

            for successor in graph[node]:
                visit(successor)
                low[node] = min(low[node], low[successor])

            if num == low[node]:
                component = tuple(stack[stack_pos:])
                del stack[stack_pos:]
                result.append(component)
                for item in component:
```

```
                              low[item] = len(graph)


            for node in graph:
                  visit(node)

            return result


def vertexSummary(g):
      yield [
            "Variable",
            "Cycles variable belongs to",
            "In degree",
            "Out degree"
      ]

      for v in g.vertices:
            yield [
                  g.getVertexName(v),
                  len(list(g.cyclesContaining(v))),
                  len(list(g.getEdgesToVertex(v))),
                  len(list(g.getEdgesFromVertex(v)))
            ]
      yield [
            "Total",
            len(g.uniqueCycles()),
            "",
            ""
      ]

def cycleRemovalSummary(g):
      """
      Summary table of a directed graph's feedback loops.

      """
      #  yield  ["Removed  Vertex",  "#feedback",  "#reinforcing",
"#balancing"]
      yield           ["Intact",           len(g.uniqueCycles()),
len(g.reinforcingCycles), len(g.balancingCycles)]

      for vertex in g.vertices:
            cycles      =      len([1      for      cycle      in
g.uniqueCycles().itervalues() if vertex not in cycle])
            balancingCycles    =    len([1    for    cycle    in
g.balancingCycles if vertex not in cycle])
            reinforcingCycles    =    len([1    for    cycle    in
g.reinforcingCycles if vertex not in cycle])
            #gv = g.withoutVertex(vertex)
            #cycles = len(gv.uniqueCycles())
            #balancingCycles = len(gv.balancingCycles)
            #reinforcingCycles = len(gv.reinforcingCycles)
            yield        [g.getVertexName(vertex),        cycles,
reinforcingCycles, balancingCycles ]

def linkCountSummary(g):
```

```
	"""
	matrix[i][j] = the number of times there is an edge from i to j in a cycle within the graph
	"""
	matrix = [[0 for j in g.vertices] for i in g.vertices]
	for cycle in g.uniqueCycles().itervalues():
		# convert a cycle as a tuple, into a list of the edges it is formed from
		# [0,4,1] => [(0,4), (4,1), (1,0)]
		edges = zip(cycle, cycle[1:]+[cycle[0]])
		# count the edges
		for i,j in edges:
			matrix[i][j] += 1
	# the title row of the excel sheet
	yield ["From variable", "To variable", "Count"]

	# output data [from vertice, to vertice, count]
	triples = [(g.getVertexName(i), g.getVertexName(j), matrix[i][j]) for i in range(len(matrix)) for j in range(len(matrix[i])) if matrix[i][j] > 0]
	triples.sort(key=lambda e: e[2], reverse=True)

	for triple in triples:
		yield list(triple)

balanceStrings = {
	True : "Balancing",
	False: "Reinforcing",
}

def vertexLoopList(g, v):
	yield [
		"Loops that start with",
		g.getVertexName(v),
	]

	yield [ ]

	loops = []

	for cycle in g.cyclesContaining(v):
		vIndex = cycle.index(v)
		orderedCycle = cycle[vIndex:] + cycle[:vIndex]
		names = map(lambda c: g.getVertexName(c), orderedCycle)
		isBalancing = g.cycleIsBalancing(cycle)
		data = [balanceStrings[isBalancing],""]+names
		loops.append(data)

	loops.sort(key=lambda x:x[2:])
	for loop in loops:
		yield loop


def listAllLoops(g):
	cycles = list(g.uniqueCycles().itervalues())
```

```
	names = [[g.getVertexName(v) for v in row] for row in
cycles]
	balance = [balanceStrings[g.cycleIsBalancing(row)] for row
in cycles]
	cycles = [[b,""]+name for b,name in zip(balance,names)]
	#cycles = [(g.cycleIsBalancing(row),[g.getVertexName(v)
for v in row]) for row in cycles]
	cycles.sort(key=lambda x:x[2:])
	return cycles


class GraphNotSquareError(Exception):
	def __init__(self,w,h):
		super(GraphNotSquareError, self).__init__()
		self.width = w
		self.height = h


def isSquare(listOfLists):
	l = len(listOfLists)
	for r in listOfLists:
		if len(r) != l:
			return False
	return True


def graphFromSpreadSheet(filename, graphRange,
includesTitles=True):
	"""
	graphRange is a string specifying an excel range that
covers the matrix.
	"""
	with open(filename, 'rb') as f:
		wb = load_workbook(f)
		ws = wb.active
		mat = [[c.value for c in row ] for row in
ws.iter_rows(graphRange)]
		if not isSquare(mat):
			h = len(mat)
			if h > 0:
				w = len(mat[0])
			else:
				w  = 0
			raise GraphNotSquareError(h=h, w=w)

		if includesTitles:
			titles = [c for c in mat[0][1:]]
			mat = [row[1:] for row in mat[1:]]
		else:
			titles = None

		def parse(x):
			try:
				return float(x)
			except:
				print "failed to parse:", x
```

```
                    return 0
            #adjMat = []
            for i,row in enumerate(mat):
                  for j,val in enumerate(row):
                        try:
                              mat[i][j] = float(val)
                        except:
                              pass
                              #print "failed to parse:", val, "at",
i, j

            #mat = map(lambda x: map(parse,x),mat)
            g = Graph(mat, titles)
            return g


def writeToSheet(ws,data):
      for i,row in enumerate(data):
            for j,value in enumerate(row):
                  cell = ws.cell(row=i+1, column=j+1)
                  cell.value = value



def writeLoopsToSheet(ws,data):
      for i,data in enumerate(data):
            balancing,names = data
            ws.cell(row=i+1,          column=1).value          =
balanceStrings[balancing]
            for j,value in enumerate(names):
                  ws.cell(row=i+1, column=j+3).value = value

helpText = """Causaul loop diagram analysis script.

This script will count the number of feedback loops, reinforcing
and
balancing, that exist in a causaul impact matrix. The script
also
lists what effect eliminating a node from the CIM has on the
feedback loops.

Excel .xlsx spreadsheets are used for input and output.

Usage:
python cla.py <input_filename> <matrix-range> <output_filename>
      input_filename: an excel .xlsx file containing a cross
      matrix_range:  the  excel  range  that  covers  the  matrix
(including labels)
      output_filename: the name to the output spreadsheet to

example:
python cla.py myCIM.xlsx A1:E5 analysis.xlsx

Note, first row and column of the 'matrix range' must contain
the labels
of the matrix.
```

```
"""

def createOutputWorkbook(g):
	summary = list(cycleRemovalSummary(g))

	vertex_summary = list(vertexSummary(g))
	wb = Workbook()
	ws = wb.active
	ws.title = "Cycles and variable removal"
	header     =     ["variable     removed",     "#feedbacks",
"#reinforcing", "#balancing", "\% remaining"]
	for c,v in zip(xrange(len(header)), header):
		ws.cell(row=1, column=c+1).value = v

	rowoffset = 2
	totalLoops = float(summary[0][1])

	for i,row in enumerate(summary):
		for j,value in enumerate(row):
			cell = ws.cell(row=i+rowoffset, column=j+1)
			cell.value = value
		if totalLoops > 0:
			pct = float(row[1]) / totalLoops * 100.0
		else:
			pct = ""
		ws.cell(row=i+rowoffset,  column=len(row)+1).value  =
"%s" % pct

	ws1 = wb.create_sheet()
	ws1.title = "Variable summary"
	writeToSheet(ws1, vertex_summary)

	wsc = wb.create_sheet()
	wsc.title = "All loops"
	writeToSheet(wsc, listAllLoops(g))

	linkCountSheet = wb.create_sheet()
	linkCountSheet.title = "Link count"
	writeToSheet(linkCountSheet, linkCountSummary(g))

	# create a page listing the loops for each vertice
	for v in g.vertices:
		wsl = wb.create_sheet()
		try:
			wsl.title = g.getVertexName(v) + " loops"
		except SheetTitleException as e:
			fixed_title  =  wsl.bad_title_char_re.sub("  ",
g.getVertexName(v) + " loops")[:30]
			wsl.title = fixed_title

		loops = vertexLoopList(g,v)

		writeToSheet(wsl, loops)

	return wb
```

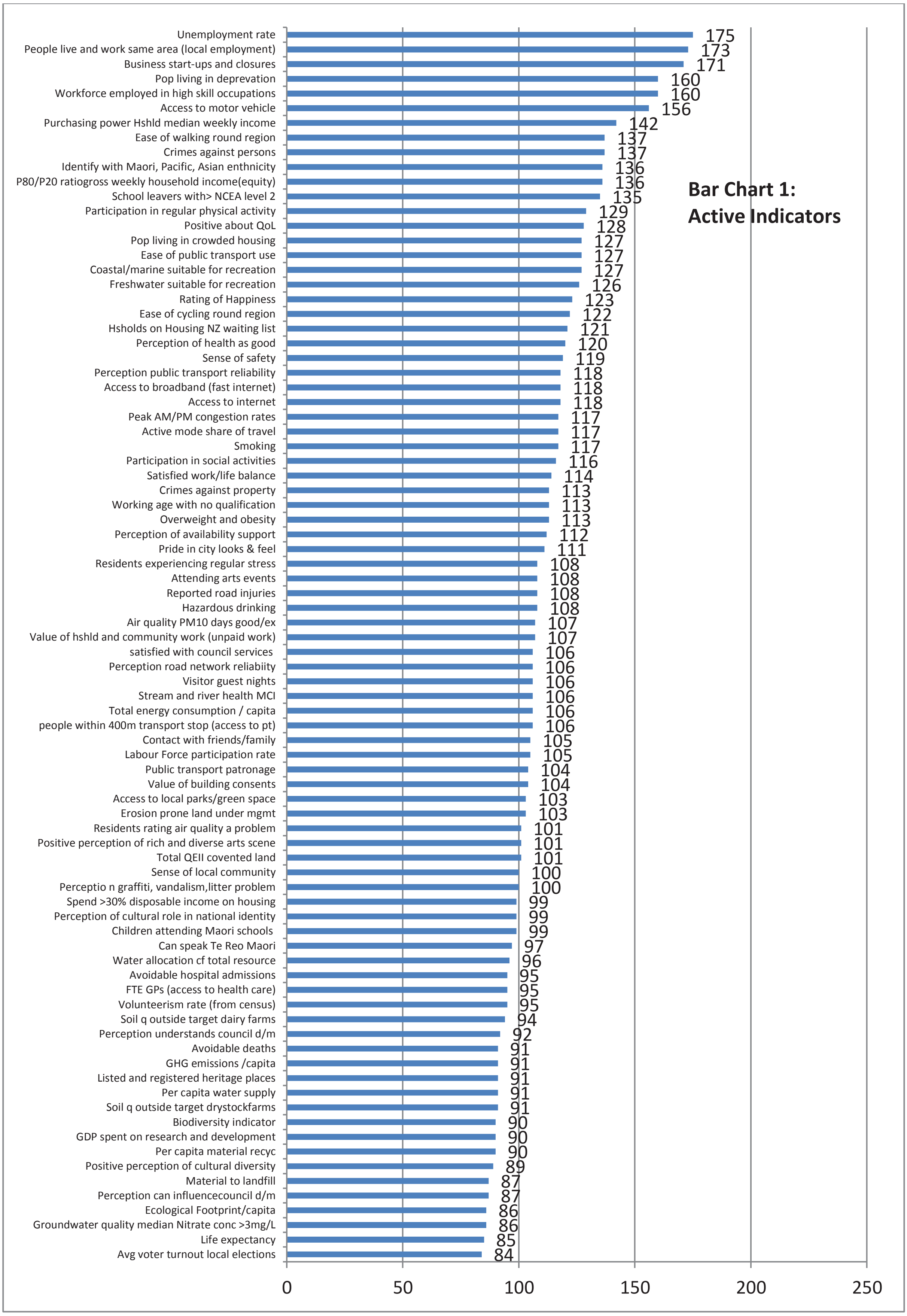
```
def json_summary(g):
	json_nodes = []
	for i in g.vertices:
		json_nodes.append({ 'name': g.getVertexName(i) })

	json_edges = []
	for edge in g.edges:
		src, target, value = edge
		json_edges.append({  'source':  src,  'target':target,
'value': value })

	return {
		'nodes': json_nodes,
		'links': json_edges
	}

def main():
	from sys import argv
	if len(argv) < 3:
		print helpText
		return

	filename = argv[1]
	graphRange = argv[2]
	output_filename = None
	if len(argv) > 3:
		output_filename = argv[3]

	try:
		g = graphFromSpreadSheet(filename, graphRange)
	except GraphNotSquareError as e:
		print "The specified range, %s, is not square. It is
%s wide and %s tall" % (graphRange, e.width, e.height)
		return
	for component in g.stronglyConnectedComponents():
		print component

	if output_filename is not None:
		wb = createOutputWorkbook(g)
		wb.save(output_filename)
	else:
		summary = list(cycleRemovalSummary(g))
		vertex_summary = list(vertexSummary(g))
		for row in summary:
			print " ".join(map(str,row))
		for row in vertex_summary:
			print " ".join(map(str,row))
	if False:
		#json output
		with open("test.json",'w') as json_file:
			import json
			outputObj = json_summary(g)
			json_file.write(json.dumps(outputObj))

if __name__ == '__main__':
	main()
```

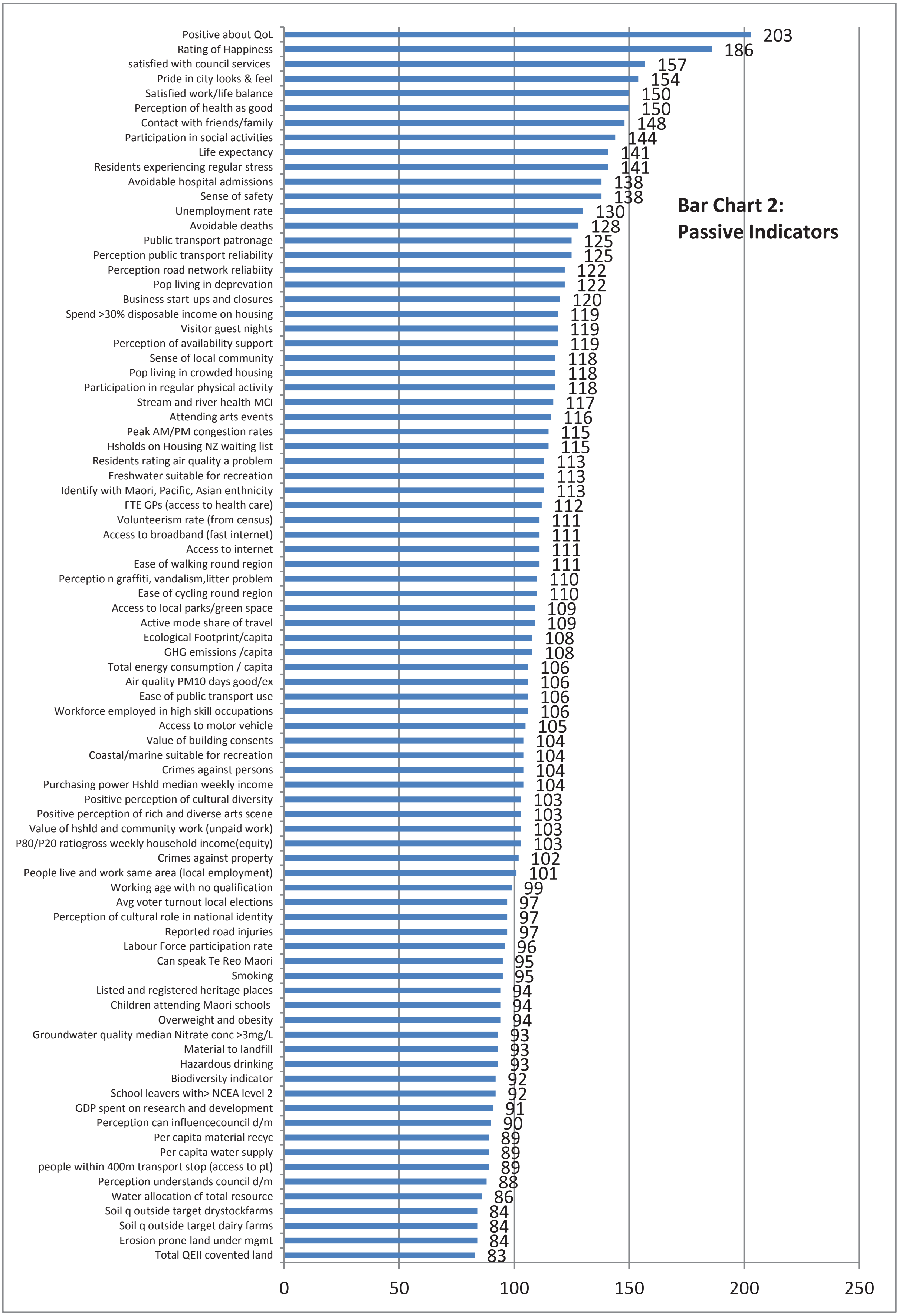
Appendix 3a: WR-GPI indicator identifiers and descriptions

Identifier	Indicator full name	Indicator website name
PC001	Labour force participation rate	Labour force participation
PC002	Unemployment Rate	Unemployment
PC003	Percentage of employed residents working and living in the same area	Local employment
PC004	P80/P20 ratio of equivalised gross weekly household income	Equity
PC005	Purchasing power (median household income adjusted by CPI)	Income
PC006	Value of household and community work	Value of unpaid work
PC007	Value of building consents (residential and non-residential)	Building activity
PC008	Percentage of the working age population with no qualifications	Educational qualification of the workforce
EI001	Percentage of GDP spent on Research & Development	Investment in R&D
EI002	Business start-ups as a percent of business turnover (start-ups and closures)	Business growth
EI003	Percentage of workforce employed in highly skilled occupations (skill level 1, 2 or 3 by ANZSCO)	Highly skilled workforce
EI004	Percentage of school leavers with NCEA level 2 or above	School leaver qualifications
HE001	Air quality	Air quality
HE002	Residents rating of air pollution as a city problem	Perceptions of air pollution
HE003	Fresh water suitability for recreation	Fresh water quality
HE004	Coastal/marine water suitability for recreation	Coastal/marine water quality
HE005	Groundwater quality	Groundwater quality
HE006	Stream and river health	River and stream health
HE007	Per capita water supply	Water consumption
HE008	Soil quality of dairy farm sites	Dairy farm soil quality
HE009	Soil quality of drystock sites	Drystock soil quality
HE010	Volume diverted from landfills per capita	Recycling
HE011	Landfill waste per capita	Landfill waste
HE012	QEII covenanted areas	QEII covenants
HE013	Erosion prone land under effective management	Erosion control
HE014	Total Ecological footprint (local hectares per capita)	Ecological footprint
HE015	Total energy consumption per capita	Energy use
HE016	Greenhouse gas emissions per capita	Greenhouse gas emissions
HE017	Biodiversity indicator	Pest management
CC001	Peak AM/PM congestion rates	Congestion
CC002	Ease of walking around the region	Ease of walking
CC003	Ease of cycling around the region	Ease of cycling
CC004	Active mode share of total household travel	Active travel
CC005	Public transport boardings (ferry, bus, train) per capita	Public transport use
CC006	Percentage of people living within 400m of public transport stop	Access to public transport
CC007	Ease of making a journey across the region by public transport	Ease of using public transport
CC008	Percentage of households with access to a motor vehicle	Access to a motor vehicle
CC009	Percentage of households with access to the internet	Home internet access
CC010	Percentage of households with access to broadband	Broadband access
QL001	Percentage of population living in deprivation	Living in deprivation
QL002	Percentage of households that spend more than 30% of their disposable income on housing costs	Housing affordability
QL003	Percentage of population living in crowded households	Crowded households
QL004	Number of households on Housing New Zealand waiting lists	Housing waiting lists
QL005	Percentage of people positive about quality of life	Overall life satisfaction
QL006	Residents rating of their happiness	Self-reported happiness
QL007	Residents satisfaction with worklife balance	Work/Life balance
QL008	Perception of safety and security	Feeling of safety walking alone
QL009	Recorded offences for crimes against the person- rate per 10,000 people	Crime against people
QL010	Recorded offences for crimes against property- rate per 10,000 people	Crime against property
QL011	Ease of access to local parks or other green space	Access to open spaces
QL012	Participation in social activities	Participation in social activity
QL013	Visitor guest nights	Visitor guest nights
SP001	Percentage people with sense of pride in way city looks and feels	Sense of pride in city
SP002	Perception that graffiti, vandalism and litter is a problem	Perception of graffiti, vandalism & litter
SP003	Percentage of people who think the region (or their City in the Wellington Region) is a great place to live	Region as great place to live
SP004	Residents' sense of community in local neighbourhood	Sense of community
SP005	Residents reported contact with friends & family	Contact with friends & family
SP006	Volunteerism rates	Volunteering rates
RF001	Water allocation compared to total water resource	Sustainable water use
RF002	Perception of council services such as water supply, drainage, rubbish collection and roads	Perception of council services
RF003	Perception of road network reliability	Perception of road network reliability
RF004	Perceptions of public transport reliability	Perception of public transport reliability
RF005	Security of electricity supply - # of days with loss of supply	Power outages
HC001	Prevalence of overweight / obesity	Obesity
HC002	Prevalence of hazardous drinking	Risky alcohol consumption
HC003	Prevalence of adults participating in regular physical activity	Physical activity
HC004	Prevalence of smoking	Smoking
HC005	Number of reported road injuries per 100,000 population	Road injuries
HC006	Residents perception of health	Perception of health
HC007	Residents regularly experiencing stress	Stress

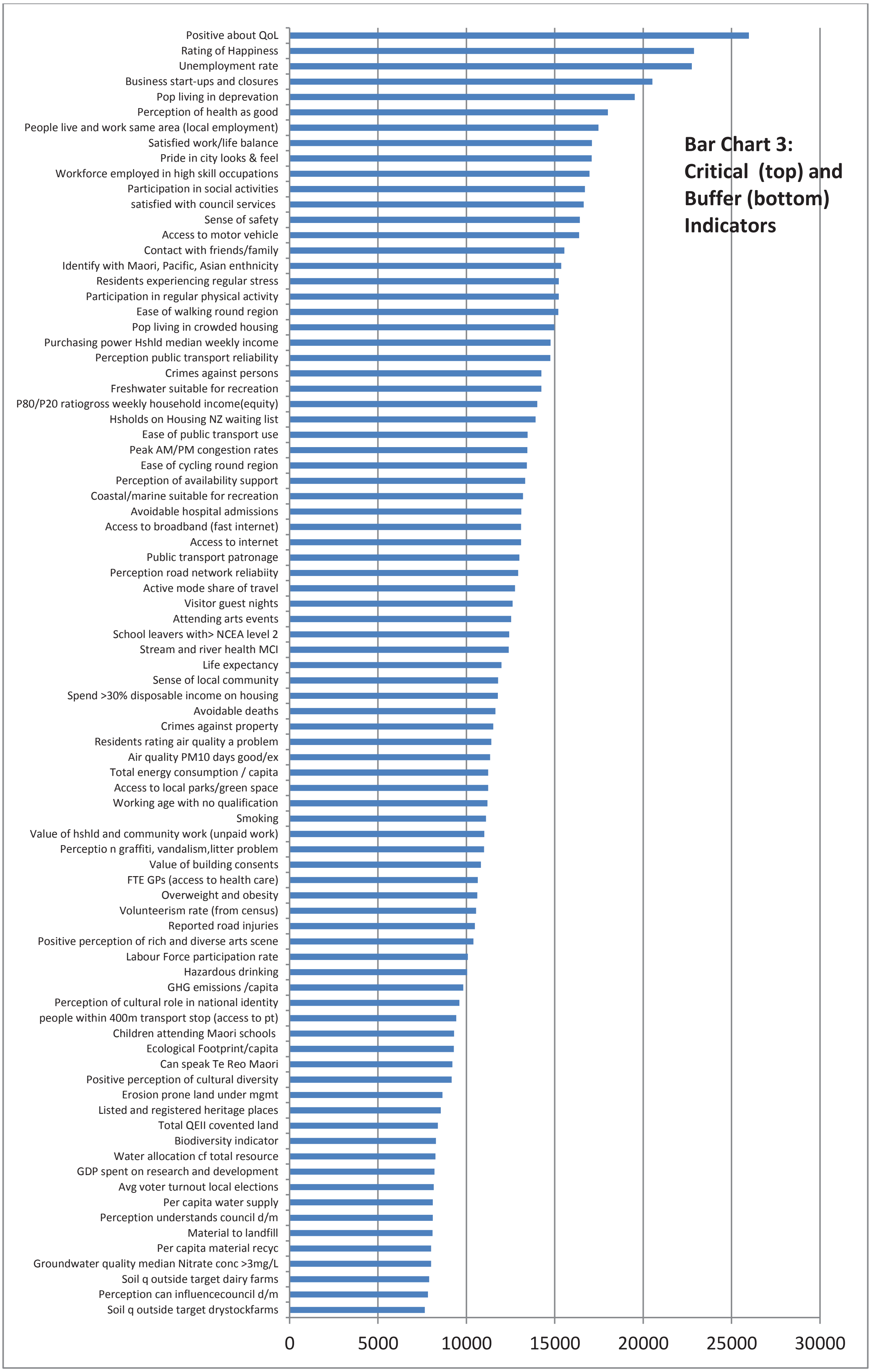
HC008	Expected years of life from birth	Life expectancy
HC009	FTEs for GPs per 100,000 people	Access to primary health care
HC010	Avoidable hospital admissions rate per 100,000 people	Avoidable hospital admissions
HC011	Amenable mortality rate per 100,000 people	Avoidable deaths
ST001	Residents perception of availability of support	Perception of social support
ST002	Average voter turnout in local council, DHB and regional council elections	Voter turnout
ST003	Perception that the public understands council decision-making	Perception of understanding of council decisions
ST004	Perception that the public can influence Council decision-making	Perception of influence on council decisions
ST005	Overall positive perception of cultural diversity	Perception of cultural diversity
ST006	Percentage of people who can speak te reo Māori	Speakers of te reo Māori
ST007	Percentage of the population identifying with the Māori, Pacific and Asian ethnic groups	Ethnic diversity
ST008	Listed and registered heritage places	Heritage places
ST009	Perception of the role of culture and cultural activities in forming a sense of national identity	Perception of role of culture in forming national identity
ST010	Overall positive perception of a rich and diverse arts scene	Perception of arts scene
ST011	Percentage of people attending arts events	Attendance at arts events
ST012	Percentage of children attending te kohanga reo and Māori medium schools	Children enrolled in Māori language education

Appendix 3b: Roles of WR-GPI indicators





Bar Chart 2:
Passive Indicators
Positive about QoL 203
Rating of Happiness 186
satisfied with council services 157
Pride in city looks & feel 154
Satisfied work/life balance 150
Perception of health as good 150
Contact with friends/family 148
Participation in social activities 144
Life expectancy 141
Residents experiencing regular stress 141
Avoidable hospital admissions 138
Sense of safety 138
Unemployment rate 130
Avoidable deaths 128
Public transport patronage 125
Perception public transport reliability 125
Perception road network reliabiity 122
Pop living in deprevation 122
Business start-ups and closures 120
Spend >30% disposable income on housing 119
Visitor guest nights 119
Perception of availability support 119
Sense of local community 118
Pop living in crowded housing 118
Participation in regular physical activity 118
Stream and river health MCI 117
Attending arts events 116
Peak AM/PM congestion rates 115
Hsholds on Housing NZ waiting list 115
Residents rating air quality a problem 113
Freshwater suitable for recreation 113
Identify with Maori, Pacific, Asian enthnicity 113
FTE GPs (access to health care) 112
Volunteerism rate (from census) 111
Access to broadband (fast internet) 111
Access to internet 111
Ease of walking round region 111
Perceptio n graffiti, vandalism,litter problem 110
Ease of cycling round region 110
Access to local parks/green space 109
Active mode share of travel 109
Ecological Footprint/capita 108
GHG emissions /capita 108
Total energy consumption / capita 106
Air quality PM10 days good/ex 106
Ease of public transport use 106
Workforce employed in high skill occupations 106
Access to motor vehicle 105
Value of building consents 104
Coastal/marine suitable for recreation 104
Crimes against persons 104
Purchasing power Hshld median weekly income 104
Positive perception of cultural diversity 103
Positive perception of rich and diverse arts scene 103
Value of hshld and community work (unpaid work) 103
P80/P20 ratiogross weekly household income(equity) 103
Crimes against property 102
People live and work same area (local employment) 101
Working age with no qualification 99
Avg voter turnout local elections 97
Perception of cultural role in national identity 97
Reported road injuries 97
Labour Force participation rate 96
Can speak Te Reo Maori 95
Smoking 95
Listed and registered heritage places 94
Children attending Maori schools 94
Overweight and obesity 94
Groundwater quality median Nitrate conc >3mg/L 93
Material to landfill 93
Hazardous drinking 93
Biodiversity indicator 92
School leavers with> NCEA level 2 92
GDP spent on research and development 91
Perception can influencecouncil d/m 90
Per capita material recyc 89
Per capita water supply 89
people within 400m transport stop (access to pt) 89
Perception understands council d/m 88
Water allocation cf total resource 86
Soil q outside target drystockfarms 84
Soil q outside target dairy farms 84
Erosion prone land under mgmt 84
Total QEII convented land 83
0
50
100
150
200
250


Bar Chart 3: Critical (top) and Buffer (bottom) Indicators
Positive about QoL
Rating of Happiness
Unemployment rate
Business start-ups and closures
Pop living in deprevation
Perception of health as good
People live and work same area (local employment)
Satisfied work/life balance
Pride in city looks & feel
Workforce employed in high skill occupations
Participation in social activities
satisfied with council services
Sense of safety
Access to motor vehicle
Contact with friends/family
Identify with Maori, Pacific, Asian enthnicity
Residents experiencing regular stress
Participation in regular physical activity
Ease of walking round region
Pop living in crowded housing
Purchasing power Hshld median weekly income
Perception public transport reliability
Crimes against persons
Freshwater suitable for recreation
P80/P20 ratiogross weekly household income(equity)
Hsholds on Housing NZ waiting list
Ease of public transport use
Peak AM/PM congestion rates
Ease of cycling round region
Perception of availability support
Coastal/marine suitable for recreation
Avoidable hospital admissions
Access to broadband (fast internet)
Access to internet
Public transport patronage
Perception road network reliabiity
Active mode share of travel
Visitor guest nights
Attending arts events
School leavers with> NCEA level 2
Stream and river health MCI
Life expectancy
Sense of local community
Spend >30% disposable income on housing
Avoidable deaths
Crimes against property
Residents rating air quality a problem
Air quality PM10 days good/ex
Total energy consumption / capita
Access to local parks/green space
Working age with no qualification
Smoking
Value of hshld and community work (unpaid work)
Perceptio n graffiti, vandalism,litter problem
Value of building consents
FTE GPs (access to health care)
Overweight and obesity
Volunteerism rate (from census)
Reported road injuries
Positive perception of rich and diverse arts scene
Labour Force participation rate
Hazardous drinking
GHG emissions /capita
Perception of cultural role in national identity
people within 400m transport stop (access to pt)
Children attending Maori schools
Ecological Footprint/capita
Can speak Te Reo Maori
Positive perception of cultural diversity
Erosion prone land under mgmt
Listed and registered heritage places
Total QEII covented land
Biodiversity indicator
Water allocation cf total resource
GDP spent on research and development
Avg voter turnout local elections
Per capita water supply
Perception understands council d/m
Material to landfill
Per capita material recyc
Groundwater quality median Nitrate conc >3mg/L
Soil q outside target dairy farms
Perception can influencecouncil d/m
Soil q outside target drystockfarms
0
5000
10000
15000
20000
25000
30000

Appendix 4a: OECD links

Link #	From	To	P*	Explanation for link
1	Civic engagement	Life satisfaction	s	Increased civic engagement and participation in civil society increases life satisfaction as civil and political rights are important determinants of life satisfaction and happiness.
2	Community	Worklife balance	o	Increased community responsibilities (including family childcare/elder care) decreases worklife balance.
3	Community	Education	s	Community networks support education (by providing assistance/encouragement for study and fundraising for schools).
4	Community	Life satisfaction	s	Community engagement (your social support network) contributes to your life satisfaction as you have help when needed and are not isolated.
5	Community	Health	s	Community engagement (your social support network) increases your health (how healthy you are) as this network provides emotional support during both good and bad times (as well as access to jobs, services and other material opportunities).
6	Community	Safety	s	Community engagement (your social support network) increases your safety by checking you are ok and neighbourhood watch.
7	Education	Jobs	s	Educational attainment makes a person more employable and able to do a broader spectrum of work. It thereby provides more job security.
8	Education	Income	s	Education plays a key role in providing individuals with the knowledge, skills and competencies needed to participate effectively in society and in the economy. Education increases your income (household income and financial wealth).
9	Education	Community	s	Education increases community participation and connections made through friends, family, sport, leisure activities, voluntary work and community service.
10	Education	Safety	s	Higher levels of education increase safety. Educated people are less likely to work in a hazardous job or commit crime.
11	Education	Civic engagement	s	Increased education contributes to increased civic engagement. Research indicates educated people are more likely to vote than the less educated.
12	Education	Health	s	Education increases health as people can learn about how to get/stay healthy, care for children etc.
13	Environment	Life satisfaction	s	Good environment quality, (actual and perceived) has a significant positive effect on life satisfaction. Includes things like access to green spaces.
14	Environment	Health	s	Good air quality, food and water quality, not being exposed to toxic substances etc keeps people healthy.
15	Environment	Jobs	s	Increasing environment (maintaining natural capital) will provide the resources to increase jobs over the long term (after a delay period). Job creation in green technology, environment protection and management, recycling, water treatment etc.
16	Health	Education	s	Healthy people (physically and emotionally) are more able to get/benefit from education and learn new skills.
17	Health	Jobs	s	Healthy people (physically and emotionally) are more able to get/hold jobs.
18	Health	Life satisfaction	s	If health increases life satisfaction increases. Health is one of the most important drivers of life satisfaction.
19	Housing	Safety	s	Affordable housing increases safety. Overcrowding leads to violence.
20	Housing	Health	s	Affordable housing that is warm, dry and ventilated, contributes to good health and avoids spread of diseases from overcrowding.
21	Housing	Life satisfaction	s	More affordable housing and home ownership improves life satisfaction.
22	Income	Housing	s	Higher income increases house affordability (decreases spending on housing as a percent of income).
23	Income	Safety	s	Higher income levels allow people to live in safer areas and afford more security systems.
24	Income	Worklife balance	s	Higher incomes allow people to increase their worklife balance by working less hours. There are diminishing marginal gains from additional income due to relativity.
25	Income	Education	s	Higher income levels improve educational achievement of students. Provides extra tuition, access to high decile schools, space for homework, role models etc.
26	Income	Environment	o	Higher income levels decrease environmental quantity and quality. Income level determines consumption levels and the demand for goods and services.
27	Income	Civic engagement	s	High income levels lead to more active civic engagement.

28	Income	Life satisfaction	s	High income people are happier (though life satisfaction does not increase proportionally as income increases).
29	Income	Health	s	Increases in income improve health care affordability, and healthy eating and life style options.
30	Jobs	Income	s	Increased jobs increase income (household income and financial wealth).
31	Jobs	Environment	o	An increase in jobs decreases the environment as jobs consume resources and generate pollutants.
32	Jobs	Life satisfaction	s	Employment increases overall life satisfaction. Gives life purpose and meaning.
33	Jobs	Health	s	When jobs are available this improves health. Provides self-esteem, motivation.
34	Life satisfaction	Health	s	High life satisfaction improves health (happy people are healthier and live longer).
35	Life satisfaction	Civic engagement	s	Life satisfaction and happiness increases trust of public service and willingness to participate.
36	Safety	Community	s	Safety increases community networking and social opportunities (is possible to walk, travel to see friends, family and social interaction).
37	Safety	Education	s	A safe situation at school, at home, for commuting etc facilitates educational achievement.
38	Safety	Health	s	Safe situations allow people to interact, exercise, active commuting which improves health.
39	Worklife balance	Community	s	An increase in worklife balance (how much you work/play) has a positive impact on community (quality of your social support network) as having regular work hours provides time/contacts for building/engaging with social support network (community).
40	Worklife balance	Health	s	An increase in worklife balance (how much you work/play) has a positive impact on health (less pressure, stress).
41	Worklife balance	Life satisfaction	s	An increase in worklife balance (how much you work/play) has a positive impact on life satisfaction. [People overworked are dissatisfied and unhappy and feel they lack of control over their lives. People underworked lack opportunity to reach their potential.]

P*=polarity
o=opposite
s=same

Appendix 4b: Rationale for links used in OECD model

1. Civic engagement to Life Satisfaction

"The available evidence suggests a weak but significant relationship between participation in civil society and subjective wellbeing."[1]

2. Community to Worklife Balance

Community (includes family and friends) commitments can impact on worklife balance as much as paid work. This can be especially problematic for Māori or working couples with young families or dependent elders.

3. Community to Education

Communities undertake fundraising for schools, and support education by providing free assistance. Community support for schools increases educational achievement.

4. Community to Life Satisfaction

Community (includes family and friends) are a source of social support, and provide individuals with a sense of belonging. Not having help in a crisis has a negative impact on life satisfaction. Good social relationships (staying in touch with family and friends) helps contribute in a positive way to life satisfaction. Community these days can be local, national, and global. "Many studies have also highlighted the importance of relationships with family, friends, and others in the community on subjective wellbeing. Having strong bonds of social support through close friends, the frequency of socialisation (visiting or being visited), not feeling socially isolated, and trusting others were strong predictors of life satisfaction. Formal aspects of social life and community relationships, such as volunteering, were less predictive of subjective wellbeing." [1]

5. Community to Health

Community (includes family and friends) are a source of personal support which helps people deal with stressful events when they occur. Good social relationships contribute to mental health. Community activities (involving exercise) improve physical health.

6. Community to Safety

Communities that know their neighbours are more likely to have a neighbourhood watch, and foster a safe environment for children to play in etc.

7. Education to Jobs

High-school graduation rates provide a good indication of whether a country is preparing its students to meet the minimum requirements of the job market. There are increasingly less job opportunities for people without this minimum level.[2] Good education greatly improves the likelihood of finding a job. Highly-educated individuals are less affected by unemployment trends, typically because educational attainment makes an individual more attractive in the workforce. Across OECD countries, 83% of people with university-level degrees have a job, compared with just below 56% of those with only a secondary school diploma.[2] Education is a big factor in the type of work people able to do. Having needed skills impacts on ability to work. Following a decline in manual labour over previous decades, employers now favour a more educated labour force.[2]

Over the past 30 years, the digital revolution has displaced many mid-skill jobs such as typists, travel agents, bank tellers and production line jobs. In the past, innovation has killed some jobs but created new and better ones in the long-term. In the short-term there has been wider income gaps and social dislocation. Prosperity from the digital revolution has gone to the owners of capital and highest skilled workers.[3] Workers abilities and aptitudes remain unequal – some will find job prospects dimmed and wages squeezed. Increasing the minimum wage accelerates the move from human workers to computers. [3]

8. Education to Income

Good education greatly improves the likelihood of earning enough money to satisfy needs. Average earnings are 24% higher for those with a tertiary education compared to those with only upper secondary and post-secondary non-tertiary education. A substantial body of evidence shows that a graduate with higher levels of education faces a lower risk of unemployment, and has greater access to further training opportunities and higher average earnings. Differences in earnings are a measure of the premium paid for the likelihood of enhanced skills and/or higher productivity.[4]

9. Education to Community

Studies show that educated individuals participate more actively in politics and in the community where they live, and rely less on social assistance.[2] "While gender has little impact on social network support, there is a clear relationship between the availability of social support on the one hand, and people's education level, on the other. Only 84% of people who have completed only primary education report having someone to count on for help in times of need, compared with over 93% for people who attained tertiary education. A weak social network can result in limited economic opportunities, a lack of contact with others, and eventually, feelings of isolation. Social isolation may follow family breakdown, the loss of a job, illness or financial difficulties. Once socially isolated, individuals may face greater difficulties not only reintegrating into society as a contributing member, but also fulfilling personal aspirations with respect to work, family and friends." [5]

10. Education to Safety

Education reduces likelihood that individuals will work in the most hazardous jobs. Studies show that educated individuals commit fewer crimes.[2] "… the quality and proliferation of educational opportunities can indicate the quality and proliferation of other things too, including safety."[7]

11. Education to Civic Engagement

Studies show that educated individuals participate more actively in politics.[2] There is evidence of a causal relationship between education and civic participation. Education provides bureaucratic competence, civic skills, general cognitive capacity, discussion of social and political issues, student governance, youth activities that foster involvement and engagement, service learning, social norms.[6] The link is not just related to socio-economic status. However complete understanding of the relationship between education and civic engagement is not possible due to lack of data. Studies made have been based on formal education attainment rather than adult learning.[6] Voter turnout has not risen in the wake of higher education levels. The conjecture is the decrease would have been even greater without education. [6]

While policy makers widely recognise the fact that education serves as an engine for economic growth through the accumulation of human capital, education is also strongly associated with boosting levels of social capital. Indeed, an important justification for the large expenditures on education within many democratic nations is its social, and not purely economic, impact – these social consequences being the benefits an educated electorate brings to civil society.[6] Research has shown that people who are more highly educated, are much more likely to vote than those who are less educated;, and that older people are more likely to vote than younger ones.[8]

12. Education to Health

"Those with more years of schooling tend to have better health and well-being and healthier behaviours. Education is an important mechanism for enhancing the health and well-being of individuals because it reduces the need for health care, the associated costs of dependence, lost earnings and human suffering. It also helps promote and sustain healthy lifestyles and positive choices, supporting and nurturing human development, human relationships and personal, family and community well-being. There is considerable international evidence that education is strongly linked to health and to determinants of health such as health behaviours, risky contexts and preventative service use. Moreover, we find that a substantial element of this effect is causal."[6] Studies also show that educated individuals live longer.[2] Ethnicity, gender, historical and social contexts all moderate the effects of education on health.[6] Education appears to confer a lifelong advantage for healthy aging. "The data that the authors present show that the more educated report having lower morbidity from the most common acute and chronic diseases (heart condition, stroke hypertension, cholesterol, emphysema, diabetes, asthma attacks, ulcer). More educated people are less likely to be hypertensive, or to suffer from emphysema or diabetes. Physical and mental functioning is also better for the better educated. The better educated are substantially less likely to report that they are in poor health, and less likely to report anxiety or depression. Finally, better educated people report spending fewer days in bed or not at work because of disease, and they have fewer functional limitations."[9]

13. Environment to Life Satisfaction

"The more specific literature on environmental conditions and subjective well-being is strongly focussed on exposure to "bads" (e.g. air pollution), rather than access to "goods" (e.g. green space). In their review of the literature available at that time it was concluded that evidence of the impact of pollution on subjective well-being was very limited. In recent years, there has been a growing body of literature, much of which supports the existence of such a relationship."[10] There is a negative relationship between local environmental problems and life satisfaction.[12]

Robust correlations have been shown between individuals subjective well-being (i.e. life satisfaction), and environmental awareness about issues like ozone depletion and biodiversity loss. Caring about nature has a positive impact on life satisfaction.[11] "Good empirical evidence exists that environmental factors affect people's sense of subjective well-being. Nonetheless, one of the lessons emerging from this literature is that there is no one-to-one relationship between actual pollution levels and reported satisfaction with environmental quality. In addition, the relationship between reported satisfaction with environmental quality and life satisfaction varies. It is, therefore, necessary to assess both: (a) the factors (including environmental conditions) which affect one's level of satisfaction with environmental quality, and (b) the impact that this has on subjective well-being (and how this relationship differs across socio-demographic groups)." [10]

“Reporting dissatisfaction with personal health decreases someone’s life satisfaction score by 0.95. By comparison, reporting dissatisfaction with two or three of the measures of environmental quality in our index decreases someone’s life satisfaction by 0.48 – i.e. roughly half a step lower on the Cantril Scale (when compared to someone with an environmental quality score of zero). It was found that actual and perceived environmental quality has a significant effect on life satisfaction, with the magnitude being approximately half that of self-reported health status.”[10] Happiness and sustainability go together.[13] There is a relationship between natural capital and life satisfaction that is not compensated for by any other variable and needs to be included in analysis of life satisfaction.[14]

There is support for a strong link between environment and subjective well-being measures.[15]

14. Environment to Health

There is a complex relationship between environmental factors and human health. Air pollution, noise, chemicals, poor quality water and loss of natural areas combine with lifestyle changes to impact on health. UK researchers found moving to a green space had a sustained positive effect, unlike pay rises or promotions, which only provided a short-term boost. A study has shown people living in greener areas display fewer signs of depression or anxiety. As they were less stressed they made more sensible decisions and communicated better.[16] Environmental features may have positive effects (natural landscapes, interaction with plants and wildlife) as well as negative effects (pollution, aesthetic degradation) on well-being. Surgery patients who stayed in rooms with a view of trees had shorter hospital stays and needed less medication than those who stayed in rooms with windows that faced brick walls.[17] A better view improved office worker job performance and was also correlated with fewer negative health symptoms.[18]

15. Environment to Jobs

Environment is a key positive input into jobs. The social and economic systems are sub-systems of the environment so these processes depend on resources extracted from the environment and the environments ability to assimilate the wastes produced. The environment fosters jobs through:

- Activities where the environment is a primary natural resource or input into the economic process – Agriculture, forestry, mining, electricity generation and water supply

- Activities concerned with protection and management of the environment – Waste recycling, pollution & sewage control and environmental management
- Activities dependent on environmental quality – Environment related tourism

Around one-third of all industrial sectors have significant environmental links in terms of biodiversity and eco-system services. This contribution of biodiversity and eco-system services to the economy comes through:

- provisionary services, such as food, fibre, fuel and water;
- regulating services, i.e. benefits obtained from ecosystem processes that regulate the environment, such as the regulation of climate, floods, disease, wastes, and water quality;
- cultural services such as recreation, aesthetic enjoyment and tourism; and
- supporting services, i.e. services that are necessary for the production of all other ecosystem services, such as soil formation, photosynthesis, and nutrient cycling.

16. Health to Education

Good health facilitates the ability to learn and achieve high levels of education. Absence from school due to sickness (especially primary level) for many children is a barrier to learning as once children drop behind they struggle to catch up.

17. Health to Jobs

Ability to work is impacted by the health of the population. People with poor health have more sick days from work or are unable to hold down a job.

18. Health to Life Satisfaction

In many studies health has been found to be a strong driver of overall life satisfaction. Life satisfaction is greater among people who are in good physical and mental health.[1][19] Without good health, people are less able to participate fully and enjoy living and are therefore likely to be less satisfied with life. "Data obtained from the 2005 Behavioral Risk Factor Surveillance System, an ongoing, state-based, random-digit telephone survey of the non-institutionalized U.S. population aged ≥18 years had an estimated 5.6% of U.S. adults (about 12 million) dissatisfied/very dissatisfied with their lives. As the level of life satisfaction decreased, the prevalence of fair/poor general health, disability, and infrequent social support increased as did the mean number of days in the past 30 days of physical distress, mental distress, activity limitation, depressive symptoms, anxiety symptoms, sleep insufficiency, and pain. The prevalence of smoking, obesity, physical inactivity, and heavy drinking also increased with decreasing level of life satisfaction. Moreover, adults with chronic illnesses were significantly more likely than those without to report life dissatisfaction. Notably, all of these associations remained significant after adjusting for sociodemographic characteristics.[10]

19. Housing affordability to Safety

Overcrowding causes tension and conflict. Overcrowding is defined by the number of people who stay in a room and the amount of space they have there. Surveys show that those in rented accommodation were more likely to be victims of a violent crime than those in owner-occupied accommodation.[20]

20. Housing affordability to Health

Surveys of hospital admissions demonstrate a strong association between poor housing and poor health, especially for children. This situation is compounded by overcrowded housing which impacts on mental health and social wellbeing. Housing needs to be warm, dry and ventilated. Research indicates an association between homes with visible damp or mould and the prevalence of asthma or respiratory problems among children. Poor quality housing can also have an adverse effect on children's psychological well-being. There is social stigma associated with living in bad housing.[21]

21. Housing to Life Satisfaction

Having adequate housing improves life satisfaction. A New Zealand study showed 86% of people with no housing problems report being very satisfied/satisfied with life and only 6% very dissatisfied; compared to 80% and 9%.[22] There were significant differences in overall life satisfaction between people living in rented housing (79%) and those living in owned housing (88%).[23] Not owning one’s home has a negative effect, although the size of the coefficient is small.[1]

22. Income to Housing Affordability

Income determines the quality, location, and size of housing that is affordable. Affordable housing is defined by the proportion of households and people within those households spending more than 30% of their disposable income on housing. Affordable housing is important for people’s well-being. For lower-income households high housing costs relative to income are often associated with severe financial difficulty, and can leave households with insufficient income to meet other basic needs such as food, clothing, transport, medical care and education. High outgoings-to-income ratios are not as critical for higher-income households, as there is still sufficient income left for their basic needs. In 2009, 27% of New Zealand households spent more than 30% of their disposable income on housing costs. This was around the same level as in 2007 (26%) but an increase on the 2004 level (21%). The proportion of low-income households spending more than 30% of their income on housing was twice as high in 2009 as it was in 1988.[24]

23. Income to Safety

People with higher incomes can afford to live in safer areas and afford more security (e.g. burglar alarms). Data based on the index of deprivation (NZDep2001) quintiles (taking into account income, means-tested benefit status, access to car, household crowding, home ownership, unemployment, qualifications, sole-parent families, and access to a land-line or mobile telephone) show that there were more victims of crime in deprived quintiles than non-deprived.[25]

24. Income to Worklife Balance

Income levels impact on worklife balance as they determine the amount of time required to work to maintain your standard of living. There are diminishing marginal gains from additional income due to relativity (happiness with income level is determined with relativity to peers), and the fact the expenditure adjusts quickly to higher income levels. People in part-time employment were more likely to be satisfied with their work-life balance than people in full-time employment.[26]

25. Income to Education

Family income levels impact on the achievement level of students. Higher socio-economic groups provide more financial support for schools, pay school fees etc. Students' socio-economic background tends to have an impact on their education. People who are successful as a result of their education are role models for others. They are also more likely to encourage and financially support their children to achieve high levels of education. On average across OECD countries, there is a 99-point difference in Programme for International Student Assessment (PISA) scores between the students with the highest and lowest socio-economic background.[2]

The level of knowledge and skill in a country's population are significant factors determining differences in in wealth and economic growth. This in turn impacts the amount spent on education. Therefore, when people study for longer and gain more knowledge, this knowledge will eventually serve to increase the economic growth of their country.[27]

26. Income to Environment

Income determines the demand for goods and services by households. Higher income levels result in increased depletion of raw materials extracted from natural capital and greater waste production for assimilation by natural capital. The environmental Kuznet curve has not been effective for global issues such as greenhouse gases and ocean acidification. “Generally speaking, as household consumption grows, environmental pressures grow. Our purchasing choices directly and indirectly involve the consumption of natural resources and the generation of waste, as goods and services are produced and delivered. The purchase of goods and services can also be directly linked to harmful environmental effects (for example, air pollution produced in manufacturing processes).”[28]

27. Income to Civic Engagement

How well-off you are also affects how likely you are to vote. Voter turnout generally increases with individual income and on average there is an 11 percentage point difference estimated between the top 20% of the population and the bottom 20%.[8] Income inequality has a negative impact on civic engagement. “Inequality may depress participation, either directly or indirectly, through its effects on trust. First, where inequality is higher, the poor may feel powerless. They will perceive that their views are not represented in the political system and they will opt out of civic engagement. Second, trust in others rests on a foundation of economic equality. When resources are distributed inequitably, people at the top and the bottom will not see each other as facing a shared fate. Therefore, they will have less reason to trust people of different backgrounds. Also, trust rests on a psychological foundation of optimism and control over one’s environment. Where inequality is high, people will be less likely to believe that the future looks bright, and they will have even fewer reasons to believe that they are the masters of their own fate. Inequality leads to lower levels of trust and thus may also have an indirect effect on civic participation.” [29]

28. Income to Life Satisfaction

Adequacy of income has an impact on life satisfaction. Wealthier people are happier than those on lower incomes, however life satisfaction does not increase proportionally as income increases. Evidence suggests it is relative income rather than absolute income that matters and that there is a diminishing marginal gain with increased income. Studies have concluded that efforts to become richer as a way to increase happiness are self- defeating due to the notion of relativity. Rather than absolute levels of material satisfaction, it is how we compare with peers that counts. This explains the diminishing marginal gains in happiness/life satisfaction as income increases.[1]

29. Income to Health

Both individual income (material circumstances) and income inequality (relative income) make a difference to health. Within any particular society, those with higher incomes do better on a range of outcomes. Therefore there is a 'social gradient' in health, which means that every step up the socio-economic ladder leads to an increase in health. It is less clear whether every step up the ladder improves health by the same degree. The most plausible explanation for income inequality's apparent effect on health and social problems is 'status anxiety'. This suggests that income inequality is harmful because it places people in a hierarchy that increases status competition and causes stress, which leads to poor health and other negative outcomes. Further theorising around 'status anxiety' would be helpful to consider how 'status anxiety' works in practice, given people's different reference groups, their knowledge (or lack of knowledge) about social stratification and the complex nature of 'status' and self-esteem.[30] Effect of income on health is at least as great as the effect of education on health.[6] Not all research studies have shown an independent effect of income inequality on health and social problems. Some studies highlight the role of other factors such as material circumstances (individual income), culture/history, ethnicity and welfare state institutions/social policies.[30]

30. Jobs to Income

Jobs and the type of jobs people do (or don't do) are the main determinant of income level and distribution of income. Jobs provide people with incomes to enable them to meet their basic needs and to contribute to their material comfort. Jobs give them options for how to live their lives. Real wages for workers are not increasing despite increases in productivity. Productivity gains have gone to a select minority (mostly those who own capital). Even in countries like Sweden inequality among the employed has risen sharply. There is a long term trend towards lower levels of employment in rich countries like the USA, where capital is being substituted for labour. [3]

31. Jobs to Environment

All jobs involve the consumption of raw materials and the production of waste. This impact can be reduced by: (1) Limiting use of all resources to rates that ultimately result in levels of waste that can be absorbed by the ecosystem (2) Exploiting renewable resources at rates that do not exceed the ability of the ecosystem to regenerate the resources (3) Depleting non-renewable resources at rates that, as far as possible, do not exceed the rate of development of renewable substitutes.[31] Higher environmental standards (along with other factors such as the price of labour) can result in a loss of jobs to countries with lower standards. There is also potential for job creation in the new technologies to bring about environmental protection and greater resource efficiency.[32]

32. Jobs to Life Satisfaction

There are significant differences in overall life satisfaction between the unemployed (67%) and the employed (87%).[33] From NZ data "Evidence from the literature shows that unemployment has a strong negative effect on life satisfaction, after controlling for other factors associated with employment. The impact of unemployment on life satisfaction is one of the strongest findings from the literature. It has been suggested that it is the loss of social relationships and social esteem associated with work especially hard hit. Not surprisingly, there is a strong positive association between job satisfaction and life satisfaction. A meta-analysis of 34 studies determined an average correlation of 0.44 between job satisfaction and life satisfaction."[34] Not being able to work (or engage in social activity) reduces cognitive reserves and lowers quality of life. Both actual and perceived lowering of quality of life can be disabling for an individual.[35]

33. Jobs to Health

Research shows that losing your job has the next highest impact on health after divorce and death. Jobs contribute to self-esteem, self-discipline, company and purpose in life which impacts positively on health. Jobs also contribute the income for health care and healthy accommodation. There can be negative health effects from jobs – e.g. work related deaths and injuries, as well as stress and pressure from work people don't enjoy. Stress, for example, can contribute to range of problems like heart disease and depression. Job quality also impacts on health. Workers in high-strain jobs, who don't receive adequate support to cope with difficult work demands, are more likely to suffer from job burnout, to develop musculoskeletal disorders, hypertension, and cardiovascular disease. A recent OECD study shows that in Europe, 20% of employees report difficult working conditions, facing multiple job 'stressors' and little support or resources to deal with these. Half of the employees in high-strain jobs say work impairs their health, compared to only 15% for those in low-strain jobs. Interactions with colleagues, support from managers, work content, autonomy in decision-making, earnings and job security all contribute to well-being at work. [36]

34. Life satisfaction to Health

People who are satisfied with life are happier which has a positive impact on health. "A review of more than 160 studies of human and animal subjects has found "clear and compelling evidence" that – all else being equal – happy people tend to live longer and experience better health than their unhappy peers… Your subjective well-being – that is, feeling positive about your life, not stressed out, not depressed – contributes to both longevity and better health among healthy populations." [37]

35. Life satisfaction to Civic Engagement

People satisfied with life are more inclined to be trusting of public service and participate in civil duties such as voting and submission making. Civil and political rights include ability to: participate in decision-making by voting; be fairly represented in government; seek redress for discrimination; and conduct business with public officials in an open and transparent manner, without fear of involvement in corrupt practices. Dissatisfaction in life breeds apathy, resulting in poor civic engagement from these individuals.

36. Safety to Community

Crime affects not only individuals but also society as a whole. There are the tax-payer expenses of hospital care and law enforcement, as well as the loss of the victim's input into their community. The victim's family and friends are likely to suffer grief and anger. They may have to care for someone who is temporarily or permanently incapacitated and who may lose their livelihood. Crime and the fear of crime may also reduce social cohesion within communities. Crime may restrict people's freedom of movement, for example, they may stay away from certain areas or avoid going out because of a fear of crime.

37. Safety to Education

Students who feel safe in their educational environment and at home are likely to study more effectively.

38. Safety to Health

Being able to safely exercise and commute (by walking or cycling) contributes to health. In this respect urban design is important. "Safety is fundamental to health: violence and avoidable injuries, at their most extreme, threaten life itself and corrode quality of life in many ways. Both safety and security are important. Safety is freedom from physical or emotional harm, while security is freedom from the threat or fear of harm or danger. Physical injury causes pain and incapacity, reducing victims' enjoyment of life and their ability to do things that are important to them. Property crime, such as burglary, also affects people's wellbeing. In addition to the direct losses associated with crime of this sort, evidence suggests the threat of burglary is a more significant worry for many people than the threat of violence. Psychological effects are often as important as the physical ones. Victims of violence or injury often retain emotional scars long after their physical wounds have healed. They may suffer from depression or face other mental health issues." [38]

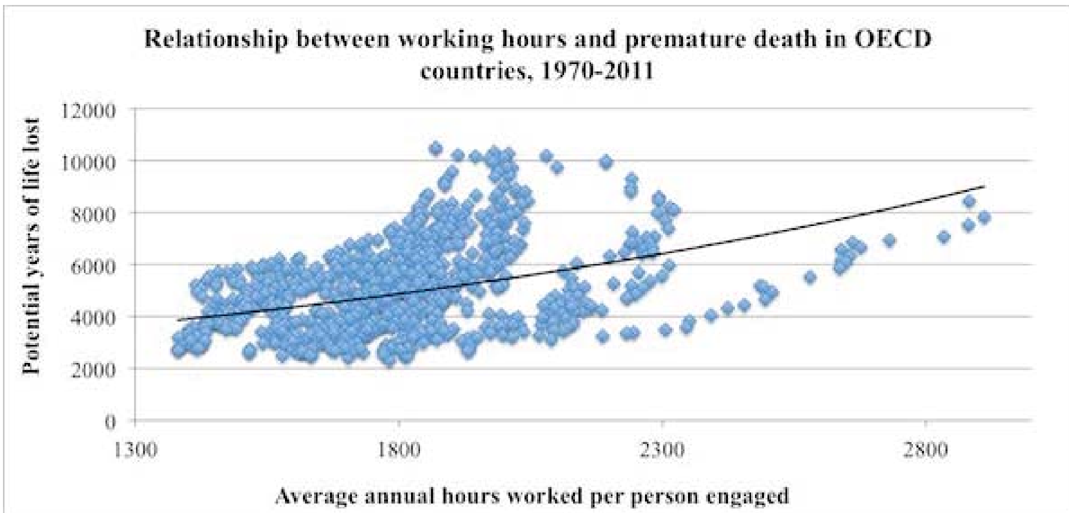
39. Worklife balance to Community

If people work less hours they are able to connect with people, participate in voluntary work, sports, cultural activities, community service etc. that contribute to community. This does not always happen as people also spend free time on other activities such as shopping, house renovation, travel, computers, watching television. Having leisure time is a crucial part of a balanced lifestyle. Participating in arts and cultural activities can add meaning to life, and create a sense of identity and connectedness for people and communities.

Studies show that time spent with friends is associated with a higher average level of positive feelings and a lower average level of negative feelings than time spent in other ways. Helping others can also make you happier. People who volunteer tend to be more satisfied with their lives than those who do not. Time spent volunteering also contributes to a healthy civil society. On average, people across selected OECD countries, spend four minutes per day in volunteer activities. People in New-Zealand, Ireland and the United States spend more than twice that time volunteering. [39]

40. Worklife balance to Health

Working shorter hours may be good for your health. The graph below shows the relationship between working hours and "potential years of life lost" (PYLL), both of which were taken from the OECD. PYLL is a measure of premature mortality, which estimates the average number of years a person would have lived if they had not died prematurely. It gives more weight to deaths among younger people. The recorded data of PYLL goes from 1970-2011, and is shown on the graph below.



Longer working hours seem to lead to higher premature mortality. (the strength of the relationship is significant, with an r-squared of 0.2). The implication that over-work is bad for you concurs with lots of research which links long working hours with poor health. Stress, for example, can contribute to range of problems like heart disease and depression. The pattern is not completely clear. The outlying figures to the right are those for South Korea. The country is famed for its long working hours, but also its healthy food, which may lower the risk of things like heart attacks and thereby reduce premature death rates. On the other side, Hungarians seem to get really stressed out at work – their PYLL is high despite working relatively short hours. If there is such a relationship between working hours and health, then shorter work hours might actually raise a person's total lifetime work by allowing them to live and work for longer. [40]

Commuting times (stress of long commutes and traffic jams) and international travel for work reduces worklife balance. This impacts physical and mental health. A study of diary entries found commuting the least enjoyable activity in a day. [41]

41. Worklife balance to Life Satisfaction

A balance between work and time to devote to family, community and other interests contributes significantly to Life Satisfaction. Some people opt to turn down promotions to maintain this balance.

References for links used in OECD model

[1] Brown, D., Woolf, J., & Smith, C. (n.d.). *The Determinants of Subjective Wellbeing in New Zealand: An Empirical Look at New Zealand's Social Welfare Function*. Wellington: Statistics New Zealand.

[2] http://www.oecdbetterlifeindex.org/topics/education/

[3] The Economist. (2014). Coming to an office near you. *The Economist, Jan 18 2014*.

[4] http://www.educationcounts.govt.nz/indicators/main/education-and-learning-outcomes/1919

[5] http://www.oecdbetterlifeindex.org/topics/community/

[6] OECD, 2006

[7] Florida, R. (2008). *Who's your city?* New York: Basic Books.

[8] http://www.oecdbetterlifeindex.org

[9] (http://www.nber.org/digest/mar07/w12352.html)

[10] Silva, J., F. de Keulenae, & Johnstone, N. (2012). *Environmental Quality and Life Satisfaction: Evidence Based on Micro-Data*.

[11] Engelbrecht, H.-J. (2009). Natural capital, subjective well-being, and the new welfare economics of sustainability: Some evidence from cross-country regressions. *Ecological Economics, 69*(2), 380-388. doi:http://dx.doi.org/10.1016/j.ecolecon.2009.08.011

[12] Ferrer-i-Carbonella, A., & Gowdy, J. M. (2007). Environmental degradation and happiness. *Ecological Economics, 60*, 509-516.

[13] Zidansek 2007 cited in Engelbrecht, 2009.

[14] Vemuri, A., & Costanza, R. (2006). The role of human, social, built, and natural capital in explaining life satisfaction at the country level: Toward a National Well-Being Index (NWI). *Ecological Economics, 58*, 119-133.

[15] Chiesura and de Groot 2003, Kahneman and Sugdens (2005) cited in Engelbrecht (2009)

[16] http://www.bbc.com/news/science-environment-25682368

[17] Ulrich (1984) cited by Ferrer-i-Carbonella, A., & Gowdy, J. M. (2007)

[18] California Energy Commission (2003) study cited by Ferrer-i-Carbonella, A., & Gowdy, J. M. (2007)

[19] New Zealand General Social Survey 2008 data (NZGSS)

[20] New Zealand General Social Survey 2008 data (NZGSS) (see figure 6.4). P.26 Crime Victimisation Patterns in New Zealand

[21] (http://www.scie.org.uk/publications/briefings/briefing19/)

[22] http://nzdotstat.stats.govt.nz/wbos/Index.aspx?DataSetCode=TABLECODE7904

[23] http://socialreport.msd.govt.nz/life-satisfaction/overall-life-satisfaction.html

[24] http://socialreport.msd.govt.nz/economic-standard-living/housing-affordability.html

[25] Statistics New Zealand (2010). Crime victimisation patterns in New Zealand: New Zealand General Social Survey 2008 and New Zealand Crime and Safety Survey 2006 compared. Wellington: Statistics New Zealand see Figure 6.5

[26] http://socialreport.msd.govt.nz/paid-work/satisfaction-work-life-balance.html

[27] Whetzel, D. L., & McDaniel, M. A. (2006). Predictions of national wealth. *Intelligence, 34*(5), 449-458.

[28] (https://www.mfe.govt.nz/environmental-reporting/consumption/)

[29] Uslaner, E., & Brown, M. (2005). Inequality, Trust, and Civic Engagement. *American Politics Research, 33*(6).

[30] (http://www.jrf.org.uk/sites/files/jrf/inequality-income-social-problems-full.pdf).

[31] Daly, H. (2005). Economics in a Full World. *Scientific American, 293*(3), 100–107.

[32] European Commission. (2015). *Green Jobs: Employment Potential and Challenges. Thematic Fiche*. Retrieved from http://ec.europa.eu/europe2020/pdf/themes/2015/green_jobs.pdf

[33] http://socialreport.msd.govt.nz/life-satisfaction/overall-life-satisfaction.html

[34] Tait, Padgett and Baldwin cited Brown, D., Woolf, J., & Smith, C. cited in Brown, D., Woolf, J., & Smith, C. (n.d.).

[35] Lounsbury, D. W., Hirsch, G. B., Vega, C., & Schwartz, C. E. (2014). Understanding social forces involved in diabetes outcomes: a systems science approach to quality-of-life research. *Qual Life Res, 23*, 959-969. doi:DOI 10.1007/s11136-013-0532-4

[36] http://www.oecdbetterlifeindex.org/blog/jobquality-itsnotjustabouthavingajob.htm

[37] (http://news.illinois.edu/news/11/0301happy_EdDiener.html

[38] http://socialreport.msd.govt.nz/safety/index.html

[39] http://www.oecdbetterlifeindex.org/topics/community/

[40] The Economist. (2014). Get a life – or face the consequences. *The Economist, Jan 30 2014*.

[41] Kahneman, D., Krueger, A. B., Schkade, D., Schwarz, N., & Stone, A. (2004). Toward national well-being accounts. *The American Economic Review, 94*(2), 429–434.

Appendix 5: The Workshop Process

The interlinked thinking method requires participants to attend two half day workshops. For the case studies these were held a week apart to avoid loss of momentum and to demonstrate the speed of completion. The Greater Wellington Regional Council workshops were organised by Richie Singleton. The Social Report workshops were organised by Philip Walker at Statistics New Zealand, and Peter Salter at the Ministry for Social Development. The workshop objective is shown in Figure x. If there is no requirement to assess the value added from using the interlinked thinking method the workshop process would be simplified.

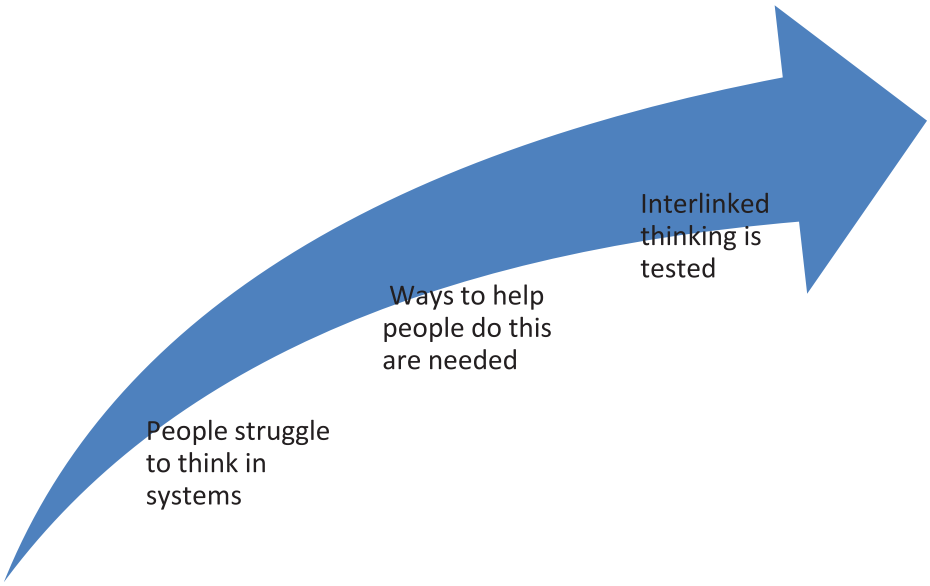


Figure A5: Workshop objective

Steps undertaken prior to the Workshop 1

Step 1	The host organisation determined who the participants would be at the workshops, sent out invitations and organised the venue. Participants were people actively engaged with the WR-GPI and Social Report processes.
Step 2	A list of the indicators to be linked was provided to the researcher by the host organisation. This was reduced by the researcher to make the interlinked process more manageable. The reduced set of indicators was agreed on by the workshop organisers.
Step 3	Using Vensim software (free on line) the indicators were randomly placed on a 'model page' and then printed out on large A1 sheets of paper.

The steps undertaken at Workshop 1 (duration 3 hours)

Step 1	The researcher introduced participants to the Sustainable Pathways 2 project and the research question of interest.
Step 2	The indicator set to be linked was discussed. The discussion covered what the definition of each indicator encompassed (definitions also provided as a print-out) and how the indicator set was arrived at. It was emphasised that the indicators were not set in concrete. Participants could add or reduce the set if they considered this appropriate.
Step 3	Participants filled out a questionnaire to establish their level of understanding and confidence in the indicator set as current used.

Step 4	An example of systems thinking was presented. The interlinked thinking method was explained and the type of output generated shown.
Step 5	An example of a CLD was provided and the CLD rules explained. The difference between a direct and indirect relationship was emphasised.
Step 6	Participants work in groups of 3-4 people to connect the indicators printed randomly on the A1 sheets. The small group structure mixes different levels of authority together and allowed all participants to collaborate. Small groups reduce problems associated with power dynamics. Participants link indicators by drawing in the *direct* links and designating the polarity of the links (i.e. whether the effect is an increase or decrease with an increase in the initial indicator). If the effect is likely to take place over time, the approximate length of that delay is indicated. The appropriate time unit depends of the system being studied and can represent hours, days, years, or any other weighting. Units are not important for the analysis. The rationale for each link is documented on A4 sheets provided. This is especially valuable for the researchers when links are less intuitive (see Appendix 6h for an example sheet).
Step 7	While participants work on the linking the researcher moves from group to group answering questions, querying links, making sure the CLD rules are followed correctly and clarifying issues that arise. At the end of the time allowed (approximately 1.5 to 2 hours) the researcher collects the A1 sheets and A4 logic sheets.

The steps undertaken between workshops by the researcher (a one week period)

Between workshops analysis of the links is carried out by the researcher. Analysis is done for the linked models constructed by each group and for the model of the combined links as follows:

Step 1	The links from the A1 charts were entered into the Vensim model page. The A4 logic sheet is used to check link logic. Any questionable links remaining are noted for discussion at Workshop 2.
Step 3	Links from the A1 charts are transferred to a *links matrix* constructed in Excel. Links where an increase/decrease in Indicator A resulted in an increase/decrease in Indicator B a given a value of 1. Links where an increase/decreases in Indicator A resulted in an decrease/increase in Indicator B a given a value of -1
Step 4	The roles of indicators are calculated from the absolute values in the *links matrix* spreadsheet.
Step 5	The *algorithm* is run using the *links matrix* as input. This generates an Excel *output spreadsheet* that gives: (i) For the whole system a summary of the unique loops in the system (this removes the double counting you get using the Vensim software); (ii) The feedback loops for each indicator and whether they are reinforcing or balancing; (iii) The total number of loops an indicator is part of and the number of links 'to' and 'from' that indicator; (v) the number of loops that would remain if an indicator was removed from the system; and (vi) the strong links in the system
Step 6	Loops generated via the algorithm are checked using Vensim software. This check makes sure no links have been missed/incorrectly transcribed in the matrix.

Step 7	Intervention points are calculated by transcribing the delays drawn between indicators into a separate Excel spreadsheet to construct the *cross time matrix*. Each link has a time period assigned. The time categories appropriate to use depends of the system being studied. In the case studies the following were used: No delay = 1; Short delay =3; Long delay = 10
Step 8	Using Vensim software construct tree branches. Tree branches expand each variable into its components. The branch ends when there are (i) no predecessors, (ii) an element has already been identified in the tree structure or (iii) link length gets to 3 which is the limit of the free Vensim software. Cause trees give the backward links that feed into that indicator, and use trees give the forward links that flow from that indicator.
Step 9	Map out the longest and shortest reinforcing and balancing loops in the system.
Step 9	An example of a what-if is sketched using the model developed by participants to show how linked indicators and the associated polarities can be used to explore impacts through the system.

The steps undertaken at Workshop 2 (duration 3 hours)

Step 1	The introduction to Workshop 2 emphasises that the objective of interlinked thinking to share and increase agreement on the real world conceptualisation of the system being studied (in this case well-being). The interlinked thinking method by design aims to better take into account relationships and complexity and thereby allow: (i) better understanding of the system which is essential for problem solving; (ii) participants to share mental model by making them explicit (to themselves and others); (iii) enhanced dialogue between participants; and (iv) make the system visible to all involved.
Step 2	Questionnaire results from Workshop 1 are presented so participants see the current level of knowledge/engagement with the indicator set in use.
Step 3	The researcher presents the analysis undertaken between workshops for each of the models. Diagrams of the individual models participants generated at Workshop 1 are presented as well as the combined model. Observations made by the researcher from doing the analysis are provided. For example statistics on the links common to all models or unique to individual models.
Step 4	The what-if is worked through. Participants first draw a behaviour-over-time graph of how they think change will occur and then the implications of the what-if are followed through and discussed.
Step 5	Participants fill out a questionnaire to establish the extent that interlinked thinking has changed their understanding of the system as it is represented and they feel they are better equipped to work with complexity.

The changes that were made after the WR-GPI workshops for the Social Report workshops:

- The indicators on the A1 sheet were given specific titles to ensure they are not misinterpreted. In addition a sheet with a more detailed description of each indicator was provided.
- The individual models as well as the combined model were analysed and reported on.

The changes after the Social Report workshops that will be done in future workshops (these are discussed in section 10.4.11):

- To avoid the start point influencing the links the method will stipulate different groups start in at the same random place.
- A longer discussion of indicators and their purpose at the start of Workshop 1. Indicators will be positioned in the bulls-eye framework to show what is included/excluded. More emphasis will be placed on the flexibility to add or remove indicators.
- Participants need to spend time towards the end of the first workshop considering whether any of their links are indirect, given only direct links should be included.
- Time should be allowed in the second workshop for participants to work through some of the balancing and reinforcing CLDs generated. The advantage of doing this is an increased understanding of flow-on effects and ability to examine what-ifs. It is also a mechanism to reconsider the legitimacy of the links and whether or not polarities have been correctly labelled.
- From the researcher’s perspective it would be an interesting exercise for participants to explore retrospectively why their model resulted in the specific roles (e.g. active, passive) being assigned to the various indicators.
- Placing a limit to the number of links allowed so that people put more thought into prioritising the links in their system could be experimented with.
- Highlight on the printed models the links that are different between the groups.
- Explore more what-ifs as requested by participants.

Appendix 6a: Questionnaire responses from workshop participants

WR-GPI responses

Participants at workshops were asked to fill in questionnaires at the start and end of the process to provide their view on the value of taking an interlinked approach. Copies of the questionnaires and graphs of the responses are in Appendices 6b, 6d and 6e.

The *pre-workshop* questionnaire was designed to gauge:

- Confidence in the current WR-GPI to measure well-being

The *post-workshop* questionnaire was designed to gauge:

- The added value of the CLD approach.
- Whether understanding of the relationships between indicators had changed.
- If new knowledge generated as a result of interconnected indicators was sufficient to increase participants understanding of policy interventions to move towards sustained well-being.
- If new knowledge generated as a result of interlinked indicators was sufficient to increase participants understanding of policy options to move towards sustained well-being
- Strengths and weaknesses of the CLD approach.
- Measurable change as a result of working with the CLD approach.
- Ways to improve the CLD approach.

Confidence in the current WR-GPI to measure well-being (Pre-workshop survey)

Most participants agreed that "the WR-GPI is an accurate way to measure well-being in the region" (Q1: 10 out of 10 agree). There was less certainty as to whether "the community outcome aggregated trends are an accurate representation of what is happening in the community" (Q2: 5 out of 10 agree or strongly agree; 3 neutral; 1 disagree; 1 no reply). There was greater confidence that "the aspect level (economic, social, environmental and cultural) aggregated trends provide an accurate representation of reality" (Q3: 7 out of 10 agree; 3 neutral).

Views on "providing a graph that shows the aggregated WR-GPI compared to GDP is useful for decision-making" were split (Q4:4 out of 10 agree; 1 strongly agree; 5 neutral). That "the aggregated WR-GPI provides a more meaningful measure of well-being than GDP" was an opinion more widely shared (Q5: 8 out of 10 agree or strongly agree; 2 neutral).

There was less consensus on the usefulness of the WR-GPI for policy and decision-making purposes. Only 2 respondents answered the question “the WR-GPI is used in policy discussions in my workplace” positively (Q6:2 agree; 4 neutral; 4 disagree). Most respondents did not think “the WR-GPI assists decision-making in my workplace” (Q7: 3 out of 10 agree; 4 neutral; 2 disagree; 1 strongly disagree). Respondents were more positive about “the WR-GPI brings important well-being issues to the attention of decision-makers” (Q8: 5 out of 10 agree or strongly agree; 3 neutral; 2 disagree) and that “the WR-GPI assist understanding of how well-being has changed in the region” (Q9: 6 out of 9 agree; 2 neutral; 1 disagree).

Participants were split on whether “the WR-GPI assists understanding of how well-being will change in the region” (Q10: 5 out of 10 agree or strongly agree; 3 neutral; 2 disagree). There was a similar split for the statement “the WR-GPI format makes relationships between indicators visible” (5 out of 10 agree; 3 neutral; 2 disagree).

Respondents were positive “the WR-GPI encourages integrated thinking” (Q12: 7 out of 10 agree or strongly agree; 3 were neutral). Just over half of participants were of the view that “the WR-GPI communicates the complexity of well-being in a regional context” (Q13: 5 out of 9 agree; 4 neutral; 1 no reply).

In summary, it could be said that the participants viewed the current WR-GPI positively, were happy with how information was presented, and felt that the aggregated indicator provided a reliable way to portray well-being in the region.

The added value of the CLD approach (from here on post-workshop questionnaire)

Respondents were positive that “my insight into the WR-GPI has increased due to the Causal Loop Diagram (CLD) process” (Q1: 6 out of 6 agree or strongly agree).

Everyone agreed “CLDs are a useful tool for assessing which WR-GPI indicators are important for measuring well-being in the region” (Q6: 6 out of 6 agree, or strongly agree). Most respondents also thought that “CLDs could be used to assist decision-making in my workplace” (Q8: 5 out of 6 agree or strongly agree; 1 neutral) and that “CLDs should be used to bring important well-being issues to the attention of decision-makers” (Q9: 5 out of 6 agree or strongly agree; 1 neutral).

That CLDs “assist understanding of how well-being changes occur in the region” to enable us to be proactive was agreed on by all respondents (Q10: 6 out of 6 agree or strongly agree).

“CLDs help communicate the complexity of well-being in a regional context” was agreed on by all but one respondent (Q11: 5 out of 6 agree or strongly agree; 1 neutral).

No respondent disagreed that “CLDs result in a *better* communication between participants than the WR-GPI trends and indicator graphs” but there was less certainty about this statement (Q17: 4 out of 6 agree or strongly agree; 1 neutral; 1 DK, N/A).

It was not generally considered that “CLDs give insight more quickly compared with the WR-GPI trends and indicators” (Q16: 3 out of 6 agree or strongly agree; 2 neutral; 1 disagree). A comment made was that it depended on the audience.

Whether understanding of the relationships between indicators has changed

“CLDs make relationships between indicators more visible” was strongly agreed on by four respondents (Q2: 4 out of 6 strongly agree; 1 agree; 1 neutral). There was endorsement that “CLDs help communicate the relationships of the WR-GPI” (Q3: 5 out of 6 agree or strongly agree; 1 neutral).

There was total agreement that “CLDs encourage integrated thinking” (Q12: 2 out of 6 agree; 4 strongly agree).

New knowledge generated as a result of interlinked indicators was sufficient to increase participants understanding of policy interventions to move towards sustained well-being

There was a positive response to “The impact matrix to identify potential intervention points in a system is useful” (Q4:2 out of 6 agree; 4 strongly agree). The scenario example was liked by all the respondents. This was done to assess whether “discussing intervention points through a CLD lens helped me understand interactions in a complex system” (Q5: 3 out of 6 agree; 3 strongly agree).

“Considering CLDs in a shared (group) context is a useful way to identify possible unintended consequences from possible intervention” was thought worthwhile by most people (Q13: 5 out of 6 agree or strongly agree; 1 disagree). There was less agreement that “considering CLDs a shared (group) context is a useful way to identify the time delays between a change in one indicator, and a consequence in another” (Q14: 4 out of 6 agree; 2 neutral).

New knowledge generated as a result of interlinked indicators was sufficient to increase participants understanding of policy options to move towards sustained well-being

It was generally agreed that “CLDs give more insight into well-being drivers than the WR-GPI trends and indicators” (Q15: 5 out of 6 agree or strongly agree; 1 neutral). There was also some agreement that “CLDs could assist when the WR-GPI is used in policy discussions in my workplace” (Q7: 4 out of 6 agree or strongly agree; 1 neutral; 1 DK N/A). A comment was added by one of the respondents, who agreed with this statement, but thought that how CLD's are used in the workplace needs more thinking through. .

Strengths and weaknesses of the CLD approach

There was general agreement concerning the need for more and better tools to deal with complexity. All respondents disagreed with the statement "CLDs show the world is too complicated and best not go there!" (Q18; 4 disagree; 2 strongly disagree).

Ways to improve the CLD approach

The last section of the questionnaire asked three open ended questions. These were: a) What were the best features of the session? b) What were the most disappointing features or problems of the session? c) What specific suggestions would you make if meetings like these were to be organised or held again?

Comments provided indicated the strength of the CLD approach was considered to be:

- "Ability to show complexity and critical elements all together.
- Insights into interrelationships are really valuable to discussions around indicators.
- Overview of complex thinking, causal loops, feedbacks. Excellent working group sessions.
- Having a chance to assess the value of particular indicators and challenge each other on their relationships.
- Excellent discussion. Presentation examples very good.
- I think highlights challenges and complexity and helps bring the reality of a situation to the fore and helps focus on what we can do in what otherwise may be overwhelming."

Of all the respondents, there was only one complaint, and that was that there was no "final product". This is something which is easily rectified with a report if warranted. ??A problem raised was the lack of a "final product".

Respondents provided the following suggestions for how the CLD approach could be improved for future use:

- From a council perspective politicians should test how useful the CLD approach is for decision-making, reporting, evaluation etc.
- More diverse representation is needed.

- Start to explore Council mechanisms - what are the levers? Are these different for different Territorial Authorities? What is the extent of Council contribution/influence on these levers?
- Provide data/knowledge/information above what is known (evidence-based) about associations as this can sometimes be counterintuitive.
- Systems links may be different by population group e.g. Pacifica/Māori, older or younger etc. It would be a good exercise to explore this.
- Having longer sessions would be beneficial.
- Starting with a high layer analysis or common system belief could give a more consistent CLD.
- The indicators on the A1 sheet need to have accurate titles to ensure they are not misinterpreted.
- Use a logic intervention model to structure the intervention process.

Social Report responses

Participants at workshops were asked to fill in questionnaires at the start and end of the process to provide their view on the value of taking an interlinked approach. Copies of the questionnaires and graphs of the responses are included in Appendices 6c, 6f and 6g.

The pre-workshop questionnaire was designed to gauge:

- Understanding of the current indicators used to measure well-being

The post-workshop questionnaire was designed to gauge:

- The added value of a CLD approach
- Whether understanding of the relationships between indicators has changed
- If the new knowledge generated as a result of interlinked indicators was sufficient to increase participants understanding of policy interventions to move towards sustained well-being.
- If the new knowledge generated as a result of interlinked indicators was sufficient to increase participants understanding of policy options to move towards sustained well-being.
- Strengths and weaknesses of the CLD approach.
- Measurable change as a result of working with the CLD approach
- Ways to improve the CLD approach

Understanding of the current indicators used to measure well-being (Pre-workshop survey)

Most participants agreed that "the suggested Social Report indicators will provide an accurate way to measure well-being in NZ" (Q1:10 out of 14 agree, 2 neutral, 2 DK N/A), and that "the suggested Social Report indicators will identify the important variables to measure social well-being in NZ" (Q2: 11 out of 14 agree or strongly agree, 3 DK N/A). The extent to which "the suggested Social Report indicators will be used in policy discussions in my workplace" was less certain (Q3: 6 agree; 4 neutral; 4 DK N/A).

The "Social Report indicators will increase understanding of policy options to move towards sustained well-being" was mostly agreed on, though one person strongly disagreed (Q4: 10 out of 14 agree or strongly agree; 3 neutral; 1 strongly disagree). That the "Social Report indicators will increase understanding of policy interventions to move towards sustained well-being" was also agreed on (Q5:12 out of 14 agree or strongly agree; 2 neutral).

"Social report indicators should be used to bring important well-being issues to the attention of decision-makers" was unanimously agreed (Q6: 14 out of 14 agree or strongly agree) as was "will assist understanding of how well-being has changed in NZ (Q7: 14 out of 14 agree or strongly agree). Participants were positive that the "Social Report indicators will assist understanding of how well-being might change in NZ" (Q8: 13 out of 14 agree or strongly agree).

Participants generally did not think that "relationships between Social Report indicators are visible" (Q9: 3 out of 14 agree; 6 neutral; 2 disagree; 1 strongly disagree; 2 DK N/A) and there was an even split between those that though the "Social Report indicators encourage integrated thinking" and those that were neutral or disagreed (Q10: 7 out of 14 agree or strongly agree; 5 were neutral; 1 disagree and 1 strongly disagree). Just over half of participants were of the view that the "Social Report indicators communicate the complexity of well-being in a national context" (Q11: 8 out of 14 agree; 3 neutral, 2 disagree, 1 DK N/A).

The added value of the CLD approach (from here on post-workshop questionnaire[93])

Most respondents agreed "my level of understanding of the Social Report indicators has increased due to the CLD process" (Q1: 8 out of 11 agree or strongly agree; 2 neutral; 1 DK). There was also some agreement that "CLDs make the relationships between Social Report

[93] Only 11 of the 18 participants who attended this session completed the questionnaires. A lesson learnt from this was in the future to include the questionnaire in the workshop rather than ask people to fill it in when the workshop was finished. This avoids missing the responses from people keen to get going.

indicators *more* visible than the normal reporting format" (Q2: 7 out of 11 agree or strongly agree; 2 neutral; 1 disagree; 1 DK).

The majority of respondents, though not everyone, believed "CLDs identify the important variables to measure well-being in NZ" (Q6: 7 out of 11 agree or strongly agree; 4 neutral). There was a similar response to the question "CLDs help communicate relationships between the Social Report indicators more than the normal reporting format" (Q3: 6 out of 11 agree or strongly agree; 3 neutral; 1 disagree; 1 DK).

"CLDs should be used to bring important well-being issues to the attention of decision-makers" was agreed on (Q9: 10 out of 11 agree or strongly agree; 1 neutral).

"CLDs assist understanding of how well-being might change in NZ" was agreed with (Q10: 9 out of 10 agree or strongly agree; 1 neutral; 1 no reply). A comment was added that there would be added value from considering population sub-groups such as gender, children, elderly, etc.

That "CLDs communicate the complexity of well-being in a national context" was agreed on by those answering this question (Q11: 9 out of 9 agree or strongly agree; 2 no reply). The comment that there would be added value from considering population sub-groups such as gender, children, aged etc. was also made for this question. No respondent disagreed that "CLDs result in a *better* communication between participants than the Social Report trends and indicators graphs", but there was a high degree of non-committal responses (Q17: 4 out of 11 agree or strongly agree; 6 neutral; 1 don't know; 1 no reply). There was obvious uncertainty about the extent to which CLDs were a better communication tool.

It was not considered that "CLDs give insight *more* quickly compared with the Social Report trends and indicators" (Q16: 3 out of 11 agree or strongly agree; 4 neutral; 2 disagree; 1 don't know).

Whether understanding of the relationships between indicators has changed

There was general agreement that "CLDs encourage integrated thinking" (Q12: 10 out of 11 agree or strongly agree; 1 neutral)

If the new knowledge generated as a result of interlinked indicators was sufficient to increase participants understanding of policy interventions to move towards sustained well-being

"The Impact Matrix approach to identify potential intervention points in a system is useful" was a statement generally agreed on (Q4: 8 out of 11 agree or strongly agree; 2 neutral; 1 don't know). "Discussing intervention points through a CLD lens helped me understand interactions in a complex system" was strongly endorsed (Q5: 10 out of 11 agree or strongly agree; 1 neutral).

Respondents were generally positive that "CLDs could assist understanding of policy options to move towards sustained well-being" (Q8: 9 out of 11 agree or strongly agree; 2 neutral).

"Considering CLDs in a shared (group) is a useful way to identify possible unintended consequences from possible intervention" was approved of (Q13: 10 out of 11 agree or strongly agree; 1 neutral). There was less agreement that "considering CLDs in a shared (group) context is a useful way to identify the time delays between a change in one indicator, and a consequence in another" (Q14: 7 out of 9 agree; 2 neutral; 1 disagree; 1 no reply).

If the new knowledge generated as a result of interlinked indicators was sufficient to increase participants understanding of policy options to move towards sustained well-being

Most respondents felt that "CLDs could assist understanding of policy options to move towards sustained well-being" (Q7: 10 out of 11 agree or strongly agree; 1 neutral).

There was divided opinion in the ability of CLDs to "give *more* insight into well-being drivers than the Social Report trends and indicators" (Q15: 5 out of 10 agree or strongly agree; 4 neutral; 1 disagree; 1 don't know; 1 no reply). A comment was made CLDs were more a supplement, not a primary or standalone measure.

Strengths and weaknesses of the CLD approach

There was general agreement that tools to deal with complexity are needed. All but one respondents disagreed with the statement 'CLDs show the world is too complicated and best not go there!" (Q18: 10 out of 11 disagree or strongly disagree; 1 neutral).

Ways to improve the CLD approach

The last section of the questionnaire asked four open ended questions. These were: a) What were the best features of the session? b) What were the most disappointing features or problems of the session? c) What specific suggestions would you make if meetings like these were to be organised or held again? d) What specific applications do you think the CLD approach could be used for?

The strength of the CLD approach was considered to be the discussion/debate that resulted from the interlinking process between staff from a range of agencies. The following comments were provided:

- Group work and discussion/debate
- Discussing in a diverse group the linkages involved in well-being and in doing so gaining a better understanding.
- Group discussions about the causal loops and understanding other people's mental model
- Group exercises
- For me having results for three groups was very useful as it highlighted that even in a structured activity results can vary considerably. This does not reflect badly on the methodology but rather highlights that an empirical exercise can be strongly influenced by the process followed and the discipline participants come from. This is highly relevant to discussion around composite measures and the importance of applying both qualitative and quantitative approaches to analysis of interventions and when setting priorities.
- It was also great to have participants from a range of agencies and an academic perspective (although this group already interacts regularly).
- The discussion in groups and the overall analysis done with explanations.
- Getting a group of fairly tightly connected central government people together and seeing the diversity in the implicit world/system views alongside the common threads.

Only one respondent expressed a disappointing feature or problem. This was a concern about comparing of the Social Report indicator approach with the CLD approach and the fact this was not fully discussed. [From the authors point of view the objective was to compare the two approaches only from the perspective of whether or not a *better understanding of the relationships between indicators allow stakeholders to increase their understanding of policy interventions or policy options to move towards sustained well-being.* It was not intended as a critique of the Social Report indicator process.]

In reply to the question on how the CLD approach could be improved for future use the following suggestions were made:

- In the model it would have been good to highlight the lines showing the differences between the three groups.
- The start point may influence the links drawn in, so the methodology should stipulate different groups start in the same place.

- A wider cross section of organisations participating will achieve a greater understanding of interlinkages between indicators and hence policy interventions.
- We would like to repeat the exercise at a domain, or sub-domain level.

Appendix 6b: WR-GPI measured change from participant responses

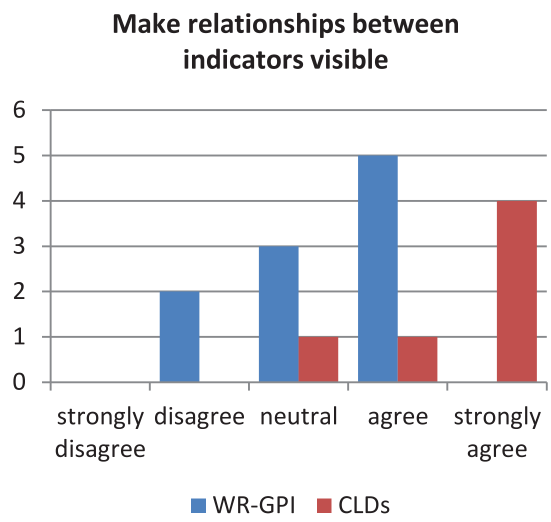
Seven of the pre and post questionnaires questions were aligned to compare participant's views on the different capabilities of the WR-GPI and CLDs (see graphs below). The participants viewed CLDs as consistently more effective than the WR-GPI stand-alone indicators. In the few situations where CLD's scored lower so did the WR-GPI.

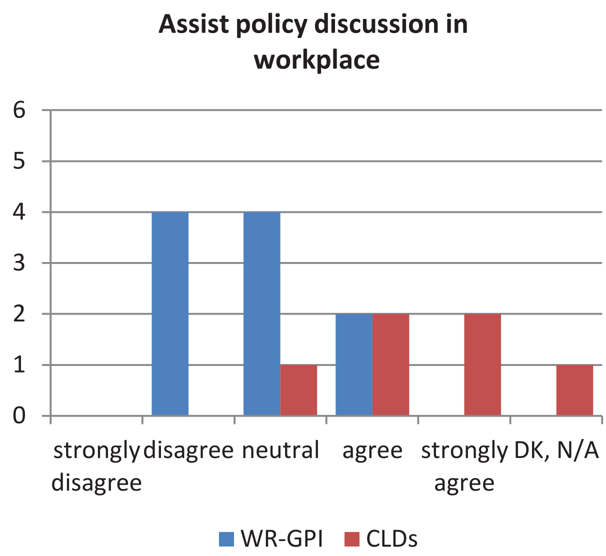
A comparison of responses based on the percentage of participants that agree or strongly agreed with a statement (% number) showed that:

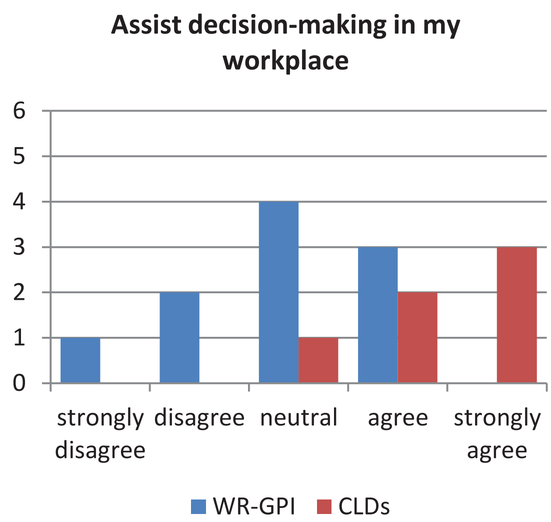
1. CLDs (83%) were convincingly considered a better way to make relationships between the WR-GPI indicators more visible than the WR-GPI reporting format (50%).
2. CLDs (67%) were considered significantly more effective than WR-GPI stand-alone indicators (20%) in assisting policy discussion in the workplace.
3. CLDs (83%) were considered significantly more effective than WR-GPI stand-alone indicators (30%) in assisting decision-making in the workplace.
4. CLDs (100%) were considered significantly more effective than WR-GPI stand-alone indicators (50%) in assisting understanding of how well-being change occurs.
5. CLDs (67%) were more effective than WR-GPI stand-alone indicators (40%) to bring important issues to the attention of decision-makers.
6. CLDs (83%) were considered better than the WR-GPI (50%) stand-alone indicators to communicate the complexity of well-being.
7. CLDs (100%) and the WR-GPI stand-alone indicators (70%) were considered to encourage integrated thinking.

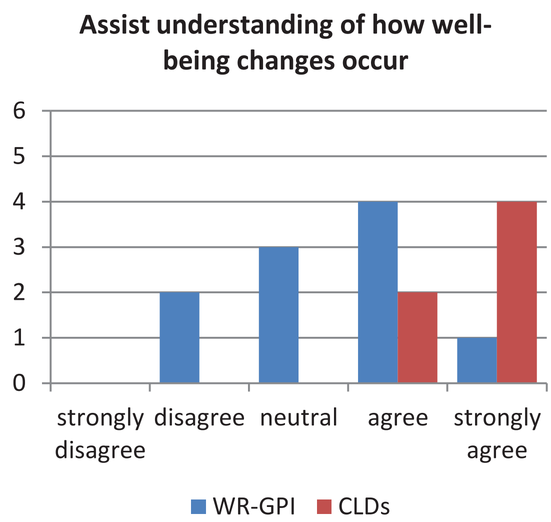
Graph Notes:

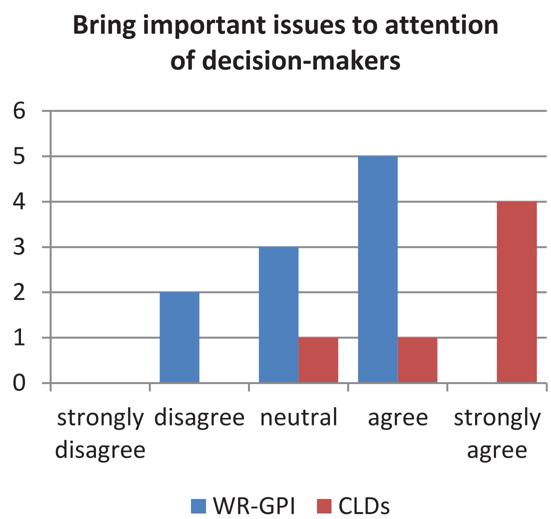
- The x axis shows the responses for the WR-GPI (blue) and CLDs (red) respectively. The y axis shows the number of responses in each of the categories from 'strongly disagree' to 'strongly agree'. DK, N/A (don't know, not applicable) categories were only included when there was a response in this category.
- The number of participants that filled in the WR-GPI survey was greater than for the CLD survey. Apologies were received from participants at the second workshop due to the unexpected Supercity announcement.

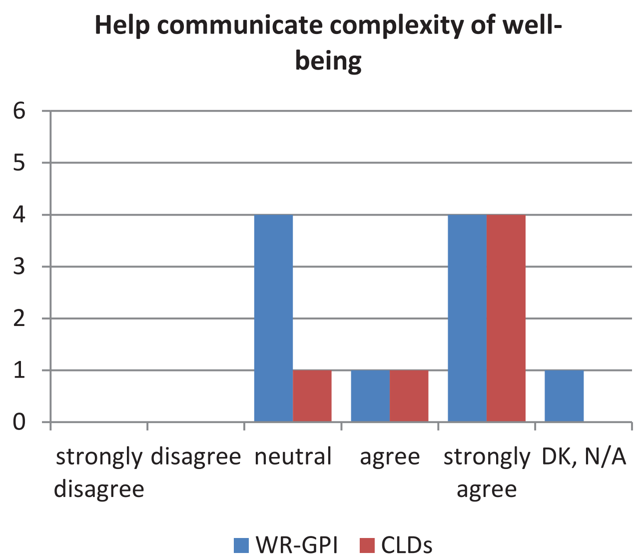

Make relationships between indicators visible
6
5
4
3
2
1
0
strongly disagree
disagree
neutral
agree
strongly agree
WR-GPI
CLDs

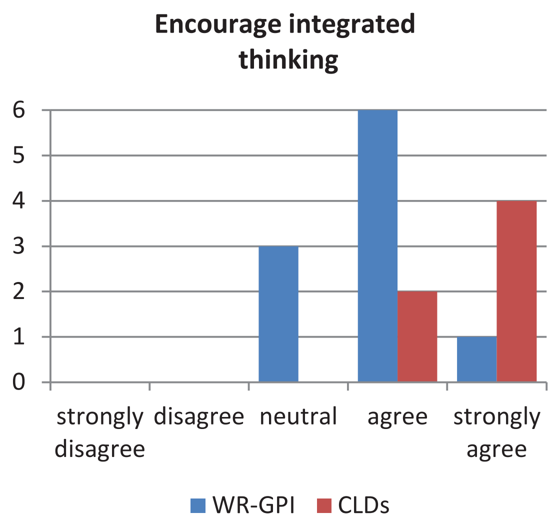

Assist policy discussion in workplace
6
5
4
3
2
1
0
strongly disagree
disagree
neutral
agree
strongly agree
DK, N/A
WR-GPI
CLDs


Assist decision-making in my workplace
6
5
4
3
2
1
0
strongly disagree
disagree
neutral
agree
strongly agree
WR-GPI
CLDs


Assist understanding of how well-being changes occur
6
5
4
3
2
1
0
strongly disagree
disagree
neutral
agree
strongly agree
WR-GPI
CLDs


Bring important issues to attention of decision-makers
6
5
4
3
2
1
0
strongly disagree
disagree
neutral
agree
strongly agree
WR-GPI
CLDs


Help communicate complexity of well-being
6
5
4
3
2
1
0
strongly disagree
disagree
neutral
agree
strongly agree
DK, N/A
WR-GPI
CLDs


Encourage integrated thinking
6
5
4
3
2
1
0
strongly disagree
disagree
neutral
agree
strongly agree
WR-GPI
CLDs

Appendix 6c: Social Report measured change from participant responses

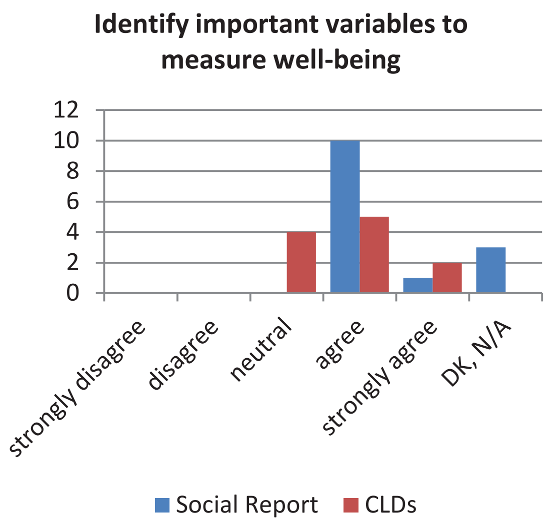
Eight of the pre and post questionnaires questions were aligned to compare participant's views on the different capabilities of the SR and CLDs. The participants viewed the SR stand-alone indicators as similar in effectiveness to CLDs in 5 of the 8 questions. CLDs were more effective in terms of making relationships visible, encouraging integrated thinking and communicating complexity.

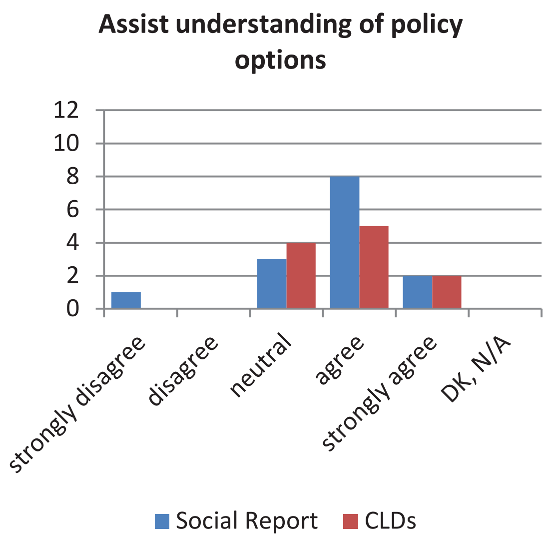
A comparison of responses based on the percentage of participants that agree or strongly agreed with a statement (% number) showed that:

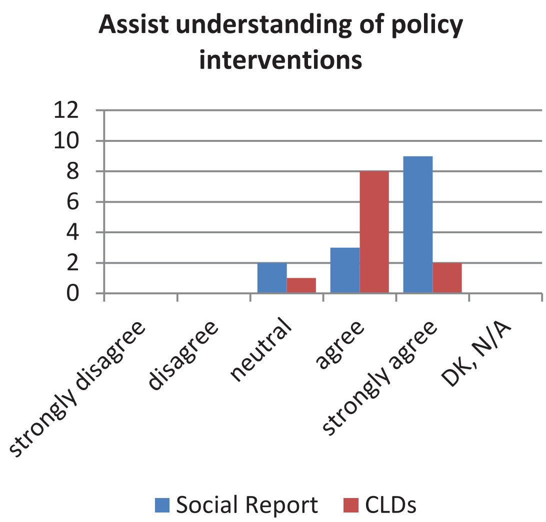
1. Both the SR stand-alone indicators (78%) and CLDs (64%) were considered satisfactory ways to identify important variables to measure well-being in New Zealand.
2. Both the SR stand-alone indicators (71%) and CLDs (64%) were considered satisfactory ways to assist understanding of policy options.
3. Both the SR stand-alone indicators (86%) and CLDs (91%) were considered able to assist understanding of policy interventions.
4. Both the SR stand-alone indicators (100%) and CLDs (91%) were considered able to be used to bring important issues to the attention of decision-makers.
5. Both the SR stand-alone indicators (93%) and CLDs (91%) were considered able to assist understanding of how well-being might change.
6. CLDs (63%) were considered a better way to make relationships between the SR (21%) indicators more visible.
7. CLDs were considered to encourage integrated thinking (91%), more than SR stand-alone indicators (50%).
8. CLDs were considered able to communicate the complexity of well-being (82%) more effectively than SR standalone indicators (57%).

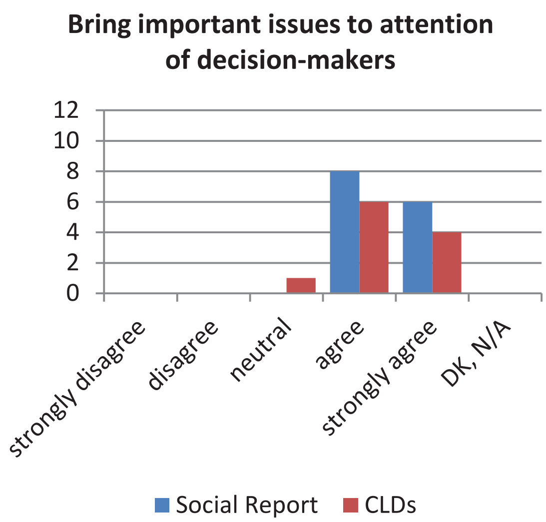
Graph Notes:

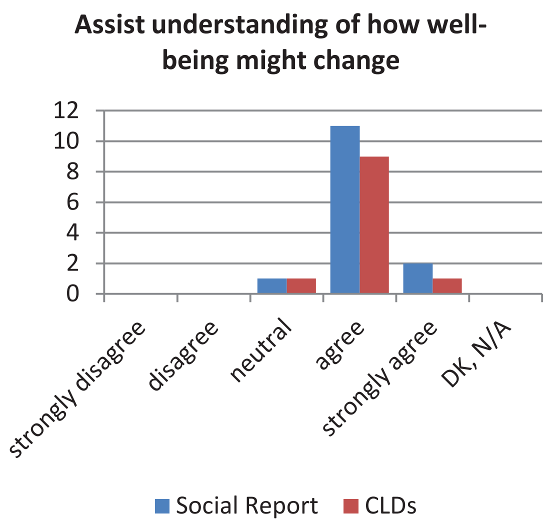
- The x axis shows the responses for the SR (blue) and CLDs (red) respectively. The y axis shows the number of responses in each of the categories from 'strongly disagree' to DK, N/A (don't know, not applicable).

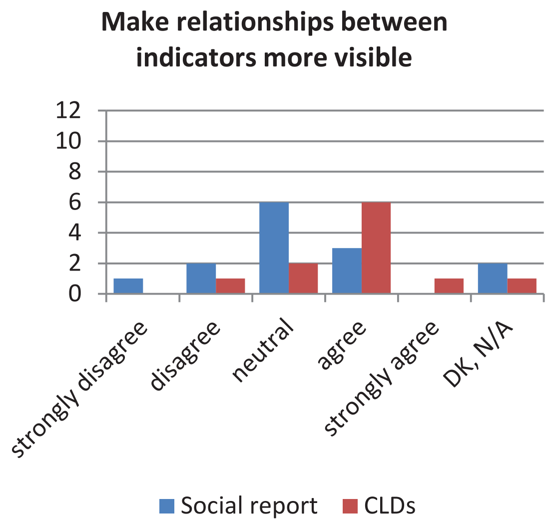

Identify important variables to measure well-being
12
10
8
6
4
2
0
strongly disagree
disagree
neutral
agree
strongly agree
DK, N/A
Social Report
CLDs

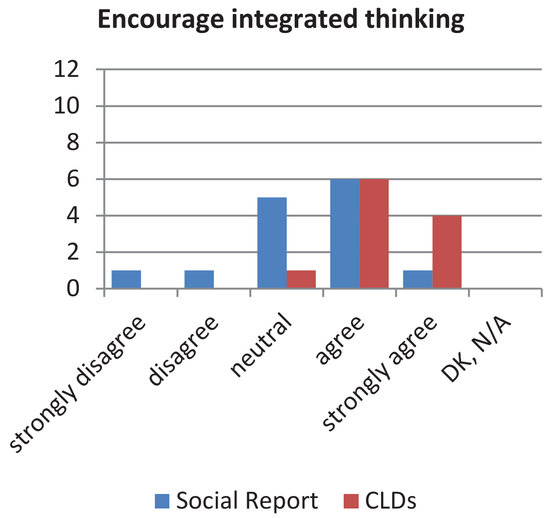

Assist understanding of policy options
12
10
8
6
4
2
0
strongly disagree
disagree
neutral
agree
strongly agree
DK, N/A
Social Report
CLDs

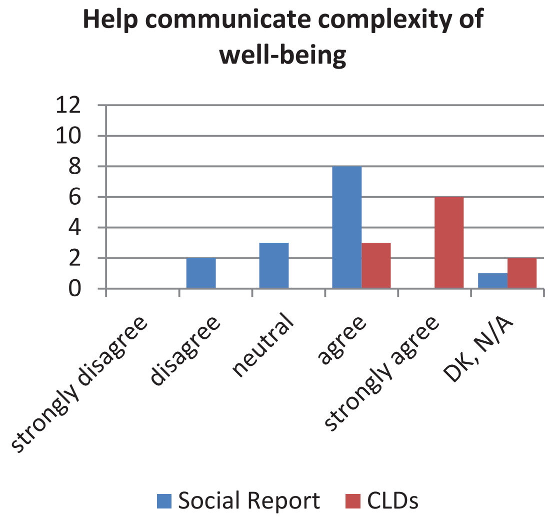

Assist understanding of policy interventions
12
10
8
6
4
2
0
strongly disagree
disagree
neutral
agree
strongly agree
DK, N/A
Social Report
CLDs


Bring important issues to attention of decision-makers
12
10
8
6
4
2
0
strongly disagree
disagree
neutral
agree
strongly agree
DK, N/A
Social Report
CLDs


Assist understanding of how well-being might change
12
10
8
6
4
2
0
strongly disagree
disagree
neutral
agree
strongly agree
DK, N/A
Social Report
CLDs


Make relationships between indicators more visible
12
10
8
6
4
2
0
strongly disagree
disagree
neutral
agree
strongly agree
DK, N/A
Social report
CLDs


Encourage integrated thinking
12
10
8
6
4
2
0
strongly disagree
disagree
neutral
agree
strongly agree
DK, N/A
Social Report
CLDs


Help communicate complexity of well-being
12
10
8
6
4
2
0
strongly disagree
disagree
neutral
agree
strongly agree
DK, N/A
Social Report
CLDs

Appendix 6d: WR-GPI pre-workshop questionnaire

The Sustainable Pathways 2 (SP2) project is about providing tools and processes to support local government with undertaking more integrated, dynamic, strategic decision-making.

A series of Mediated Modelling workshops were held in Wellington in 2010 with stakeholders from central and local government, business and voluntary organisations. The topic selected by stakeholders for further research by the SP2 team was whether or not the WR-GPI could be made more dynamic by looking at the interlinkages between indicators.

The objective is to advance measures of well-being (such as the WR-GPI) so they can better support decision-making by users (politicians, communities, officials).

My Research Question is: *Does better understanding of the relationships between selected indicator categories incorporated into a dynamic GPI allow stakeholders to have an increased understanding of policy interventions or policies required to move towards sustained well-being?*

These questions are to get feedback on your current view of the WR-GPI:

	strongly disagree	disagree	neutral	agree	strongly agree
1. The WR-GPI **indicators** are an accurate[94] way to measure well-being in the region					
2. The **community outcome** aggregated trends are an accurate representation of what is happening in the community					
3. The **aspect level (economic, social, environmental and cultural)** aggregated trends provide an accurate representation of reality					
4. Providing a graph that shows the **aggregated WR-GPI** compared with GDP is useful for decision-making					
5. The aggregated WR-GPI provides a more meaningful measure of well-being than GDP					
6. The WR-GPI is used in policy discussions in my workplace					
7. The WR-GPI assists decision-making in my workplace					
8. The WR-GPI brings important well-being issues to the attention of decision-makers					
9. The WR-GPI assist understanding of how well-being has changed in the region					
10. The WR-GPI assists understanding of how well-being will change in the region (i.e. enables us to be proactive)					
11. The WR-GPI format makes relationships between indicators visible					
12. The WR-GPI encourages integrated thinking					
13. The WR-GPI communicates the **complexity** of well-being (in a regional context)					

[94] Accurate= you think the measure is meaningful enough to be used in decision-making.

Appendix 6e: WR-GPI post-workshop questionnaire

The following questions are to get feedback on the last two workshops. Please indicate your post-workshop view.

	strongly disagree	disagree	neutral	agree	strongly agree
1. My insight into the **WR-GPI** has increased due to the Causal Loop Diagram (CLD) process.					
2. CLDs help communicate the dynamics of the WR-GPI					
3. The process of constructing and discussing CLDs improved my understanding of systems thinking					
4. CLDs make relationships between indicators visible					
5. Using the Impact Matrix to identify potential intervention points in a system is useful					
6. Discussing intervention points through a CLD lens helped me understand actions in a complex system					
7. CLDs are useful to assess which WR-GPI **indicators** are accurate to measure well-being in the region					
8. CLDs could assist when the WR-GPI is used in policy discussions in my workplace					
9. CLDs should be used to assist WR-GPI decision-making in my workplace					
10. CLDs should be used to bring important well-being issues to the attention of decision-makers					
11. CLDs help understand how well-being has changed in the region					
12. CLDs help understand where well-being will change in the region (i.e. enables us to be proactive)					
13. CLDs communicate the **complexity** of well-being in the region					
14. CLDs encourage integrated thinking					
15. The use of behaviour-over-time graphs (line graphs) assist thinking about future well-being in the region					
16. Considering CLDs in a shared (group) context is a useful way to identify possible unintended consequences					
17. Considering CLDs in a shared (group) context is a useful way to identify delays					
18. CLDs give *more* insight than the WR-GPI trends and indicators					
19. CLDs give insight *more* quickly compared with the WR-GPI trends and indicator graphs					
20. CLDs result in a *better* communication between participants than the WR-GPI trends and indicator graphs					
21. CLDs show the world is too complicated and best not go there!					

Suggestions for the future sessions

The WR-GPI journey has a way to go still! The follow questions will help plan future sessions.

a) What were the best features of the session?

b) What were the most disappointing features or problems of the session?

c) What specific suggestions would you make if meetings like these were to be organised or held again?

Appendix 6f: Social Report pre-workshop questionnaire

The Sustainable Pathways 2 (SP2) project is about providing tools and processes to support government to undertake more integrated, dynamic, strategic decision-making. My specific research interest is advancing measures of well-being so they can better support and inform end-user decision-making.

My Research Question is: Does better understanding of the relationships between selected indicator categories allow stakeholders to have an increased understanding of policy interventions or policies required to move towards sustained well-being?

These questions are to get feedback on your view of the suggested Social Report Indicators for 2015:

Please mark the box that best expresses your opinion.

	strongly disagree	disagree	neutral	agree	strongly agree	DK N/A
1. The suggested **Social Report** indicators will provide an accurate [95] way to measure well-being in NZ						
2. The suggested **Social Report** indicators will identify the important variables to measure well-being in NZ						
3. The suggested **Social Report** indicators will be used in policy discussions in my workplace						
4. **Social Report** indicators will increase understanding of policy options to move towards sustained well-being						
5. **Social Report** indicators will increase understanding of policy interventions to move towards sustained well-being						
6. **Social Report** indicators should be used to bring important well-being issues to the attention of decision-makers						
7. **Social Report** indicators will assist understanding of how well-being has changed in NZ						
8. **Social Report** indicators will assist understanding of how well-being might change in NZ (i.e. enables us to be proactive)						
9. Relationships between **Social Report** indicators are visible						
10. **Social Report** indicators encourage integrated thinking						
11. **Social Report** indicators communicate the ***complexity*** of well-being in a national context						

[95] Accurate= you think the measure is meaningful enough to be used in decision-making.

Appendix 6g: Social Report post-workshop questionnaire

The following questions are to get feedback on the last two workshops. Please indicate your view with a mark in the box that best expresses your opinion.

	strongly disagree	disagree	neutral	agree	strongly agree	DK N/A
1. My understanding of the **Social Report** Indicators has increased due to the Causal Loop Diagram **(CLD)** process						
2. **CLDs** make the relationships between **Social Report** indicators more visible than the normal reporting format						
3. **CLDs** help communicate relationships between the **Social Report** indicators more than the normal reporting format						
4. The Impact Matrix approach to identify potential intervention points in a system is useful						
5. Discussing intervention points through a **CLD** lens helped me understand interactions in a complex system (scenario example)						
6. **CLDs** identify the important variables to measure well-being in NZ						
7. **CLDs** could assist understanding of policy interventions to move towards sustained well-being						
8. **CLDs** could assist understanding of policy options to move towards sustained well-being						
9. **CLDs** should be used to bring important well-being issues to the attention of decision-makers						
10. **CLDs** assist understanding of how well-being might change in NZ (i.e. enables us to be proactive)						
11. **CLDs** communicate the ***complexity*** of well-being in a national context.						
12. **CLDs** encourage integrated thinking						
13. Considering **CLDs** in a shared (group) context is a useful way to identify possible unintended consequences from possible intervention						
14. Considering **CLDs** in a shared (group) context is a useful way to identify the time delays between a change in one indicator, and a consequence in another						
15. **CLDs** give *more* insight into well-being drivers than the **Social Report** trends and indicators						
16. **CLDs** give insight *more* quickly compared with the **Social Report** trends and indicators						
17. **CLDs** result in a *better* communication between participants than the **Social Report** trends and indicator graphs						
18. **CLDs** show the world is too complicated and best not go there!						

Suggestions for the future sessions

a) What were the best features of the session?

b) What were the most disappointing features or problems of the session?

c) What specific suggestions would you make if meetings like these were to be organised or held again?

d) What specific applications do you think the CLD approach could be used for?

Thank you!!

Appendix 6h: Links sheet

+ If A increases (or decreases) B will **in**crease (or **de**crease)

- If A increases (or decreases) B will **de**crease (or **in**crease)

2= Short term (2 years) indicator A reacts with a short time delay to changes in indicator B

5= Middle-term (5 years) indicator A reacts with a moderate time delay to changes in indicator B

10= Long term (10 years) indicator A reacts with a long time delay to changes in indicator B.

See example is provided below.

From	To	+ /-	Delay	Reason
EI1	*EI2*	*+*	*5*	*An increase in GDP invested in R & D increases business start-ups after a delay of approximately 5 years*