System Innovation for Sustainability:

A Scenario Method and a Workshop Process for Product Development Teams

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ABSTRACT

The overall objective of this research was to effectively link the activities/decisions at product development (micro-innovation) level in companies with the transformation which needs to take place at the societal (macro-innovation) level to achieve sustainability. The research took place in three phases. In the first phase a broad literature review was carried out which covered areas of sustainability science, futures studies and system innovation theory. In the second phase, based on the findings and insights gathered from the review of the literature, a theoretical framework was developed explaining how activities and decisions at product development level relates to the long term and structural changes required at the socio-technical system level to achieve sustainability. This theoretical framework was used to develop a scenario method to help product development teams in planning for system innovation for sustainability. The third phase of the research consisted of field work carried out to test, improve and evaluate the scenario method following an action research methodology.

The results of the field work indicated that the scenario method can aid product development teams to incorporate sustainability issues into their decision making in an effective way and can influence the business transformation which needs to take place as part of the societal transformation to achieve sustainability. Three outstanding issues related to the scenario method remain as potential areas for improvement and/or further research: 1) The trade-off between the time/cost efficiency of the scenario method and the depth of the output which can be achieved using it; 2) The conflict between the time horizon prescribed to be used by the scenario method and the planning periods conventionally used by businesses which is only a fraction of the time required to transform socio-technical systems, and; 3) The wider application scope of the scenario method.

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Abbreviations

ARC	Action Research Cycle
BM	Biomimicry
DfBoP	Design for Bottom-of-Pyramid contexts
CAS	Complex Adaptive Systems
CTC	Cradle-to-Cradle Design
CP	Clean(er) Production
DfE/S	Design for Environment/Sustainability
EIA	Environmental Impact Assessment
EC	European Council
ED	Eco-Design
EE	Eco-Efficiency
EF	Ecological Footprinting
EMS	Environmental Management Systems
EU	The European Union
EuP	EU's Ecodesign of Energy Using Products Directive (EC, 2005)
GT	The Great Transition Project
IE	Industrial Ecology
IPCC	Intergovernmental Panel on Climate Change
IPP	EU's Integrated Product Policy (EC, 2003a)
LCA	Life-Cycle Assessment
MEA	Millennium Ecosystem Assessment
MfE	New Zealand Ministry for the Environment
MLP	Multi-Level Perspective (of system innovation)
NGO	Non-Governmental Organisation
PCC	Planning of Strategic Innovation in a Polymeric Coating Chain Project
PP	Pollution Prevention
PSS	Product-Service Systems
RoHS	EU's Restriction of Hazardous Substances Directive (EC, 2003b)
SCORE	Sustainable Consumption Research Exchanges Network Project
SEA	Strategic Environmental Assessment
SNM	Strategic Niche Management
SNMap	Scenario Network Mapping

STD	The Dutch National Inter-Ministerial Programme for Sustainable Technology Development
STS	Socio-technical Scenarios
SusHouse	The European Union funded Strategies towards the Sustainable Household Project
TBL	Triple Bottom Line
TNS	The Natural Step
UNEP	United Nations Environment Programme
WBCSD	World Business Council for Sustainable Development
WCED	World Commission on Environment and Development
WG	Workshop Group
WRI	World Resources Institute

1. INTRODUCTION

1.1. SUSTAINABILITY, TECHNOLOGY AND SYSTEM INNOVATION

It is now commonly accepted that, in order to achieve sustainability, there is a requirement for societal transformation. This transformation covers institutional, social/cultural, organisational as well as technological change (Loorbach, 2007). The wide topic of the research behind this thesis could be referred to as sustainable technology development. However, it is widely recognised that sustainability is a system property rather than a property of system components in isolation (Clayton & Radcliffe, 1996). In this regard, technologies individually cannot be defined as sustainable or unsustainable and they should be considered within the socio-technical system they are meant to be used in. Only if the socio-technical system of concern is sustainable, then the technologies therein can be regarded as sustainable. Following this reasoning, in this research technology development is conceptualised as taking place in a system of socio-technical interactions. Therefore, the wide topic of this thesis is the transition to sustainable socio-technical systems or system innovation for sustainability.

Currently, significant effort is being put into developing a theory of system innovation for sustainability. The research in this area mainly focuses on governance of system innovation (or transition management as preferred by some researchers). Therefore, the area of system innovation is mainly studied for the purposes of developing science and technology policies in the broad interdisciplinary area of science and technology studies. Among the scholars contributing in the development of the theory of system innovation for sustainability, there is a common consensus that system innovation cannot be mandated or controlled via top-down approaches but can only be steered at its best (Loorbach & Rotmans, 2006; Geels & Schot, 2007; Loorbach, 2007). There is also evidence that bottom-up interventions play a significant role in societal change for system innovation (eg. Smith, 2004; 2007; Seyfang & Smith, 2007). The structural changes needed are long term, highly uncertain and disputed processes (Loorbach, 2007). In addition, in the long term, there is a lack of governmental policy and law to oversee societal processes (Holling, 2001). Even in shorter terms (in democracies), politicians cannot make decisions that involve structural changes without the support of societal groups and/or individuals who have stakes in the assumed/proposed changes (P. Weaver, personal communication, 27 March 2008). One of these major stakeholder groups within the society is industry. Industry constitutes the scope of this research.

1.2. Scope and Focus of the Research: Companies and Product Development Teams

Industry is one of the major causes of environmental deterioration, as well as the main agent for economic and social development (Schot, Brand & Fischer, 1997). Industry is a subset and an integral part of the society. It provides products and services for need fulfilment and well-being. It facilitates economic and social development as well as cultural exchange. It also facilitates human and technological development through generation of knowledge and plays an important role in job creation and employment. The companies are not only responsible to, and driven by, the interests of their shareholders. They also are responsible to, and influenced by, all stakeholders that they come in contact with, either directly (consumers, employees, governmental institutions, supply chain, etc.) or indirectly (competitors, educational institutions, public in general).

Initially, the scope of this research was limited to the manufacturing industry. However, separating the manufacturing and service industries was dismissive of the fact that these two industries are indeed very interrelated. There are no solid boundaries between products and services since each product is providing a service. For example, the service provided by a pen is to enable writing. The same service is provided also by the keyboard of a computer. Neither the pen, nor the keyboard would have any meaning or relevance in a society which had not invented writing. Therefore, (manufactured) products in a sense are mediators of services demanded in a society. Also, at the level of socio-technical systems, products and services cannot be separated from each other by meaningful boundaries since they jointly provide solutions of systemic property. For example, public transportation is provided through a combination of products and services such as buses driven by drivers, bus-stops built by the city councils, tickets sold by ticket agencies, etc. In endeavouring to achieve innovation at system level, this research focused on industry without making any distinction between the manufacturing and service industries.

The foundations of system innovation theory started to be established in early 1990s (e.g. Kemp, 1994). The past five years (as of 2010) saw a very intense development in the theory. These recent developments sufficiently articulated the dynamics within the socio-technical system (e.g. Geels, 2005a; Smith, Stirling & Berkhout, 2005), identified transition typologies (e.g. De Haan & Rotmans, 2007; Geels & Schot, 2007), developed transition arenas and even a management approach to such transitions (Loorbach, 2007), etc. This enormous intellectual accumulation provided explanations regarding how individual companies fit into the big and long-term picture of system innovation to a certain extent. Recent contributions articulated different perspectives on system innovation including business perspective, design perspective and consumer perspective through cases, examples, and some models (e.g. Van Bakel, Loorbach, Whiteman & Rotmans, 2007; Tukker, Charter, Vezzoli, Stø & Andersen, 2008). However, the question related to how to achieve empowerment of companies to enable their active participation towards system innovation for sustainability remained unanswered.

Existing tools and approaches for business sustainability have not been sufficient to guide the industry towards system level innovation. Two case studies Van Bakel et al. (2007) found that system innovation for companies poses a unique challenge. This unique challenge requires companies to run shadow-track strategies for developing new technologies in line with sustainability requirements while continuing their regular business practices. This unique challenge highlighted the requirement that companies needed to start intervening in their day-to-day activities and strategies. These interventions should be in such a way as to realise the required shift in their organisational models and technological output in the longer-term to achieve sustainability at societal level. In other words, innovation at system level requires companies to start aligning their products/services, strategies and business models with the society's long-term sustainability visions in a systemic way. This alignment process probably is the most important part of a shadow-track strategy.

This research found its niche in this alignment requirement. The lack of sufficiently detailed theory positioning companies in system innovation and tools developed for the use of companies to align their strategies with societal level visions of sustainability are identified as gaps to be filled by this research. Even though theory around system innovation is now very elaborate, not much effort has been put into how activities at product development level can be related to the change which needs to take place at the wider societal level. However, addressing product development level is crucial in system innovation because:

1. Product development function is the key business function of companies who are among the most important actors of system innovation;
2. Product development activity is the operational and strategic level within which the required business transformation will manifest itself over time;
3. Product development level is where the new technologies and products/services of these technologies will be developed;

4. Product development level is where the new markets and new user profiles of new socio-technical systems will be envisioned, and;
5. Product development level is where the technical characteristics and social meaning of the new products and services will be determined.

As a result, this research was formulated around the emerging need for tools and methods that would enable product development teams of companies to take system innovation on their agenda and start planning for it.

1.3. Research Objective and Aims

The overall objective of this research was to effectively link the activities/decisions at product development (micro-innovation) level in companies with the transformation which needs to take place at the societal (macro-innovation) level to achieve sustainability. The research took place in three distinguishable phases. The findings of each phase guided the direction of the following one. From the research objective, three main aims and several sub-questions were progressively formulated. Figure 1 shows these aims and questions in order of progression along with the findings of each phase as an input to the following phase.

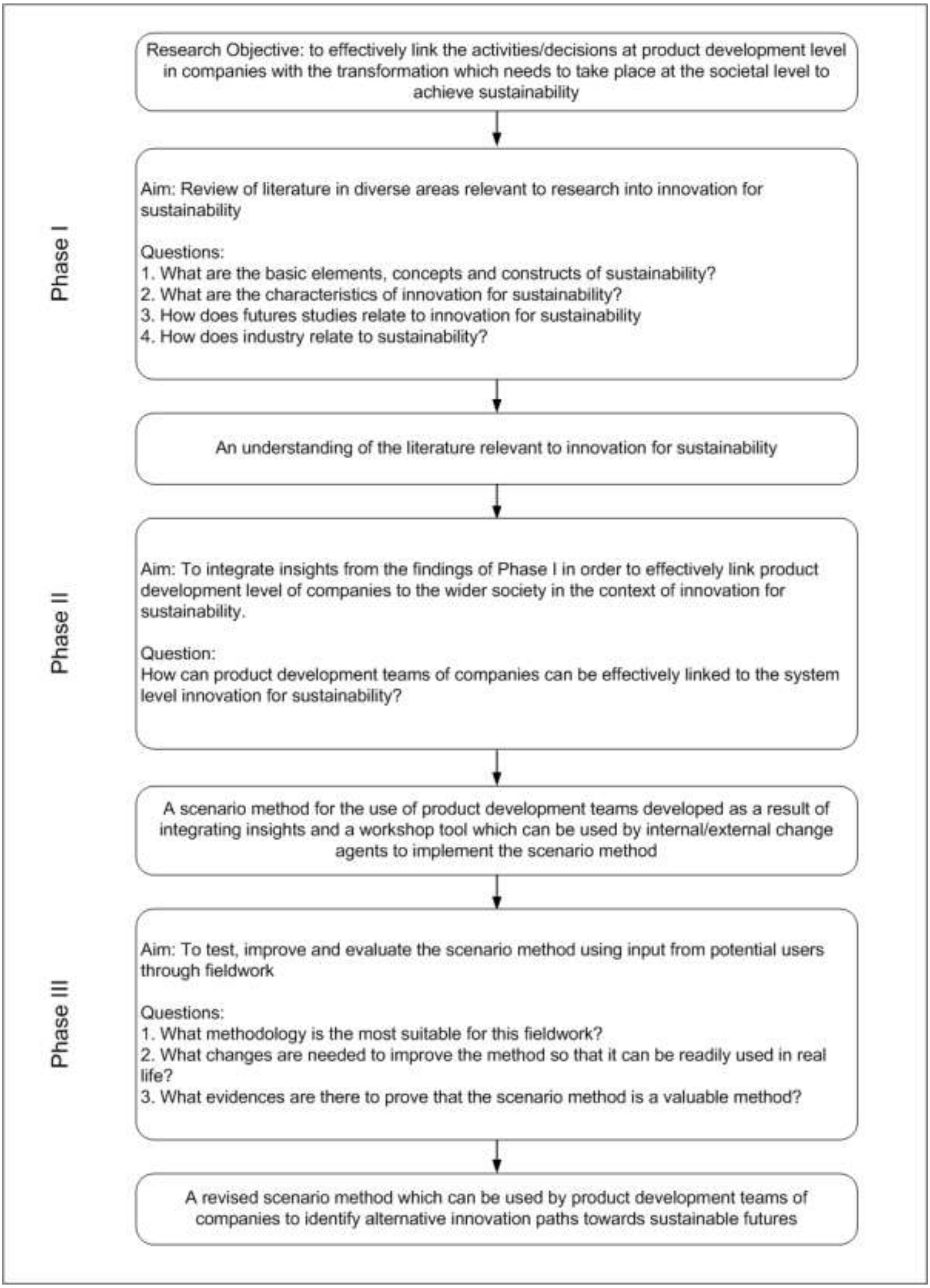

Figure 1. The progression of research aims and questions

1.4. RESEARCH CONTRIBUTION

In line with the research objective and aims, the contributions of this research can be summarised as:

- Integrating insights from a broad review of literature (Chapter 2, 3, 4 and 5) covering the areas of sustainability science, futures studies and system innovation to develop a theory and conceptual models about system innovation for sustainability at product development level (Chapter 6);
- Development, testing, improvement and evaluation of a scenario method and its operational tool (i.e. a workshop design) which is systemically linking the activities and strategic decisions of product development teams to the long term transformation which needs to take place at the level of socio-technical systems to achieve a sustainable society (Chapter 7, 8 and 9), and;
- For the social embedding of the research outcome, development and distribution of a step-by-step Facilitator’s Guide which can be used by change agents to run workshops (Appendix V).

The contribution of research is discussed in detail in Chapter 10 under Section 10.1 where the overall research outcomes and contributions are discussed.

1.5. STRUCTURE OF THE THESIS

This thesis is structured in three parts. The first two parts reflect the three progressive phases of the research as explained under Section 1.3. The final part completes the thesis by providing a review and discussion of the overall research as well as conclusions. Figure 2 shows this structure.

The first part of the thesis reports the findings of the review of literature relevant to innovation for sustainability. The chapters in this part respectively investigate the concept of sustainability and elements of sustainability science (Chapter 2), characteristics of innovation for sustainability and theory of system innovation (Chapter 3), the relationship between futures studies, sustainability and system innovation (Chapter 4), and finally the role of industry in achieving sustainability (Chapter 5).

The second part reports the development of the scenario method. It builds on the findings of the first part and integrates the insights gathered during the literature review. In this part, initially, the theoretical framework developed to explain how product development level relates to system innovation for sustainability is presented (Chapter 6). Following the articulation of the theoretical framework, the scenario method complete with its operational tool developed to aid product development teams in planning for system innovation for sustainability are outlined (Chapter 7). The scenario method is then tested, improved and evaluated through field work. For this aim, first the research methodology and design followed to carry out the field work are explained (Chapter 8). This is followed by reporting and discussing the results of the field work (Chapter 9).

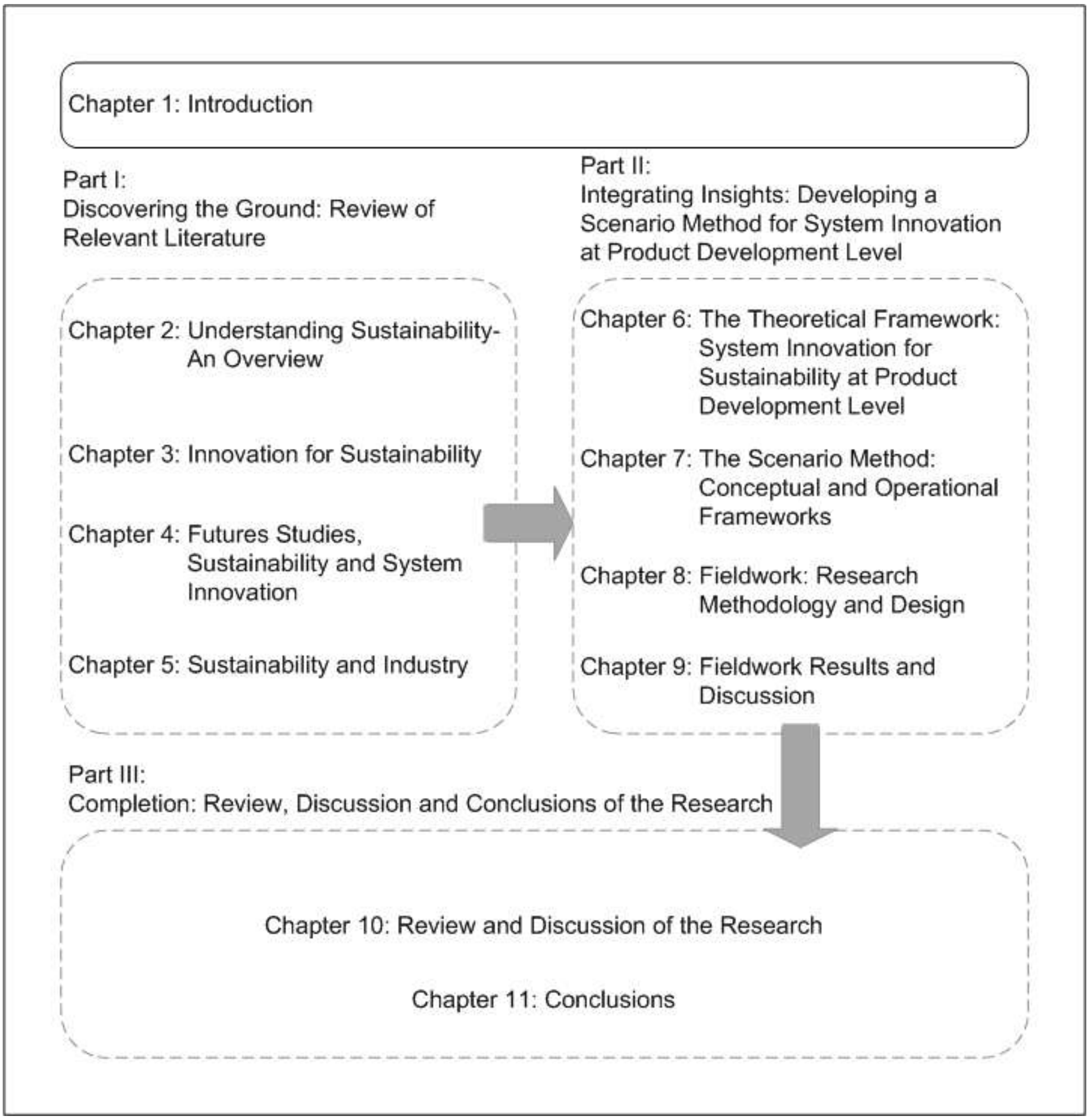

Figure 2. The structure of this thesis

The final part provides a review and discussion of the overall research (Chapter 10) and conclusions (Chapter 11) to complete the thesis. This part revisits the research objective and discusses the scientific and societal outcomes of the research. It articulates the contribution this research has made and provides suggestions for further research to carry the work undertaken in this research forward.

PART I

DISCOVERING THE GROUND: REVIEW OF RELEVANT LITERATURE

2. UNDERSTANDING SUSTAINABILITY – AN OVERVIEW

2.1. INTRODUCTION

The knowledge provided by sustainability science has to be one of the major building stones of any genuine attempt in the industry towards achieving sustainability. Sustainability science focuses on the dynamic interactions between the nature and the society, and therefore, it is identified to have different characteristics than of traditional disciplines (e.g. Kates et al., 2001; Clark & Dickson, 2003). A recent research which investigated the citation network in the field of sustainability science has identified 15 main research clusters under the field of sustainability science (Kajikawa, Ohno, Takeda, Matsushima, & Komiyama, 2007). Some of these clusters mainly receive input from natural sciences (e.g. biodiversity), some mainly from social sciences/humanities (e.g. rural sociology). However, most of these clusters are interdisciplinary areas and receive input from both natural sciences and social sciences/humanities (e.g. ecological economics, urban planning, etc.). All of these research clusters operationalise sustainability differently since their primary foci significantly differ from each other. However, all of the operationalisations of sustainability in any field are either explicitly or implicitly based on three fundamental and interwoven choices. The first of these choices relates to the sustainability model adopted. The second is the choice of the (sustainability) assessment method and is based on the adopted sustainability model. The third choice is the time frame within which sustainability is being assessed.

This chapter presents the findings of the literature review carried out to investigate the basics of sustainability science. It also explains and justifies how sustainability is operationalised in this research.

2.2. THE TWO MODELS OF SUSTAINABILITY

The widely quoted definition of sustainable development is ‘development that meets the needs of the present without compromising the ability of future generations to meet their own needs’ (World Commission on Environment and Development (WCED), 1987, p. 43). In this definition, there is no explicit reference either to the environment or to the economy, but the full emphasis is on the society. Therefore, concluding from the definition, the conceptual priority of sustainable development is sustaining human society and societal functions through preservation, (re)generation and equitable distribution of all assets supportive for human development.

Even though some of those assets are not solely in material form (education, safety, security, equal opportunity, etc.), they are associated closely with and require those assets in material form (need of physical infrastructure for education, safe and easy access to clean water, etc.). These assets are derived either directly from nature (i.e. ecosystem services) or through economic activities involving exchange of labour and materials with financial assets. In today's society, especially in industrial and post-industrial communities, the majority of individuals are not involved in obtaining resources directly from nature. Those resources reach individuals generally through a long supply chain and after numerous processes, which change the primary qualities of components and combine them in a different form and/or function. Thus, the goal of sustaining society requires understanding of all interactions and interdependencies taking place within society itself and among society, environment and economy.

There are two main models of sustainability, i.e. weak and strong. These models differ from each other according to the conceptualisation of interrelationships between environment, society and economy.

As defined by Flemmer and Flemmer (2005), the weak sustainability model suggests that 'the community can use its natural resources and degrade the environment as long as it is able to compensate for the loss with human capital (skills, technology, buildings, machinery, etc.) (p.31)'. As shown in Figure 3, this model is represented by three intersecting circles, each of which representing one of the pillars. Gowdy (2005) criticises the weak sustainability model as relying on the unrealistic assumption that 'either unlimited substitution among different kinds of capital is possible or that money is the universal substitute for anything' (p.216). He also argues that the weak sustainability model equates welfare with consumption. Sartorius (2006) points out that the assumption which equates welfare with consumption has limited accuracy since, for many types of natural assets, technical substitutes do not exist. In addition, the weak sustainability model does not take into account that the future benefit society will derive from capital cannot be predicted with certainty (Figge, 2005). Therefore, the weak sustainability model contradicts the requirement of not compromising the ability of future generations to meet their needs.

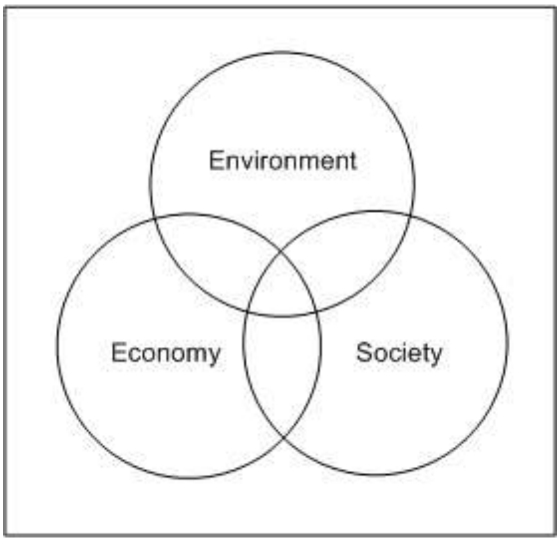

Figure 3. The weak sustainability model

The strong sustainability model (Figure 4) is also represented by three circles. However, for this model, the circles are concentric; environment is the outermost circle and followed respectively by society and economy. This model, contrary to the weak sustainability model, suggests that the different kinds of capitals subsumed by environment, society and economy cannot be substituted (Gray, 1992). These different capitals complement each other rather than substitute (Daly, 1990).

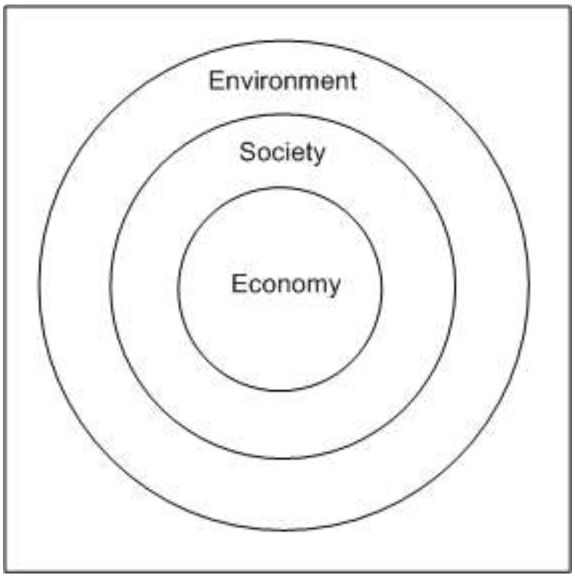

Figure 4. The strong sustainability model

Any operationalisation based on the weak sustainability model aims for sustaining the overall quantity of assets embedded in these interconnected aspects assuming that quality and/or quantity of individual aspects may be compromised. Any operationalisation based on the strong sustainability model, however, aims to sustain both overall and individual qualities and quantities of all assets embedded in all three aspects. The strong sustainability model captures the interconnectedness of environment, society and economy better than the weak sustainability model does. As a result, the model provides a holistic standpoint which allows a better understanding of the effects of interrelationships taking place between the environment, society and the economy. As stated previously, the conceptual priority of sustainable development is society. Nevertheless, hierarchical interdependencies dictate the environment to be the operational priority since both society and economy are dependent on the environment as the provider of resources necessary to live and to produce. The economy is the subset of society as being both the result and the cause of some societal activities.

There is a shift both in research and in policy development areas towards adopting the strong sustainability model. This research also adopts this model due to its better comprehension of the hierarchical and irreversible interrelationships between the three aspects of sustainable development.

Faber, Jorna, and Van Engelen (2005) carried out a study to determine conceptual foundations of sustainability and unravel how the use of the concept has changed among researchers since the 1960s. They analysed the definitions of sustainability within a framework consisting of three aspects; i.e. kind of artefact (what is to be sustained?), the goal orientation (absolute or relative perspectives in goal definition to achieve sustainability), behavioural interaction (whether sustainability is conceived as a static or a dynamic state). They concluded that both theoretical (definitions) and practical (operationalisations) contributions pointed to the evolution of the concept from being static and absolute to dynamic and relative.

This evolution points to a shift from an idealised, generalised, unidentifiable, and therefore, an unassessible concept to one which provides a ground for continuous improvement through comparative assessment. The static conceptualisation assumes no change over time within the subject artefact itself and between other artefacts in its environment. On the contrary, the dynamic conceptualisation of sustainability realistically assumes both internal and external changes will occur over time and space.

Along the same lines as Faber et al.'s findings, Hjorth and Bagheri (2006) define sustainability as a 'moving target' (p. 76), which is updated on a continuous basis as a result of continuously improving understanding. This dynamic approach gives us the opportunity to adapt our goals as we have new findings and/or if there is a change in conditions. Internal and external forces influencing change over the environment, society and economy continuously alter the conditions of sustainability. In relation to their definition of sustainability as a moving target, Bagheri and Hjorth (2007), suggest a process-based, multi-scale and systemic approach to planning for sustainability guided by a target/vision instead of traditional goal-based optimisation approaches.

2.3. COMPLEXITY AND CO-EVOLUTION

The meta-system of global ecological, economic, and social relationships can be analysed separately by defining boundaries. Nevertheless, any attempt to achieve sustainability will be meaningless if this analysis is carried out without taking the interdependencies of ecological, economic and social relationships into account. When the sub-systems under the meta-system and their interrelationships are taken into consideration, it is realised that both the meta-system and its sub-systems are complex systems. As a result, research and implementation regarding sustainability requires dealing with complex systems.

Defining complex systems is not an easy task. As a starting point, it can be said that complex systems are what simple systems are not. The major distinguishing characteristics of simple systems are predictable behaviour, small number of components with few interactions among them, centralised decision-making and decomposability (Casti, 1986). Therefore, through negation of these characteristics, the major characteristics of complex systems are identified as unpredictable behaviour, large number of components with many interactions among them, decentralised decision-making and limited or no decomposability. A distinction between complicated and complex systems is also useful here. Cilliers (1998) argues that if a system has a very large amount of components but yet can still be fully analysed, the system is complicated rather than complex. A complex system, on the contrary to a complicated one, has intricate sets of non-linear feed-back loops so that it can only be partially analysed at a time. In this sense a machine of any kind with large quantity of parts is complicated whereas a human being or an ecosystem is complex.

Funtowicz and Ravetz (1994) classify complex systems as ordinary and emergent. They argue that ordinary complex systems tend to remain in a dynamic stability until the system in overwhelmed by perturbations such as direct assaults like fire or invaders. Conversely, in emerging complex systems there is continuous novelty and these systems cannot be fully explained mechanistically or functionally since some of their elements possess individuality, intention, purpose, foresight and values. Any system involving society is thus an emergent complex system.

Hjorth and Bagheri (2006) state that complex systems cannot be fragmented without losing their identities and purposefulness. Similarly, Linstone (1999) refers to the general illusion or misassumption that we can break complex systems into parts and study these parts in isolation. He calls this as ‘a crucial assumption of reductionism (p.15)’ and points to the fact that such implied linearity is not a characteristic of complex systems. Indeed, in complex systems, the complexity is not determined by the characteristics of the components of the system but rather the relationships and the interaction between the components (Manson, 2001). The interaction between the components is not necessarily physical but can be in the form of information exchange as well (Cilliers, 1998). Mant (1997) gives an illustrative example of irreducibility of complex systems in his frog and bike analogy. One can dismantle a bicycle, carry out maintenance and reassemble it. The bicycle is still a bicycle and works perfectly. Nevertheless, if you separate a part of frog for any reason and keep on breaking it apart, the frog will perform unpredictable adjustments to survive until a time comes and the system (i.e. frog) tips over into collapse. Therefore, it is not possible to study complex systems meaningfully by breaking them into their components. At times when there is a need to define system boundaries, this should be done acknowledging how the part under study relates to the rest of the system.

In addition to irreducibility and emergent behaviour, the other characteristics of complex systems are self-organisation, continuous change, sensitivity to initial conditions, learning, irreducible uncertainty, and contextuality (Cilliers, 1998; Gallopín, Funtowicz, O'Connor & Ravetz, 2001; Manson, 2001; Cooke-Davies, Cicmil, Crawford & Richardson, 2007). Complex systems in general are hierarchic or have multiple-levels and each element is a subsystem and each system is part of a bigger system (Casti, 1986; Gallopín et al. 2001; Holling, 2001; Gallopín, 2004). Hierarchical structures have adaptive significance (Simon, 1974). This adaptive significance is not due to a top-down authoritative control but rather due to the formation of semi-autonomous levels which interact with each other and pass on material and/or information to the higher and slower levels (Holling, 2001).

It is impossible for an analyst to understand a complex system totally and correctly. However, some requirements can be extracted with references to characteristics counted above. First, emergent behaviour, sensitivity to initial conditions and learning which takes place by system components imply time-dependency of complex systems. This time-dependency is two-fold; both history of the system and the particular moment the analysis is undertaken will affect the outcome. Since context is important to understand adaptive systems, and there are multiple-levels in a system, an analysis should include more than one level as well as the different perspectives present in the system (Gallopín et al. 2001; Gallopín, 2004). For an effective analysis, the analyst needs to oversee the (sub)system being analysed from a vantage point. This vantage point should be at a higher or preferably meta-level to identify a context specific perspective while still acknowledging the interconnections between the (subsystem) being analysed and the rest (Espinosa, Harnden & Walker, 2008).

The three major subsystems of the meta-system (i.e. ecology, economy, society) and most of the sub-systems of these components (e.g. evolutionary processes, market operations, individual animals, companies, etc.) are classified under a special category of complex systems terminologically known as complex adaptive systems (CAS). The distinguishing feature of CAS is that 'they interact with their environment and change in response to a change (Clayton & Radcliffe, 1996, p.23)'. They are resilient; therefore, they 'can tolerate certain levels of stress or degradation (p. 31)'. As a result, sustainability of a CAS can be achieved if the adaptive capacity of it is not destroyed.

The sustainability of a single entity is dependent on and determined by sustainability of the other components with which that single entity has interactions. Together all these components form a system, and therefore, sustainability can only be achieved using non-reductionist, dynamic systems thinking. The subsystems of a system should be adaptable to changes which occur both in the other subsystems, and as a result, in the entire system. The subsystems must co-evolve to render sustainability possible.

The term co-evolution was first coined by Ehrlich and Raven in 1964 to explain the mutual evolutionary processes of plants and butterflies (Ehrlich & Raven, 1964). Even though the term first emerged in the area of evolutionary biology, it spread in other, especially interdisciplinary, domains studying interactions between natural and human-made systems (Norgaard, 1984, 1995; Winder, McIntosh, & Jeffrey, 2005; Rammel, Stagl, & Wilfing, 2007). Some of the other domains which use the co-evolutionary approach to explain, analyse and manage interacting natural and social systems include technology studies, organisational science, environmental and resource management, ecological economics and policy studies (Rammel et al., 2007; Kallis, 2007a).

It is important here to note that, despite many similarities between biological evolution and social, cultural, technological and economic change, there are differences as well (Rammel & Van Den Bergh, 2003; Kallis, 2007b). In the wider context of sustainable development, co-evolutionary change does not necessarily happen on a reactionary basis as generally happens in ecosystems. Rather, in socio-economic or socio-technical levels, it can also be deliberately aimed at both the individual and collective levels by system components in accordance with changing system conditions (Holling 2001;

Cairns Jr, 2007; Kemp, Loorbach, & Rotmans, 2007). Co-evolution is reflexive and refers to the mutual change of all system components. During this mutual change, one component may or may not dictate a change over other(s).

2.4. OPERATIONAL TIMEFRAME

When considering sustainability, selection of a temporal frame of analysis becomes an important issue since, as discussed in the previous section, the systems of concern are time-dependent. These systems change over time and their interdependent components have different paces of change. The change speed of one component influences the change speed of others. Even though the length of time frame to be used when planning for sustainability is still being debated, the concept intrinsically requires a long-term future orientation. Long term is not a static, predetermined time span to be applied to the whole of the meta-system. Rather, it is determined in line with the nominal temporal (and also spatial) scales of the system component whose sustainability is of concern (Costanza & Patten, 1995). For cities, for example, the nominal life span can be accepted to be 1000 years or more. However, for a human being, the nominal life span, and hence the 'long term' in which sustainability is monitored and assessed will be around 70 years.

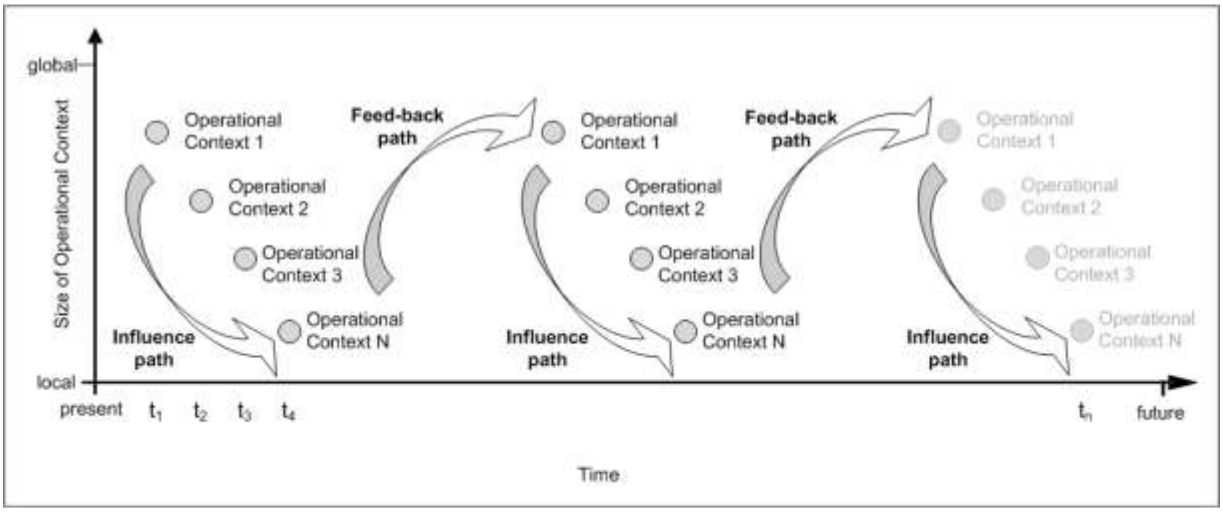

Figure 5. Temporal and spatial scale versus size of the operational context (adapted from Gaziulusoy & Boyle, 2008)

When sustainability of a complex system is of concern, from smaller (smallest) to broader (broadest), there is a continuum of hierarchically interdependent operational contexts to which the concept of sustainability can be applied (Figure 5). According to the operational context, the length of 'long term' should change; as the operational context widens, the length of planning should extend in order to cover subsumed operational contexts and to connect them both spatially and temporally

(Gaziulusoy & Boyle, 2008). Nevertheless, this is not a one-way linear relationship. While planning at higher-order operational contexts requires longer and wider scales to cover lower-order contexts, lower-order contexts are externally bound by this larger scale no matter what their internal scale is (Holling, 2001). As an illustrative example, climate and vegetation can be considered. Climatic cycles are much longer than vegetation cycles. Successive generations of the same type of vegetation are dependent on annual rainfall and temperature. In accordance with the resilience of vegetation, variations in rainfall or temperature between years are tolerable to some extent. But as climatic change affects the rainfall or temperature over the long term, first, some characteristics of the vegetation and then the type of vegetation will need to change. This also applies to human-nature interactions, as the previous example could easily be adapted, for example, to agriculture-climate or technology-resource cases. Therefore, lower-order operational contexts should be aware of issues and scales of higher-order operational contexts, first, to guarantee their success and, second, to guarantee sustainability of higher-order contexts.

2.5. ASSESSING SUSTAINABILITY

Gasparatos, El-Haram and Horner (2008) recently carried out a critical review of some approaches to assess progress towards sustainability. The approaches they reviewed are classified as monetary tools, biophysical models, and, sustainability indicators and composite indices. Their analysis concluded that, the available approaches to assess sustainability are reductionist, each promote a particular and different sustainability vision and, despite their advantages, individually they are not capable to address the complexity and adaptation associated with the systems being considered.

Pope, Annandale and Morrison-Saunders (2004) analysed some of the other, more comprehensive sustainability assessments. Some of the sustainability assessments they analysed are derived from environmental impact assessment (EIA) and strategic environmental assessment (SEA) by incorporating social and economic considerations along with environmental ones. This incorporation does not perform an integrated approach. EIA- and SEA-driven sustainability assessments demonstrate a Triple Bottom Line (TBL) approach and reflect the weak sustainability model by considering the environment, society and economy separately and measuring the overall impact. Therefore, EIA- and SEA-driven sustainability assessments promote trade-offs, often at the expense of the environment and they also have practical challenges and limitations (Pope et al., 2004).

Another type of sustainability assessments Pope et al. (2004) analysed are objectives-led integrated assessments. These assessments derive from objectives-led SEA and are more compatible with the concept of sustainability since the assessment is carried out by comparison against aspirational objectives. However, this particular type of sustainability assessments demonstrates the problem of conflicting strategic goals at different planning levels. The general criticism of Pope et al. (2004) is that integrated assessments are 'direction to target' approaches in which the target is an unknown, undefined sustainability state. As a result of their criticism regarding EIA-/SEA-driven and objectives-led integrated assessments, Pope et al. (2004) recommend the use of sustainability principles as criteria for assessment.

Nevertheless, principles based assessments come with their own problems. Defining sustainability principles can be useful and meaningful for decisions covering long term, but this is a very challenging task if not impossible. These either have to be very general or should be subjected to reassessment and refinement in line with the knowledge that is increased or elaborated within time or as the system conditions change. In the former case of setting very general principles, the assessment will have high subjectivity due to possible different interpretations of these general principles. The latter case is not less challenging than the former one but it better reflects the dynamic and complex characteristics of the sustainability concept.

In line with the dynamic concept of sustainability, Costanza and Patten (1995) argue that sustainability can only be determined after the fact. We cannot really know whether an action, a product or a process is sustainable. Sustainability is not an absolute goal. The dynamic nature of the meta-system and its subsystems and the new knowledge gathered about those systems continuously alter our assessment criteria. Assessing sustainability cannot be done before the actual event takes place and, once the event happens, there is no possibility for a precautionary action. In addition, what is regarded as sustainable today may not be so in the future. As the system conditions change, the sustainability requirements will change as well. Therefore, principles based assessments will either be unsatisfactory in meeting long-term sustainability requirements or will be over-precautionary taking into consideration the worst case scenario about the system of concern. An under-precautionary approach can cause the system to collapse as a result of crossing tipping points in the system. On the other hand, an over-precautionary approach can cause an unnecessary decrease in the utilisation of system potential towards meeting intergenerational and intragenerational needs and, therefore, can slow the process of sustainable development down.

Sustainability does not refer to an infinite life span but rather 'A system is sustainable if and only if it persists in nominal behavioral states as long as or longer than its expected natural longevity or existence time' (Costanza & Patten, 1995, p. 195). Consequently, anything which reduces a system's natural longevity will reduce its sustainability. Boyle (2004) suggests that 'probability of an event causing the conditions of a system to become non-operational for the system determines how likely the system is to be unsustainable' (p. 20). Both Costanza and Patten (1995) and Boyle (2004) point out that sustainability is time and space dependent, that is to say, there is a temporal and spatial hierarchy of systems and sub-systems which should be taken into account when considering sustainability. The nominal lifespan of a system will be longer than the lifespan of any of its sub-systems to render evolution possible. Boyle (2004) also points out the location-specific characteristic of sustainability. She gives the examples of effects of acid rain and air emissions being different in different locations due to different local conditions.

Boyle (2004) suggests using risk assessment when planning for sustainability within long term. Instead of setting principles, she sets two goals (i.e. humans will be here and current cities will be here) and makes four assumptions (i.e. the basic laws of physics and thermodynamics will still hold; materials and energy will still be required to meet human needs and will have to be provided from existing global resources; basic human physical and psychological needs will not have changed; human society will still be part of a complex, dynamic interaction of systems which will include the environment) in order to establish a frame within which a 'risk-to-sustainability assessment' will be carried out. Boyle's framework is a conceptual and foundational approach, which is promising in dealing with the dynamism and complexity embedded in the sustainability concept.

Adopting a risk approach to sustainability is also justified when the scope and focus of this research, i.e. companies and product development teams, is considered. General risk assessment is well understood and widely used by companies. If sustainability issues can be framed in line with approaches well understood and used by companies, a proactive behaviour can be encouraged in companies to address sustainability issues. Therefore, a risk approach to assessing sustainability is adopted in this research.

2.6. SUMMARY OF FINDINGS AND INSIGHTS GATHERED IN THIS CHAPTER

This chapter investigated the basics of sustainability science and explained how sustainability is operationalised in this research. The key findings of and insights gathered in this chapter are:

- The conceptual priority of sustainable development is sustaining the society and societal functions through preservation, (re)generation and equitable distribution of all assets supportive for human development;

- Sustaining society requires understanding of all interactions and interdependencies taking place within society itself and among society, environment and economy. Among the two models of sustainability, the strong sustainability model better comprehends the hierarchical and irreversible interrelationships between these three components.
- The environment, economy, society and most of the sub-systems of these components are classified as CAS. Therefore, they interact with each other and respond to a change taking place in their environment;
- Sustainability is a system property and not a property of the system components in isolation. Therefore, in order to study and to work towards sustainability of a single entity, the system within which that entity resides has to be considered with a non-reductionist approach and by utilising dynamic systems thinking. In order to achieve sustainability at system level, the subsystems must co-evolve;
- Sustainability is not an absolute goal but rather is a moving target, requirements of which continuously change both as a result of changing system conditions and since our understanding about the system under the study improves over time. Therefore, our assessment criteria alter continuously;
- Sustainability does not equate to an eternal continuity of the entity under study. If an entity persists in nominal behavioural states as long as or longer than its expected natural longevity or existence time, it can be accepted as sustainable;
- In order to establish whether something has persisted in nominal behavioural states as long as or longer than its expected natural longevity or existence time, a final assessment on the sustainability of that thing can only be made after that time span has passed, i.e. after the fact;
- In order to be able to assess whether something has persisted in nominal behavioural states as long as or longer than its expected natural longevity or existence time or not, i.e. whether it was sustainable or not, a long-term orientation is necessary. Long term is not a static, predetermined time span but rather is determined in line with the nominal temporal (and also spatial) scales of the system component whose sustainability is of concern;
- Since an entity or a system can be accepted as being sustainable if, at the time of the assessment, it is concluded to have persisted in nominal behavioural states as long as or longer than its expected natural longevity or existence time, anything which reduces a system's natural longevity will reduce its sustainability;
- Since sustainability is a dynamic target, it can only be determined after the fact and since anything which reduces a system's natural longevity will reduce its sustainability, probability of an event causing the conditions of a system to become non-operational for the system

determines how likely the system is to be unsustainable. Therefore, a risk approach to assessing sustainability can be useful to identify and mitigate factors reducing system longevity.

3. INNOVATION FOR SUSTAINABILITY

3.1. INTRODUCTION

Traditionally innovation has mainly been the interest of business and economics literature. In the past decade or so, innovation theory has become increasingly interesting for scholars of many disciplines dealing with sustainability. Innovation - not only technological but also institutional, organisational and social/cultural - is considered to be a crucial element to achieve sustainability. A coherent and comprehensive theory specifically dealing with innovation for sustainability is currently emerging. This emerging theory explains innovation differently than purely economical and/or sociological theories of innovation, merging them under a co-evolutionary and socio-technical understanding of innovation to initiate a transformation towards sustainability and, expanding the general innovation theory at the same time. This chapter provides a critical review of this emerging literature about innovation for sustainability.

3.2. CONTEXT: A CO-EVOLUTIONARY FRAME

In innovation studies there are two main schools of thought, one following Schumpeter (1934) and the other, Schmookler (1966). The Schumpeterian school accepts that technological change happens as a series of shocks or explosions unevenly distributed over time and space. On the other hand, the Schmooklerian school argues that innovations respond to demand pressures or changes in factor costs within the economy (Freeman, 1992). The former innovation model is referred widely as 'technology-push' or 'radical' and the latter is known as 'demand-pull' or 'incremental' models. Many authors accept both of these taxonomic models as valid (see for example, Freeman, 1992; Pavitt, 1984; Dosi, 1982).

At the company level, OECD (1997) defines three types of innovation: product innovations (p. 31), process innovations (p. 32), and organisational innovations (p. 36). OECD (1997) breaks down product innovations into two as technologically new product (i.e. radical innovation) and technologically improved product (i.e. incremental innovation) according to the degree of novelty or change they bring about.

Rennings (2000) criticises the OECD definition as being useful but insufficient for innovation research purposes within the context of sustainable development. He argues that the OECD definition does not involve explicit reference to environmental and non-environmental innovations separately, even though determinants of environmental innovations differ from those of non-environmental ones. Klemmer, Lehr and Löbbe (1999) cited in Rennings (2000, p. 322) refer to environmental innovations as 'eco-innovations' and define them broadly as:

> … all measures of relevant actors (firms, politicians, unions, associations, churches, private households) which:
>
> - develop new ideas, behaviour, products and processes, apply or introduce them and
> - which contribute to a reduction of environmental burdens or to ecologically specified sustainability targets.

The importance of making a distinction between environmental and non-environmental innovations lies in the peculiarity that regulatory framework is a key determinant for eco-innovations (Rennings, 2000; Cleff & Rennings, 1999). This argument is supported through empirical evidence provided by Green, McMeekin and Irwin (1994), Porter and van der Linde (1995), and Kemp (1997). Rennings (2000) and Cleff and Rennings (1999) define this peculiarity as 'regulatory push/pull' effect (Figure 6). Rennings (2000) states that specific regularity support is needed for eco-innovations since these innovations are generally not self-enforcing and factors of technology-push and market-pull alone are not strong enough. Rubik (2002) as cited in Rehfeld (2006) adds company specific features as the fourth determinant of eco-innovations.

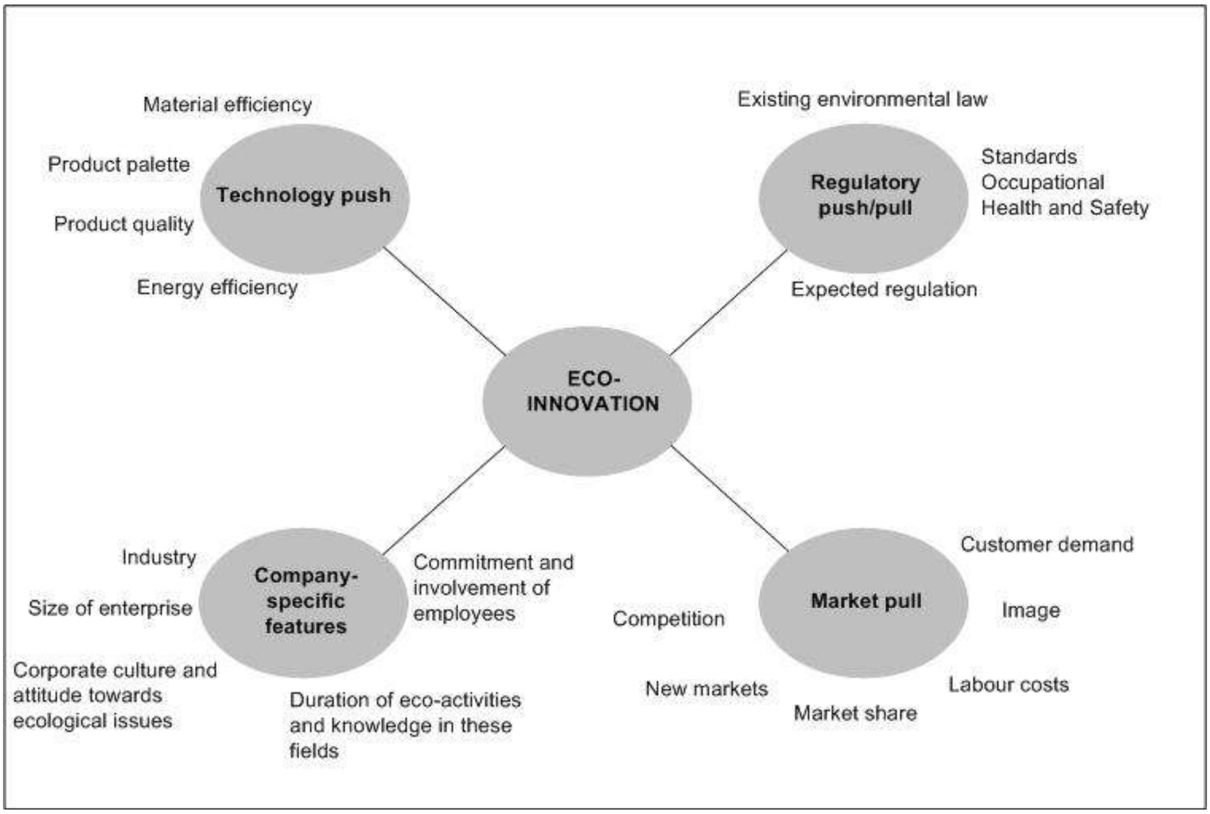

Figure 6. Determinants of environmental innovations (Adapted from Rennings (2000), Cleff and Rennings (1999) and Rehfeld (2006))

Cleff and Rennings (1999) and Rennings (2000) focus on product and process innovations and do not cover system innovations in their analysis. In addition, they consider only environmental aspects of innovations. However, they place environmental product and process innovations in a socio-technical system, in which the interrelations of environment, society and economy influence technological innovation. Rennings (2000) defines four types of innovation within the context of eco-innovation: 1) technological; 2) organisational; 3) social; and 4) institutional (p. 322). In discussing the hierarchical relationship between these types of innovations, Freeman (1992) points out that:

> Successful action depends on a combination of advances in scientific understanding, appropriate political programmes, social reforms and other institutional changes, as well as on the scale and direction of new investment. Organisational and social innovations would always have to accompany any technical innovations and some would have to come first (p. 124).

Within the general hierarchy mentioned above, technological innovations will influence change in institutional and social structures as well as organisational culture and vision and will be influenced by these on a mutual and continuous basis as shown in Figure 7.

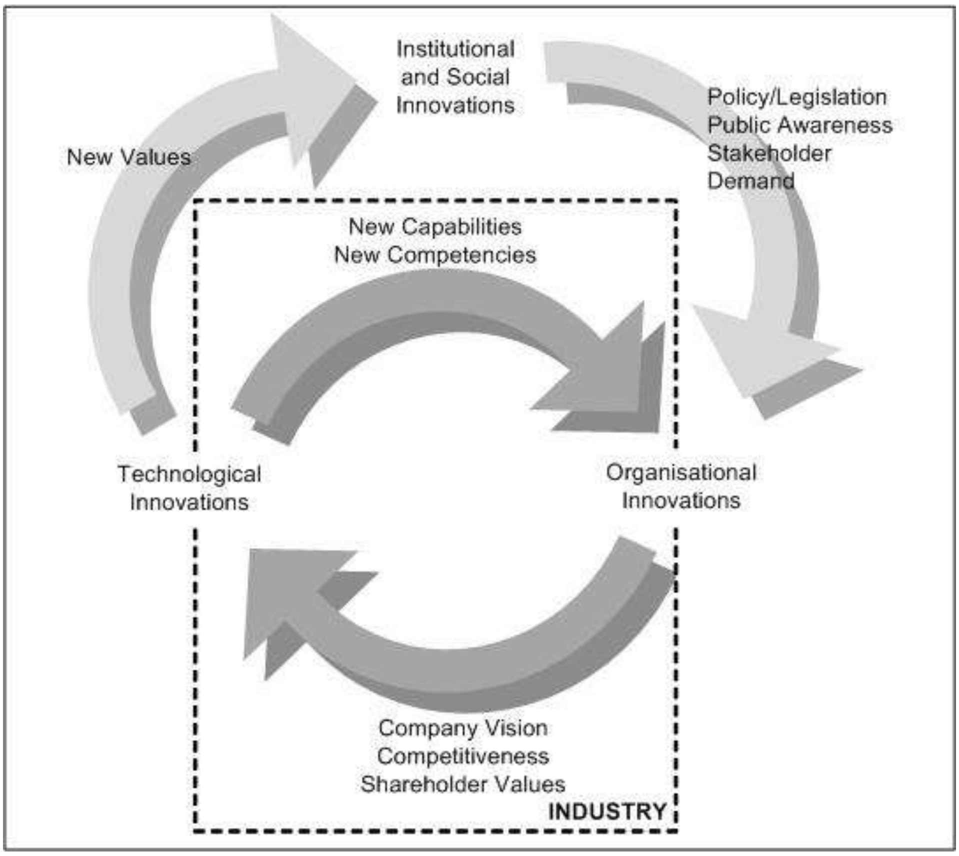

Figure 7. Co-evolutionary innovation model for the industry (Reproduced from Gaziulusoy, Boyle & McDowall, 2008)

Brand (2003) carries out a critical analysis of two main approaches advocated to achieve sustainability, which are technology-oriented and behaviour-oriented approaches. Costanza (2000) defines these two different approaches as two worldviews:

> The "technological optimist" world view is one in which technological progress is assumed to be able to solve all current and future social problems. It is a vision of continued expansion of humans and their dominion over nature. This is the "default" vision in our current Western society, one that represents continuation of current trends into the indefinite future.
>
> …
>
> The "technological skeptic" vision is one that depends much less on technological change and more on social and community development. It is not in any sense "anti-technology." However, it does not assume that technological change can solve all problems. In fact, it assumes that some technologies may create as many problems as they solve, and that the key is to view technology as the servant of larger social goals rather than the driving force (p. 4).

Brand (2003) criticises the technology-oriented approach as being undemocratic and doomed to be unsuccessful in the long run due to inevitable but neglected human interactions which alter technologies from their intended original function. He also mentions the associated rebound effects and risk potentials of some technologies. His criticism about the behavioural-oriented approach is that this approach has a top-down notion in which heroic compromises are expected from individuals of the society. The values underlying these heroic compromises are promoted by different 'top's (such as governments, organisations, company managers/owners, educators, leaders, etc.) who might have different biases in line with their own self-interests. Brand (2003) identifies approaches which acknowledge this dichotomy to some extent by involving sociological aspects of technological change. In his words, technological determinists are those 'who pay undue attention to how the technical realm influences the social realm, … The reciprocal position, which grants too much emphasis on how society shapes technology, is known as technological voluntarism (p. 32)'.

It is also possible to trace a similar dichotomy in different perspectives of general innovation theory. In innovation theory, there is a general acceptance of the existence of interrelationships between society and technology. Nevertheless, each of the different perspectives focuses on different components of the socio-technical system which it accepts as dominating the technological change. The approach which considers interactions between different components of the socio-technical system in technological change (regardless of on which components of the socio-technical system the emphasis is put) is known as the co-evolutionary approach to innovation.

The co-evolutionary approach to innovation is an overarching theme in general innovation theory. Geels (2005a) provides a non-exhaustive but sufficiently detailed overview of approaches to technological change in his book. His classification of co-evolutionary approaches to technological change is grouped under three main topics: sociological approaches, socio-technical approaches and economic approaches. He further elaborates these three approaches as:

1. Sociological approaches:
    - Social construction of technology;
    - Socio-cognitive approaches;
    - Domestication;
    - Social mechanisms;
2. Socio-technical approaches:
    - Actor-network theory;
3. Economic approaches:
    - Technology life-cycle approach;
    - Economic path-dependence perspective;
    - Technological substitution models;
    - Economic substitution approaches, and;
    - Evolutionary economics.

He points out that co-evolutionary approaches take into consideration two or three aspects (e.g. co-evolution of science and technology, co-evolution of technology and culture, co-evolution of technology and users, etc.) and a broader study of co-evolution, which is looking at co-evolution at socio-technical system level, is lacking. Nevertheless, both technological change in general and innovation in a sustainability context in particular require consideration of interlinks between institutional, social/cultural, organisational and wider technological levels. Sartorius (2006) states that 'coevolution implies that successful innovation in general and successful sustainable innovation in particular, has to acknowledge the involvement of, and mutual interaction between, more than the mere technical and economic spheres (p. 274)'. Therefore, to understand the dynamics of technological change to plan for and develop sustainable technologies, a co-evolutionary approach which acknowledges the interaction between all components of socio-technical system is essential.

3.3. EXTENT: RADICAL CHANGE

Freeman (1992) argues that incremental innovation has its limitations, which cannot be overcome by experience, learning, organisational and technical improvements. He states that there is a tendency for any incremental improvement to asymptote towards economical and/or technical limits. Beyond these limits, any additional minor improvement comes with increasing additional cost. Also, at an organisational level, radical innovations are argued to be critical for long-term success of firms (Christensen, 1997; Hamel, 2000; McDermott & O'Connor, 2002).

Within the sustainability context, the requirement for dematerialization of production and consumption and the needed decreases in greenhouse gas emissions are not likely to happen through the current technological path (Schmidt-Bleek, 1994; Rennings, 2000; Jansen, 2003; Ryan, 2008a). Thompson et al. (2001) as cited in Jansen (2003), point out that the eco-efficiency factor the society should achieve in line with growing population and desired welfare level varies from 2 to 50 depending on assumptions. Jansen (2003) states that achieving these eco-efficiencies will require fundamental change at systemic level. He sees eco-efficiency improvements as an essential element of sustainability but states that it will not be sufficient in the long run for two reasons. First, because eco-efficiency improves only environmental performance and does not address any of the social issues which require solving and, second, because eco-efficient growth will reach the earth's limits eventually. But, probably before reaching the earth's limits, eco-efficiency will reach its own practical limits since there cannot be any technology which is 100% efficient. Therefore, besides the immensely challenging eco-efficiency improvements, 'Solutions are needed that break existing trends in current development processes (Weaver, Jansen, van Grootveld, van Spiegel & Vergragt, 2000, p.44)'. Also, using current production systems as a starting point carries the risk of providing only incremental improvements and delaying or preventing the introduction of new and more sustainable systems (Andersson, Eide, Lundqvist & Mattson, 1998). Therefore, what we should aim for is path-breaking innovation in current technologies, or, as defined by Dosi (1982), a breakthrough shift from the current 'technological paradigm' towards a new one. This type of radical change is defined as system innovation.

3.4. SCOPE: SYSTEMIC TRANSFORMATION

The type of radical change, which requires a shift in the technological paradigm, is far more challenging than radical innovation at company/product level. Radical innovations at company/product level, which are unequally divided over industry sectors and over time as discontinuous occurrences, result from systematic research and development endeavours of companies and/or research institutions (Freeman & Perez, 1988). This type of innovations can be achieved in the existing technological paradigm without major change at the market and/or user level. A shift in the technological paradigm, however, requires changes at the system level as a prerequisite. Innovation at the system level covers not only product and process innovations but also changes in user practices, markets, policy, regulations, culture, infrastructure, lifestyle, and management of firms (see, for example, Berkhout, 2002; Kemp & Rotmans, 2005; Sartorius, 2006; Geels, 2006) to give way to and support diffusion of those new technologies. Therefore, in developing sustainable technologies, the importance of adopting a co-evolutionary understanding of innovation is even more significant. In addition, there is a need for a systemic approach which covers not only the industrial system (market-user-company) but also, at a higher level, the whole socio-technical system. In line with the requirement of adopting a systemic approach, the focus of innovation and environment studies has tended to shift from company-level processes to wider, linked processes at the socio-technical system level within which needs for housing, mobility, food, communications, etc. are satisfied (Smith et al., 2005).

System innovations bring fundamental changes to the entire society, not only on the technical side but also on the user side (Geels, 2002a; 2005a). Geels (2005a) defines system innovation as 'a transition from one socio-technical system to another (p. 2)'. Elsewhere, he defines technological transitions as 'major technological transformations in the way societal functions such as transportation, communication, housing, feeding, are fulfilled (Geels, 2002a, p. 1257)' (Even though 'societal function' seems to be the preferred version of the term among system innovation theorists, in this thesis 'social function' version is used except in direct quotations since the latter version is the preferred term among the product designers/developers).

Kemp and Rotmans (2005) state that 'For the purposes of managing change processes to sustainability it is useful to use the concept of a *transition* rather than system innovation' since it brings into focus the new state, the path towards the end state, the transition problems and the wide range of internal and external developments which shape the outcome (p. 36). In this thesis, both of these terms are used but not interchangeably. The term 'system innovation' refers to the general and broad body of literature dealing with innovation at system level. The terms 'transition theory' or 'transition management', however, refer to a particular research stream which is pioneered by a group of EU (mainly the Netherlands) based scholars. The term 'system innovation', wherever it is used, covers the transition management theory along with other contributions in the theory of system innovation. However, the term 'transition theory/management' only stands for that particular research stream.

The interest in system innovation, especially in the EU, has increased substantially in the past twenty years. This interest is mainly due to the sustainability promise of system innovations (Geels, 2005a). The major projects carried out so far as a result of this increasing interest were:

- The Dutch National Inter-Ministerial Programme for Sustainable Technology Development (STD) which took place between 1993 and 2001 (Weaver et al., 2000);
- EU funded Strategies towards the Sustainable Household (SusHouse) Project which took place between 1998 and 2000 (Vergragt, 2000);
- Industrial Transformation Project of International Human Dimensions Programme on Global Environmental Change (Vellinga & Herb, 1999);
- Our Common Journey Project by the US National Research Council, Board on Sustainable Development (National Research Council, 1999);
- The Great Transition (GT) Initiative by Tellus Institute (Raskin et al., 2006), and;
- EU funded Sustainable Consumption Research Exchanges (SCORE) Network Project which took place between 2005 and 2008 (Tukker et al., 2008).

As a result of this increasing interest, the system innovation theory is rapidly developing, very vibrant and continuously evolving. The Dutch Knowledge Network for System Innovations and Transitions is comprised of 80 researchers from several universities and research institutions (KSI, 2009). Currently 32 of the researchers are PhD students who are expected to graduate in 2010 (E. Kamphorst, personal communication, July 07, 2009).

Even though the interest in system innovation for sustainability started in the early 1990s and the theoretical development is rapid in this area, a systematic theory on system innovations in general and how to use this theory to influence socio-technical transformations towards sustainability in particular are currently emerging areas and the research is not consolidated. An up-to-date outline and a critical analysis of the theory of system innovation are provided in the following two sections.

3.5. THEORY OF SYSTEM INNOVATION – AN OVERVIEW

As part of the review of literature relevant to this research, one fast growing body of research on system innovation has been identified. This body of research has an understanding of the complexity embedded in the socio-technical system and is based on co-evolutionary theories of innovation. In a recent review, Andersen (2008) identifies this body of research as two interrelated, yet somehow separate and relatively mature, transition policy frameworks, i.e. transition management (developed mainly by Loorbach (2007; 2010)) and socio-technical regime transformation (developed mainly by Geels (2005a)). Exploring the theory of system innovation here is part of establishing a theoretical background to this research. Explaining, expanding and clarifying these frameworks are only done to the extent required for, and in line with, the objective of this research. Therefore, a detailed review is not given here but, rather, fundamental concepts and models of these frameworks are explained. Readers who would like to obtain more detail about these frameworks are referred to the resources cited in this section.

As a means to understanding how system innovation occurs, a group of scholars developed the multi-level perspective of system innovation (MLP) building on evolutionary innovation theory (e.g., Kemp, 1994; Van den Ende & Kemp, 1999; Kemp, Rip & Schot, 2001). Following the early development of the model, MLP was refined and clarified by Geels (2005a, 2005b) and by Geels and Schot (2007). Figure 8 shows the latest version of the MLP model. MLP model portrays the dynamic nature of system innovation through a layered structure. There are three levels of the MLP model; socio-technical landscape, socio-technical regime and niche innovations.

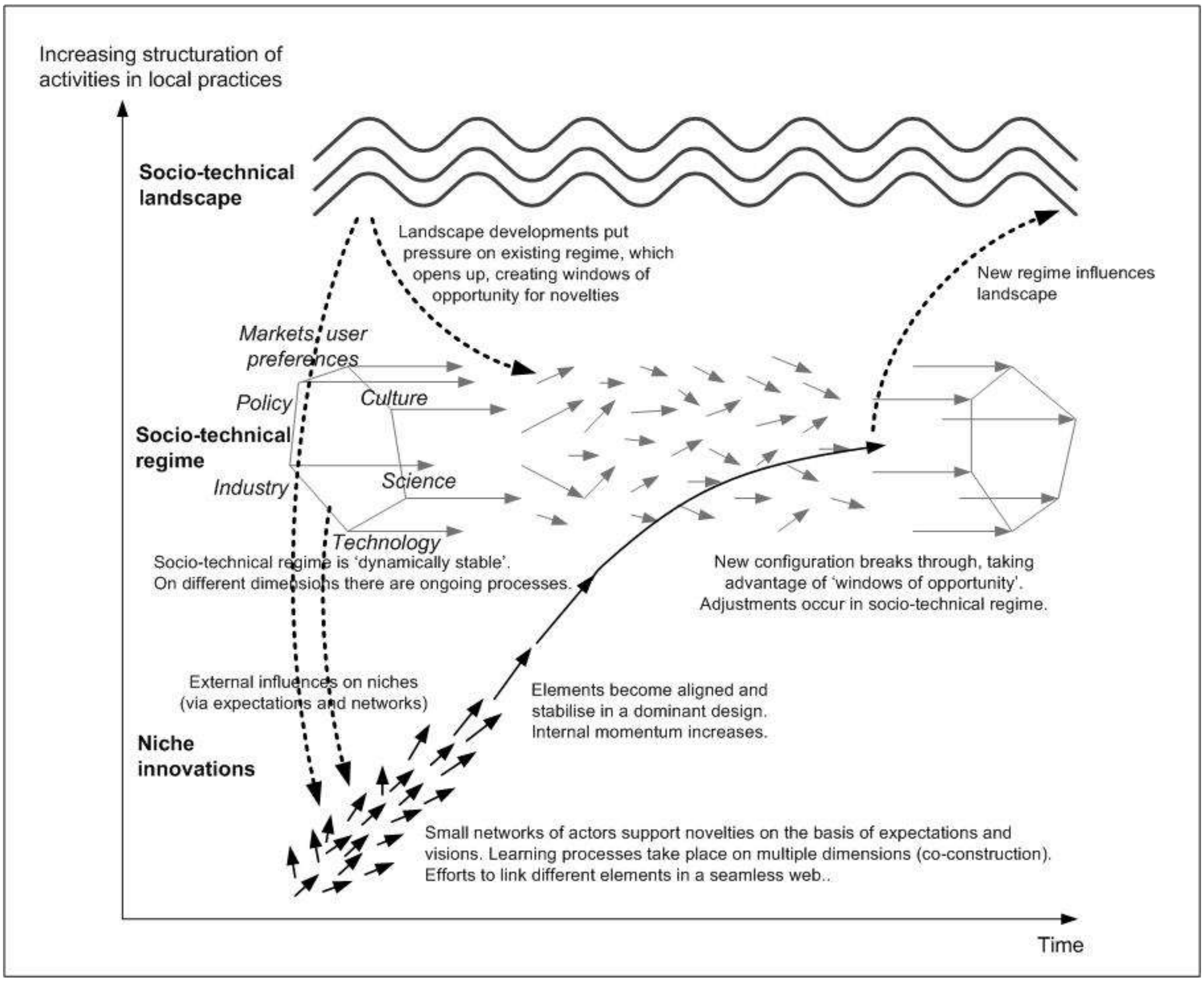

Figure 8. A dynamic multi-level perspective on system innovations (Reproduced from Geels, 2002a, p. 1263; 2005b, p.685; Geels & Schot, 2007, p. 401)

In this layered model, the central focus is at the middle where the socio-technical regime resides. Socio-technical regimes are formed by dynamically interacting components (i.e. technologies, user practices, markets, regulations, culture and infrastructure) which should be considered altogether when investigating and planning for innovation at system level (Geels, 2006). Socio-technical landscapes, i.e. the uppermost level in the MLP model, represent deep structural trends and the context influencing the whole of the society (Geels, 2005a). Landscapes are beyond the direct influence of components of the socio-technical regime and cannot be changed at will (Geels, 2005b). The lowermost level is formed by the niches. Radical innovation emerges from the niche level (Geels, 2005a; 2005b). All these three levels constitute the socio-technical system.

Another important concept in understanding the MLP model in particular and in studying system innovations in general is agency. Agency is the ability to act and influence change over the course of events (Giddens, 1984). In the context of socio-technical system transformation and from a co-evolutionary innovation perspective agency is the ability to intervene and change the balance of pressures influencing selection of technologies or of the adaptive capacity of the system or system components (Smith et al., 2005). A component of the socio-technical system with agency is referred to as an actor.

MLP model explains how change takes place in the socio-technical system based on the structuration theory of Giddens (1984). According to the MLP model, the stability increases and rate of change decreases towards upper levels of the socio-technical system, but the depth and influence of change increases towards lower levels. Nevertheless the change does not happen in a linear fashion and, as Geels (2005a) states, the relationship between the three levels is similar to a nested hierarchy. The layers have internal dynamics and influence changes at other levels. Geels (2005a) explains these internal dynamics:

> First, novelties emerge in technological and/or market niches. Niches are crucial for system innovation, since they provide the seeds of change. The emergence of niches is strongly influenced by existing regimes and landscape, … [T]he influence from the regimes on niches is stronger and more direct than the influences from landscapes, which is more diffuse and indirect (p. 83).

The niches are loosely structured and there is much less co-ordination among actors than there is among the regime actors. The regimes are more structured than niches and the rules of the regimes have co-ordinating effects on actors through a strong guidance of the activities of the actors. Landscapes are even more structured than regimes and are more difficult to change (Geels, 2005a). Nevertheless, as Figure 8 suggests, landscapes influence change both on niches and regimes; in return, niches (may) change the regimes and the new regime changes the landscape in the longer term. The socio-technical landscape in this model is relatively static, stands for the external context and represents the physical, technical and material setting supporting the society, and cannot be changed by the actors in the short term (Geels & Schot, 2007). Landscapes are constituted by rapid external shocks, long-term changes and factors that do not change or change only very slowly (Van Driel & Schot, 2005).

Kemp et al. (2001) identify three strategies for changing regimes. The first strategy is promoted by economists and calls for changing the structure of incentives and allowing market forces to function. This strategy is problematic especially when used in relation to environmental improvements. In order for policies targeting functioning of market forces to have an impact, these policies have to be drastic. In addition, the use of economic incentives may lead to windfall profits for manufacturers and dead weight losses for consumers temporarily. Another problem with this strategy is that the taxes and subsidies need to be supported by corrective measures so that there will be some sort of control on possible harmful effects of alternative technologies which are favoured by the tax regime.

The second strategy Kemp et al. (2001) identify is 'to plan for the creation and building of a new sociotechnical system based on an alternative set of technologies, in the same fashion as decision makers have planned for large infrastructure works, like coastal defence systems or railway systems (p. 279)'. This approach is also problematic since, as a result of the co-evolutionary dynamics between technologies and social systems, planning a completely new technological system is not possible. The final strategy they identify is to 'build on the ongoing dynamics of sociotechnical change and to exert pressures so as to modulate the dynamics of sociotechnical change into desirable directions. For this strategy, the task for policy makers is to make sure that the coevolution of supply and demand produces desirable outcomes, both in the short run and in the longer term (p. 280)'. Kemp et al. (2001) prefer this third strategy since it appears to be the only feasible one in contemporary society. In order to manage transitions through this strategy, the lowest level of MLP model, i.e. the niches level, plays an important role since niches are where radical innovations emerge (Geels, 2002a). The niches consist of promising technologies and they have to be protected in order to enable them to develop from an idea or a prototype to a technology which is actually used. This process is defined as Strategic Niche Management (SNM) by Kemp et al. (2001).

SNM is very important from a governance perspective and there is a wide and mature literature available (e.g. Kemp, Schot & Hoogma, 1998; Hegger, Van Vliet & Van Vliet, 2007; Caniëls & Romijn, 2008). In this research, however, the relevance of SNM lies in the selection criteria of technologies to be developed. This research is not about the governance of transitions towards sustainability from a policy development perspective but it is related to involvement of individual companies as actors who have limited agency in selection, but high agency in creation and physical development of the niches. Therefore, this research does not focus on details of articulation of pressures on the regimes for selection of desirable niches. It focuses on the anticipation and development of desirable niches by companies.

3.6. Typologies of Systemic Change

Typologies of systemic change complement the theory of system innovation. These typologies provide theoretical insights about different possible ways socio-technical regimes can change. There are three typologies proposed so far.

3.6.1. BERKHOUT-SMITH-STIRLING TYPOLOGY

The first typology is proposed by Berkhout, Smith and Sterling (2004) and Smith et al. (2005). They argue that regime change is a function of two processes. The first of these processes is shifting the selection pressures which bear on the regime. The second process is the co-ordination of resources available inside and outside the regime to adapt to the pressures on the regime. Based on these processes, transition contexts can be mapped according to:

- whether change is deliberate (envisaged and co-ordinated) or emergent (outcome of normal behaviour of regime agents), and;
- whether the resources needed to respond to selection pressures are available within the regime or outside the regime.

These two dimensions are used to identify four types of transition (Figure 9). These four types represent ideal types and they may all play out operationally at different levels of aggregation, covering not only the niche level but also the regime level.

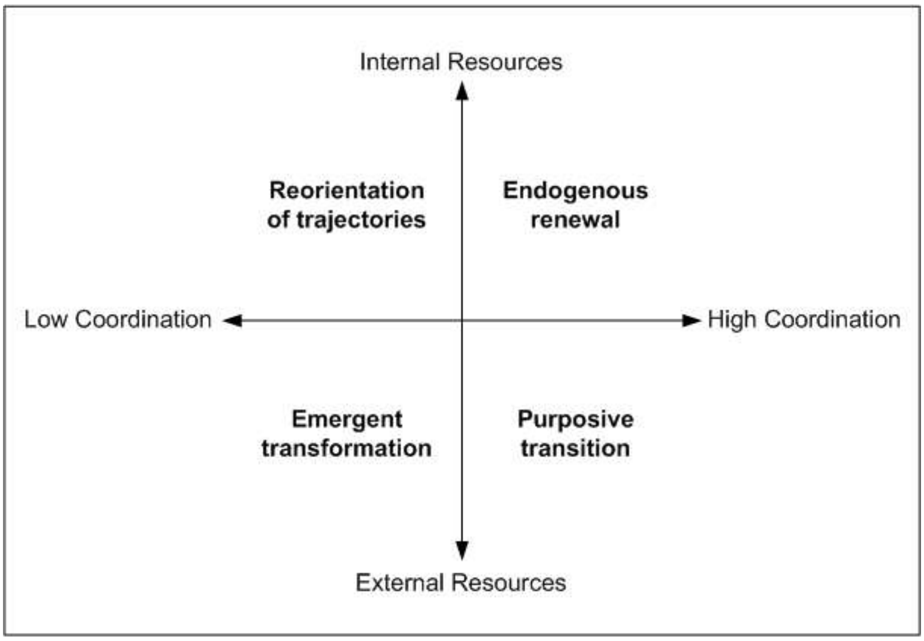

Figure 9. Berkhout-Smith-Stirling typology of transitions (Reproduced from Berkhout et al. (2004) and Smith et al. (2005))

Summarising from Berkhout et al. (2004) and Smith et al. (2005):

- In endogenous renewal, regime actors make conscious efforts to respond to the perceived competitive threats to a regime. There is high co-ordination among the actors and the resources originate within the regime. Since the innovative activity is shaped from within the regime itself, the transformation is likely to be incremental and path following. In hindsight, the transformation may seem to be radical but this will happen through the alignment of small changes;

- Reorientation of trajectories applies to regimes where there is high level of interconnectedness but low co-ordination among the actors. In this type of transition, the regime changing trajectories may be radically altered due to some sort of shock, either internal or external to the regime. But the response to this shock is formed within the regime. In this type of transition, the co-evolutionary developments are highly unpredictable;
- In emergent transition, the co-ordination is low and resources needed are outside the regime. This type of transition creates new pervasive technologies. The co-evolutionary patterns can be observed but which of the alternative technologies will have a chance to diffuse is highly unpredictable since there is no preference. The change in emergent transition is autonomous;
- Similar to emergent transitions, the resources are outside the regime in purposive transitions but, contrary to emergent transitions, there is high co-ordination. In this type of transitions, the change is deliberately intended and pursued from the outset, reflecting explicit societal-level expectations and vision.

3.6.2. Geels and Schot Typology

Geels and Schot (2007) develop a transition typology with references to MLP model and based on the Suarez and Olivia's (2005) typology on organisational transformation due to environmental change. Suarez and Olivia (2005) define five different organisational transformation types in line with five different types of environmental change (Table 1). They use the term 'environment' to indicate the contextual forces surrounding the firm (i.e. firm environment) as used in management literature.

Table 1. The organisational transformation typology of Suarez and Olivia (2005)

Frequency	Amplitude	Speed	Scope	Environmental Change
Low	Low	Low	Low	Regular
High	Low	High	Low	Hyperturbulence
Low	High	High	Low	Specific Shock
Low	High	Low	Low	Disruptive
Low	High	High	High	Avalanche

Geels and Schot (2007) adapt the above typology to identify four transition pathways based on different multi-level dynamics. They exclude hyperturbulence since 'Such high-frequency changes may occur in markets, but are unlikely for landscape dynamics (p. 404)'. Geels and Schot's (2007) typology is based on the combination of two criteria: timing of interactions and nature of interactions. They argue that the transition pathways will be different depending on the maturation level of niche innovations at the time when the landscape pressure appears. The interactions of the niches and the landscape developments with the regime may have reinforcing or disruptive effects on the regime. If the landscape developments have reinforcing effects on the regime there will not be drivers for transition but the regime will move towards stabilisation. Only if the landscape developments put pressure on the regime, will there be an impulse to change in the regime. Similarly, niche innovations may either be competing with the regime to replace it or may have a symbiotic relationship if they can be adopted to solve problems in the existing regime. A summary of Geels and Shot's (2007) typology for transitions is given in Table 2.

Table 2. Geels and Shot (2007) typology of transitions

Type of Transition	Type of Landscape Pressure	Niche Maturation	Interaction with the Regime	Result
Transformation	Disruptive	Not fully developed	N/A	Existing regime modifies the direction of development paths and innovation activities and eventually transforms. The new regime grows out of the old one but the basic architecture of the regime does not substantially change.
De-alignment/ re-alignment	Avalanche	Not fully developed	N/A	De-alignment of regime due to landscape pressures and competing niche innovations in the beginning, re-alignment of regime after dominance and success of one niche innovation.
Technological substitution	Shock Avalanche Disruptive	Fully developed	Competing	Niche innovations breakthrough and replace the existing regime.
Reconfiguration	Regular	Fully developed	Symbiotic	Niches are initially adopted by the regime to solve local problems. They subsequently trigger further adjustments. The new regime grows out of the old one but the basic architecture of the regime substantially changes.

3.6.3. ROTMANS AND DE HAAN TYPOLOGY

Rotmans (2005) bases his typology on five different types of transformation processes identified by Boulding (1970) (as cited in Rotmans, 2005) and the typology developed by Berkhout et al. (2004) and Smith et al. (2005). The five processes identified by Boulding (1970) are accidental, deterministic, evolutionary, dialectic and teleological (target-oriented) (as cited in Rotmans, 2005). Rotmans' (2005) typology has three dimensions depending on whether the transition is teleological or emergent, the degree of co-ordination and the level of aggregation. These three dimensions result in identification of eight types of transitions as shown in Figure 10.

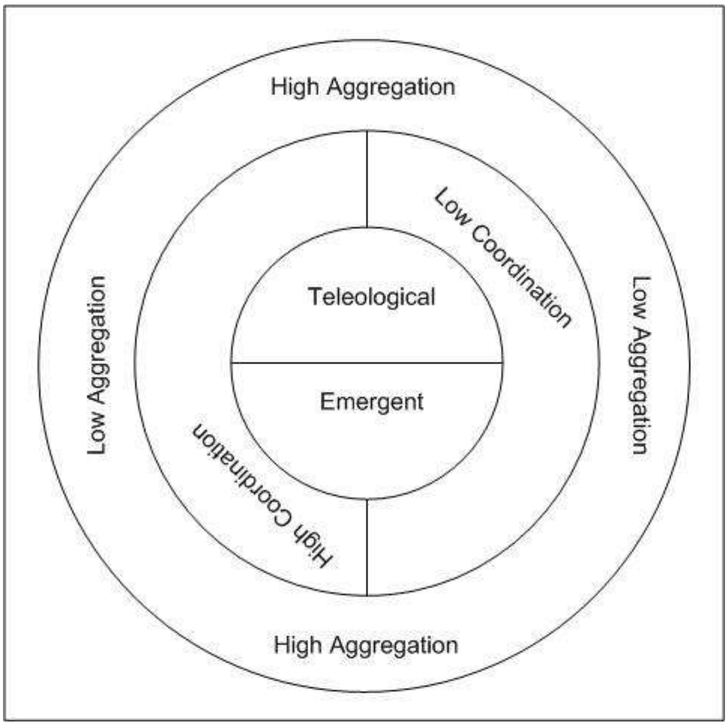

Figure 10. Rotmans (2005) typology of transitions

Another typology for transitions is proposed by De Haan and Rotmans (2007). De Haan and Rotmans' typology is an articulation of Rotmans' typology rather than a stand-alone one. This typology rises from the Pillar Theory of transitions which is currently being developed by De Haan and Rotmans (2007). According to the Pillar Theory, societal transitions can be modelled through three pillars: 'The first, *conditions*, deals with the state of the societal system and the conditions for transitional change. The second pillar, *patterns*, describes the mechanisms of transitional change. The third pillar, *paths*, concerns the manifestations of transitional change (De Haan & Rotmans, 2007, p. 3)'. The conditions for change come from tensions between functioning of the regime and its environment, stress within the functioning of the regime and the pressure exerted by the present or emerging niche-regimes. The patterns are mechanisms explaining the emergence of niche-regimes and adaptation of the societal system to the presence of these emergences. The transition paths, or typologies, are modelled using conditions and patterns. The Rotmans and De Haan (De Haan & Rotmans, 2007) typology adopts the landscape, regime and niche concepts of MLP model and names these as macro, meso, and micro respectively. The resulting typology is given in Table 3.

Table 3. De Haan and Rotmans typology (De Haan & Rotmans, 2007)

	Path	**Functional Change**	**New System Make Up**
Micro to meso paths	Proper	Complete	New regime, with incorporated functioning of niche-regime
	Smothered	Partial-leaning to old regime functioning	Co-functioning of niche-regime and regime
	Imperfect	Partial-leaning to new regime functioning	Co-functioning of niche-regime and regime
	Backlash	None	Old regime
	Path	**Adaptation Influence**	
Meso to meso paths	Emergent	Little co-evolution. Gradual replacing of functioning from incumbent regime to new regime out of niche-regime	
	Teleological	Much co-evolution. Reformation of regime with niche-regime functioning	
	Lock-in	Much niche absorption and early co-evolution	
	Path	**Adaptation**	**Origin of functioning**
Macro to meso paths	Radical reform	Active	Internal practice
	Imposed transition	Active	External practice
	Revolution	None	Niche, possibly exogenous
	System breakdown	None	-

The differences in these three typologies cited above rise from the different perspectives and research interests of the researchers who have developed them. For example, the core interest of Geels and others is explaining how major technological change happens in a co-evolutionary and multi-level context. On the other hand, Berkhout and others are interested in governance of socio-technical transitions. Rotmans and De Haan are interested in societal innovation in its broadest sense, covering, but not limited to and definitely not focusing on, technological change. Their typology is more detailed than of Geels and Schot's typology. This is first because Rotmans and De Haan's primary aim in theory development is to develop computer models and simulations of transitions in order to manage and steer system innovations towards sustainable development. Such modelling requires in depth analysis of dynamics in the societal system. Second, Geels and Schot typology is centred around major technological change and the historical cases Geels have used to develop his theory (see Geels, 2002b; 2005a) were not purposive/teleological, contrary to transitions which are currently being planned and aiming towards sustainability. Third, Geels and Schot typology focuses on technological transformation, and therefore, it remains blind to broader societal-level transformations which will inevitably have an impact on the technological system. These broader societal-level patterns are explicitly given in De Haan and Rotmans typology as macro-to-meso paths.

The underlying politics of systemic change models also influence the typologies proposed. It is implicit that the MLP and related typology (Geels & Shot, 2007) is designed with a democratic and pluralistic societal context assumption in which power is distributed and thus transitions purposive from the outset are not possible. Loorbach and Rotmans (2006) share a similar stance, indicating that transitions cannot be managed in terms of command and control, yet the pace and direction can be influenced, adjusted and steered. Geels and Schot (2007) criticise the Berkhout-Smith-Stirling typology, stating that transitions cannot be planned at the outset due to the complexity of the socio-technical system. It is understood that Berkhout and others, in defining purposive transition, do not strictly imply a command-and-control model in the classical sense but possibly cover it as well as the more democratic guiding-steering model. In this regard, the Berkhout-Smith-Stirling typology is more generic than the Geels and Schot typology. The latter looks through a Euro-centric filter in insisting on the impossibility of planning a transition at the outset. However, a guiding-steering model may not be applicable in certain cultural contexts which are traditionally highly hierarchical and which require continuous top-down interventions to initiate, manage and finalise transformations. Also, in the guiding-steering model, even though the outcome targeted at the start cannot be fully achieved at the end of the transformation, having a concrete vision will help the steering of the process. Therefore, purposive type transitions in the Berkhout-Smith-Stirling typology are similar to teleological type transitions in the Rotmans and De Haan typology.

Despite the insights these typologies provide regarding how system innovation can happen, for two reasons neither will be used in this research. First, all of these typologies remain as theoretical models. Since transitions to sustainability have not taken place yet, which one of these typologies hold the most merit is not known. They are useful to speculate about how possible future transitions might happen but neither of them has been proven to be a reliable model to steer system innovation. Second, as they are these typologies explain the change mechanisms relevant for macro-level (i.e. the entire socio-technical systems) but do not provide any insights on the mechanisms relevant for changes in micro-level (i.e. companies and product development). Therefore, these typologies are not found useful in line with the objective of this research.

3.7. INTRODUCING PRODUCT DEVELOPMENT PERSPECTIVE: LEVELS OF INNOVATION FOR SUSTAINABILITY

Brezet (1997) defined four levels of innovation for sustainability. The first level is product improvement. Product improvements are focused on reducing environmental impacts for existing products. The second level is product redesign. In product redesign, product concept remains almost intact but either the product or its components are further developed or replaced. The third level is function innovation. At this level, the innovation is not limited to existing product concepts but related to how the function is achieved. The fourth and final level of innovation defined by Brezet (1997) is system innovation. At this level, the whole technology system is replaced by a new system.

Halila and Hörte (2006) criticised the four-level typology of Brezet (1997) and defined a six level typology to improve the understanding of eco-innovations. They based their new classification on three criteria; a) the degree of creativity and the kind of knowledge on which the innovation was based; b) the extent of the innovation (product component, product itself, function within a system or the complete system) and c) the expected environmental effect. The six classes they proposed were product care, minor product improvement, major product improvement, functional innovation, system innovation and scientific breakthrough. This new classification brings clarity to the levels proposed by Brezet (1997) by enabling differentiation between minor and major innovations at product redesign level and articulating the difference between function innovation and system innovation. Nevertheless, even though useful for analysis purposes, this new classification does not propose anything novel in explaining the conditions of system innovation. The sixth level, which is scientific breakthrough, is not an appropriate category for classification of technological innovations. Scientific breakthroughs are very important in enabling system innovation through broadening the knowledge base of basic science; however, they are neither a level nor a class of technological innovation. Therefore, the four-level typology of Brezet (1997) is used in this research while acknowledging Halila and Hörte's (2006) clarification with the exception of the sixth class they proposed (Figure 11).

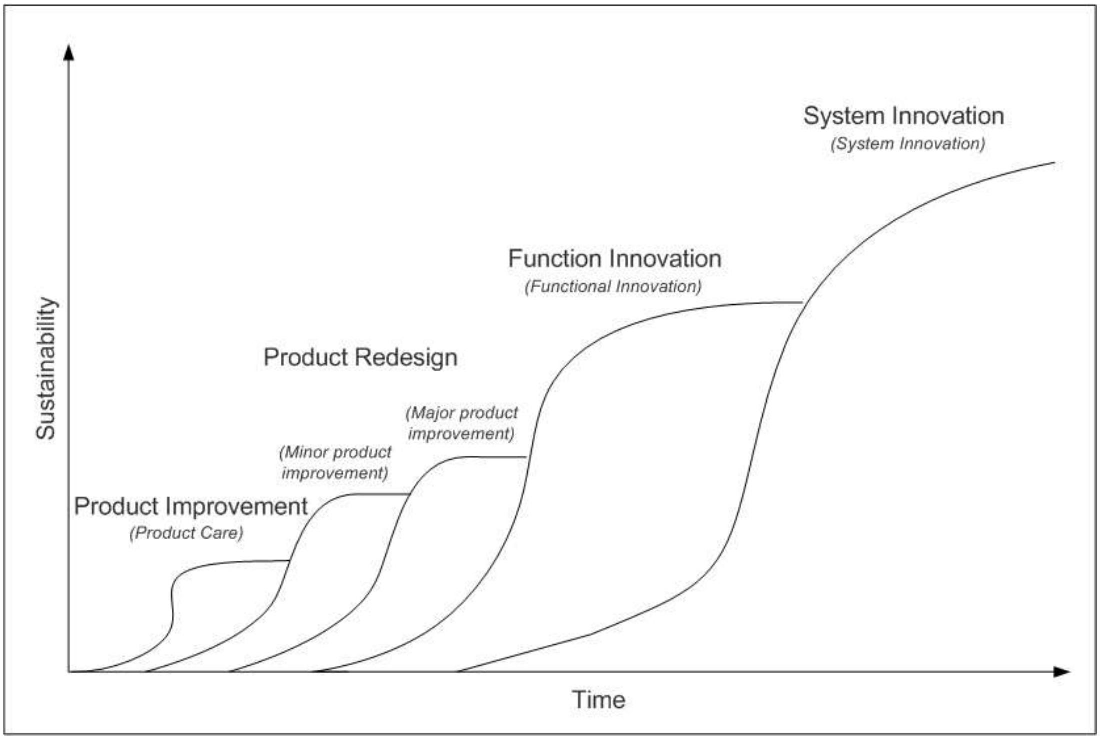

Figure 11. Levels of innovation for sustainability (based on Brezet (1997) and Halila and Hörte (2006))

In the typology of Brezet (1997), the first and second levels (which correspond to the first three levels of Halila and Hörte (2006) typology) are where most of the efforts are focused at the moment, driven mainly by the regulatory push/push mechanisms. These first two levels have a product focus and are performed within the realm of established technologies and social uptake of established technologies. The third level, function innovation, generally constitutes a transition between product focus and system focus. In function innovation, the social function of products or technologies is of concern and questioned. Currently, certain PSS applications fall into this category. Some PSS are developed and implemented by a single company, such as Interface Ltd. leasing carpets instead of selling them and replacing and recycling the old carpet into new carpets (Anderson, 1997). Some other PSS solutions require collaboration of several stakeholders, such as councils, NGOs, and in some cases, private companies. Some examples of multi-stakeholder PSS related to urban mobility solutions can be found in Keskin, Brezet, Börekci and Diehl (2008).

The theory of system innovation has been discussed in detail under Section 3.5. Some historical examples of system innovation are the transition from sailing ships to steam ships, the transition from horse-and-carriage to automobiles, and the transition from piston engine aircrafts to jetliners in American aviation (Geels, 2002a, 2002b, 2005a). Much more profound examples of system innovation are agricultural revolution and industrial revolution, both of which fundamentally changed how the society operates. The society is currently experiencing another profound system innovation determined by the rapid development and diffusion of information and communication technologies.

There is a depth of theoretical details explaining, an abundance of examples exemplifying and several operational tools operationalising the first three levels mentioned in Brezet's typology (i.e. product improvement, product re-design and function innovation) in the design/engineering literature (e.g., Design for Sustainability: A Step by Step Approach recently published by UNEP, see Crul, Diehl and Ryan, 2009). However, neither a theory nor operational tools were found during the review of literature articulating how system innovation can be addressed at product development level in companies. In the duration of this research, several personal communications were held with designers and engineers, who either actively design/develop products (i.e. who are practising designers/engineers), or, who develop theory in the joint area of sustainability and product development (i.e. who are researchers in design/engineering disciplines). These communications indicated that the theory and concepts of system innovation were found to be complex and not useful by those who design and develop products. The lack of theory and operational tools linking product development level to broader system level innovation for sustainability highlighted a need for development of a theory, and, conceptual and operational models.

3.8. Summary of Findings and Insights Gathered in this Chapter

This chapter reported a critical review of the theoretical ground dealing with innovation for sustainability. Below is the summary of key findings and insights reported in this chapter:

- To understand dynamics of technological change and to plan for and develop sustainable technologies, a co-evolutionary approach which acknowledges the interaction between all components of socio-technical system is essential. Innovation aiming to achieve sustainability should be systemic, co-evolutionary and radical;
- Achieving sustainability will require radical innovations at technological level which are influenced by other types of innovations at institutional/social and organisational level;
- A shift in the technological paradigm requires changes at system level as a prerequisite. Innovation at system level covers not only product and process innovations but also changes in user practices, markets, policy, regulations, culture, infrastructure, lifestyle, and management of firms. Therefore, it calls for societal transformation;
- The MLP model is useful to understand how system innovations happen with a broad and dynamic perspective since the model is developed as a synthesis of different approaches in innovation theory emphasising on different drivers and/or agents of change;

- So far three main typologies of systemic change are developed: Geels and Schot typology (Geels & Shot, 2007), Berkhout-Smith-Stirling typology (Berkhout et al., 2004; Smith et al., 2005) and De Haan and Rotmans typology (Rotmans, 2005; De Haan & Rotmans, 2007). Despite the theoretical merits of these three typologies in explaining the mechanisms of macro-level change, neither of them was found useful for the purposes of this research since the focus of this research is micro-level change;
- From the perspective of product development, there are mainly four levels of innovation for sustainability: product improvement, product-redesign, function innovation and system innovation. Even though there is a depth of theoretical details, an abundance of examples and several operational tools which apply to the first three of these levels, neither a theory nor operational tools were found during the review of literature which articulated how system innovation can be addressed at product development level in companies. This highlighted a need for development of a theory, and, conceptual and operational models.

4. FUTURES STUDIES, SUSTAINABILITY AND SYSTEM INNOVATION

4.1. INTRODUCTION

The systemic transformation will occur through replacement of old technologies with new ones and diffusion of these new technologies within the socio-technical system (Geels, 2005b). During this transformation, institutional, socio-cultural and organisational change will accompany technological change. Therefore, one of the issues needing to be addressed in system innovation is how to link highly structured and the 'known' present to the uncertainty inherent of the long-term future (Figure 12), considering the extent of change needed and the fact that technology development is a cumulative process (Gaziulusoy & Boyle, 2008).

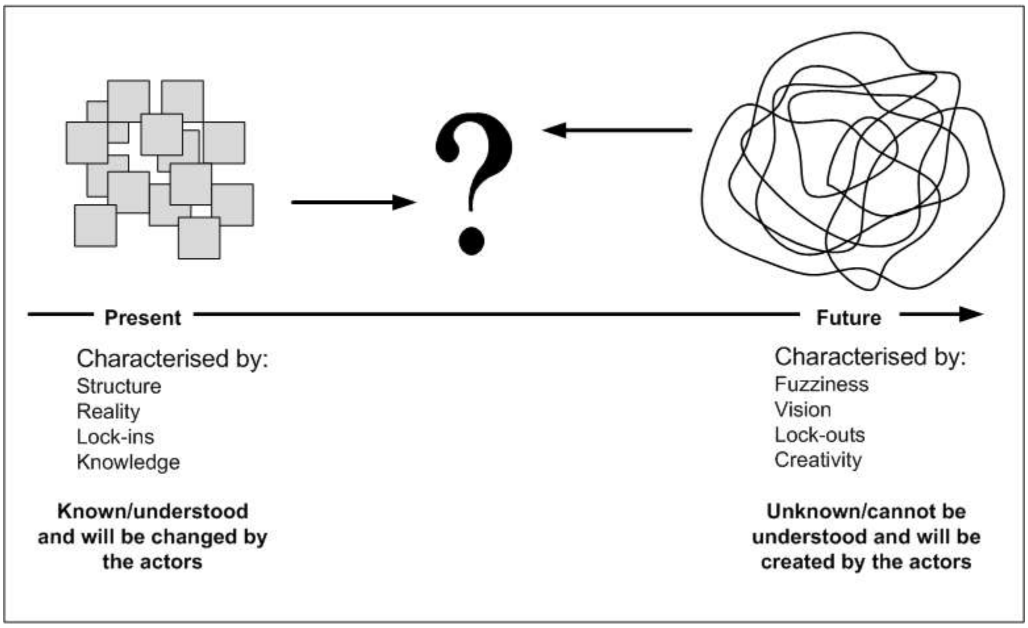

Figure 12. The problem of linking present and future in system innovation

It was stated previously that transitions of complex systems cannot be managed through command and control but can only be influenced and steered with a long-term approach in planning. In order to steer transitions, there is a need for articulating guiding concepts, normative expectations and preferences; i.e. developing future visions. Wiek, Binder and Scholz (2006) distinguish three types of knowledge which need to be generated for managing transitions. These are system knowledge, target knowledge and transformation knowledge. System knowledge provides information on the system components relevant to the transition while transformation knowledge is about how to realise the transition from the current state to the target state. The target knowledge equates to the future visions developed by articulating guiding concepts, normative expectations and preferences.

Future visions play a number of important functions in planning for and managing system innovations. Among these important functions are mapping a possibility space, establishing a heuristic and a stable frame for setting targets and monitoring progress, specifying relevant actors and network(s) of actors and directing investment (Smith et al., 2005). Future visions developed in the context of system innovation have three distinctive characteristics. These are '*objectives*, the qualitative or quantitative expression of novel future outcomes; *orders*, a set of social and institutional relationships in which these objectives can be met; and *technologies*, the means for achieving objectives' (Berkhout, 2006, p. 302).

Berkhout (2006) makes a distinction between private and collective future expectations. He states that private expectations are not likely to be socially significant yet even the collective expectations may be insufficient in aligning behaviour and motivating action. In order to achieve sustainability, creation of visions which will be engaging for all relevant actors of the socio-technical systems is required. Loorbach (2007) states that the visions and images, which will be used for managing transitions, should represent a shared definition of sustainability in a specific societal system. Therefore, a participatory approach to developing these visions has been advocated and used in several projects related to system innovation (e.g. Vergragt, 2000; Partidario, 2002; Loorbach, 2007). Quist (2007) argues that instead of taking the need for participation for granted, a more effective approach may be to consider the different purposes, degrees, types and time-frames of participation and plan for these in line with the characteristics of the project in hand.

Future visions which will be used in system innovation projects, therefore, are images of desirable as well as possible futures; desirable in terms of sustainability and possible in terms of the dynamics of the socio-technical system. These visions should be developed using a participatory approach appropriate for the project in hand.

Creating and pursuing future visions require using methods of futures inquiry. There are a multiplicity of different methods used to inquire into the future for several different purposes (for good reviews see Porter et al., 2004; Inayatullah, 2005; List 2005; Institute for Alternative Futures, 2008). The focus in this research is on scenarios. Scenario development is the most appropriate futures inquiry tool to achieve the objective this research since it is a generic tool applicable to all levels of the socio-technical system subject to this research (i.e. society, company and product development) and to all purposes relevant to this research (i.e. societal transformation, strategy development and product development). For scenarios in relation to system innovation for sustainability at societal level the reader is referred to Gallopin and Raskin (1998), Vergragt (2000), Elzen, Geels and Hofman (2002), Partidario (2002), Swart, Raskin and Robinson (2004), McDowall and Eames (2006), Sondeijker, Geurts, Rotmans and Tukker (2006), Wiek et al. (2006), IPCC (2007) and Gaziulusoy and Boyle (2008). For scenarios for strategy development at organisational level the reader is referred to Bradfield, Wright, Burt, Cairns and Van Der Heijden (2005), Van der Heijden (2005), Korte and Chermack (2007), Pillkhan (2008) and Shell International (2005; 2008). For scenarios for product development at operational level the reader is referred to Hasdoğan (1997), Saul (2002) and Salamanca (2005).

In inquiring into the future, visions and scenarios are complementary to each other. Bezold (2005) states that scenarios are 'futures for the head' while visions are 'futures for the heart' in a way to imply that for a coherent outcome both need to be used in conjunction with each other. The relationship between future visions and scenarios in the context of system innovation can be explained by referring back to the three types of knowledge required to be generated to achieve system innovation for sustainability (Wiek et al., 2006); while future visions equate to the target knowledge, the transformation knowledge is generated by developing scenarios which articulate how to reach that envisioned target state.

Future inquiry methods including visioning and scenario development are studied under an interdiscipline called futures studies. This chapter initially provides an overview of the literature on futures studies and scenario development as a background. This is followed by an in-depth review of literature investigating CAS in the context of futures studies. Then a review of futures studies literature specifically about system innovation for sustainability is given. Finally, major previous projects which used futures inquiry methods to plan for and manage system innovation for sustainability are critically analysed.

4.2. FUTURES STUDIES

4.2.1. AN OVERVIEW

Humans have been interested in the future since pre-historic times and tried to know, understand and control what is going to happen with the aims of surviving, acquiring and/or sustaining power, making strategic decisions and so on. There are three main phases in human inquiry into the future:

the pre-scientific phase, the (quantitative) forecasting phase and the alternative futures thinking phase (List, 2005).

In the pre-scientific phase, the main attempts used to understand the future were astrology and prophecy; people used biological cycles, beliefs in destiny and chance to deal with their fatalistic perception of the future (Inayatullah, 2005; List, 2005). In the nineteenth century, the pre-scientific phase ended and, until the mid-twentieth century, quantitative forecasting (or similar extrapolation methods) became the sole acceptable approach to predicting the future (for a detailed historical account of forecasting see List, 2005, pp. 14-18). Forecasting, even though a very useful method for certain purposes and short time periods, proved to give inaccurate results. Some detailed accounts of forecasting errors can be found in Wise (1976), Moyer (1984), Collopy and Armstrong (1992) and Armstrong (2001). The major reasons for inaccuracies in forecasting are (List, 2005):

- For forecasting to predict values and probabilities, variables must have already been identified. These variables may not be relevant anymore, their meaning may change in time or new variables may come into play;
- Forecasts are extrapolations of the present with the assumption that the future will be an extension of present. Therefore, forecasts cannot inform about discontinuities or emergent factors. The illusionary overconfidence about having control over the future may result in the collapse of an entity which relied on forecasts in decision making about future, and;
- Forecasts do not have any objective basis to predict the future of entities where human choice is a main determining factor.

There are three types of reactions to future: passivity, adaptation and voluntarism (Godet, 1983, as cited in List, 2005). Current thinking is representative of voluntarism which is about creating one's future (List, 2005). This type of reaction marks the start of the alternative futures movement in the field of futures studies in the mid-twentieth century. Alternative futures thinking is based on the idea that there is no single possible future but multiple possibilities and creation of a desired future is embedded in present choices and decisions (Slaughter, 2005). Therefore, alternative futures thinking is about understanding the possible, probable and plausible futures and selecting preferable one(s) to act upon and to create (Bell, 2005). The transformational quality of alternative futures thinking is especially important now since the society and the environment are facing unprecedented change and continuation of current trends poses extreme risks to the sustainability (Bell, 2005; Inayatullah, 2008).

The differentiation between possible, probable and preferable futures was first made by Amara (1981) to categorise different roles of futurists and different methods used in relation to these roles. According to him, possible futures answer the question of what can happen and aims to conceive and describe possible paths. This arm of futures studies is image driven and visionary. The probable futures answer the question of what may happen and examines particular paths in details. This arm is analytically driven and exploratory. The third arm, i.e. preferable futures, is value driven and normative and tries to answer the question of what should happen.

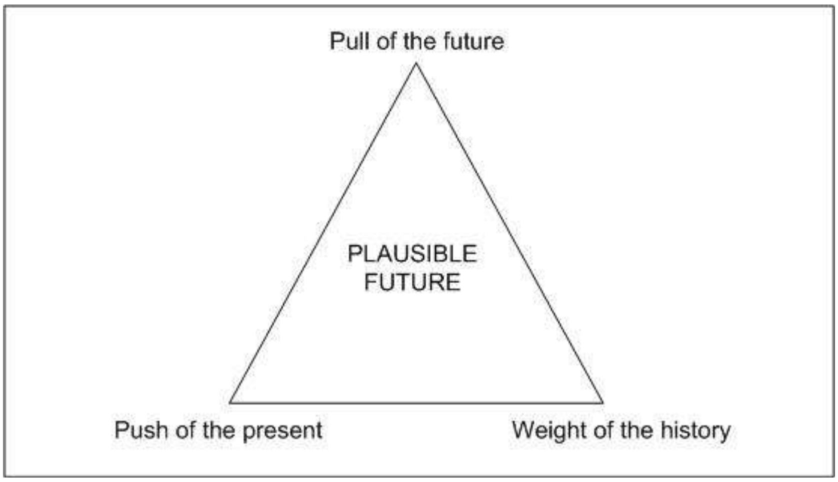

Figure 13. The futures triangle (adapted from Inayatullah, 2008)

Inayatullah (2008) identifies three forces in play to affect our understanding of future today (Figure 13). In this triangle, the images of the future pull and current trends push us forward. The weights of the past constitute barriers to change. Identification of plausible futures requires analysis of these forces and the implications of their interaction. He defines six pillars to futures studies which relate to methods and tools of futures studies. These are mapping the past, present and future (using the futures triangle), anticipation, timing, deepening, creating alternatives and finally transforming. Mapping the past, present and future gives us hindsight, insight and foresight and enables us to position ourselves in a broader context of external influences and generate a vision of our desired future. Anticipation is about identifying the emerging issues and possible outcomes of probable happenings. Timing relates to grand patterns of history and identification of models of change. Deepening is for generating more elaborate insights about the dynamics or causes of change since there are multiple influences affecting future events and different perspectives on the core causes. Creating alternative futures is the fifth pillar. This is mainly done through scenarios. Finally, the sixth pillar, transforming, requires alternatives to be narrowed down to one or more preferable ones. The preferable future(s) can result from scenarios but can also be identified through certain visioning techniques.

List (2005) classifies futures methods under four main groups; methods of exhaustive comparison (e.g. morphological analysis), methods of sequential projection (e.g. backcasting), methods of mental imagery (e.g. visioning), and methods of increased understanding (e.g. causal layered analysis). He states that 'scenario' as a term can be used in multiple senses and reports that a large proportion of scenarios in academic literature are outcomes of numerical forecasting. However, he restricts his definition of scenarios to the broader, narrative sense of multiple futures in line with his research interest, i.e. developing a social inquiry method based on scenarios. Therefore, he refers to scenarios under methods of mental imagery. Inayatullah (2005, 2008) defines scenarios as the *par excellence* tool of futures studies and uses the term in the same sense List (2005) does. Use of the term scenario in this sense is typical of alternative futures thinking. In alternative futures thinking, scenarios are useful because 'they give us distance from the present, allowing the present to become remarkable or problematic. Thus, they "open up" the present and allow the creation of alternative futures (Inayatullah, 2005)'.

Bishop, Hines and Collins (2007) count forecasting among the scenario techniques and refer to the confusion about the term 'scenario' in theory and in practice:

> A more subtle confusion is equating the term "scenario" with "alternative future." In other words, all descriptions of alternative futures are deemed to be scenarios. A more narrow definition of scenario would focus only on stories about alternative futures. With this narrow definition, other forecasting methods might produce alternative futures, but not scenarios. In practice, however, the broader definition of scenario as alternative future, whether they are in story form or not, has prevailed. Thus, the complete collection of methods for scenario development includes almost all forecasting methods since they also produce alternative futures. In fact, very little is said about the actual creation of the stories in most methods. More attention is paid to generating the scenario kernel or logic, which can be done by any number of methods. We decided that it does not make sense to fight the battle for a narrower definition, and thus our list of methods is based on current practice and includes the incorporation of forecasting methods whether or not they produce a story (p. 6).

Different uses of the term scenario are relevant to research dealing with sustainability issues. Among these different uses are quantitative scenarios such as population forecasts, scenarios resulting from system modelling such as climate scenarios and scenarios used in the product design/development field such as user scenarios. It is hard to isolate one particular use of the term and there is a need to acknowledge the different uses in different but relevant fields. Therefore, in this research, scenario is defined as 'any representation of a future state'. That future state may either be predicted or preferred, may either be expressed quantitatively, through a narrative or graphically, and may either be in the short, medium, or long term, or cover a sequence of events which span one or more of these terms.

4.2.2. Scenarios – Types, Methods and Functions

Several scenario typologies have been suggested by various authors based on different classifications (e.g. Masini & Vasquez, 2000; Postma & Liebl, 2005; Chermack, Lynham & Ruona, 2001; Van Notten, Rotmans, Van Asselt & Rothman, 2003; Börjeson, Höjer, Dreborg, Ekvall & Finnveden, 2006). The most detailed typology was developed by Van Notten et al. (2003). Their typology has been expanded by List (2005). Van Notten et al. (2003) identified three overarching themes to classify scenarios. These themes are project goal, process design and scenario content. List (2005) identified scenario use as an additional theme. The amalgamated typology is given in Table 4 where italics indicate the aspects added by List.

Table 4. Scenario typology (Van Notten et al., 2003 and List, 2005)

Overarching theme	Scenario type
A. Project goal: Exploration vs. decision support	1. Inclusion of norms? Descriptive vs normative 2. Vantage point: forecasting vs backcasting 3. Subject: issue-based, area-based, institution-based 4. Time scale: long term vs short term 5. Spatial scale: global/supranational vs national/local
B. Process design: Intuitive vs. formal	6. Data: qualitative vs quantitative 7. Method of data collection: participatory vs desk research 8. Resources: extensive vs limited 9. Institutional conditions: open vs restrained *10A. Time taken for scenario development: short vs long* *10B. Formality of process: rigid vs flexible* *10C. Method of development*
C. Scenario content: Complex to simple	10. Temporal nature: chain vs snapshot 11. Variables: heterogeneous vs homogeneous 12. Dynamics: peripheral vs trend 13. Level of deviation: alternative vs conventional 14. Level of integration: high vs low *15. Number of scenarios: few vs many* *16. Detail in each scenario: little vs much* *17. Number of scenario iterations: 1 vs. 2* *18. Shared content: standard vs unique*
D. Scenario use: Internalised vs. externalised	*19. Promulgation: internal secret vs wide publication* *20. Use: direct input into planning vs better understanding* *21. Timescale: immediate use vs kept for reference*

Another scenario typology is proposed by Börjeson et al. (2006). This typology classifies scenarios in line with the possible-probable-preferable futures framework of Amara (1981). In this typology, there are three categories -predictive, explorative and normative- and six types related to these categories (Figure 14).

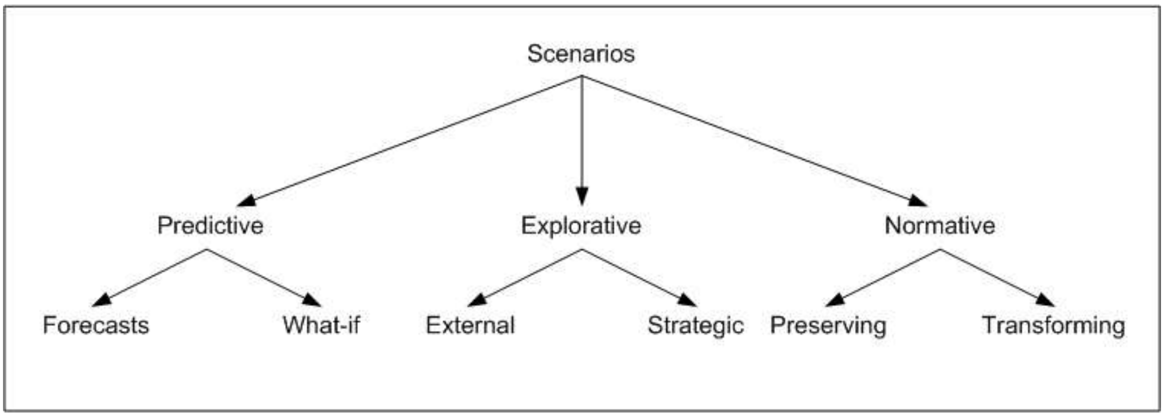

Figure 14. Börjeson et al. (2006) typology of scenarios

According to the typology of Börjeson et al. (2006), the predictive scenarios answer the question 'what will happen?'. Under predictive scenarios, forecasts identify what will happen if the likely developments unfold while what-if type scenarios try to predict future developments on the condition that some specific events happen. Explorative scenarios answer the question 'what can happen?'. External scenarios explore what can happen regarding an external development. In this type, the scenario developer is the object and studies a subject which is external to itself and beyond its control. Strategic scenarios explore what can happen if the scenario developer acts in a certain way, and therefore, in this type the scenario developer is both the object and the subject of scenario development. Normative scenarios answer the question 'how can a specific target be reached?'. Preserving type scenarios try to reach a particular aim through adjustments to the current system. However, if the current system is seen as blocking the way to the aimed future, then transforming scenarios come into play.

Bishop et al. (2007) identify eight general scenario development methods: judgement, baseline, elaboration of fixed scenarios, event sequences, backcasting, dimensions of uncertainty, cross-impact analysis and systems modelling; however, only a few of these methods have been used. The scenario development methods List (2005) identifies are intuitive logics, critical uncertainties and prospective. He leaves often soft-ware based and partly quantitative proprietary methods and impact-based methods out of his analysis scope. Börjeson et al. (2006) classify scenario development methods under three categories according to their purpose; generating methods, integrating methods and consistency methods. For Inayatullah (2008), scenarios serve mainly to creating alternative futures which is the fifth of six pillars described above. The methods he elaborates are single-variable, double-variable, archetypes, organisational and integrated.

Wiek et al. (2006) identify six essential aspects of scenario development. These are functions, goal formation, procedure, results, operating agents and strategic agents. They differentiate between the functions of scenarios (result) and functions of scenario development (procedure). The most commonly cited function of scenarios is to assist in decision making as a basis for assessment, strategy development and as an input for modelling. The functions of scenario development are generating scenarios, building competence, facilitating and organising teamwork, and counselling decision makers. During goal formation, which is a prerequisite for the quality of process and results, expected results, system boundaries, function and knowledge base should be identified. The procedure refers to the methods used and can be either intuitive or formal but generally these two combine in real life applications. The parameters which can be used to characterise results are complexity, desirability, plausibility, and consistency. Results from a scenario development exercise can either focus on a specific component of a system or the whole system. The operating agents are the people who develop the scenarios and can either be experts or laymen. The group comprising operating agents needs to be established taking the goal and function of the scenario development into account. Strategic agents frame the elements of scenario development and use the results in strategic decisions.

Despite the various definitions, purposes, uses and methods, scenarios share some common attributes. They describe hypothetical possible future pathways and dynamic processes which are causally related over a period of time (Rotmans et al., 2000). Since future is not predictable but will be influenced by individual and collective decisions along the way, and in the context of this research, the future is the future of complex systems, it is necessary to explore the relationship of futures studies and complex systems.

4.3. FUTURE STUDIES AND CAS

Summarising from Chapter 2 Section 2.3, CAS are characterised by unpredictable and emergent behaviour, limited or no decomposability, self-organisation, continuous change, sensitivity to initial conditions, learning, irreducible uncertainty, and contextuality. Some of the elements of CAS (e.g. humans) possess individuality, intention, purpose, foresight and values. These characteristics of CAS are currently changing the way how causality is conceptualised by the society. The linear and uni-dimensional conceptualisation of reality is slowly leaving its place to one which reflects the increasing knowledge about the properties of CAS. How causality is conceptualised has implications on selection and use of the futures inquiry approaches.

Western thinking about causality has evolved from the Aristotelian multi-causality understanding to the now dominant single-causality understanding which started in the seventeenth century with the Newtonian mechanistic understanding of the world (Aaltonen, 2007a). Nevertheless, a mechanistic, linear and single-causality understanding is not suitable to explain and manage the real and intertwined systems of the world (Holling, 1992; 2001; Ulanowicz, 1999, 2004; Hjorth & Bagheri, 2006). In dealing with complex systems, the conventional linear understanding of cause and effect as a chain cannot be rehabilitated since there is a network of interactions with many loops and feedback chains which act as small causes interacting with each other to determine system behaviour (Cilliers, 2007). Similarly, in socio-technical systems, there are so many dynamics interplaying with each other, only some of which can be known at a given time. There are also circular influences which create loops, thus reinforcing an occurrence in the system. Therefore, the concept of linear cause and effect is not sufficient to study the future of these systems since almost any event has multiple influences rather than one determining 'cause' (D. List, personal communication, July 10, 2007) and some of those influences might be reinforcing themselves (i.e. might be both the cause and the effect).

The influences or causes, due to the feedback loops within and across systems, may be reflexive (i.e. affect themselves) giving way to a circular causality. The activities taking place at the micro-level of systems as a result of interacting system components influence change at the macro-level of the system which is manifested as observable behaviour known as emergence (Aaltonen, 2007a; Cilliers, 2007). Emergent properties, due to circular causality, are not only effects of macro-level behaviour but also causes of micro-level activities and there is a top-down process as well as a bottom-up one (Cilliers, 2007; Harris, 2007). However, it should be noted that, the circular cause/effect chain is indeed not time-independent as the term circle implies, but rather, both causes and their effects and the causal implications of those effects flow through time. By the time effects (i.e. results/implications) of causes (or influences) affect the cause which generated itself, the cause changes and becomes a determinant of the new initial conditions of the system.

In line with sensitivity to initial conditions of CAS, the future becomes unpredictable, indeterminate and emergent (Driebe & McDaniel, 2005; Aaltonen & Sanders, 2007; Harris, 2007). Therefore, present-time choices of system elements determine the future of the system without being able to accurately identify what those future changes will be. Identifying systems' new initial conditions may be used to influence future (Aaltonen & Sanders, 2006; Aaltonen, 2007b). Identifying these new initial conditions requires an understanding of the past thus any attempt to inquire into future will only be meaningful with hindsight and insight as well as foresight.

Along with flow of cause/effect (or influence/implication) chains over time, there is also a multiplicity of causes giving way to a particular result at any given time. Mitleton-Kelly (2007) argues that Aristotelian conceptualisation of four different aspects of cause (material, efficient, formal and final) interact with each other to give way to an emergent whole; however, in line with Newtonian conceptualisation of the world, traditionally only the efficient cause is taken into consideration. Nevertheless, understanding the dynamics of and steering change in complex systems requires consideration of all these aspects of cause and the interaction within. Similarly, Inayatullah (1998; 2008) identifies different, nested causal layers for deeper analysis of problems which can then be used to generate alternative futures scenarios and action plans to achieve these futures. Aristotelian conceptualisation of cause is well suited to understanding physical phenomena whereas the layers identified by Inayatullah (1998) (i.e. litany, social/systemic causes, discourse/worldview, myth/metaphor) investigate causation in a societal context. Therefore, these two conceptualisations complement each other in analysing socio-technical systems. Even though Inayatullah's causal layers are layered to deepen the understanding of the social cause, Aristotelian aspects of cause are not necessarily layered in a deepening way but juxtaposed to broaden (instead of deepen) our understanding. While Aristotelian causation can be used equally efficiently for reductionist science when analysing a single component or part of a system, the layers proposed by Inayatullah require a systemic and contextual perspective.

There is no possibility of tracking down all of the causal relationships within CAS and the best an analyst can do is to search for patterns in a system (Cilliers, 2007). Since CAS are contextual -i.e. not universally deterministic but dependent on time, locality and initial conditions- and interdependent to other CAS both at lower and higher levels in a nested hierarchy, it is impossible to draw closed system boundaries and have an all-encompassing understanding of the system. In understanding causal patterns, analysing CAS and steering CAS towards a desired future, the self-positioning of the analyst is a determining factor for success. In this regard, with references to the nested hierarchies therein, the best strategy seems to be focusing on a part of CAS -i.e. identifying a focal system- to be worked on and acknowledging the interrelationships between that focal system and the rest of the CAS.

4.4. FUTURES STUDIES AND SYSTEM INNOVATION FOR SUSTAINABILITY

Most of the futures methods were developed during 1970s or before, and therefore, they are not designed to deal with qualities of CAS. Recently in the futures field, there has been a call for methodological renewal in line with systems thinking (e.g. Aaltonen & Sanders, 2006; Floyd, 2008).

When radical change is needed, conventional planning methods such as forecasting, which is basically an extrapolation of prevailing trends, remains insufficient (Dreborg, 1996; Höjer & Mattsson, 2000; Wehrmeyer, Clayton & Lum, 2002). As discussed before, forecasting is classified under anticipatory or predictive futures inquiry methods (List, 2005; Börjeson et al., 2006). Höjer & Mattsson (2000) argue that forecasts can act as an alarm to inform that the prolonging trend will lead us to an undesired future state, but have nothing beyond to offer as a planning tool should long-term radical change be necessary. As Slaughter (1998) argues, creating images of future through 'speculative imagination' can feed our capacities for speculation, imagination and social innovation. This image creation through scenario building is referred as foresighting. Wehrmeyer et al. (2002) state the main applications of foresighting as: 1) to improve long-term decision making; 2) to guide technology choices; 3) to generate alternative trajectories for future developments; 4) to improve preparedness for emergencies and contingencies; and 5) to motivate change. The foresighting process involves three phases:

- Working with groups both inside and outside the institutionalised planning processes to identify possible future scenarios;
- Identifying, comparing and evaluating a range of possible future options;
- Backcasting (Wehrmeyer et al., 2002, p. 29).

Backcasting can be defined basically as planning backwards from a desired future state, thus, enabling the identification of alternative multiple paths towards that desired future (List, 2005). Backcasting also can be used to avoid undesired future states through development of a worst case scenario, identifying steps realising that undesired scenario and developing strategies to avoid those steps (Inayatullah, 2008). Dreborg (1996) states that backcasting is useful when the problem to be studied is complex, affecting many sectors and levels of society, when there is a need for major change since dominant trends are part of the problem and when the time horizon is long enough to allow considerable scope for deliberate choice. While forecasting is an extrapolation of the present towards an unknown state in the long-term future, backcasting is an interpolation towards present from an already envisioned future state (Figure 15).

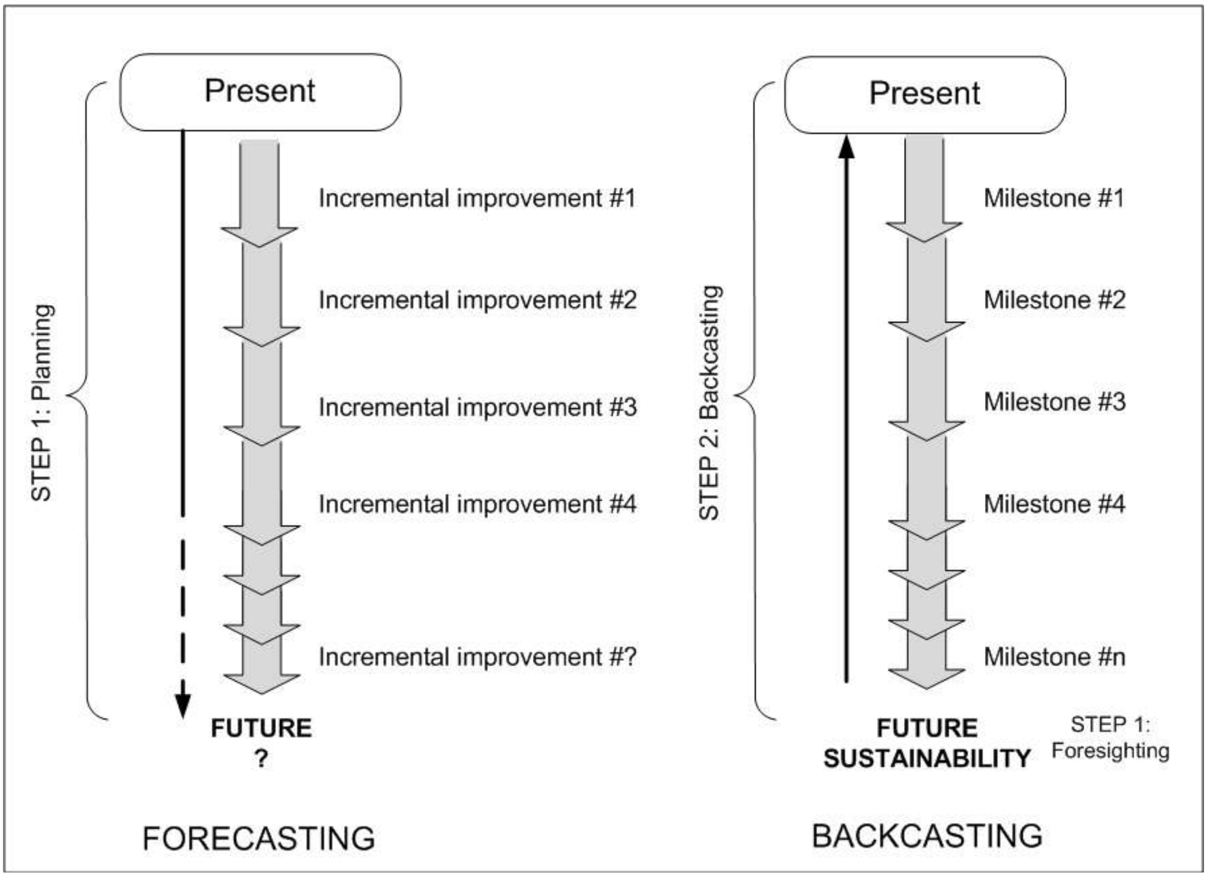

Figure 15. Forecasting versus Foresighting-Backcasting

Backcasting is not a new concept in planning for the future. It has been used in numerous applications from policy making to sustainable technology development mainly in European countries. Quist and Vergragt (2004) provide a detailed historical development and a summary of past applications. The past studies relevant to the scope of this research are also discussed in detail in the next section.

4.5. Critical Review of Previous Work

This section provides a critical analysis of two main scenario development approaches used in previous studies for envisioning sustainable technologies. The methodologies of these approaches are analysed in terms of:

- The extent of co-evolutionary approach to innovation;
- The time-frames used;
- The sustainability approach, and;
- The flow direction of scenarios.

4.5.1. Sustainable Technology Development and Derivatives

The three major projects, which will be analysed under this sub-heading, are:

- The Dutch National Inter-Ministerial Programme for Sustainable Technology Development (STD) (1993-2001);
- The European Union funded Strategies towards the Sustainable Household (SusHouse) Project (1998-2000), and;
- Planning of Strategic Innovation in a Polymeric Coating Chain (PCC) Project.

Both STD and SusHouse projects were about sustainable need fulfilment with a long-term approach (Quist & Vergragt, 2004; Quist & Vergragt, 2006). The former one focused on policy development to influence sustainable innovations (Weaver et. al, 2000), and the latter one focused on developing design-orienting scenarios to influence sustainable technological and social innovations (Green & Vergragt, 2002). The STD project adopted a 50 year time frame consistent with the time period needed for radical innovations and used a backcasting approach aiming at Factor 20 reductions (Weaver et al., 2000). The SusHouse methodology was derived from STD methodology, and therefore, adopted the same time frame and Factor X reduction target. Both of the projects involved different stakeholders into backcasting process because of their context specific knowledge and for endorsement of results and realising implementation (Quist & Vergragt, 2006). STD was focused on nutrition, transport/mobility, buildings and urban spaces, water services and, materials/chemicals (Weaver et al., 2000). The project schedule consisted of following steps:

> Develop long-term vision:
> Step 1: Strategic problem orientation and definition
> Step 2: Develop future vision
> Step 3: Backcasting – set out alternative solutions
> Develop short-term actions
> Step 4: Explore solution options – identify bottlenecks
> Step 5: Select among options – set up an action plan
> Implementation
> Step 6: Set up co-operation agreements – define roles
> Step 7: Implement research agenda (p. 76).

The SusHouse project focused on three household functions (Vergragt, 2000; Green & Vergragt, 2002). These functions were food (shopping/cooking/eating), clothing care and shelter (heating/cooling/lighting). The methodology consisted of stakeholder creativity workshops, scenario writing, environmental assessment of scenarios, economic assessment of scenarios, consumer acceptance research on scenarios, and backcasting workshops (Vergragt, 2000).

The PCC project had a sectoral focus in two countries; the Netherlands and Portugal (Partidario, 2002; Partidario & Vergragt, 2002). The methodology used was similar to the STD and SusHouse methodologies (scenario development, participatory workshops, stakeholder involvement and backcasting) and 'based on social interactivity and on a social learning process (e.g. the product chains, policy making) creating conditions to promote innovation (Partidario, 2002, p. 171)'. The study was focused on environmental sustainability, had a 50 year time frame and used a Factor X concept, similar to STD and SusHouse.

All three projects focused not only on influencing technological innovations but also social, institutional and organisational innovations (Weaver et al., 2000; Vergragt, 2000, Partidario, 2002). Even though these projects focused on different types of innovations in the wider socio-cultural context, the understanding about the formation of these innovations was linear and one-way rather than co-evolutionary and the whole approach was explicitly techno-centric. The innovation ideas were evaluated against consumer/society acceptance according to current cultural values. Consideration of current cultural values or social acceptance is vital for the realisation of short-term actions. Nevertheless, on a long-term scale, innovations or technological developments can influence the demand side and render diffusion possible. Saviotti (2001) argues that for radically new products which fall beyond consumers' imagination, there can be no demand. Elsewhere he states that in 'these cases, preferences and demand are created gradually as an innovation diffuses and as various forms of learning take place, both on the consumer and of the producer side (Saviotti, 2005, p. 19)'. He points to the mutual nature of learning in the sense that producers should inform their consumers about the innovation at the beginning, and then, as the innovation diffuses, producers gradually learn how to evaluate demand.

Using a 50 year time frame is justified as it is consistent with the amount of time required for developing radical innovations (Weaver et. al, 2000). Also it meets the requirement for long-term orientation. However, the selection of this time frame is based on innovation dynamics rather than sustainability and, by placing a temporal limit, ignores unsustainability issues which may extend beyond or become significant after this pre-determined time frame.

Factor X reduction targets, which are based on a single indicator, i.e. the ecological footprint (Chapter 5), suffer from an over-generalisation of sustainability issues. It does not make any differentiation between various problems and treats them as if they pose equal amount of risk and require equal amount of improvement within the same temporal frame. However, for example, consumption of renewable resources has different implications than consumption of non-renewable resources, and therefore, will require a different approach in considering renewal rate. Factor X can be used effectively to set general dematerialization targets but cannot provide information on single allocation issues at a systems level. The simplified context can be effectively used in a very local sense, but when the global flow of materials is considered, local dematerialization targets and implementation of these will not be meaningful in the larger systemic contexts. Factor X is focused on tackling present undesirable trends; therefore, planning which relies solely on Factor X assessment will be prone to failure in the case of an unanticipated change. Factor X deals only with material/energy flows in a technological system and aims to meet pre-set efficiency targets. Therefore, it can only favour environmental sustainability and fails to provide a systemic coverage. Thus, Factor X should not be the only indicator to guide decisions during scenario development, selection and backcasting.

The research projects discussed in this section investigated ways of influencing radical technology development in large operational contexts such as policy development (Weaver et al., 2000). The smallest operational context focused on in research was a particular industrial sector (Partidario, 2002). As a result, how an individual company relates to larger operational contexts such as a whole sector or policy in planning for sustainable technologies remains as a gap to be filled. Weaver et al. (2000) emphasise firms as key entities in carrying innovation forward but they also state that radical innovations rarely arise from established firms. One of the major characteristics of their project is to 'ignore existing technological solutions and, instead, develop new solutions from new starting points, such as the "need" to be met or the "task" to be performed (Weaver et al., 2000, p. 64)'. Focusing on 'need' is essential within a sustainability context. Nevertheless, ignoring existing technologies and vested interests of established firms in the existing markets, despite the creative potential it brings, is not sufficiently realistic to influence sustainable technologies. Technology is not a stand-alone, independently functioning or developing entity. Rather, as mentioned before, the functioning and creation of technology resides in a socio-technical system, which consists of many agents enforcing the stability of or influencing change in that system. In addition, technological development is dependent on cumulative knowledge and new technologies, even the most radical ones, will be built on and add to the existing knowledge base. Therefore, STD and its derivatives' approach to development of sustainable technologies is weak, since it neglects the 'present' completely and focuses only on the future. The potential of focusing on a visionary future state to achieve sustainable technologies could be strengthened with an in depth analysis of the current socio-technical system to identify barriers to change such as technological lock-ins and social networks in support of the status-quo and develop strategies to overcome these.

4.5.2. Socio-technical Scenarios

The neglect of co-evolution of technology and society in anticipating the future technologies has several pitfalls (Geels & Smit, 2000). Policies based on overly simplistic assumptions about how technologies develop and diffuse are prone to failure and such anticipations do not allow for the consideration of some types of strategies and policies due to their implicit assumptions about technology development (Geels, 2002c). Building on the multi-level perspective of socio-technical change and his criticism about linear and simplistic scenario methods, Geels and others developed the socio-technical scenarios (STS) methodology. The multi-level perspective constitutes the conceptual framework for STS.

Elzen, Geels, Hofman and Green (2004), pointing to the high complexity and uncertainty during transitions, list the following features as a minimum which should be covered by socio-technical scenarios:

1. Transition scenarios should show socio-technical development, that is, the co-evolution of technology and its societal embedding ('leapfrog' dynamic). This implies attention for different types of actors, their goals, strategies and means. Concrete features like technologies, investments and infrastructures should not appear automatically but must be made plausible as the result from interactions between actors. Thus, transition paths do not come out of the blue but it becomes clear *why* they develop.
2. Learning processes and niche dynamic should be visible in the scenarios. Important questions to deal with are: What happens in niches? Which innovations are developed? What are the problems and possibilities? In which direction are solutions sought? What learning takes place on technology, new user practices, regulation, etc.? Which actors are involved in the learning processes?
3. Spread of novelties should not only describe diffusion of individual innovations but also have attention for their development and the interaction between niches, e.g. in linking of individual technologies (hybridisations) and synergistic effects.
4. Market take-up should also address the development of innovations through successive niches (niche-accumulation) (p.256).

The method to develop and implement socio-technical scenarios is to (Elzen et al., 2002):

- Characterise the current regime in terms of the embedded technologies, the main actors that constitute the regime, its dynamic and, based on this, the main trends in the recent past that are likely to carry on into the near future;
- Identify 'potentially interesting' niches and characterise them;
- Identify the main landscape factors that (could) influence the dynamic in the niches and regime;
- Design choices at various levels, notably:
    - 'macro-level' choices: choose landscape level factors that define the macroenvironment in which the scenario-developments take place;
    - 'micro-level' choices: choose which niches will make a 'breakthrough' as a prelude to a transition.

These tasks can be carried out in a number of consecutive steps, notably:

- Step 1: Design choices and contours of the scenarios
- Step 2: Inventory of potential linkages as promising transition elements
- Step 3: Analysis of dynamic of the existing regime
    - Regime characteristics, problems, strategies and trends
    - Landscape factors and 'enabling technologies'
    - Relevant niches: opportunities and barriers for transition
- Step 4: Develop scenario skeletons
- Step 5: Make the scenario
- Step 6: Reflect on the scenarios
- Step 7: Develop policy recommendations (p.15).

This method has been used to explore transitions towards sustainability in energy (Elzen et al., 2002; Hofman, 2005) and transportation (Geels, 2002c; Elzen et al., 2004) sectors. The strength of the STS method is obviously the emphasis it puts on co-evolution of technology and society. The elaboration of socio-technical regime characteristics combined with analysis of macro-level circumstances (landscape level) and micro-level developments (niche level) provides an understanding of the present dynamics of the existing regime. Understanding the present dynamics is essential since the new technologies or the socio-technical regimes these technologies will be a part of will either improve or replace existing technologies. The method not only enables such an understanding but also, since the scenarios rise from the causal relationship between present and future, has the potential to bring realistic policy recommendations which will influence the regime change. The scenarios can help to identify alternative transition paths and policies can be directed towards realisation of a preferred path (if it exists).

Despite the strengths of socio-technical scenarios method, it is designed to be used for policy development. Policy development takes place at societal level (i.e. large operational context). Even though the multi-level perspective that the method uses provides grounds for the analysis of influence of niches on regime, niches are not 'operational contexts'. Therefore, how individual companies (i.e. smaller operational contexts) relate to innovation at the system level remains vague. As significant regime actors, individual companies play an important role both in generating, enforcing and overcoming lock-ins as the group of companies in a sector determine, to a large extent, how the niches are created and which ones are developed. Also, from the perspective of an individual company, understanding the likely changes in the socio-technical regime it operates within is important in developing future strategies.

STS have so far been used in energy and transportation areas (Elzen et al., 2002; Elzen et al., 2004; Geels, 2002c; Hofman, 2005). Energy and transportation regimes are especially hard to change due to involvement of many stakeholders. These regimes are almost overarching regimes in modern society, with regimes entirely or partially dependent on these overarching regimes. Indeed, there is a hierarchy of regimes in relation to level of dependency on other regimes. This hierarchy should be acknowledged at the socio-technical regime level when analysing and building strategy for regimes, which are lower in the hierarchy, i.e. which highly depend on other regimes.

The major pitfall of the use of this method so far in influencing transitions towards sustainability is the lack of a basis, which defines or measures 'sustainable'. It can be seen from the above-mentioned previous studies that there are assumptions about what a sustainable energy or transportation regime should be like. For example, in Elzen et al. (2004), the scenarios are built around two visions of sustainability. In the first scenario, the outcome is high-tech, individual mobility with extremely low carbon dioxide emission cars. The second scenario replaces personal automobiles with self-drive vehicles, which are leased instead of purchased. The scenarios' main starting points are issues related to congestion and fuel emissions. Therefore, the outcome scenarios are focused on mitigation of these two issues and land use impacts are not taken into account. Accordingly, there are no references in the scenarios to deal with land use impacts of continuing individual mobility. Therefore, in these scenarios, there are no references as to how urban planning and public transport will change, which, indeed, may change policy recommendations substantially.

STS have so far been developed as expert scenarios. All decisions including the quantity of scenarios to be developed and time frame to be used are made by an analyst (or a group of expert analysts) who is a policy expert. The selection criteria for these decisions are vague as are the criteria for identifying a certain transition path as 'promising a better sustainability performance'. The STS method can be improved through input from different expert groups, such as experts from sustainability science and related fields, as well as participation of non-expert stakeholders. In addition, an integrated scenario development approach, as proposed and used by Rotmans et al. (2000) in Visions for a Sustainable Europe Project can improve the outcome of STS substantially. Rotmans et al. (2000) used a combination of expert and participatory scenario approaches in developing visions for a sustainable Europe. The expert input was used to provide scientific accuracy and integrity in sustainability issues, whereas the participatory part was used to enhance broadness and richness of the scenarios as well as to enable dialogue and credibility among stakeholders. Similarly, providing input from scientists in the sustainability area and incorporating a participatory aspect into STS methodology can improve the outcome in following ways:

- Scientific input about sustainability issues can help to provide an assessment frame for transition paths, and therefore, the policy recommendations can be done accordingly;

- The participation of different stakeholders can provide more insight about creation and development of niches suitable for a transition path preferred in line with sustainability requirements, and;
- The participation of different stakeholders will potentially increase the success of implementing the policies as these will be developed in consultation with the parties to be affected by those decisions.

Finally, the method on how to develop STS is not transparent enough for potential users to repeat the steps in detail. What has been documented so far provides a skeleton of the methodical steps rather than the method itself. The causal relationship between consecutive events is apparent in the scenario narratives, i.e. the flow of events is logical. But, it is not clear why event B, instead of C, followed event A, where C also can logically follow A. This is most probably a result of key assumptions and decisions made by the scenario developer. Nevertheless, if the assumptions and decisions are made transparent, following the logical flow of scenarios could be improved. This transparency can also provide a ground for improvement and/or reassessment and refinement of scenarios as underlying assumptions change or by different experts. Progress needs to be made to clarify the decisions and construction methods behind STS (F. Geels, personal communication, June 22, 2007). Therefore, there is ground for development and improvement of STS method in its present form.

4.6. SUMMARY OF FINDINGS AND INSIGHTS GATHERED IN THIS CHAPTER

This chapter provided an overview of the futures studies, the relationship between futures studies and CAS and the role of futures studies in system innovation. The chapter also reported a critical review of some previous work of major significance in relation to system innovation for sustainability. Below is the summary of key findings and insights reported in this chapter:

- In order to realise system innovation three types of knowledge needs to be generated; knowledge of the system and its components subject to transition (i.e. system knowledge), knowledge on how to make the transition from the current state of the system to the desired state (i.e. transformation knowledge), and knowledge of the desired state (i.e. target knowledge). Target knowledge is the vision of the sustainable state of the system of concern. Therefore, generation of visions is crucial for system innovation. In order to establish the transformation knowledge which will enable the society to move from the current state to the desired state, using a suitable futures inquiry method/tool is needed. The most commonly used futures inquiry in system innovation related projects is scenario development. Scenarios are also widely used in organizational strategy development as well as product development. This makes utilization of scenario development as the most suitable approach for the overall objective of this research, i.e. to effectively link the activities/decisions at product development (micro-innovation) level in companies with the transformation which needs to take place at the societal (macro-innovation) level to achieve sustainability;

- There are several different scenario development methods/tools and several different types of scenarios generated as a result of the method/tool used. Different types of scenarios can be used for different purposes. The simplest typology suggests three types of scenarios: predictive, exploratory and normative. These scenario types are analogous to the three types of knowledge which need to be generated to manage system innovation for sustainability. Predictive scenarios (such as population forecasts) can aid in generating system knowledge. Normative scenarios (i.e. visions of sustainable futures) can aid in generating target knowledge. Exploratory scenarios can aid in generating the transformation knowledge. Therefore, in planning for system innovation for sustainability all three types of scenarios are relevant;
- Increasing scientific knowledge about CAS is changing how causality is understood and conceptualised. There is a shift from a mechanistic and linear understanding of cause and effect chains to an understanding accommodating dynamically interacting multiple influences and circular causes. Interventions to influence the future of CAS, and thus, of socio-technical systems which need to be transformed towards sustainability should also adopt this latter understanding of causality;
- Future of CAS is unpredictable, indeterminate and emergent. The present-time choices of system elements determine the future of the system without being able to accurately identify what those future changes will be. In order to push/pull a socio-technical system towards a desired state any attempt to inquire into future will only be meaningful with hindsight and insight as well as foresight;
- There is no possibility of identifying all of the causal relationships influencing CAS. Also, CAS can be influenced both by internal dynamics and external factors. Therefore, it is impossible either to draw closed boundaries or to have an all-encompassing understanding of a system. In order to steer a large CAS -such as a socio-technical system- towards a desired future the best strategy seems to be focusing on a part of CAS, and thus, identifying a focal system to be worked on and acknowledging the interrelationships between that focal system and the rest of the CAS, and;
- Analysis of some major previous work in the area of system innovation for sustainability (in terms of the extent of co-evolutionary approach to innovation, the time-frames used, the measure of sustainability adopted, and the flow direction of scenarios) concluded that, despite

the strengths of each methodology used in these projects, none of them is fully capable to influence system innovations towards sustainability especially at product development level.

5. SUSTAINABILITY AND INDUSTRY

5.1. INTRODUCTION

Industry has a double-faceted role in achieving sustainability. It is the major cause of environmental deterioration, as well as the main agent for economic and social development (Schot et al., 1997). Nidumolu, Prahalad and Rangaswami (2009) argue that sustainability is now the key driver for innovation in companies since incorporating it into the business can reveal technological and organisational innovation opportunities which have significant potential for economic return. They state that becoming a sustainable enterprise is a five stage journey from seeing compliance as an opportunity to creating next-practice platform by questioning and replacing the current logic of business. Replacing the current logic of business is indeed innovation at the system level. Shifting companies' sustainability approach to such high-level understanding is an incredibly challenging mission given the dominant, growth-oriented economic paradigm as well as the consumption culture prevailing in the post-industrial and developing countries and becoming increasingly widespread in emerging economies. The required transformation of industry will take place as part of the broader societal transformation to achieve sustainability. In order to facilitate the transformation of industry, the role of industry in achieving sustainability needs to be investigated and the current drivers and barriers for industry to move towards sustainability needs to be understood. With this aim, this chapter critically reviews the literature addressing sustainability and industry. In the following three sections (5.2, 5.3 and 5.4), the role of industry in achieving sustainability, the current drivers and barriers for industry to move towards sustainability, and the significance and implications of sustainability risks for the industry are discussed. The advantages and disadvantages of different strategic orientations and existing tools and approaches are analysed in Sections 5.5 and 5.6.

5.2. THE ROLE OF INDUSTRY IN ACHIEVING SUSTAINABILITY

Industry is a subset and an integral part of society. It facilitates economic and social development as well as cultural exchange. Industry provides products and services for need fulfilment and well-being. It facilitates human development through knowledge generation and technological development and it plays an important role in job creation and employment. Companies are not only responsible to, and driven by, interests of shareholders but they also are responsible to, and influenced by, all stakeholders that they come in contact with, either directly (employees, governmental institutions, supply chain, etc.) or indirectly (consumers, competitors, educational institutions, public in general).

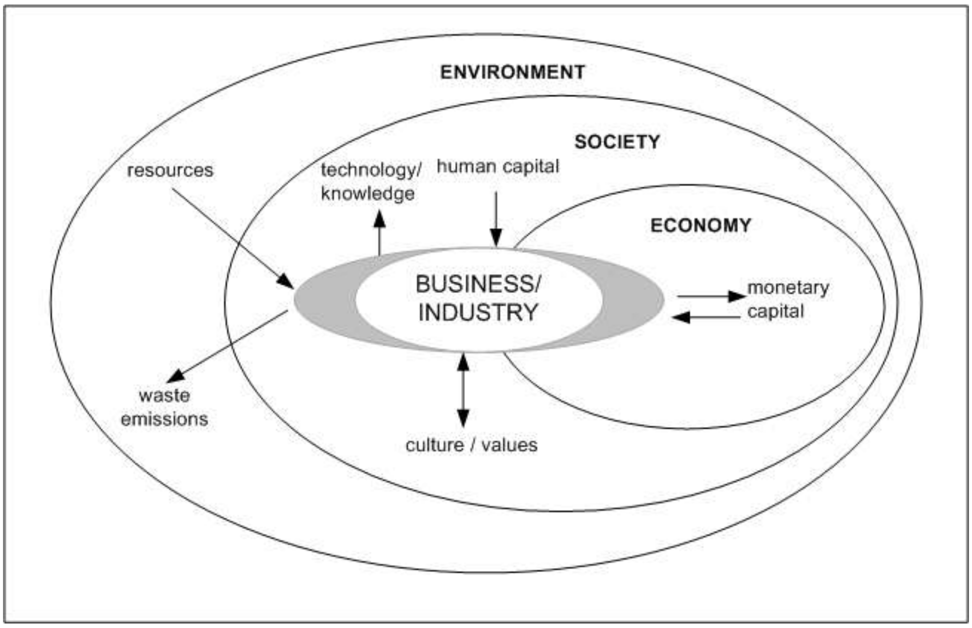

Figure 16. The main interactions between industry and the environment, society and economy

Industry is strictly subject to the irreversible hierarchy of the strong sustainability model (Figure 16). Without resources, processes and technologies would not be possible. Without human capital input, physical and intellectual labour requirements would not be met due to the very limited interchangability of different capitals provided by the environment, society and economy. In addition, industry and the whole network of production and consumption influence socio-cultural change in the short, medium and longer terms through life style changes by development of new technologies. In a strong sustainability model, the role of businesses is not only limited to improving direct impacts (input-output) rising from the interaction with the environment, but as an actor in the socio-technical system, businesses can have indirect yet effective influence on consumption patterns (Málovics, Csigéne & Kraus, 2008). Businesses have a pivotal role to play in sustainable consumption and production since a significant amount of resources, capabilities and mechanisms needed for the transformation towards sustainability are held by them (Charter, Gray, Clark & Woolman, 2008). Influenced by technological change, social and cultural norms and perceptions change. Therefore, industry itself is an agent of change which can facilitate the change required within the socio-cultural context needed to achieve sustainability. As a summary, Figure 17 shows the business in the context of social influences. In this web of interaction, businesses have multiple roles to play including:

- development of new technologies and practices;
- promoting sustainability in up and downstream chains;

- promotion of sustainable consumption;
- influencing changes in the economic and legal incentives which shape both production and consumption patterns, and;
- influencing changes in the values and discourse which shape the culture of business, government, media and public.

Although this figure may imply suppliers exist in a vacuum, they are also influenced by governments, markets, consumers and media. In addition, businesses increasingly require responsible performance and green products from their suppliers.

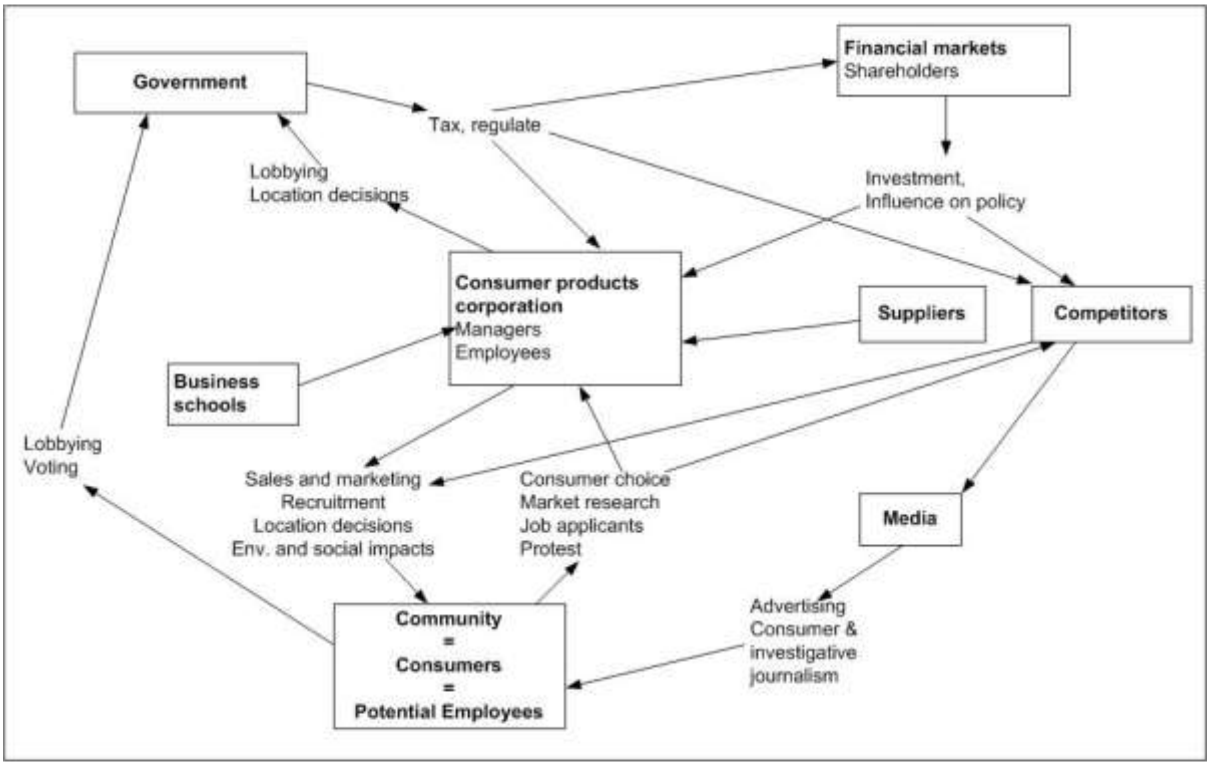

Figure 17. Interaction web of social influences on the business (reproduced from Michaelis, 2003)

Society and industry are interdependent and, thus, sustainability of industry is required to sustain society and vice versa. Therefore, an understanding of the interactions and interdependencies between industry and society and the addressing of these interactions and interdependencies with an integrated and holistic approach is necessary to achieve sustainability.

5.3. DRIVERS AND BARRIERS FOR CHANGE TOWARDS SUSTAINABILITY

There are both drivers and barriers for industry to move towards sustainability. Table 5 presents a summary of these drivers and barriers classified under institutional, social/cultural, organisational and technical/technological components of the socio-technical system.

Table 5. Drivers and barriers for industry to move towards sustainability

	Institutional	Social/Cultural	Organisational	Technological
Drivers	Legislation/ regulation enforcing sustainable practices Promising niche markets Current economic paradigm encouraging businesses to actively seek opportunities and see risk as an opportunity	Consumer demand/pressure Stakeholder demand/pressure	Competition Company culture/values Reputation/ Legitimacy Shareholder pressure Employee pressure Financial gains	Limits/challenges by biophysical environment Emerging enabling technologies
Barriers	Current economic paradigm encouraging growth-oriented business practices Legislation/ regulation enforcing established unsustainable practices Legislation/ regulation too stringent to be encouraging Lack of policy context for radical systemic innovation Lack of economic incentives for radical systemic innovation Lack of understanding on how to steer and manage radical systemic innovation	Consumption culture Lack of lead markets for niche technologies Challenge of activating and organising collective transformative movements	Organisational inertia Commitment at managerial level Company culture/values Need for long-term orientation Return rate of investment Costs (perceived and real) Threat of cannibalising own business Lack of understanding in the industry of how to be involved in radical systemic innovation	Lock-in effects for diffusion of new technologies Lack of enabling technologies

Hart (1995) argues that the constraints and challenges posed by the biophysical environment are among the most important drivers for firms to develop new resources and capability. He sees action taken towards sustainability by firms as a result of natural limits as a potential to enhance competitive advantage through development of firm-specific competencies which are not easy to imitate by competitors. He argues that the aim of establishing and protecting company legitimacy and reputation influences firms to adopt company-wide holistic approaches in relation to environmental performance covering all products and processes. Crises relevant to environmental pressures and rising energy and petrol prices are currently among the significant drivers for the industry to consider changes in their practices in line with sustainability requirements (Charter et al., 2008). Shrivastava (1995a) emphasises competitive advantage, pointing out that ecologically oriented strategies give companies 'first mover' advantage (gained by being the first occupant in a market segment) in environmentally sensitive markets.

Porter and van der Linde (1995) argue that properly designed stringent environmental regulation will influence and facilitate innovation in companies. There is a body of empirical research supporting this argument, especially in relation to end-of-pipe pollution reduction/prevention-oriented legislation (e.g., Greenstone, 2003; Taylor, Rubin & Hounshell, 2005). Increasingly, this end-of-pipe pollution prevention/reduction-oriented early legislation is being supported by product and producer responsibility-oriented policies. More detail on this is given under Section 5.6.1.

Increasing public concern about environmental and social issues is being reflected by consumer purchase decisions (Brown & Wahlers, 1998). Consumer pressure is one of the major incentives for companies to adopt environmental self-regulation measures (Anton, Deltas, & Khanna, 2004). There is a consumer group referred to as 'ethical consumers' which include non-activists (concerned, buy and boycott products if the issues are obvious but do not feel guilty about unethical buying) and activists (passionate and more interested in social and environmental issues than in brand names) and comprise more than one fifth of the population according to Cowe and Williams (2001). Ethical consumers are not solely concerned with environmental issues but also animal rights/welfare and human rights (Tallontire, 2001). Even though the proportion of ethical consumers to the whole of the population is not sufficient to produce any significant marketplace action (Cowe & Williams, 2001), Wheale and Hinton (2007) state that most companies recognise that there are profitable niches for products which have a higher environmental and social performance.

González-Benito and González-Benito (2006) identify five internal (i.e. company size, degree of internationalisation, position in the value chain, managerial attitude and motivations, and company strategic attitude) and two external (i.e. industrial sector, geographical location) factors as determinants of environmental proactivity in companies. They state that stakeholder pressure is central and essential to adoption of voluntary self-regulation activities and, indeed, all the other factors affect either the intensity of this pressure or the company's capacity to perceive it. Henriques and Sadorsky (1996) explicitly define shareholder and employee pressure as part of stakeholder pressure, which influences companies' environmental performance. A recent study carried out in Japan by Nakao, Amano, Matsumura, Genba and Nakano (2007) statistically supported the hypothesis that a firm's environmental performance has a positive impact on its financial performance.

Shrivastava (1995a) argues that competition through innovation is one of the major drivers for industrial sustainability. Charter et al. (2008) state that sustainable innovation is an area emerging as a response to the needed radical systemic change. This type of innovation includes product and process innovations but goes well beyond to compete for the future innovations to meet sustainability requirements. Personal experience also indicated that, in some companies, senior management have started to recognise the need for radical change and that all company processes in the future have to be sustainable (C. Gianni, personal communication, November 20, 2006; M. Elmore, personal communication, July 28, 2008).

There are limits to exclusively internal (developed within a single company) strategies for sustainability since there is a need at systemic level to alter socio-technical systems by redefinition/redesign of technological/social infrastructures and changing consumer behaviours (Hart, 1995). However, this is a more challenging process than incremental and improvement-based eco-innovation which can be managed internally in a company. For change to take place at systemic level, various preconditions must be fulfilled such as availability of lead markets, entrepreneurship and venture capital, stability in policy and institutional context, and, convincing shareholders of the need of long-term planning and investment (Charter et al., 2008).

More fundamentally, the history of research investigating how radical systemic transformation can be managed is not very long (Chapter 3). No outcomes from this body of research have yet been widely observed. Therefore, there is a lack of understanding at policy-making level on how to steer and manage system innovation. As a result, within the industry, there is a lack of understanding on how to be involved in and plan for the systemic and large-scale transformation which needs to take place to achieve sustainability. Neither is there sufficient funding available at the disposal of companies to encourage the necessary research and capacity/capability development. The two case studies carried out by Van Bakel et al. (2007) pointed out that system innovation poses a unique challenge for established companies. These companies, on the one hand, have to continue regular business practices within their existing socio-technical regime and, on the other hand, they have to develop and run shadow-track strategies for developing niche innovations to challenge the regime they are running their businesses in.

Hart (1995) points out that the need for having a long-term orientation in business planning along with short and medium terms and associated costs, as well as the slow return rate of investments, are discouraging companies from taking action towards sustainability. Stone and Wakefield (2000) and Stone (2006) emphasise the required change in company values and the need for commitment at the managerial level as the barriers at the organisational level. Conceição, Heitor and Vieira (2006) report, as a conclusion to their empirical study carried out among innovative Portuguese firms, that lack of organisational flexibility and consumer receptivity are the two most relevant innovation barriers. There are more challenges in the systemic level. In order to gain the competitive advantage mentioned in the previous paragraph, there must be cohesion and flow of information within the organisation and between organisations and stakeholders to accept and integrate ecological (Shrivastava, 1995a), social and economic signals from the external environment.

Even though an understanding of barriers and drivers for industry to move towards sustainability is essential to manage system innovation, it is impossible to prepare a checklist of all drivers and barriers which can be used to initiate and manage all projects of system innovation for two main reasons. First, empirical research on drivers and barriers is limited and generally consists of case studies (for a recent review of the literature see del Río González, 2009). Therefore, all-encompassing, generic knowledge of drivers and barriers is not available. For example, Labonne (2006) found that how larger companies deal with environmental issues differ significantly from how SMEs deal with same issues. Second, some of these drivers and barriers are not mutually exclusive and act as both which makes their use in managing system innovation complicated. For example, the current liberal economic system, by promoting a competitive paradigm, encourages companies to see sustainability issues as potential innovation opportunities. On the other hand, as much as a driver, the current economic system is also one of the major barriers in front of the industry because ecological and social costs are external to the cost of production. The current economic system, by promoting a competitive and growth-oriented business paradigm, forces the companies to reduce the price of the products and services they deliver and try to increase their sales. Nevertheless, there is not yet a system capable to cope with the resulting resource depletion and waste generation. In addition to, and reinforced by, this cycle of resource depletion and waste generation, consumerism in the society prevails.

5.4. Sustainability Risks and Industry

The relevance of sustainability risks to industry is that if the society fails or global environmental deterioration continues, the businesses cannot succeed (Reinert, Jayjock & Weiler, 2006). In the discourse of the business case for sustainable development, many authors have identified risk as a major driver of behaviour and adopting 'beyond compliance' policies even though currently these policies cannot be justified from an economic point of view (Evans, Brereton & Joy, 2007).

Shrivastava (1995b) points out that managing companies to optimise production variables is insufficient and corporations should also manage risk variables. He argues that this does not mean an expansion to include new risks but it requires substitution of 'the production orientation of existing paradigms with the risk orientation of a new paradigm (p. 123)' and, '[organisations] need an orientation that focuses centrally on technological and environmental risks, that is, one that does not treat risks as externalities but treats them as the core *problems* of management (p. 127)'. The profit-centred risk orientation should be extended by internalisation of sustainability related risks in order to be able to identify the costs associated with sustainability and their impact on profit.

The Millennium Ecosystem Assessment (MEA) report by World Resources Institute (WRI) identifies six major changes which are having or will have profound negative impacts on ecosystems as relevant to businesses, either individually or collectively. These six changes are water scarcity, climate change, habitat change, biodiversity loss and invasive species, overexploitation of oceans, and nutrient overloading (MEA, 2005). In addition to impacts of ecosystem changes, certain social trends and practices are becoming increasingly relevant to the business decisions such as population growth, ageing of population in developed countries, vulnerability of people to climate change, poverty, conditions of labour and, increased risk of social conflict and political instability in certain regions (ILO, 2005, 2006; UN, 2007a, 2007b; UNDP, 2007; UNEP, 2007).

The World Business Council for Sustainable Development (WBCSD) counts sustainability risks among the new mega-risks of the century and points that these risks 'present unprecedented challenges to companies and governments alike' (WBCSD, 2004, p. 13). The key message of WBCSD addressed to companies is that these risks are systemic, complex and interrelated in nature, have greater uncertainty than traditional risks, and are owned not by a single entity but by the whole of the society. Therefore, companies should adopt longer-term strategies to tackle the challenges rising from these risks and should collaborate with society and government in mitigation and/or management of these risks.

The risks rising from sustainability related issues both pose threats to and provide opportunities for businesses. Businesses likely to evolve and avoid decline are those adaptable to the changes such as environmental crises, rising energy and material prices and global trends through rejuvenating entrepreneurship, experimentation, learning and strategic innovation (Charter et al., 2008). Naturally, those companies which are aware of the required change and underlying dynamics have the advantage of creating, improving and orienting their core competencies towards sustainable practices. This awareness allows identification of related risks and opportunities. For example, MEA (2005) argues that water scarcity is potentially of greatest importance for businesses; there will be increasing regulations on water use and businesses will compete for water. Those businesses basing their decisions and strategies in line with long-term water supply will avoid associated risks and those directing their innovative efforts towards increasing water efficiency will have increasing opportunities in the market. Another example of sustainability risks affecting the whole of the society is climate change due to release of excessive amounts of greenhouse gases. The indirect opportunities rising from carbon trading schemes are already recognised by some less-polluting companies. Similarly, allocating specific investment funds for companies developing renewable energy technologies or products utilising renewable energy resources is becoming common practice among venture capitalists. Also, existing or expected policies aiming at reduction of carbon emissions increased the speed of development of biofuel sector as well as diffusion of low emission cars.

It should be noted that not all sustainability risks can directly be transformed into opportunities for all business. Awareness about sustainability issues is essential for viability of businesses since it will initiate early action, either to realise and exploit an opportunity or to identify and mitigate a business risk rising from sustainability risks. Awareness about broader implications of sustainability risks over industry can increase the speed of identification of opportunities and risks. As a result, timely action can be taken for exploitation of opportunities and, mitigation of/adaptation to risks rising from inevitable changes which are due both in environmental and socio-technical systems. Therefore, in dealing with businesses, which are conventionally run by opportunities, the limitations of this approach to achieve sustainability should be emphasised. In addition to opportunities, which are essential for businesses to move towards sustainability especially in the short term, there should also be a focus on identification and mitigation of/adaptation to risks that cannot be transformed into or defined in terms of opportunities.

From an organisational point of view, sustainability is achieved by adaptation to external forces (Faber et al., 2005) through management of internal change. The sustainability of industries and companies will depend on their adaptive capability to manage the challenges of resource limits, social and environmental problems and regulatory measures. The ability to foresee these challenges and implement strategic business planning accordingly will be the most important core capability in firms for future competitiveness. In conclusion, industry is an integral part of society, and as a result, the sustainability of industry is dependent on the sustainability of the environment and society. Therefore, the risks posed to the sustainability of industry should be understood and managed by considering the interrelations between the industry, the environment and society following a systemic approach.

5.5. The Role of Strategic Orientations in Change towards Sustainability

Konopa and Calabro (1971) (as cited in Singh, 2004), define the marketing concept as 'the external consumer orientation as opposed to internal orientation around the production function; profit goals as an alternative to sales goals; and complete integration of organisational and operational efforts (p. 10)'. Market orientation has become synonymous with customer orientation and 'market orientation demands a market consciousness that goes beyond normal functions and encompasses the whole organization. This means a clear understanding of customer needs, good leadership, an appropriate culture and a clear awareness of the external environment (Singh, 2004, p. 13)'. In simplest form, a purely production-oriented company has the logic of 'we sell what we can produce', whereas, in a marketing-oriented company, the logic is 'we produce what we can sell'.

In production-oriented companies, decisions on product development are determined mainly in relation to the engineering capabilities and cost criteria (Keith, 1960). Quality is perceived as the main customer demand and competitive strategy is based on cost reduction and quality improvement.

In marketing-oriented companies, the whole focus is on customer demands (Konopa & Calabro, 1971, as cited in Singh, 2004). Marketing departments carry out consumer-focused market research, identify market specific customer demands and provide feedback to product development teams. In purely marketing-oriented companies, the marketing department provides the main input in decision-making for the characteristics of the product to be developed. The marketing department also identifies potential new markets for the company, researches market characteristics and develops identified new markets through extensive communication with the consumers.

In general, these strategic orientations and roles co-exist in contemporary companies producing end-user products (Shapiro, 1977). The dominance of a specific strategic function over others is dependent on the company culture, historical development and competitors' strategic orientation. However, Shapiro (1977) points out the importance of decreasing conflicts and increasing co-operation between production and marketing functions for company success while utilising both functions to the highest extent within their roles.

Jaworski and Kohli (1993) carried out empirical research covering 102 companies in the USA to test several hypotheses regarding antecedents and consequences of a market orientation. Their findings suggested that 'the market orientation of a business is an important determinant of its performance, regardless of the market turbulence, competitive intensity, or the technological turbulence of the environment in which it operates (p.64)'. Stone and Wakefield (2000) defined eco-orientation as an extension of market orientation and concluded that firms responsive to eco-oriented issues have better business performance in the market place since both purchasing agents and consumers are able to differentiate between ecologically oriented and non-ecologically oriented suppliers. Therefore, it is important for a company to identify present and future market trends related to sustainability issues for these are and will be translated into consumer preference either directly or through legislative measures.

In general, market orientation gives companies the opportunity to understand consumer demand with an intense focus on consumer needs. In companies with well-established marketing departments, it is more likely that the environmental and social considerations, which influence consumer preferences, will be incorporated in product development. These companies will be taking socio-cultural trends, which have implications for consumer preferences, into consideration. Nevertheless, a solely market-focused sustainability-orientation has the following weaknesses:

- it can only identify sustainability issues when they are evident in market trends, causing a possible delay in necessary action;
- it cannot inform the needed radical innovations as these fall beyond consumers' imaginations and demands, and;
- market trends are only one of the several risk factors, and therefore, only one of the drivers which influence companies' sustainability performance.

On the other hand, a strategic orientation focusing mainly on production function may result in:

- being short-sighted about market dynamics which becomes more significant when the longest business planning period (five years) cannot cover the delivery time (design, development, production and launch) for products having major innovation content (approximately ten years, see for example, Lynn, Morone & Paulson, 1996; Veryzer Jr., 1998; Abetti, 2000);

- designing and developing products without having sufficient understanding of consumer preferences, thus putting the company at significant risk of 'misreading' the market, and;
- focusing only on cost reduction and quality as the competition ground and disregarding other issues which influence the competitive edge such as consumer expectations for social and environmental performances of companies.

From the analysis above, it is evident that, in order to be successful as a business while adopting sustainability as a strategic priority, it is important to be aware of the current market and possible near future market changes as well as to have an approach accommodating an innovative capacity in the organisation to address the necessary societal transformation. This requires converging short-term goals with longer-term aspirations.

It was stated earlier in this chapter that system innovation for sustainability poses a unique challenge for established companies since these companies have to continue regular business practices within their existing regime while running a shadow-track strategy to develop niche innovations which will enable taking part in the creation of and shifting to another socio-technical regime. For start-up companies, the situation is different. These companies have the opportunity to build their business from the very beginning to address sustainability issues. Established or start-up, any company genuinely willing to undertake sustainability issues on board need to be future oriented.

5.6. A Critical Review of Existing Tools and Approaches

5.6.1. Legislation

Legislative measures play a major role in directing industrial activities towards environmental improvements. Generally, the first steps taken by companies in relation to sustainability are due to regulatory requirements. According to the results of a research carried out by Cleff and Rennings (1999) to investigate determinants of innovative behaviour in companies, compliance with existing legislation is the top driver for environmental innovations. They make a distinction between product and process innovations and state that the influence of market goals is significant for product innovations but, for process innovations, environmental regulations are determinant.

There is an observable trend towards integration of relevant policies, such as innovation policy, education policy and consumer policy, with environmental policies. This is most significant in the European Union (EU), which emphasised integration of requirements of sustainable development into policy making in all areas as a fundamental goal through the Treaty of Amsterdam (EU, 1997). Not only in the EU but worldwide, end-of-pipe pollution reduction/prevention-oriented early legislation, which is effective only during manufacturing phase, is being supported by product and producer responsibility-oriented policies. These policies have an integrated approach covering all life phases of products. Producer responsibility issues, which generally require producers to be responsible for the impacts of their products throughout the whole life-cycle from raw material extraction to final disposal covering reuse/recycle phases, render environmental/ sustainability measures to be considered at very early stages of product development and bring design improvements. Among these policies, EU's Integrated Product Policy (IPP) (European Council (EC), 2001; 2003a) which gave birth to Ecodesign of Energy Using Products (EuP) (EC, 2005) and Restriction of Hazardous Substances (RoHS) (EC, 2003b) can be counted. Similar policies are being adopted in other countries (see, for example, Economy Trade and Industry Ministry of Japan (1991) for Japan; California State Senate (2003) for California, USA; Ministry for the Environment (MfE) (2004, 2005) for New Zealand; Grace Compliance Specialist LLC (2006) for China).

5.6.2. Voluntary Initiatives

Voluntary initiatives are policy instruments, which are undertaken by the industry without the presence of mandated provisions. These initiatives generally are closely linked with economic incentives. The benefits of these economic incentives may be direct and prompt, e.g. energy and/or material savings, or may be indirect, e.g. protecting/influencing brand recognition, or both. In some cases, where sustainability is already embedded in the company culture, the company may adopt and implement some practices without economics being the primary driver. Nevertheless, this does not imply that such companies would carry out those practices where there is no economic gain.

Paton (2000) groups voluntary environmental initiatives under four categories: unilateral initiatives, private codes, voluntary challenges and negotiated agreements. Unilateral initiatives are activities undertaken within a single firm as a means to improve environmental performance. Private codes are initiatives by industry associations, non-governmental organisations and standards organisations. Voluntary challenges are government sponsored programs and negotiated agreements are those reached between government and industry.

Among unilateral initiatives, environmental management systems (EMS) act as an umbrella under which all of a company's relevant activities are determined and managed. Companies adopt EMS either as a competition tool or due to commitment to environmental improvements or as a combination of both. Johnstone, Scapecchi, Ytterhus and Wolff (2004), following a survey carried out among 2000 European firms, concluded that 'the introduction of environmental management systems and the integration of environmental management with general management strategies are key determinants of firms' propensities to undertake technical measures which reduce environmental impacts (p. 705)'. Nevertheless, it has not been proven that companies implementing a formalised standard perform better than those which do not have any formalised EMS (Freimann & Walther, 2001). Annandale, Morrison-Saunders and Bouma (2004), following an empirical study they carried out in Western Australia with 40 companies, concluded that stakeholder pressure has greater influence on environmental performance than EMS. Kautto (2006) undertook an empirical survey investigating the relationship between EMS and environmentally improved product development in companies and concluded that the link between EMS and product development was either very weak or completely missing. The commitment to improvement at the managerial level is a key determinant for effective implementation of EMS. Even though effective and committed implementation of EMS has the potential to bring significant improvements in the environmental performance of the companies, it is not sufficient to move the companies towards sustainability. EMS focuses only on the ecological impacts of companies and operates within a weak sustainability context.

5.6.3. Product and Process Centred Approaches

As more businesses shift towards environmentally and socially responsible practices, consumer awareness increases and legislation world-wide becomes more stringent, environmental and social considerations have been incorporated into default product design criteria along with conventional ones like profitability, functionality, aesthetics, ergonomics, etc (Shahbazpour & Seidel, 2006). The process-centred approaches are pushed to some extent by well-developed end-of-pipe emission prevention/reduction legislation. However, there is no legislative requirement enforcing the adoption of product-centred approaches except the EU's EuP Directive (EC, 2005) which mandates a life-cycle approach in product development. In general, product-centred approaches are undertaken by the industry as voluntary initiatives at the moment. But, due to the current shift towards product/producer centred legislation development, it is likely that, in the short to medium term, more countries will adopt legislation mandating product-centred approaches.

Product and process approaches can be grouped under three topics: process-centred approaches, product-centred approaches and assessment tools/methods. Assessment tools/methods applies to both process- and product-centred approaches and can be used either before or after an implementation. Table 6 shows the main categories under these three topics.

Table 6. Product and process-centred approaches and assessment methods

Process-Centred	**Product-Centred**	**Assessment**
Pollution Prevention (PP)	Design for Environment (DfE)	Life-Cycle Assessment (LCA)
Clean(er) Production (CP)	Design for Sustainability (DfS)	Eco-efficiency (EE)
Industrial Ecology (IE)	The Natural Step (TNS)	Ecological Footprinting (EF)

PP is the earliest of these approaches adopted by industry for environmental protection. It aims for waste and emissions prevention/reduction/minimisation and initially and generally implements legislative provisions. More information on PP can be found in Bishop (2000) and Farthing, Marshall and Kellett (2003).

CP aim for resource efficiency, ecosystem protection and preventive environmental management (Jackson, 1993). IE, as its name implies, adopts a systemic approach towards industrial activities and makes use of the analogy of industry being a system of organisms (as in an ecosystem) where one company's waste becomes another's resource (e.g. Socolow, 1994; Graedel & Allenby, 1995; Cohen-Rosenthal & Musnikow, 2003; Green & Randles, 2006). Both CP and IE focus only on environmental impacts and have no reference to social issues. These approaches use either LCA or EE for assessment purposes. Despite the potential of bringing environmental and economic improvements, neither CP nor IE are sufficient to achieve sustainability on their own.

The difference between DfE and DfS is that DfE is concerned only with improving environmental performance while in DfS, in addition to environmental performance, there is also a concern about social performance. In both DfE and DfS related literature, there are a multiplicity of proposed and implemented tools and methods (e.g. Fiksel, 1996; Graedel and Allenby, 1996; Abele, Anderl & Birkhofer, 2005). The most widely known of these tools and methods are eco-design (ED), product-service systems (PSS), design for the bottom-of-pyramid (DfBoP), biomimicry (BM), and cradle-to-cradle design (CTC). Table 7 shows the basic design principle of these tools/methods along with major references.

Table 7. DfE, DfS tools/methods

Design Approach	Design Principle	Major References
ED	decreasing overall environmental impacts of products through a life-cycle approach	Brezet and van Hemel (1997) Charter and Tischner (2001) Wimmer, Züst and Lee (2004)
PSS	dematerialization through function fulfilment via combinations of tangible products and intangible services	Goedkoop, van Helen, te Riele and Rommens (1999) Mont (2000) Tukker and Tischner (2006)
DfBoP	improving quality of life in developing and under-developed communities	Charter and Tischner (2001) Crul and Diehl (2006)
BM	imitating biological/natural processes and principles in design	Benyus (2002)
CTC	closing the loop by aiming at waste from one product to be input either for another technological or biological cycle	McDonough and Braungart (2001)

ED is probably going to be the most widely adopted approach by companies since the EuP Directive (EC, 2005) mandates its implementation along with LCA by companies marketing energy using products in the EU. The strength of ED lies in its emphasis on the whole life-cycle phases of products. ED might shift companies' business priorities towards inclusion of environmental concerns and adoption of ED principles in default design criteria. Nevertheless, from a sustainability perspective, ED can only bring environmental improvements. In addition, it is hard to judge the potential of ED to push innovation towards the system level. Among the above mentioned design approaches, PSS falls into a special category, referred to as function (or functional) innovation in eco-design terminology (Brezet, 1997; Halila & Hörte, 2006). This category generally constitutes a transition between product focus and system focus. PSS applications not only challenge existing product concepts and consumption patterns through alternative ways of function fulfilment but give way to different models of businesses or stakeholder collaboration (Anderson, 1997; Van der Zwan & Bhamra, 2003; Williams, 2007; Keskin et al., 2008). However, even though PSS corresponds to the third level of innovation for sustainability (Brezet, 1997, Section 3.7), there is a tendency to confuse PSS innovation with system innovation. There are only few studies considering PSS in the context of system level innovation (for example, see, Keskin, Brezet & Diehl, 2009).

Even though both CTC and BM challenge the status quo through using cyclic or systemic analogies from nature in design, they fail to have the strength of PSS in moving towards system innovation since neither CTC nor BM challenge consumption patterns but demonstrate an almost naïve technological optimism. The DfBoP approach has been beneficial for developing or underdeveloped communities to meet their immediate communication, sanitation and shelter needs through, most of the times, providing these communities with appropriate technologies (some case studies can be found in Crul & Diehl, 2006). However, as a business strategy, initiatives so far have not helped alleviation of poverty or development in those communities but exploited them as new markets to sell products (Simanis, Hart & Duke, 2008).

LCA is used to assess the environmental impacts of both products and processes throughout their all life stages (Graedel, 1998). Despite the methodological imperfections (e.g, Herrchen, Keller, & Arenz, 1997; Krozer & Vis, 1998; De Udo Haes, Heijungs, Suh, & Huppes, 2004), LCA is the most comprehensive tool to assess environmental impact of products even during the development phase. Even though LCA is traditionally focused on the environmental dimension of sustainability, attempts have been made to incorporate economic and social dimensions (De Udo Haes et al., 2004). LCA does not assess the sustainability of a product but it can provide a detailed assessment of the impacts products have on environment. With the addition of social and economic dimensions, LCA also has the potential to assess impacts on these areas as well to inform decision making for improvements. Incorporation of social aspects into LCA is a very recent debate and still at an immature level (e.g. Norris, 2006; Jørgensen, Le Bocq, Nazarkina & Hauschild, 2008). Up until very recently, it was not clear if this incorporation will result in integrated or separate assessments of environmental and social aspects. In the first half of 2009, a set of guidelines for social life cycle assessment of products was published under the life-cycle initiative of UNEP (UNEP, 2009a). This document established a map, a skeleton, and a technical framework for the assessment of social impacts of products throughout its life-cycle. According to the framework outlined in this document, social LCA can be undertaken separately or in combination with LCA but is a stand-alone assessment approach and not methodologically integrated into LCA.

EE was first defined by the WBCSD in 1991 and, since then, the WBCSD has promoted the concept as a business tool for sustainability. In simple terms, it is defined as ‘creating more value with less impact (WBCSD, 2000, p. 9)’. In more tangible terms, EE is decreasing the resource input and emissions output per unit of production. EE has become very popular in industry due to the potential of linking business priorities with environmental considerations (e.g. Cramer & van Lochem, 2001). Nevertheless, the EE approach has problems similar to those associated with LCA, including selection of impact categories, drawing meaningful system boundaries and dealing only with environmental (and economical) improvements (Ehrenfeld, 2005). In addition, in the long term, growth, even though eco-efficient, will still exceed Earth’s limits as population growth and consumption continues to increase (Jansen, 2003; Huesemann, 2004).

EF is a tool used to calculate, for a designated population, 'the area of productive land and water ecosystems required to produce the resources that the population consumes and assimilate the wastes that the population produces, wherever on Earth the land and water is located (Rees, 2000, p. 371)'. EF is mainly aimed at and suitable for macro scale national or regional assessments rather than individual products or facilities (Luo, Wirojanagud, & Caudill, 2001). The examples of the tool being used as an assessment tool for products or production systems are very few (Luo et al., 2001; Thomassen, & De Boer, 2005; Frey, Harrison, & Billett, 2006). EF is an effective tool for providing an overview of a product's consumption and it is complementary to other assessment tools such as LCA by making LCA results visible through a single indicator (Frey, Harrison, & Billett, 2000). Nevertheless, EF has limited applicability for product sustainability because:

- It focuses on ecological aspects and does not take into account economic and social issues;
- It provides a single indicator which, despite being easy to understand, does not give detailed information about environmental impacts through all life-cycle phases;
- Due to the limited nature of providing a single indicator, it does not give clear direction about what kinds of improvements are needed to a product, and;
- It cannot measure some forms of consumption, such as metals, nor does it have an ability to effectively include pollution or environmental degradation.

All of the above mentioned tools and approaches are generally used in conjunction with each other in the industrial system. CP and IE make use of PP principles. LCA and EE facilitate decision making in DfE/S. CP and EE acts as part of DfE/S methodologies. Both process-centred and product-centred approaches in collaboration with assessment tools have the potential to improve the sustainability of industry. Nevertheless, they are derived from and designed within the existing technology development paradigm. Even the largest extent of improvement they promise is limited to incremental innovations since they are based on present applications. Given the urgent need of radical changes in production and consumption patterns, even full company commitment to one or more of these approaches will not provide sustainable solutions. Their starting point is existing 'unsustainability'. Therefore, they can only provide 'less unsustainable' solutions rather than 'sustainable' ones. Their internal integration among themselves and external integration with institutional and organisational arrangements may facilitate sustainable industrial production only if they aim for sustainability rather than decreasing current unsustainability. The main flaw with all of these approaches is that they fail to ask the fundamental question of 'what is necessary to become sustainable'. These approaches remain generic rather than examining the system specific issues since sustainability is a system property, and therefore, time and space dependent.

Contrary to the above-mentioned approaches, TNS approach starts from an aspirational sustainable state to inform current decision making. TNS is defined by TNS (2000) as 'a methodology for successful organizational planning (p. 1)' and is basically a principles based approach to sustainability within an industrial context. TNS Framework's major argument for its validity and strength is that it is grounded on the basic science underlying the earth's systems (TNS, 2006). The principles of TNS are:

> In a sustainable society, nature is not subject to systematically increasing:
> 1. concentrations of substances extracted from the earth's crust,
> 2. concentrations of substances produced by society;
> 3. degradation by physical means;
>
> and, in that society. . .
> 4. human needs are met worldwide. (TNS, 2000, p. 8)

Three of these four system conditions stem from the Laws of Thermodynamics and the fourth one is the complementary social content. Prioritisation of nature in these conditions is aligned with strong sustainability model as a positive aspect. However, '[they] reflect a simplified material accumulation model that is not designed to account for ecological, let alone socio-economic complexity (Upham, 1999, p.93)'. Therefore, they are far from providing any operational value to address the complexity of the industrial subsystem and its relation to the wider social and environmental systems. As it is a principles-based approach lacking complexity, TNS Framework assumes the presence of a not-yet-defined sustainability state. The criticism about principles based sustainability assessments (see Chapter 2 Section 2.5 for details) applies to TNS framework as well. Upham (1999) states that the risk assessment aspect in TNS Framework is in place to support its system's conditions which are formulated without reference to critical threshold limits. Therefore it is not providing enough environmental protection. In addition, the fourth system condition on human needs is deliberately vague, most probably due to its being the most challenging requirement when present global socio-economic conditions, within which industrial production takes place, are considered. It also reflects the primary environmental nature of this approach. Therefore, TNS cannot be relied on as a sustainability framework in product development. However, TNS Framework provides basic but still undoubtedly valuable, educational material, which may be useful in influencing the mind-set change necessary for achieving sustainability. Even if it cannot change the fundamentals of the well-established, neo-classical business mind-set, it can and does initiate change by enabling the companies to relate their activities to environmental impacts (Upham, 1999). TNS can guide managerial practices only for the short term to initiate the first steps to be taken of a long journey but cannot guide a company through continuous internal change over the medium and long term.

There has been a significant increase in publications addressing system innovation in the product design/development context in the recent years (Ryan, 2008a; Tukker et al., 2008). Echoing this growing literature, several tools and methods have been developed with promising attributes to address sustainability issues in innovation. However; they fall short in one or more of the below requirements:

- A state-of-the-art understanding of system innovation theory;
- Incorporating a state-of-the-art understanding of sustainability science;
- Effectively linking present to a radically different future;
- Simultaneously leveraging technological and behavioural changes;
- Effectively and systemically linking large scale (society) to small scale (product development teams), and;
- Challenging the current business mind-set to enable transformation.

One of these recent developments is a method called 'Technology Front End'. Technology front end method addresses the needs of start-up companies developing innovative technologies and addressing sustainability (Van Onselen, Lauche, Silvester & Veefkind, 2007). This method combines technology-push and market-pull approaches for development of new products addressing sustainability issues. The method aims to aid start-up companies through the process of idea conception, development and commercialisation. Technology front end method is a valuable method from the perspective of new product development since it enables identification of potentially successful product-market combinations. However, in explanations of this method, it is not clear how sustainability issues were addressed. Initially, the method was developed to identify successful product-market combinations for photovoltaic technology (Van Onselen, 2006). Therefore, the method was developed to promote a technology already acknowledged as sustainable rather than identifying the present unsustainable technologies and trying to replace them with sustainable ones. Even though the developer of the method provided a list of eco-innovation tools which can be used in implementing the method (Van Onselen, 2006, p. 29), she stated that these tools were not used during the case study (p. 78) and therefore these tools were not evaluated in the context of the method. Therefore, the technology front end method has a strength in aiding in niche development and thus in initiation of radical innovation, but it is weak in demonstrating a state-of-the-art understanding of sustainability and linking present to a radically different future.

5.7. SUMMARY OF FINDINGS AND INSIGHTS GATHERED IN THIS CHAPTER

This chapter provided a review of the literature on the role of industry in achieving sustainability, the drivers and barriers for the industry to adopt sustainability as a strategic priority, the relevance and implications of sustainability risks for the industry and the role of strategic orientations in achieving sustainability. Finally, existing tools and approaches to help the industry towards achieving sustainability were critically reviewed. The key findings of and insights gathered in this chapter are:

- Industry is strictly subject to the irreversible hierarchy of the strong sustainability model;
- Businesses are agents of change towards sustainability and they play a variety of roles including development of new technologies and practices, promoting sustainability in up- and downstream chains, promotion of sustainable consumption, influencing changes in the economic and legal incentives which shape both production and consumption patterns, and influencing changes in the values and discourse which shape the culture of business, government, media and public;
- There are both drivers and barriers for the industry to move towards sustainability at institutional, social/cultural, organisational and technological levels. The drivers cited in the literature cover legislative and regulatory requirements, consumer and stakeholder demand/pressure, remaining competitive, protecting company reputation and legitimacy, financial gains, and, limits and challenges imposed by the biophysical environment on the production/consumption system. The barriers cover the dominant economic paradigm, lack of policy context for radical innovation, the prevailing consumption culture, lack of lead markets for niche technologies, organisational inertia and lack of commitment at managerial level, company values not aligned with sustainability, the need for long-term orientation, return rate of investment, both perceived and real costs associated with sustainability initiatives, lock-in effects of incumbent technologies, and lack of enabling technologies;
- If the society fails or global environmental deterioration continues, the businesses cannot succeed and the risks threatening the society equally apply to the industry. The risks rising from sustainability related issues both pose threats to and provide opportunities for businesses. Some of the sustainability risks have profound significance for businesses. Among these risks are water scarcity, climate change, habitat change, biodiversity loss and invasive species, overexploitation of oceans, and nutrient overloading on the ecological side and population growth, ageing of population in developed countries, vulnerability of people to climate change, poverty, conditions of labour and, increased risk of social conflict and political instability in certain regions on the social side;
- The sustainability of industries and companies will depend on their adaptive capability to tackle these challenges and the ability to foresee these challenges and implement strategic business planning accordingly will be the most important core capability in firms for future competitiveness;

- In order to be successful as a business while adopting sustainability as a strategic priority, it is important to be aware of the current market and possible near future market changes as well as to have an approach accommodating an innovative capacity in the organisation to address the necessary societal transformation. This requires converging short-term goals with longer-term aspirations;
- The existing tools and approaches pulling/pushing industry towards sustainability can be grouped under legislative and regulatory requirements, voluntary initiatives and product and process centred approaches. The critical review carried out revealed that despite their advantages none of these tools and approaches is sufficiently helpful for industry to become sustainable.

PART II

INTEGRATING INSIGHTS:
DEVELOPING A SCENARIO METHOD FOR SYSTEM INNOVATION AT PRODUCT DEVELOPMENT LEVEL

6. THE THEORETICAL FRAMEWORK: SYSTEM INNOVATION FOR SUSTAINABILITY AT PRODUCT DEVELOPMENT LEVEL

6.1. INTRODUCTION

With Chapter 6 starts the second part of this research. The first part of this thesis reported a review of the literature relevant to innovation for sustainability. The specific areas covered include basics of sustainability science, theory of system innovation for sustainability, futures studies in the context of system innovation for sustainability and the relationship of industry to sustainability issues. As a result of this review two issues became evident: 1) The current theory of system innovation for sustainability does not provide any conceptual or operational models which address how innovation at micro-level (product development in companies) is linked to innovation at macro-level (transformation at societal level). Therefore, in order to achieve the objective of this research, a theory needed to be developed; 2) A system innovation for sustainability has not taken place yet. Therefore, there are no companies which undertook and achieved the task of developing products/services and strategies in the context of system innovation for sustainability. There were no real-life cases to study the experiences of for the purposes of developing a theory on how product development level can be linked to the societal-level long-term transformation which needs to take place to achieve sustainability. This meant that the theory needed to be developed by integrating and building on the theoretical, conceptual and empirical insights from different areas relevant to innovation and sustainability gathered as a result of reviewing the literature in these areas. This chapter presents the theoretical framework developed to explain how product development level relates to system innovation for sustainability.

6.2. REFINING THE MULTI-LEVEL PERSPECTIVE ON SYSTEM INNOVATION

The MLP is useful to understand how system innovations happen with a broad and dynamic perspective since the theory and the model is developed as a synthesis of different approaches in innovation theory emphasising on different drivers and/or agents of change (see Chapter 3, Section 3.5). However, certain concepts MLP is based on require further exploration, clarification and reflection. Also, in order to use the MLP model to influence system innovation towards sustainability at product development level, the model needs to be refined. Refinement of the model is necessary in terms of how system innovations are explained (i.e as a conceptual model) and how future system innovations towards sustainability are assumed to be influenced (i.e. as a normative model).

6.2.1. Critique of MLP as a Conceptual Model

Geels (2005a) proposed the concept of socio-technical regime in order to emphasise the interaction and meta-coordination of different regimes (e.g. science regime, policy regime, technological regime, socio-cultural regime) in system innovation. Nevertheless, both explanations of previous cases of system innovation (e.g. Geels, 2002b; 2005a) and scenarios developed for future sustainability transitions (e.g Hofman, Elzen & Geels, 2004; Geels, 2007; Verbong & Geels, 2007) focused on technology development. Other factors influencing system innovation were considered only when necessary to explain technological change. This techno-centricism might have risen as a result of the national/regional context (i.e. EU, mainly Netherlands) where the theory and model was developed in line with a technologically-optimistic, post-industrial and typically Western worldview. Therefore, for the objective and aims of this research and in order to render MLP usable in any context (not limited to EU), the concepts of system innovation, social function and socio-technical regime need further elaboration and reflection.

System innovation may either consist of creation of a new system or transformation of an existing one (Kemp & Rotmans, 2005). System innovation indicates a radical change at the system level over time, i.e. a radical change in how the whole of the socio-technical system is organised compared to a previous state which can be labelled as the 'initial state' for the purposes of analysis (Loorbach & Rotmans, 2006). A radical change in how the whole of the socio-technical system is organised, however, does not indicate a radical change in all of the components constituting the socio-technical system. System innovation indicates novelty at the system level which can happen through multiple possible ways of organisation of socio-technical system components. Therefore, system innovation does not imply technological advancement *per se* but a new socio-technical organisation in which technological change is only one of the important formational components. Others include institutional, organisational and social/cultural change. In a systemic view, a new or different way of using an existing product may influence radical change within the socio-technical system. In addition, behavioural change is fundamental to system innovation since a sole focus on technological solutions (such as efficiency improvements) is associated with rebound effects (e.g. Binswanger, 2001; Throne-Holst, Stø & Strandbakken, 2007). Technological advancement is not the only alternative to achieving sustainability; with references to contextuality of complex systems as well as sustainability requirements, appropriate technologies or even low-technology solutions can be a part of innovation at system level and help in achieving sustainability in certain contexts. In support of this argument, United Nations Environment Programme (UNEP, 2003) puts emphasis on the requirement that technologies to be developed for sustainability should be compatible with the context, i.e. the society and environment, in which these technologies are going to be used.

In MLP, the concept of socio-technical regime is not clearly defined. Neither is how socio-technical regimes relate to social functions clarified. Geels (2006) defines three levels of social functions; generic functions at the top (materials and energy supply), intermediary functions in the middle (e.g. business services, transport, communication) and end use functions at the bottom (e.g. housing, recreation, feeding, etc). He points out that, regarding innovation for sustainability, only the top-level functions have been addressed with little exception, even though the low-level functions are closer to consumption side which needs to be included in planning to avoid rebound effects. Since socio-technical regimes relate to the social functions fulfilled within them, they are generally labelled the same (e.g. energy regime to refer to the socio-technical configuration through which the social function of energy supply is fulfilled). In some cases a social function might be fulfilled in different ways. For example, mobility can be fulfilled through public transport, personal cars and other types of powered vehicles (e.g. motorbikes) and bikes. The different ways of fulfilling a social function might be combined as yet another way of fulfilling that function (e.g. joint use of personal cars and public transport) or compete with each other (e.g. petrol-powered cars, hybrid cars, and electric cars). In addition, all of these alternative ways of fulfilling a function, especially those functions at the end-use level are interdependent on the ways other social functions are fulfilled. Another factor complicating identification of socio-technical regimes, especially for the purposes of future planning, is that, due to interactions between regimes during system transitions two previously separate regimes might join together to form a single regime or a symbiotic relationship (e.g. Raven, 2007). Therefore, identifying a socio-technical regime is not as easy as identifying social functions.

The conceptual background of MLP is CAS (Holtz, Brugnach & Pahl-Wostl, 2008). As discussed in Chapter 2 under Section 2.3 CAS consist of closely interacting components which mutually evolve over time and exhibit emergent behaviour. Holtz et al. (2008) consider regimes as CAS and state that a regime:

> comprises a coherent configuration of technological, institutional, economic, social, cognitive and physical elements and actors with individual goals, values and beliefs. A regime relates to one or several particular societal functions bearing on basic human needs. The expression, shaping and meeting of needs is an emergent feature of the interaction of many actors in the regime. The specific form of the regime is dynamically stable and not prescribed by external constraints but mainly shaped and maintained through the mutual adaptation and co-evolution of its actors and elements (p. 629).

Based on their definition, Holtz et al. (2008) identify the following as a non-exhaustive, minimal list of criteria which should be met by socio-technical regimes:

1. Purpose: regimes relate to social functions;
2. Coherence: regime elements are closely interrelated;
3. Stability: regimes are dynamically stable configurations;
4. Non-guidance: regimes show emergent behaviour, and;
5. Autonomy: regime dynamics are mostly shaped by internal processes.

Holtz et al. (2008) give car-based mobility (in the context of Germany) as an example of regimes meeting these criteria. The social function of car-based mobility is to meet the need for mobility (purpose). The technological elements of the car-based mobility system (i.e. cars, streets, service stations, the kind of gas provided, etc.) are closely interrelated, the design of cars is not only determined by technological capabilities but also informed by user preferences, and, laws and legislation govern the use of cars (coherence). Even though there have been technological improvements and the number of cars per capita increased, no breakthrough change has taken place (dynamic stability). The interactions between the several diverse actors of the regime (i.e. car manufacturers, oil companies, car owners, associations, etc.) give way to emergent behaviour (non-guidance). Finally, at the national level, the regime can be treated as autonomous, since at this level the regime dynamics are shaped mostly by internal processes (i.e. laws/legislation governing car use are designed at national level, there is a prevailing certain attitude towards car-based mobility, manufacturers tailor their designs in line with the requirements of the national context, etc.) (autonomy).

Konrad, Truffer & Voß (2008) propose to draw regime boundaries depending on the density and strength of couplings between the elements of socio-technical configurations in a way similar to the concept of delimitation used in systems theory. They define two types of couplings (i.e. functional and structural) and point out that these couplings may occur both within and across regimes. Cross-regime couplings may give way to the following (mutually non-exclusive) types of interactions:

- Interactions between regimes fulfilling a similar social function;
- Interactions between regimes on the basis of complementary relations, and;
- Interactions between regimes showing structural similarities.

As a result, these interactions give way to the following two types of transformations:

- Transformations on the basis of competitive relations, and;
- Transformations on the basis of complementary relations.

Defining boundaries so that the socio-technical regime will be autonomous to a certain degree as proposed by Holtz et al. (2008) may be a reasonable approach. Yet, the impossibility of achieving this without compromising or overlooking certain alternative transition paths due to systemic interdependencies is evident in Konrad et al.'s (2008) framework. Furthermore, such boundary setting as proposed by Holtz et al. (2008) can only be done if social functions are assumed to be autonomous. This assumption might hold to a reasonably sufficient degree at generic-level and to a lesser degree at intermediary-level social functions but at end-use level functions interdependencies are so high that an assumption of autonomy does not hold at all. Therefore, in order to effectively manage system innovation, the interdependencies and dynamics between socio-technical regimes need to be acknowledged, especially at the end-use level functions.

It is argued here that the lowest level of social functions defined by Geels (2006) as end-use functions demonstrates higher regime-interdependency than higher levels of social functions. Function definitions such as mobility, food, housing, health care etc. remain extremely generic compared to the richness of different functions falling under these categories and the multiplicity of ways fulfilling them. For the purposes of this research, if, as suggested by Geels (2006), there is a need to focus on these end-user functions, a more elaborate analysis of these low-level social functions is necessary. Previously, it was stated that social functions and socio-technical regimes are regarded as the same since socio-technical regimes relate to social functions. In addition, when there is a social function, there is inevitably a socio-technical regime of actors, institutions, rules etc. Therefore, the definition of a social function also defines the socio-technical regime associated with it.

In order not to get lost in interdependencies, any analysis should focus on a central function/regime and the interdependencies and leverage points should be defined as they relate to this central function/regime. This way, the levels proposed by Geels (2006) for social functions apply to socio-technical regimes and, thus, generic regimes, intermediary regimes and end-user regimes can be identified. As a result of this vertical hierarchy, lower-level regimes will be dependent on one or more of the higher level ones. In such a hierarchy, the changes in upper-level regimes are followed by changes in lower-level regimes. The range of possible alterations to these lower-level regimes will be dependent on the changes taking place in the upper-level regimes except in cases where lower-level regimes somehow manage to decouple themselves during the system transition.

In addition to the hierarchical dependencies, there are also horizontal dependencies of different regimes even at the upper-most hierarchical levels. It is asserted here that any social function can be defined as a socio-technical regime and autonomy is not possible even at large and hierarchically higher regimes. Figure 18 illustrates horizontal and hierarchical dependencies focusing on the laundry regime (as it is in developed country contexts) as an example.

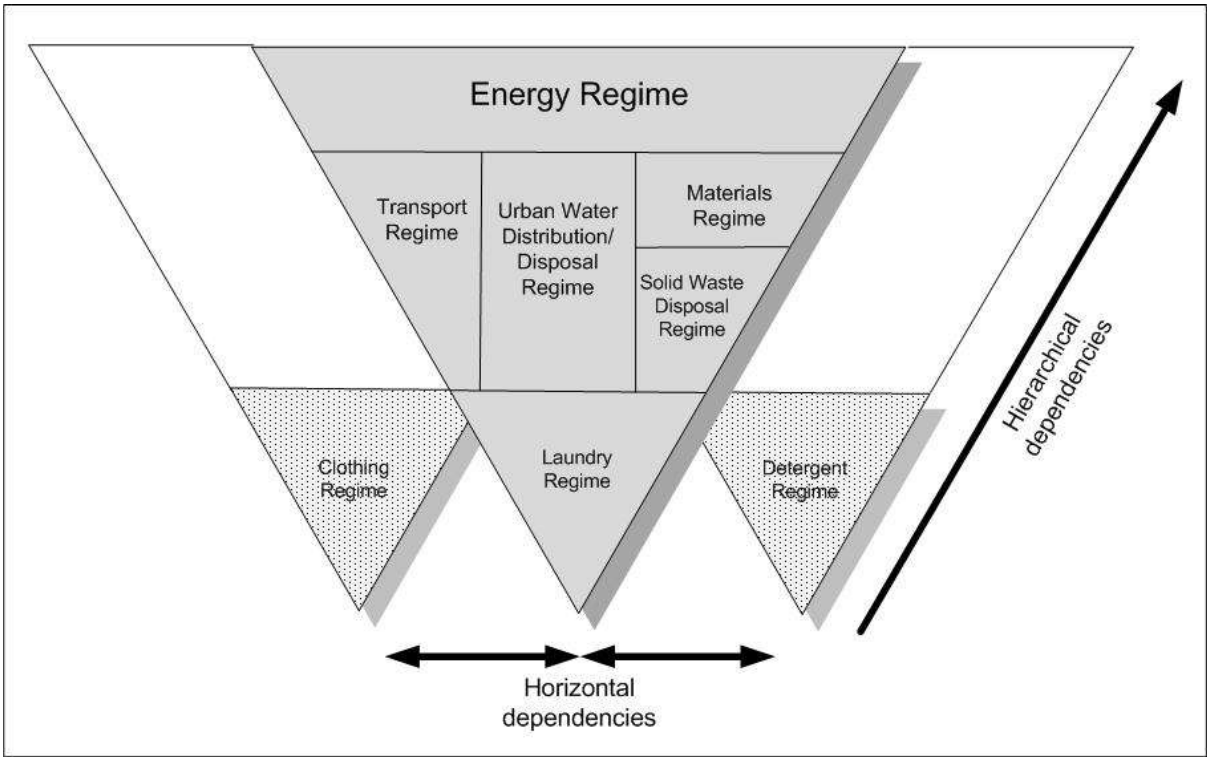

Figure 18. Regime dependencies relevant to laundry as a social function

In developed country contexts the laundry is done by households using washing machines. Clothes dryers may also be used to dry the clothes. The machines in most of the cases are privately owned by the household and used at home. In some cases, a group of households may share machines allocated to their use in a common laundry area such as a laundry room in a building. In other cases, people share the machines in commercially owned laundries (known as laundrettes, laundromats or washaterias in different countries). In any of these cases, the washing machines use water and power and dryers use power to operate. The clothes are washed by putting them in the washing machines and adding chemicals like detergents, soap, bleach, and fabric softener which are then disposed into the sewerage system along with the water they are mixed with. The washing machines and dryers are developed and produced by appliance manufacturers. In the manufacturing of these machines, several different components made of several different materials are used. The main materials used are steel, different types of plastic, and glass along with some electronic components such as printed circuit boards. Therefore, the main actors of the laundry regime are the manufacturers of washing machines and dryers, industrial associations, users and the regulatory bodies governing the manufacturing and use of the machines. The laundry regime has interdependencies with several other regimes both horizontally and vertically (i.e. hierarchical).

The laundry regime has vertical (hierarchical) interdependencies with the energy regime, the transport (freight) regime, the urban water supply and disposal regime, the materials regime, and the solid waste disposal regime. The energy regime overlies every regime covered by manufacturing industry since manufacturing is dependent on energy both for production and distribution of products. The dependency of energy-using devices on the energy regime is higher than products that do not consume energy during the use phase. Thus, the laundry regime (in developed country contexts) is highly dependent on the energy regime, both during manufacturing and use phases. Similarly, any product (contrary to services) is dependent on the materials regime. Therefore, the developments in material technologies are also relevant to regime analysis for the appliances sector, and thus, for the laundry regime. The policies and infrastructure framing the urban water distribution/disposal regime influence and are influenced by the design decisions related to water use by the laundry products. Freight constitutes another regime influencing design decisions, especially in relation to packaging. The regimes which have horizontal dependencies with the laundry regime are the clothing regime and the detergent regime. These three regimes enable, normalise and mutually determine each other in the current situation. The detergent regime enables the laundry regime which is still mainly based on water activated surfactant cleaning technology. Similarly, the current clothing regime requires cleaning of garment which normalises the laundry regime.

These horizontal dependencies may break if a cleaning technology is developed which does not use water and/or detergent, or, for example, a self-cleaning textile is invented. The dependency of the laundry regime on the energy regime is harder to break and only possible if a cleaning technology which does not use energy was in place. There are some cleaning technologies which do not use fuel energy (e.g. hand washing using a washboard or by pounding clothes on a rock) but these are not socio-culturally acceptable technologies anymore in the developed country contexts. Nevertheless, the energy regime would be irrelevant to the analysis if energy was being supplied from 100 percent renewable resources and the power generation was equal to or greater than consumption; i.e. sufficient to meet all demands.

Considering and involving these regime dependencies into analysis of the subject regime (i.e. the regime in focus) is crucial for providing a broad perspective on the potential for breakthrough innovation since development and management of any niche will require presence of enabling technologies (as well as other components of a socio-technical regime such as enabling policies, regulations, investment/finance and market conditions). These enabling technologies can be established or niche-level technologies within established or emerging socio-technical regimes. Considering the internal dynamics of socio-technical regimes as well as the interdependencies and dynamic interactions between these regimes, it is understood that managing the change which has to take place in the socio-technical system to achieve sustainability requires effectively dealing with the complexity of it. In order to acknowledge and to simplify this complexity to enable dealing with it at product development level, it is appropriate to analyse any social function as a socio-technical regime and to consider the interdependencies between the function/regime of focus. This approach provides the advantage of a systemic view. Adopting such a systemic approach in product development will potentially enable directing efforts in a way to favour preferable ways of fulfilling a function among two competing options and/or use joint solutions better if collaborative use of two means provides more preferable solutions than utilising only one option.

In addition to regime dependencies, socio-cultural values and practices increase the complexity and thus increase the difficulty of analysing and, more so, transforming regimes. Again in the example of laundry, Shove (2003) points out that, in addition to design of washing machines and developments in textiles and detergents, gender relations, values of hygiene and cleanliness, and expectations of comfort and convenience are important characteristics of the regime. These sociological aspects are less manageable within an analysis approach focusing solely on technological change yet are very important in creating markets for yet-to-be-developed technologies. The necessity to consider sociological aspects also challenges the autonomous regime concept since socio-cultural aspects of a socio-technical regime underlie other regimes as well. The socio-cultural aspects shared by different socio-technical regimes increase the regime dependencies.

6.2.2. Critique of MLP as a Normative Model

The MLP model was developed through analysing historical cases. This has certain implications which require acknowledgement. First, in analysing historical cases, the sequence of developments is easy to follow and major causal influences are evident. Therefore, through hindsight, the underlying dynamics of system innovation can easily be explained. In inquiring into future possible system innovations, however, the model remains insufficient since it does not take surprise and uncertainty (both of which result from emergent properties of evolving complex systems) into consideration as factors influencing change in socio-technical systems. The shortfall of the MLP model in accounting for surprise and uncertainty can be explained in relation to the techno-centric readings of past cases. Invention of technologies may come about as surprises; however, their development and diffusion generally require time. Therefore, in retrospective analysis of cases, surprises can be explained with references to evolutionary dynamics since more is known about the past. Nevertheless, in inquiring into the future, the surprise factor becomes important and associated unpredictability increases the complexity of managing system innovations towards sustainability. Swart et al. (2004) point to the insufficiency of conventional future inquiry methods to deal with disruptive change in interrelated social and natural complex systems. They state that the scientific uncertainties regarding sustainability issues are deep and may not be resolved. It is vital to acknowledge uncertainties and make them explicit in research output through what-if type approaches. A surprise, in the context of system innovation, might mean opening up of an unpredicted path as well as closing of all paths previously identified. Therefore, in using MLP for the specific purpose of managing system innovations towards sustainability, a surprise factor needs to be suitably incorporated in the model.

The second implication of MLP being based on historical cases is related to the model's implicit politics. The historical cases used in the development of MLP model were the transition from piston engine aircrafts to jetliners in American aviation which took place between 1926 and 1975; transition from sailing ships to steam ships in British oceanic transport which took place between 1780-1914; and the transition from horse-and-carriage to automobiles in American urban passenger transport which took place between 1860 and 1930 (Geels, 2002a; 2002b; 2005a). Geels (2002b), in his PhD thesis, discusses the influence of the time period covered by these historical cases on the outcomes of his analysis. He points out that the socio-technical configuration worked differently in 19th century than in 20th century and, therefore, at the level of mechanisms as well as of individual actors and social groups the dynamics were different. Yet, the MLP model reflects an aggregate level of analysis and, hence, the model holds for present technological transitions as well. It is acknowledged here that the model has extensive generic value which renders it usable for a current analysis or management of system innovation in general. Nevertheless, the model is representative of a growth-oriented, liberal, economic paradigm in which scarcity is (mis)assumed to be observed in the market and the environment is seen as an endless resource and waste sink open for exploitation by our socio-technical system. Therefore, the MLP model, as it is, does not explain how system innovation for sustainability can be achieved.

Geels (2005a) counts problems which are external to the system as one of the five circumstances that create windows of opportunity for the wide diffusion of novelties. According to him, environmental problems are among the examples of such negative externalities. Geels does not seem to be using the word externality strictly as used in economics; i.e. 'Externalities are *indirect* effects of consumption or production activity, that is, effects on agents other than the originator of such activity which do not work through the price system (Laffont, 2008)'. He uses the term with a more daily meaning; i.e. 'a secondary or unintended consequence (Externality, 2010)'. Who pays the cost of these externalities, such as environmental problems, is not relevant to his point. What is important is that these negative externalities are picked up and placed on the agenda of socio-technical regimes by outsiders to the system. For example, environmental NGOs or public pressure groups may demand responsibility. Therefore, these externalities are not owned by the regime actors who caused them and 'To get negative externalities on the technical agenda of firms and designers, there may be a need for consumer and political pressure, and regulatory measures (Geels, 2005a, p. 91)'.

Geels' statement may be correct for some environmental problems which do not directly affect the innovation system, such as water management measures putting regulatory pressure on water use of the industry as a result of water quality requirements and/or water scarcity. Nevertheless, most of the environmental problems putting pressure on the innovation system are actually not external anymore. Even through the problems which rise during the entire life-cycle of products are still a burden mainly on the society, recent developments in relation to product and producer-centred policies (e.g. EuP (EC, 2005), IPP (EC, 2003a), RoHS (EC, 2003b) in the EU and product stewardship schemes in New Zealand (MfE, 2005; 2010)) increasingly put regulatory pressure on or encourage voluntary participation of manufacturers to undertake more responsibility. The unexpected consequences of industrial operations and production/consumption cycle are becoming more and more important on the agendas of companies and sustainability issues increasingly put the innovation system under pressure from within. Empirical research which took place in the past decade supports this claim.

For example, based on a survey (using a sample of 159 companies in 1994 and 176 companies in 1995 with 156 companies being observed in both years), Khanna and Anton (2002) concluded that the threat of environmental liabilities, high costs of compliance, market pressures, and public pressures on companies create incentives for adopting a more comprehensive environmental management system. More recently, MIT Sloan School of Management carried out a comprehensive research covering a global survey of more than 1500 corporate executives about their perspectives on the relationship between business and sustainability (Bernz et al., 2009). The findings of this research indicated that even though more than 70 percent of the respondents said that their company has not developed a clear case for business sustainability, 92 percent of the respondents said their company was addressing sustainability in some way.

Therefore, there is a need to improve the MLP model in a way to render the influence of sustainability issues on the dynamics of the socio-technical system explicit. Konrad et al. (2008) recently attempted to address this need. They added environmental concerns and demographic changes to the landscape dynamics in a very general way in their work analysing the ongoing transformations in German utility sectors to explore potential future developments towards more sustainable sector structures. Without considering environmental concerns and demographic changes as part of landscape developments, they would not be able to address the sustainability dimension in the transformation process. This work is an indication that, there is a room to improve the MLP model in a way to include sustainability issues as a default consideration in system innovation.

In planning/managing system innovation for sustainability, the urgency of certain issues has to be considered in order not to cross the tipping points for the system. UNEP calls for responsible governance in the face of approaching critical thresholds and tipping points (UNEP, 2009b). A technology-centred system innovation perspective suggests that transition takes at least two generations or up to 50 years (e.g. Weaver et al., 2000; Jansen, 2003; Sandén, 2004). This time is required to invent, develop and diffuse radically new technological solutions. Nevertheless, behavioural change, which can be influenced through institutional and social/cultural innovations should be equally emphasised as technological solutions in order to increase the speed of overall system transformation. For example, findings of Shove (2003) regarding the values of cleanliness suggest, socio-cultural change might happen rapidly, sometimes even within the same generation. Therefore, for an effective management of regime transformation socio-cultural (i.e. behavioural) change needs to be taken into consideration as well as technological change both when analysing the current regime and when developing strategies to transform it.

6.2.3. A Refined MLP

In the light of the critique provided above and in line with the objective of this research, some refinements are brought to the MLP model. In Section 6.2.1, it was stated that a socio-technical regime cannot be autonomous and there are horizontal and vertical (hierarchical) interdependencies between regimes. Both horizontal and vertical interdependencies influence the design of products and, to a certain extent, determine the development path of new technologies. The changes in associated regimes (i.e. the regimes which have interdependencies with the subject regime) need to be taken into consideration when aiming to steer system innovation. The regime interdependencies have been considered in previous studies in an implicit way (e.g. analysis of transport and taking into consideration what happens in the energy sector). Nevertheless, the regime interdependencies need to be represented explicitly in order to better understand and analyse the subject regime, and, be aware of the possible technology development paths in associated regimes which might influence the subject regime. Therefore, in order to refine the multi-level perspective on system innovation the first step is to incorporate the regime interdependencies into the MLP model. For this aim, an additional empirical layer is added to the model horizontally (Figure 19).

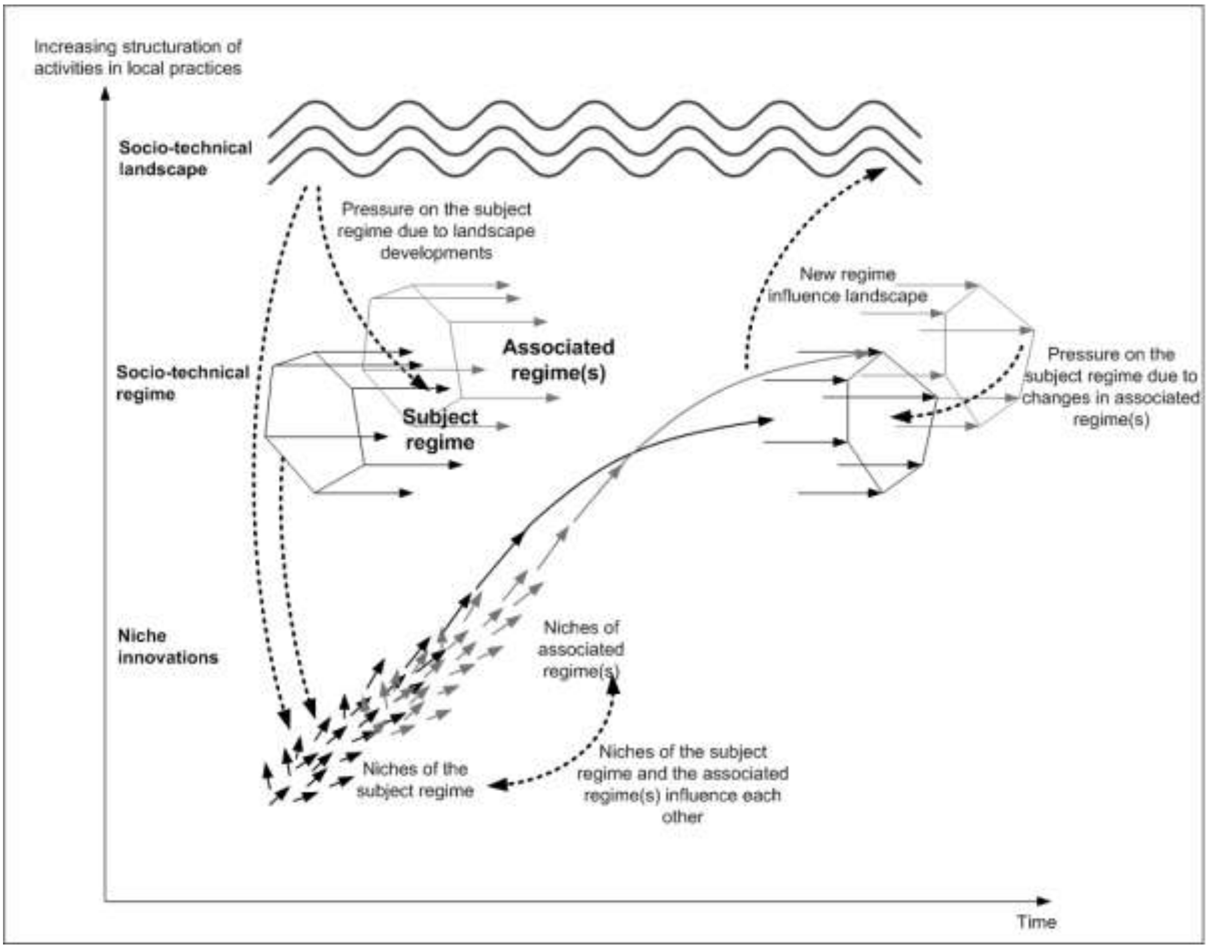

Figure 19. Multi-level perspective refined through addition of a horizontal empirical layer to represent regime dependencies

Previously it was stated that a risk approach to assessing sustainability is adopted in this research (see Section 2.5). The lack of explicit reference to sustainability risks in the MLP model was discussed as part of the critical review (see Section 6.2.2). Therefore, MLP needs to be improved in a way to incorporate sustainability risks and their influences on the subject regime. At this point, a clarification is needed about the terminology used in this thesis. Boyle's (2004) 'risk-to-sustainability' approach (see Section 2.5) is generic. In order to use this approach, initially the system, sustainability of which is being considered, needs to be identified. Only then, the risks threatening the sustainability of this system can be specified. Similarly (referring back to Section 2.4 where operational time frame has been discussed), the term 'long term' is context specific as well and determined in line with the 'nominal-life span' of the system of concern. In addition, (referring to Figure 5 under Section 2.4) there is a continuum of hierarchically interdependent operational contexts to which the concept of sustainability can be applied.

Therefore, the following two definitions are made here to bring clarity to the relationship and indicate the difference between over-arching generic risks and context specific risks, which are implications of generic risks on specific operational contexts:

- Sustainability risks: These are overarching global risks posing threat to proper functioning of the society (e.g. climate change, peak oil, multi-state conflict, etc.). Sustainability risks also referred to as first-order risks, and;
- Contextual risks: These are context dependent risks rising as a consequence of sustainability risks and pose threat to a specific operational context and/or sub-system (e.g. ecosystems, cities, industry, sectors, companies, etc.). Contextual risks are also referred to as second-order risks.

The reason for this dual definition is to relate the smaller operational contexts to the larger ones in a transparent and systemic way. Once the sustainability risks are identified, the relevance of these risks to the specific operational context of concern (e.g. a specific ecosystem, an industrial sector, a company, policy development, urban planning, etc.) can be established and the implications of these sustainability risks on that context can be analysed. Through this elaboration, a context-specific mitigation strategy can be developed and needed expertise to implement this strategy can be identified. First order risks may have different implications to or require different mitigation/ adaptation measures from different operational contexts. In this research the focus is on product development teams of companies. Therefore, the contextual risks are those second-order risks (i.e. risks rising as a result of sustainability risks) which threaten the business of companies. Hereafter, these risks will be referred to as risks-to-business.

In order to incorporate sustainability risks into the multi-level perspective on system innovation, first a risk model is developed. Then, this risk model is laid over the MLP model to complement it and to establish a risk-based MLP model. The risk model, similar to the multi-level innovation model, has three levels: the sustainability risks level, contextual risks (risks-to-business) level and the mitigation/adaptation measures level (see Figure 20). In the risk model, sustainability risks are accepted to be among landscape developments since these risks are long-term, deeply affecting the society and, cannot be changed by the actors in the short term. Sustainability risks put pressure on the socio-technical regime and give rise to contextual risks (i.e. risks-to-business in this research) within that regime. The risks-to-business may emerge from anywhere within the socio-technical system, and therefore, they may be related to policy developments, market changes due to user preferences, socio-cultural changes affecting target market and/or user preferences as well as organisational values, etc. Similar to the socio-technical regime level in the original MLP model, risks-to-business level in the risk model represents internal regime dynamics but those specifically caused by sustainability risks. In order to bring some structure to risks-to-business, the changes and related risks-to-business which may take place as a response to sustainability risks are grouped, with reference to Rennings' (2000) classification of innovation, as institutional, socio-cultural, organisational and technological.

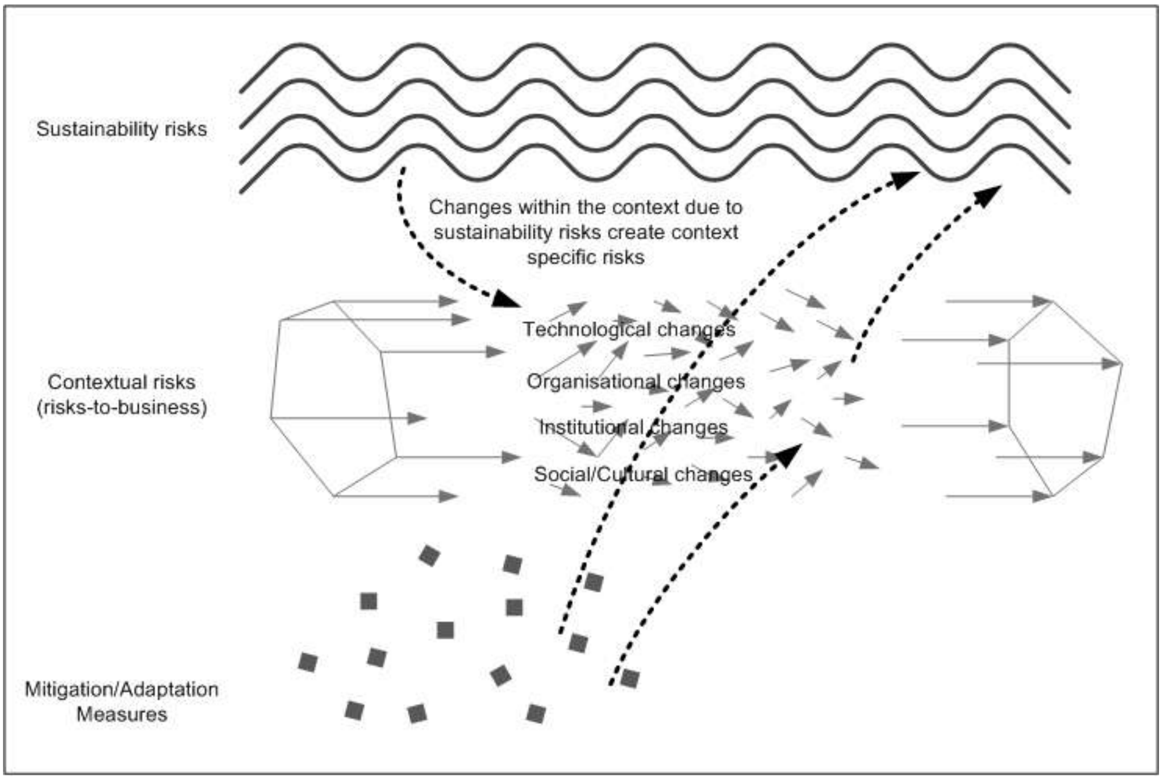

Figure 20. The risk model

The mitigation/adaptation measures correlate to the niche-level developments in the multi-level perspective on system innovation. The mitigation/adaptation measures include any required change in the socio-technical system to either mitigate or adapt to risks-to-business and, thus, to sustainability risks. Therefore, these measures should be either behavioural or technological or both. Behavioural measures cover all (i.e. managerial, administrative, economical, etc.) interventions which influence individual, organisational or community behaviour. The mitigation/adaptation measures level in this model provides a context for identifying, creating and developing solutions towards a breakthrough for system innovation. Identification of mitigation/adaption measures will help in strategic management of niches, i.e. in decision making regarding which niches to be created and developed. In order to meet the mitigation/adaptation measures, both behavioural and technological changes may be required within the socio-technical system.

Figure 21 shows the risk based MLP model developed by incorporation of the risk model to the MLP model. This risk model complements the MLP model by explicitly pointing out the risks at the upper levels and the solutions which are required to mitigate/adapt to these risks at the lowest level. The sustainability risks are represented at the same level of landscape developments. The risks-to-business complement the analysis of the subject socio-technical regime. The risks-to-business should be identified in conjunction with the regime analysis since these can only be identified through an analysis of the socio-technical regime and its dynamics.

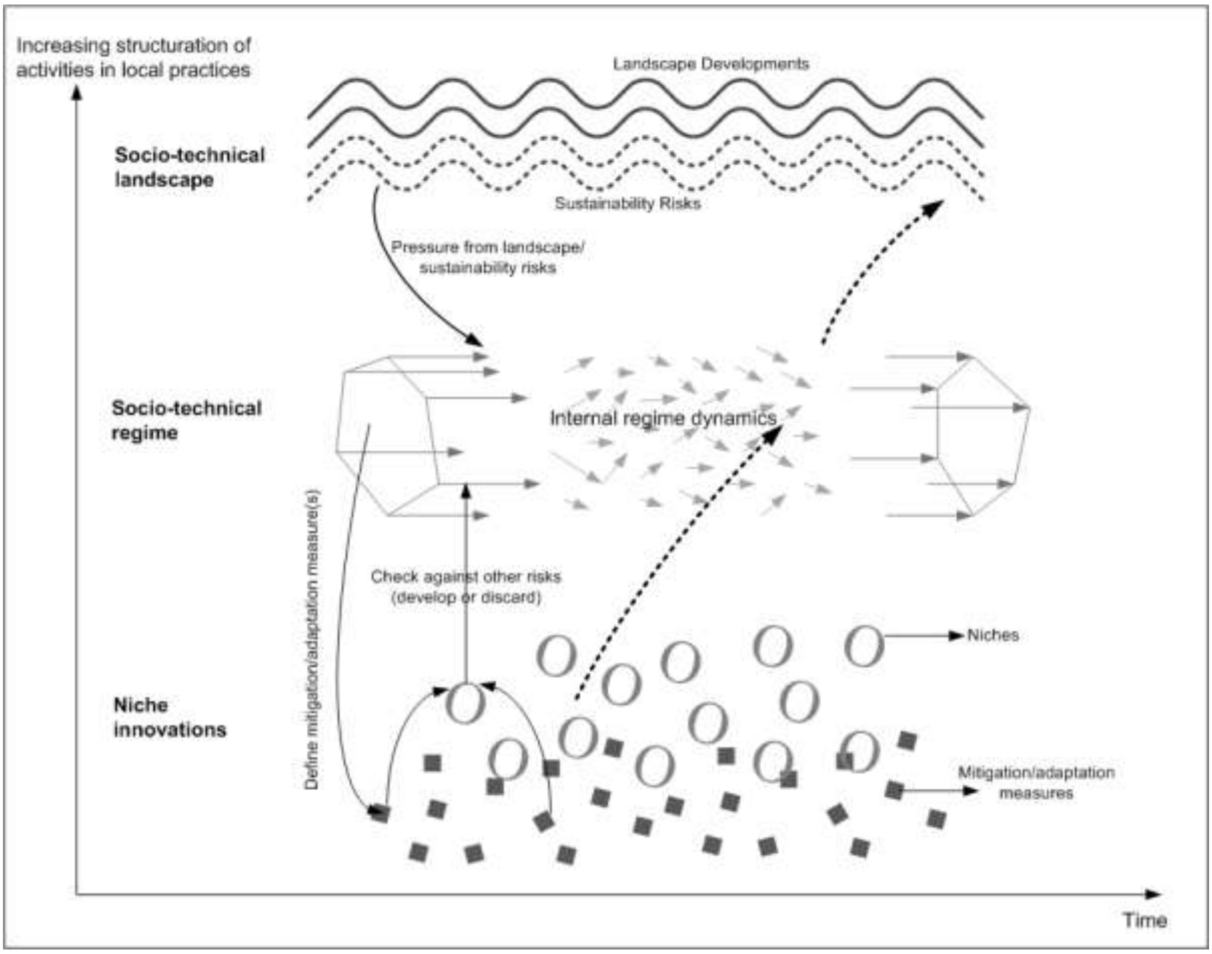

Figure 21. Risk-based MLP model

According to the risk-based MLP model sustainability risks are part of landscape developments and they put the socio-technical system under pressure from within. Sustainability risks influence change within the socio-technical regime, in institutional, social/cultural, organisational and wider technological components of the socio-technical system. These changes pose risks to business and these risks will be mitigated by regime actors through creation and/or realisation of niches at the niche level. As these niches accumulate and new technologies develop, initially the socio-technical regime will change, mitigating the business risks. Then, the changes in socio-technical regime will influence landscape dynamics and mitigate sustainability risks which are represented at the landscape level.

6.3. Co-evolutionary Dynamics within the Socio-technical System Relevant to Product Development

As discussed previously, system innovation for sustainability requires not only technological innovation but also substantial changes at the institutional, social/cultural and organisational components of the socio-technical system. At higher levels of innovation, the socio-technical system component influencing technological change on a co-evolutionary basis broadens. Therefore, for a better understanding of influencing system innovation for sustainability at product development level, there is indeed a need for analysing the dynamics of co-evolutionary influence patterns relevant to product development within the socio-technical system.

In general, society and technology shape each other on an ongoing and bilateral basis (Geels, 2005a, 2005b). Institutional and social/cultural changes generally take place before and, consequently, influence organisational and technological changes (Freeman, 1992). In general, institutional and social/cultural changes are more fundamental and powerful than organisational and technological changes. For example, science and research policy determines the direction of investment and thus influences technological change along that direction. Similarly, international laws and agreements determine the characteristics of international trade unions. Societal norms and values determine, to a large extent, how social organisation is structured.

Even though it is correct to state that institutional arrangements and social/cultural structures determine the direction of change in organisational and technological components in general, there are many exceptions to this as well especially in the large scale. An example is infrastructure as the technological foundation supporting society. Infrastructure lasts for a long time, most of the times longer than a century and in some cases for several centuries (e.g. Paris' sewerage system dates back to 1370 (Sewers of Paris, 2001)). As a result, many of technological and social activities, as well as development of policies particularly those related to public health or transport, need to take the characteristics and capacity of the infrastructure into consideration. In addition to such exceptions, even in the non-exceptional cases where institutional and social/cultural changes come before and influence organisational and technological changes, since change is continuous, in return, organisational and technological changes influence institutional and social/cultural changes. Therefore, it can be said that, chronologically there is a 'semi-hierarchy' of influence patterns; the term 'semi-hierarchy' is used to indicate that there is no strict rule about which comes first in the institutional-social/cultural and organisational-technological couples. Figure 22 shows some of the different elements of socio-technical system influencing technological change on a co-evolutionary basis. These elements are grouped under four types of socio-technical system component: institutional, social/cultural, organisational and technological. For example, user/consumer is a small-scale, social/cultural-type element while infrastructure is a large-scale, technological-type element. The circular arrows in the figure indicate that the change is continuous and dynamic, and, every element influences each other.

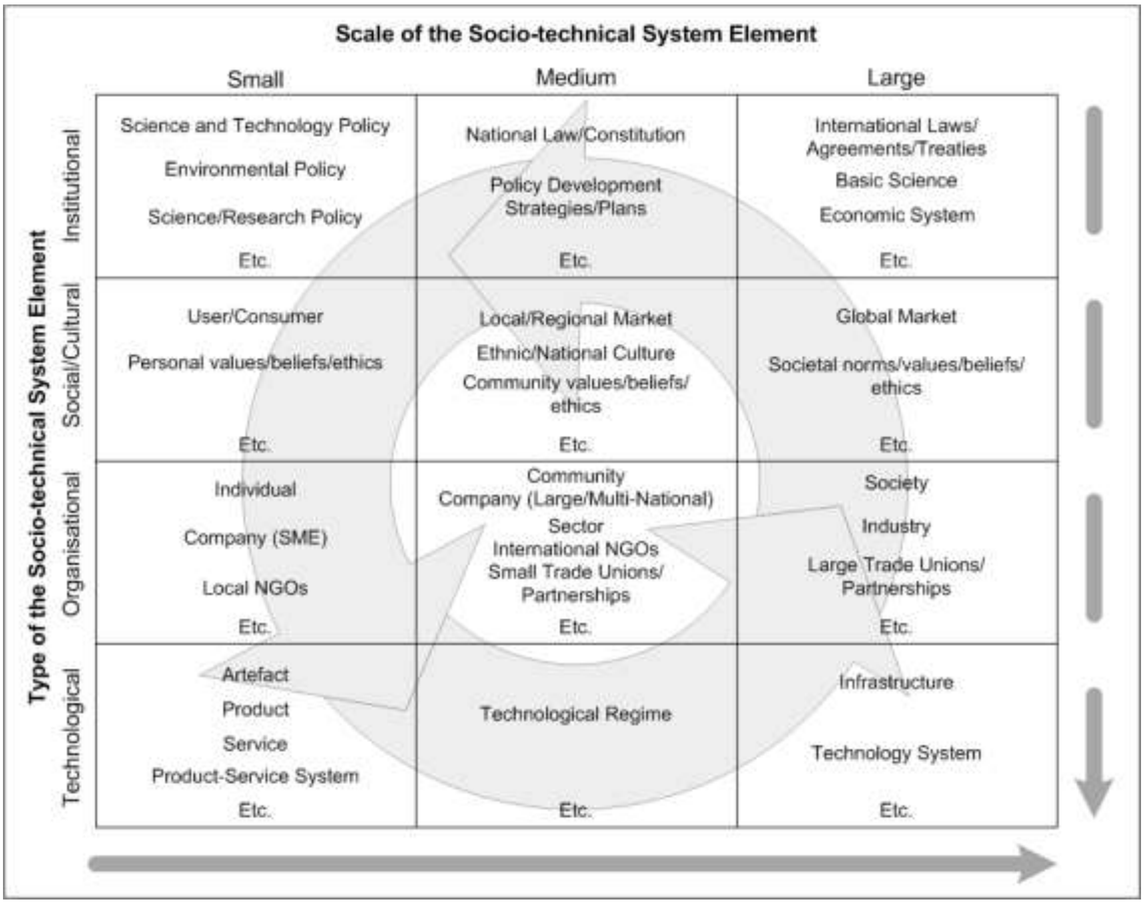

Figure 22. Co-evolutionary dynamics within the socio-technical system

Despite the hardship associated with analysing the dynamics between different types of the socio-technical system components, there are easily observable patterns between different scales of them. Complexity increases as the scale becomes larger. Consequently, as the scale gets larger, managing change becomes harder and the pace of change gets slower. Also, smaller scales of one type of socio-technical system component are hierarchically dependent on larger scales of the same type. For example, products are determined by the relevant technological regimes and the technological regimes are determined by the technology system. Similarly, change in the large scale of a particular type of socio-technical system component is likely to require change in smaller scales of the same type. Nevertheless, smaller scale socio-technical system components may or may not induce/influence change in the larger scales of the same component.

Another aspect which is very relevant to system innovation is agency. Agency, as described by Giddens (1984), is the ability to act and influence change over the course of events. In the context of transforming socio-technical systems, agency 'is the ability to intervene and alter the balance of selection pressures or adaptive capacity (Smith et al., 2005, p. 1503)'. Agency applies to organisational and social/cultural components of the socio-technical system. As the scale gets larger, agency of the socio-technical system component increases, but, organisation and management becomes harder. A community has more agency in influencing change than an individual. However, the organisation and decision/action processes undertaken by a community take longer than that of an individual.

The analysis given above renders the underlying co-evolutionary dynamics transparent without any point of reference for planning. Therefore, it can aid in planning for system innovation at any level of social organisation. For example, this generic analysis is equally valid for a policy maker and a company manager. Nevertheless, due to different hierarchies and levels of agency, different socio-technical system elements in organisational and social/cultural components of the socio-technical system can influence different elements and scales in the socio-technical system. Inevitably, the purpose of different entities that plan for system innovation will differ as will the specific planning and implementation tools. Moreover, it was concluded in Chapter 4 that it is impossible either to draw closed boundaries or to have an all-encompassing understanding of a system. In order to steer a large CAS -such as a socio-technical system- towards a desired future the best strategy seems to be focusing on a part of CAS, and thus, identifying a focal system to be worked on and acknowledging the interrelationships between that focal system and the rest of the CAS. Therefore, the specific socio-technical system component which will carry out this analysis should clearly define the purpose of such undertaking (e.g., policy development, curriculum development, product/service development etc.) and understand their agency and the temporal and spatial scale that they can influence and be influenced by. In the next section, a model, which is developed to link the co-evolutionary dynamics within the socio-technical system and the time frames required for system innovation to the product development function in companies, is presented.

6.4. Combining Levels of Innovation, Co-evolutionary Dynamics and Time-frame

The typology of levels of innovation for sustainability from the perspective of product development was introduced in Chapter 3 under Section 3.6 and the lack of theory and operational tools linking system innovation to product development in companies was highlighted. One particular challenge in linking activities of product development teams to system level innovation becomes evident when the socio-technical contexts of change required to be intervened at each level of innovation are considered (Figure 23). Towards the upper levels of innovation for sustainability, the complexity of the problem increases because the context of change required widens. At the first two levels, a company is a sufficient entity for analysis and action. However, towards upper levels the change requires the collaboration of many stakeholders, some of which are not recognised as stakeholders currently. For the system level innovation to take place there is a need for change at institutional level, i.e. at the very fundamentals of society including norms, values, socio-cultural practices, and the underlying assumptions of the economic system, as well as organisational and technological change. As a result, in planning for system innovation for sustainability, companies and product development teams face a challenge which is not comparable in scale to any previous challenges the industry has faced. On the one hand and in the short term, companies have to design/redesign products to meet immediate business priorities like decreasing the cost and time-to-market while assuring quality, market appeal, competitiveness, and compliance to ever-toughening legislation and standards. On the other hand, in addition to these generic and short-term business goals, they should develop new technologies in the medium and long term which will overcome the burden put by the prevailing production-consumption patterns on the environment and society.

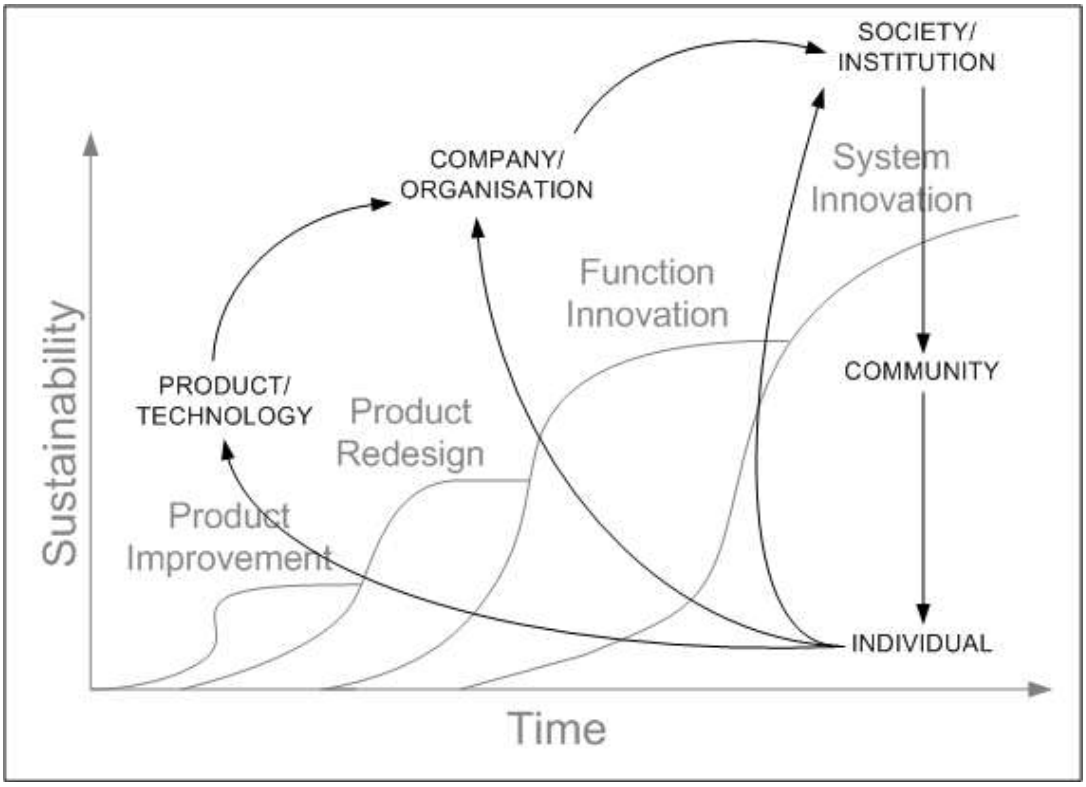

Figure 23. The contexts of change in relation to levels of innovation for sustainability

Another challenge in linking activities of product development teams to system innovation is related to the associated time frames. System innovation requires long-term planning (i.e. 50 years or more) due to the complexity embedded both in natural and social systems and the dynamic nature of sustainability requirements (Gaziulusoy et al., 2008). The time frames required for system innovation are far beyond the ones usually used by companies for planning (Jansen, 2003). Nevertheless, system innovation assumes that structural changes will take place in the socio-technical system including the major assumptions of the current economic system and the role and responsibilities of businesses within society. In addition, companies are important actors within the socio-technical regime and will have an important role in developing the technologies of the new system. Therefore, developing tools and methods which would enable active participation of companies through their business practices in planning for system innovation is necessary both in order to effectively implement any plan at policy level and to increase the adaptive capacity of individual companies with regards to the substantial change which will take place through the transition. A framework has to be established to portray the ways companies are and can further be related to system innovation, and issues needing to be solved should be identified and acknowledged in the tools and methods to be developed.

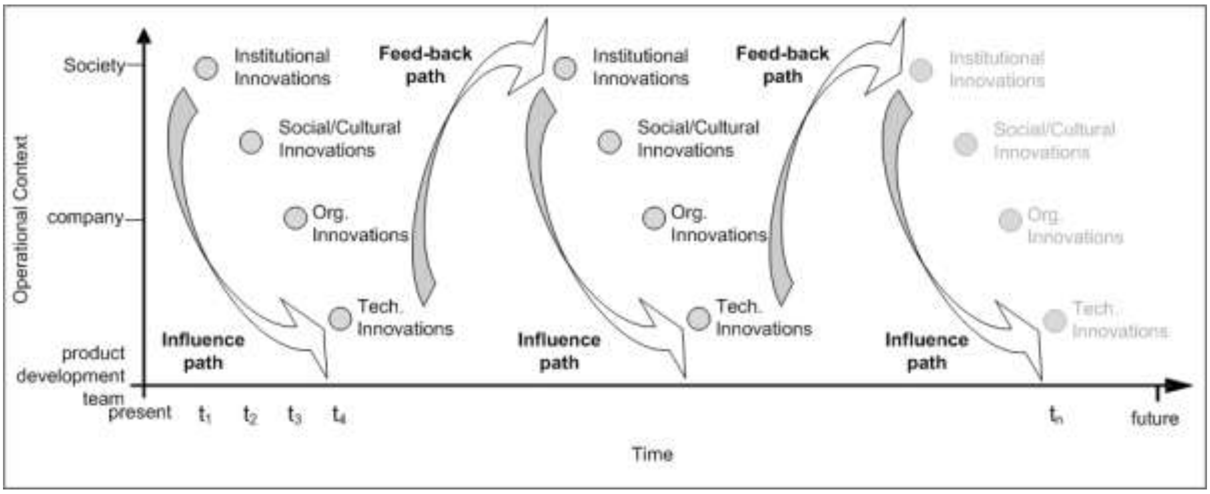

Figure 24. Temporal and spatial positioning of relevant types of innovation

Referring back to the discussion about the operational time frames (see Section 2.4), as the operational context widens, the length of planning should extend in order to cover subsumed operational contexts and to connect them both spatially and temporally. In Chapter 3 under Section 3.2, where the co-evolutionary characteristics of innovation for sustainability were discussed, it was stated that social and institutional innovations will influence organizational and technological innovations and then will be influenced by new organizational structures and technologies in a recurring manner. Therefore, based on a systemic hierarchy, society is the widest operational context relevant to system level innovation followed by the company and the product development team. Figure 24 temporally and spatially positions types of innovation relevant for different operational contexts subject to this research and relevant types of innovation based on the operational time frame model (Figure 5 in Chapter 2). According to this positioning, institutional and social/cultural innovations should be subjected to the longest planning period followed by organizational and technological innovations. There will be feedback paths established from smaller-scale, shorter-term innovations informing both each other and innovations taking place at longer time spans and in wider operational contexts as the implementation progresses.

Figure 25 combines the levels of innovation (Figure 11) and the different scales of socio-technical system components (Figure 22) in order to link system innovation to the activities of product development teams in a meaningful way. Since innovation is systemic and product development is indeed a component of another system, the activities taking place at the product development level has to be considered in the context of the company. Therefore, the product development function needs to be systemically positioned in the company, and the company needs to be systemically positioned in the society. In order to achieve this, the time frames applicable to the three operational contexts (i.e. society, company and product development) and the mechanisms of aligning the activities of product development to the transformation which needs to take place in the wider society to achieve sustainability needs to be clarified.

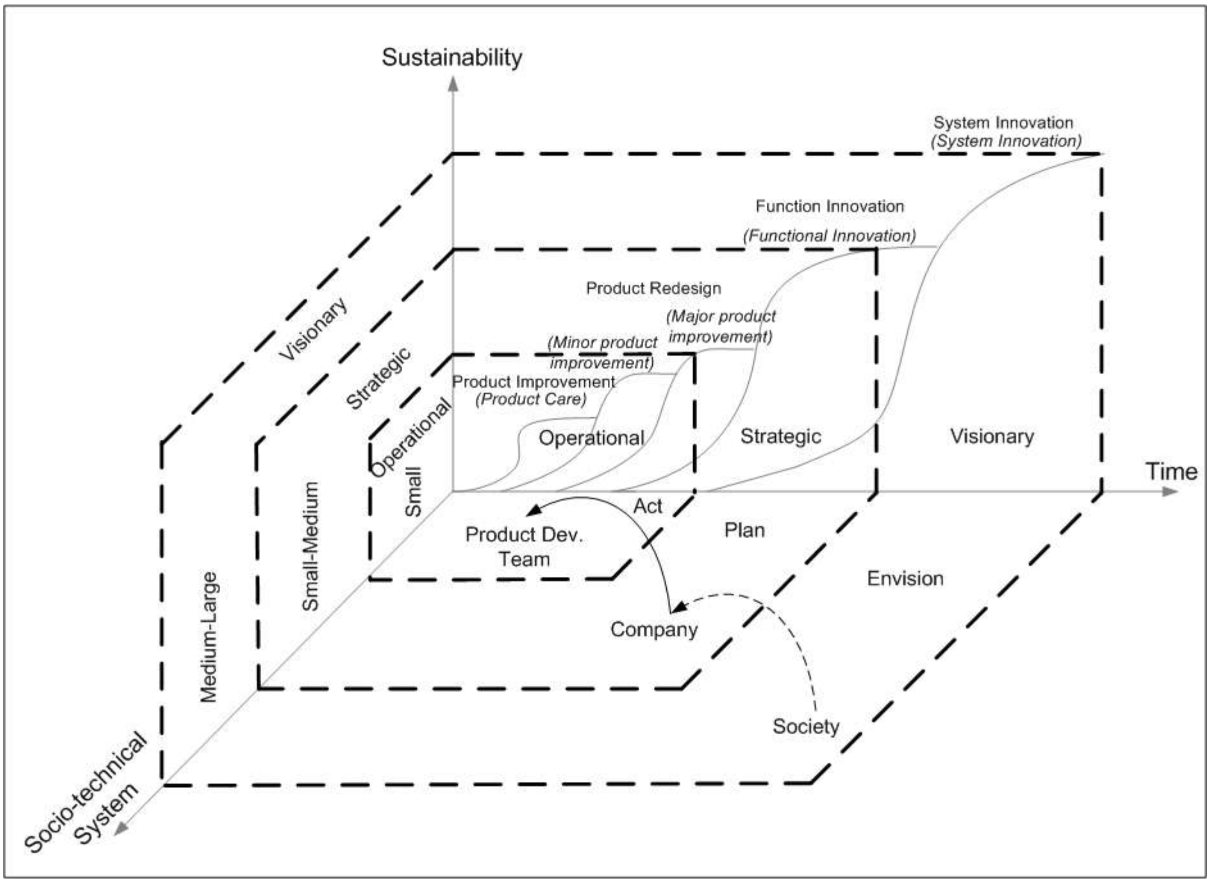

Figure 25. A model to link product development function to system level innovation

As shown in Figure 25, the planning periods applicable to the levels of innovation can be defined as operational in the short term, strategic in the medium term and visionary in the long term. The short term used here covers ten years which is the longest business planning period for most companies. It is acknowledged that there are indeed shorter periods that businesses need to make decisions and take action within, such as daily, monthly or annual periods. In addition, product development cycles are getting shorter as the global competition increases and lean product development practices become more widespread. Nevertheless, it is empirically proven that as the complexity and innovative content of products increases the development cycle becomes longer (Griffin, 1997a, 1997b). In cases of radical innovation, the technological and market uncertainties require longer learning periods, and therefore, more time needs to be invested (Herrmann, Gassmann & Eisert, 2007). Case studies (e.g. Lynn et al., 1996; Veryzer Jr., 1998; Abetti, 2000) have shown that for radical innovations, time-to-market cycles as long as and sometimes longer than ten years is common.

Therefore, the period of ten years is literally the operational period for radically new product development and needs feedback from longer planning periods if we aim for a deliberation towards sustainability. The strategic period should shape the operational period through the setting of goals at the organisational (company) level. Individual companies have very limited ability to influence change at the larger components of the socio-technical system, i.e. institutional, social/cultural, especially in the short-term. Nevertheless, it should be emphasised once again that companies are part of society and thus, even though they fall into small/medium scale within the socio-technical system, their strategic goals should not be contradictory to visions of society. On the contrary, their strategic goals should be aligned with the meta-goals desired at societal level to achieve sustainability. In order to achieve this alignment the planning periods applicable to companies (operational and strategic) need to be linked to the long-term planning period; theoretically, at the end of the long-term planning period the whole socio-technical system should have been transformed. Therefore, companies should acknowledge the long-term visions of the society during their strategy development which then will guide the product development decisions.

6.5. SOCIAL FUNCTION FULFILMENT, SYSTEM INNOVATION AND PRODUCT DEVELOPMENT

Socio-technical systems are defined by the social function fulfilled by them (Geels, 2004). Focusing on social function fulfilment enables consideration of the socio-technical regime as a (re)configuration of the system components covering but not limited to technologies. Focusing on social function enables taking all relevant regimes into consideration. Moreover, it enables an integrative perspective covering production, consumption and governance as well as dynamics among these three domains (Konrad et al., 2008).

In planning for system innovation for sustainability, focusing on social function fulfilment broadens the thinking which was previously limited to material and technical aspects of cultural, behavioural and organisational domains of innovation, and therefore, provides more leverage points to influence the system change (Ryan, 2008b). Since there is a need to shift the focus from the technological regime, recent research and theory development widely adopts the concept of social function fulfilment in defining the socio-technical regime rather than referring to a particular technology regime. Also, as discussed previously (see Section 6.2.1), isolating and identifying individual socio-technical regimes neither is possible nor is desired since there are structural couplings and interdependencies between regimes. Therefore, in planning for system innovations towards sustainability, there is a need to find alternative ways of fulfilling social functions through (re)configurations within and between the socio-technical regimes.

From the perspective of product development, innovating to find alternative ways of fulfilling a social function is not a novel concept. Indeed, this is one of the main strategies applied by product designers/developers in new product/service development (T. Allan, personal communication, August 20, 2009). The term was popularised with the rise of literature proposing PSS as possible sustainable solutions starting from late 1990s and early 2000s (see, for example, Charter & Tischner, 2001). Social function fulfilment, as currently understood from the perspective of product design/development, corresponds to the third level of innovation for sustainability (see Section 3.7). Therefore, it does not consider social/cultural and institutional innovations which are essential to achieve innovation at system level as leverage points to focus on in product development. Below, a simple model is proposed.

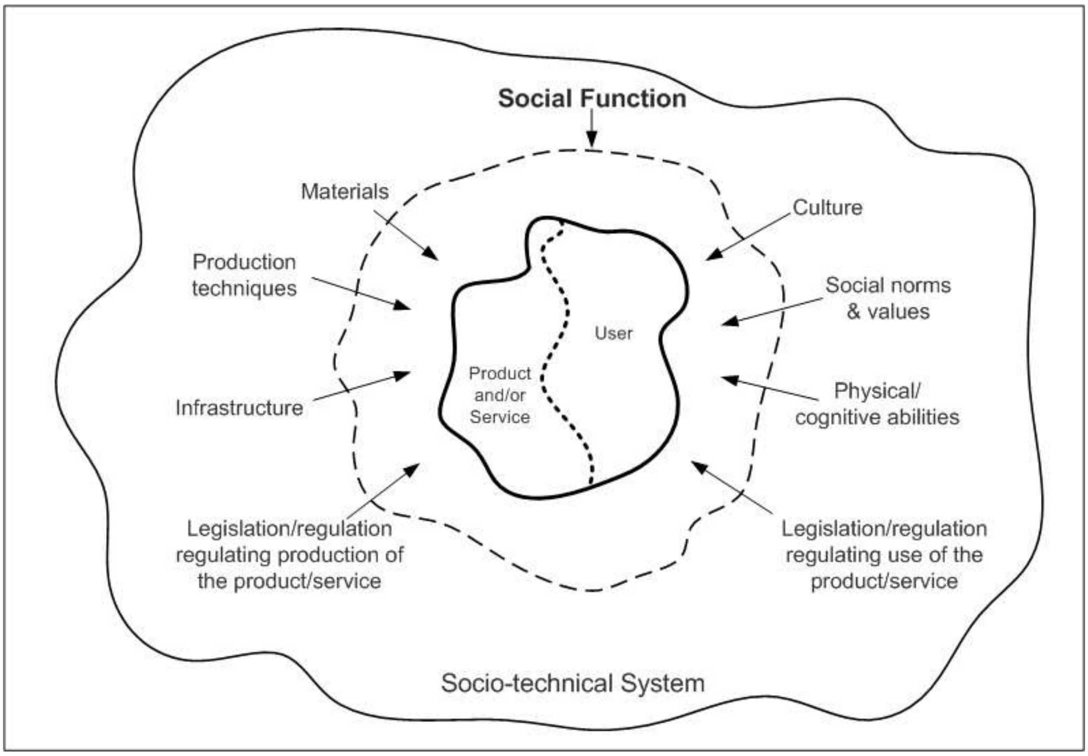

Figure 26. A model for social function fulfilment at product development level

Figure 26 is a model to describe social function fulfilment from the perspective of product development with a systemic understanding. The model conceptualises social function fulfilment in the wider context of the socio-technical system. As stated before, a socio-technical system has institutional, social/cultural, organisational and technological components. Social function cannot solely be described technologically but needs to be referenced to the other components of the socio-technical system as well. Fulfilling a social function requires consideration of several -institutional, social/cultural, organisational as well as technological- variables simultaneously. These variables include materials, production techniques, infrastructure, culture, social norms/values, cognitive/physical abilities of the user and legislation/regulation which govern the production and use of a product/service. These variables all together determine the conditions and limits of fulfilling that social function within the socio-technical system of concern. In this systemic approach to conceptualising social function fulfilment, these variables are co-dependent. Each of them is subject to change during the systemic transformation towards sustainability. Therefore, they need to be acknowledged individually yet considered simultaneously in system innovation as complementary to each other. It should be noted that the size of the physical variables (materials, infrastructure) may vary independently of the social function since a function can be met in multiple ways some of which may be more material intensive than the others.

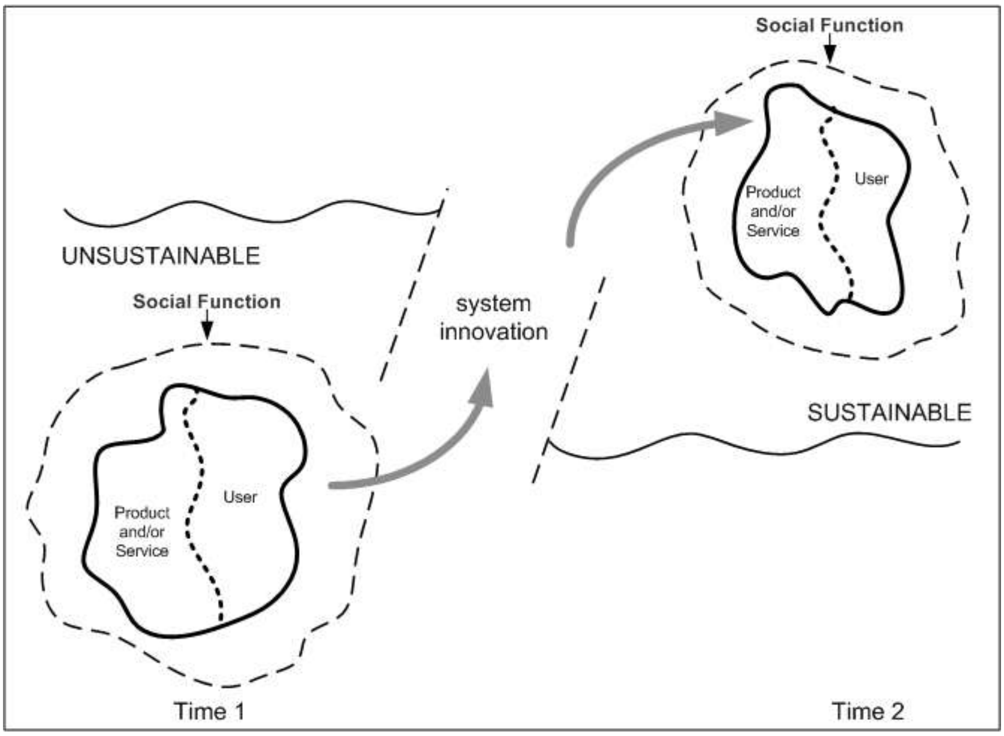

Figure 27. System innovation model from the perspective of product development

System innovation should enable fulfilment of the same social function in the future through a combination of innovations in institutional, social/cultural, organisational as well as technological contexts of the socio-technical system. From the perspective of product development this means adopting a proactive and systemic approach in design and development of the products/services by taking both physical and non-physical variables, which can be influenced at the product development phase, into consideration. Figure 27 provides a model to explain system innovation from the perspective of product development. According to this model, if in developing alternatives to fulfil a particular social function, the physical (e.g. materials, infrastructure, and production techniques) and non-physical (e.g. regulations, social norms and values, cognitive abilities of the user(s)) variables are considered and leveraged simultaneously, system level innovation can be influenced through activities and decisions at the product development level. If institutional, social/cultural, organisational and technological determinants of a social function are considered simultaneously, neither the capacity and characteristics of present technologies nor the expectations of present market and user becomes a focal point around which innovation will shape. Instead, the focal point becomes the social function to be fulfilled. This way, possible combinations of physical and non-physical variables together enabling that function to be fulfilled can be conceived. As a result, product development can have a role to play in much wider and longer-term changes which need to happen at institutional and social/cultural levels.

6.6. ADDRESSING THE ISSUE OF DIFFERENT SOCIO-TECHNICAL CONTEXTS

Previously, it was argued that radical change in the context of system innovation refers to a radical transformation at system level (see in Chapter 3). This means that there will be a transitionary period and, at the end of this period, the resulting socio-technical system will be radically different from the one at the start. However, this does not necessarily mean that everything in the socio-technical system will radically change; neither does it necessarily imply a rapid pace of change. Which interventions will succeed will depend on the particular needs of the socio-technical context of concern. Therefore, efforts of managing and steering system innovation in a particular socio-technical context should be directed towards first, understanding, and then, meeting the specific needs of that context. The focus of system innovation is not necessarily new or smart or high technologies but rather technologies which are appropriate for the particular socio-technical context they are meant to be used in. There are no one-size-fits-all solutions. Different socio-technical contexts need different solutions not only for economic, social/cultural and technological reasons but also for region-specific characteristics (different environmental problems, different climate, ecosystems with different characteristics etc.).

It was also previously argued that a techno-centric system innovation perspective suggests that transition takes at least two generations or up to 50 years since this time is required to invent, develop and diffuse radically new technological solutions. However, considering socio-cultural norms and values as well as and in conjunction with technological solutions, the speed of innovation at the system level can be increased. Therefore, socio-cultural characteristics need to be addressed in planning for system innovation at product development level. The critique of MLP as a conceptual model (see Section 6.2.1) pointed out that the model (and the theory it is based on) is techno-centric and representative of the technologically-optimistic, post-industrial and typically Western socio-technical context.

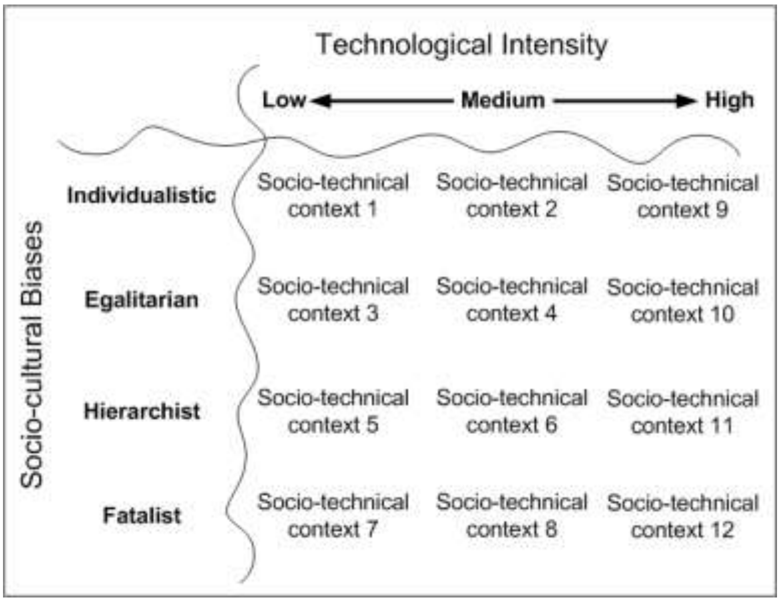

Figure 28. A suggestive and generic typology of different socio-technical contexts

In order to be able to address the characteristics of different socio-technical contexts better, Figure 28 is loosely based on Mary Douglas' work about socio-cultural biases (Mamadouh, 1999). The four socio-cultural biases are matched with the technological intensity of solutions appropriate for different contexts to generate a suggestive typology consisting of twelve generic types of socio-technical contexts. It should be noted that the socio-cultural biases are ideal types and in reality they only represent arbitrary points on a continuum. Similarly, the technological intensity row represents two opposite ends and the middle of a spectrum. Even though these 12 types are highly ideal, they serve sufficiently for the purposes of generating normative visions for different sustainable socio-technical contexts. In each socio-technical context shown in Figure 28, the same social function can be fulfilled by a different combination of physical and non-physical variables enabling fulfilling of that particular function. The importance of considering different socio-technical contexts in solution generation is two-fold. First, this typology can be used to envision a variety of possible sustainable societies, and by doing so, innovation paths which are not techno-centric can be opened. Second, different socio-cultural contexts represent different current and future markets. Therefore, by using this typology, companies which would like to be involved in system innovation for sustainability might identify more opportunities.

6.7. SUMMARY OF THIS CHAPTER

This chapter presented the theoretical framework developed to link activities and decisions at product development level to the long term and structural changes required at the socio-technical system level to achieve sustainability. The theoretical and conceptual models were developed by integrating and building on insights acquired as a result of the broad and critical review of literature which was reported in the first part of this thesis. This theoretical framework contributes to the main body of system innovation theory by clarifying and refining it as well as building on it to specifically address product development level in system innovation for sustainability. Below is a summary of the theory and models presented in this chapter:

- The MLP model is useful to understand how system innovations happen. Nevertheless, for this model to effectively influence ongoing and future system innovations towards sustainability in general, and in line with the objective of this research in particular (i.e. to effectively link the activities/decisions at product development level with the transformation which needs to take place at the societal level to achieve sustainability), certain improvements seemed necessary. One of the improvements addresses the regime dependencies by adding an empirical layer to the model to represent interdependencies between the subject regime and the associated regimes. The other improvement incorporated sustainability risks explicitly to the landscape level and business risks rising from the sustainability risks to the regime level of the MLP model. This way, decisions to develop a niche can be based on the risk mitigating capacity of that niche;
- It is hard to isolate and identify a socio-technical regime and there is a need to represent the interdependencies of regimes. Focusing on social function rather than a specific regime can address this issue since meeting a social function will carry references to all of the regimes involved in meeting that social function;
- There are four levels of innovation for sustainability relevant to product development. Each of these levels require longer planning periods progressively and require consideration of the wider co-evolutionary dynamics within the socio-technical system;
- There are different operational scales in the socio-technical system and, as the scale becomes larger, complexity increases, managing change becomes harder and the pace of change gets slower. In addition, smaller scales are hierarchically dependent on larger scales;
- Another relevant aspect in transforming socio-technical systems is agency, the ability to act and influence change over the course of events. As the scale gets larger, agency of the socio-technical system component increases but organisation and management becomes harder. Due to different hierarchies and levels of agency, different socio-technical system elements in

organisational and social/cultural components of the socio-technical system can influence different components and scales. Inevitably, the purpose of different entities which plan for system innovation will differ as will the specific planning and implementation tools. Therefore, the specific socio-technical system component which will undertake some system innovation effort should clearly define the purpose of such undertaking (e.g., policy development, curriculum development, product/service development etc.) and understand their agency and the temporal and spatial scale that they can influence and be influenced by;

- Based on the above points, a model linking the co-evolutionary dynamics within the socio-technical system and the time frames required for system innovation to the product development function in companies is developed. This model is a prescriptive model and states that companies are part of society and thus, their strategic goals should not be contradictory to visions of society and these goals should be aligned with the goals of the society envisioned to achieve sustainability. This requires companies to acknowledge the long-term visions of the society during their strategy development to guide their decisions on product development;
- A model explaining system innovation from the perspective of product development has been developed. According to this model, from the perspective of product development, system innovation provides the same social function in the future through a combination of innovations both at the technological and at the social sphere. Therefore, in developing alternatives to fulfil a particular social function, the technological aspects and social aspects should be considered and leveraged simultaneously;
- Radical transformation at system level does not imply that all components of the system will radically change. Therefore, which interventions will succeed, will depend on the particular need we are trying to meet and the particular socio-technical context we will try to bring a solution within. For this reason, care for the specific needs of the context must be given. In order to be able to address this issue in developing a scenario method for system innovation, a suggestive generic typology of socio-technical contexts is developed. The use of this typology can enable identification of non-techno-centric innovation paths as well as techno-centric ones and might help companies to be aware of the needs of different current and future markets, and therefore, help them to identify more opportunities towards system innovation for sustainability.

7. THE SCENARIO METHOD: CONCEPTUAL AND OPERATIONAL FRAMEWORKS

7.1. INTRODUCTION

This chapter presents the scenario method developed as a result of integrating the findings of the literature review (Chapter 2 to 5) and the new theory and models developed based on these findings (Chapter 6). The scenario method consists of a conceptual and an operational framework. These frameworks are progressively developed based on the theoretical framework (Figure 29). The conceptual framework is established by developing the criteria which needs to be met by the scenario method and an outline of methodical tasks necessary to meet those criteria. The operational framework presents the operational details of the scenario method; i.e. the criteria used to design the operational tool and the specific processes to be used in implementing the methodical steps identified in the outline of the scenario method.

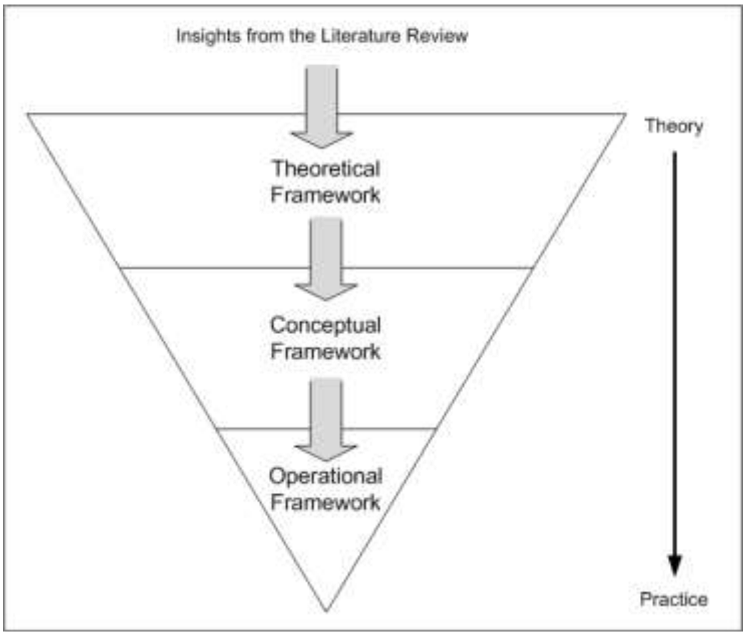

Figure 29. The progressive development of theoretical, conceptual and operational frameworks

The conceptual and operational frameworks presented in this chapter are the initial versions. The final versions are briefly presented in Chapter 9 where results of the field work are reported.

7.2. THE CONCEPTUAL FRAMEWORK OF THE SCENARIO METHOD

7.2.1. THE CRITERIA

In order to develop the criteria which need to be met by the scenario method, initially two sets of requirements were identified (Table 8). These requirements reflect the findings and insights gathered as a result of the critical review of the literature (reported in the first part of this thesis) and the theoretical framework developed in order to link the product development level in companies to the transformation which needs to take place at societal level (presented in Chapter 6). The first set of requirements is related to the structure of the method. The structural requirements are identified based on the theory of system innovation for sustainability and analysis of previous projects aimed to plan for and/or steer system innovation. The second set of requirements is about the content of the scenario method. The content requirements are identified through a review of system innovation typologies, scenario typologies and methods and drivers and barriers for businesses to adopt sustainability as a default business and product development priority.

Table 8. The structural and content requirements of the scenario method

Structural Requirements
SR1. The scenario method needs to be systemic SR2. The scenario method needs to be layered SR3. The scenario method needs to have a double-flow (forward and backward)
Content Requirements
CR1. The scenario method should enable identification of alternative innovation paths towards a sustainable future
CR2. The scenario method should aid in identification of organisational/human development requirements
CR3. The scenario method should aid in identification of technological development requirements
CR4. The scenario method should have operational, strategic, visionary periods
CR5. The scenario method should have a risk approach to sustainability

After identifying the structural and content requirements, these were consolidated to generate the criteria which need to be met by the scenario method. The resulting criteria and brief explanations recapping from previous chapters are given below.

Criterion 1 (SR1, SR2, CR4): The scenario method should link the planning periods applicable to companies (operational and strategic) to the long-term planning period (visionary) in order to enable companies to address long-term societal visions in their strategies and effectively implement these strategies in product development (Figure 30).

The planning periods applicable to the levels of innovation were identified as operational in the short term, strategic in the medium term and visionary in the long term (Section 6.4). The short term covers ten years and is the operational period for radically new product development. The strategic period should shape the operational period through the setting of goals at the organisational (company) level. The visionary period is beyond the time-periods applicable to companies. Theoretically, at the end of this period the whole socio-technical system should have been transformed. In order to align the product development level with the sustainability visions at the societal level, the company strategy should play a mediatory role between the operational and the visionary periods (i.e. between the activities of product development teams and the visions of the society). In order to play this mediatory role, the strategic goals of companies should be aligned with the goals desired at the societal level to achieve sustainability.

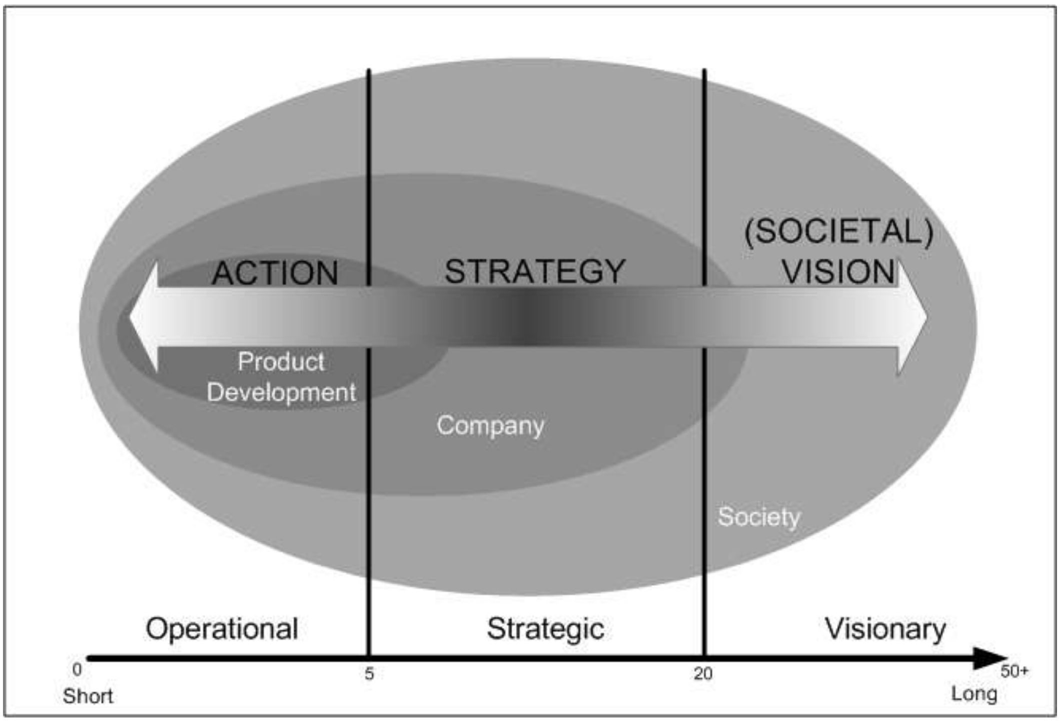

Figure 30. Criterion 1

Criterion 2 (SR1, CR2, CR3): The scenario method should aid companies in identifying not only technology development requirements but also organisational/human development requirements (Figure 31).

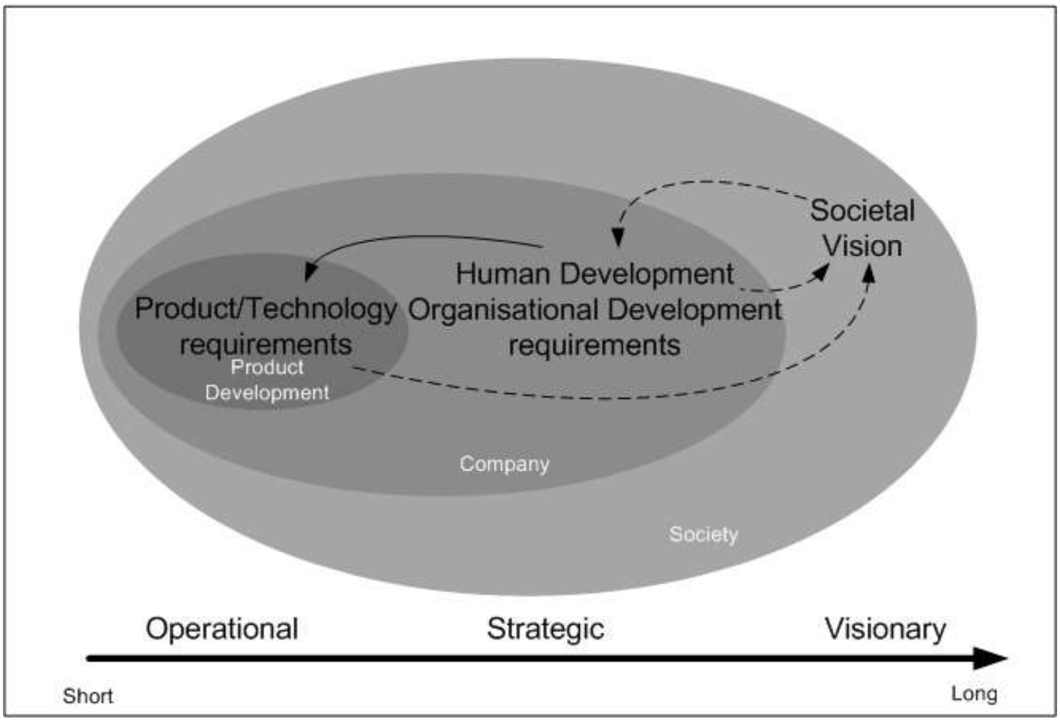

Figure 31. Criterion 2

The organisational/human context will determine the success of any technical activity since the capacity, knowledge and capability to innovate is generated, assessed, developed and used within the organisational context (Jorna, 2006). Organisational innovations should cover a longer time span than technological innovations in order to be able to influence technological innovations towards sustainability. The scenario method which will be used at company level should not only help to identify technical/engineering requirements related to product development function but also should address organisational/human dimensions of company governance. Therefore, the scenario method should enable technological development with reference to organisational strategy which should cover a longer time span in planning; i.e. which should oversee a company's product development path and guide it towards system innovation for sustainability. In this context, organisational planning plays an interface role between purely technological innovations achieved within the product development team and system innovation which will be achieved within the wider socio-technical system.

Criterion 3 (SR1, SR3, CR2, CR3, CR4): The scenario method should aid companies in developing integrated business strategies aligned with societal level sustainability visions and day-to-day business activities and should facilitate integration of all business functions in line with the company strategy (Figure 32).

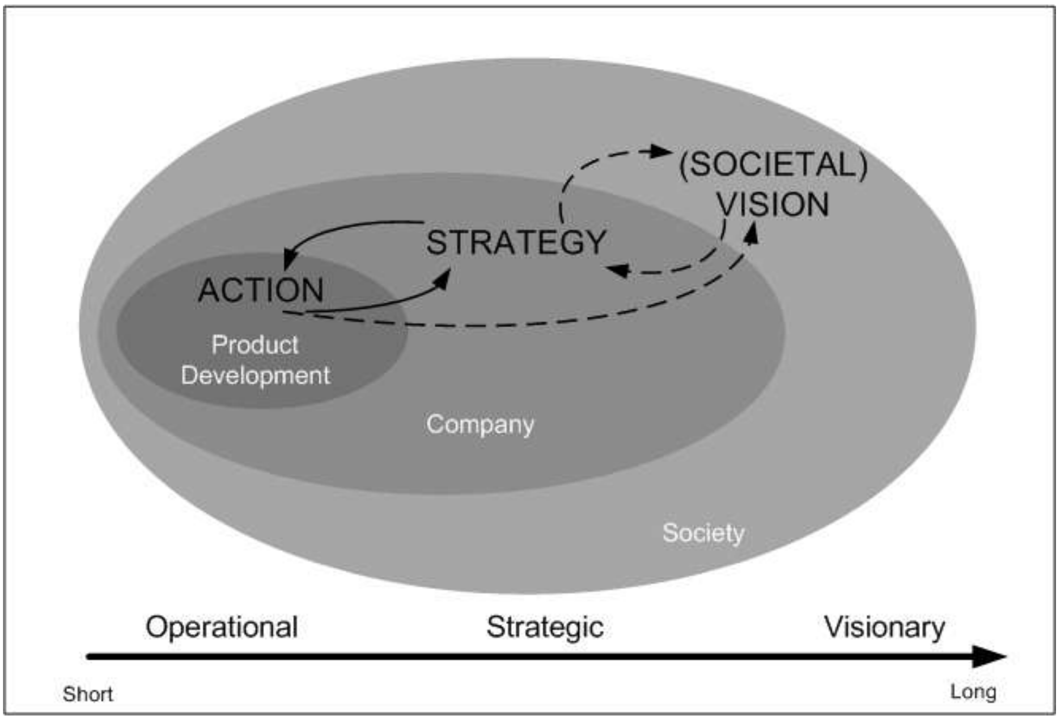

Figure 32. Criterion 3

The significance of visions for system innovation was previously discussed (see Chapter 4). Since normative sustainability visions, which need to be achieved in the long term and at a societal level (i.e. socio-technical system level), are essential in initiating and managing system innovations, the scenario method should aid in integrating the implications of these visions into day-to-day business activities. This requires internalisation of sustainability into company strategy through generic tools like Strengths Weaknesses Opportunities and Threats (i.e. SWOT) analysis, the results of which should be aligned with other business priorities. This would enable internalisation of innovation for sustainability at the product development (operational) level through identification of design criteria. Since successful product development requires integration of all major business functions within a company and since company strategy needs to be referenced to future visions in order to guide product development towards system innovation, the scenario method should enable integration of business functions in line with the organisational/strategic plan. Johansson, Greif and Fleischer (2007) provide a review of several studies which identify barriers to integration of business functions. They also refer to the studies which identify mechanisms facilitating integration which can be of technological and/or organisational nature. Therefore, construction and organisation of product development teams will play a very important role in any attempt for system level innovation to be successful. The organisational and technological barriers to integration of business functions need to be acknowledged along with possible facilitating mechanisms in developing a scenario method for the use of companies.

Criterion 4 (SR3, CR1): The scenario method should have a double-flow approach in order to link present and future in a realistic way and enable identification of alternative innovation paths which are possible from a technological point of view, acceptable from a social/cultural point of view and desirable from a sustainability point of view (Figure 33).

Major projects which addressed system innovation were critically reviewed (see Section 4.5). Some of these previous projects in the context of system innovation developed forward flowing, predictive or explorative scenarios which started from the present and flowed towards the future (e.g. Elzen et al., 2002; Hofman, 2005; Geels, 2002a; Elzen et al., 2004). Some other projects developed backward flowing, normative scenarios, starting from 50 years in the future towards present (e.g. Vergragt, 2000; Weaver et. al, 2000; Partidario, 2002). It is not possible to disprove any of these approaches since these experiments are ongoing and there is a lack of empirical data to test and verify these methodologies against some success criteria of steering system innovations. However, for two reasons it is suggested to combine these two approaches to establish a double-flow method (Figure 33).

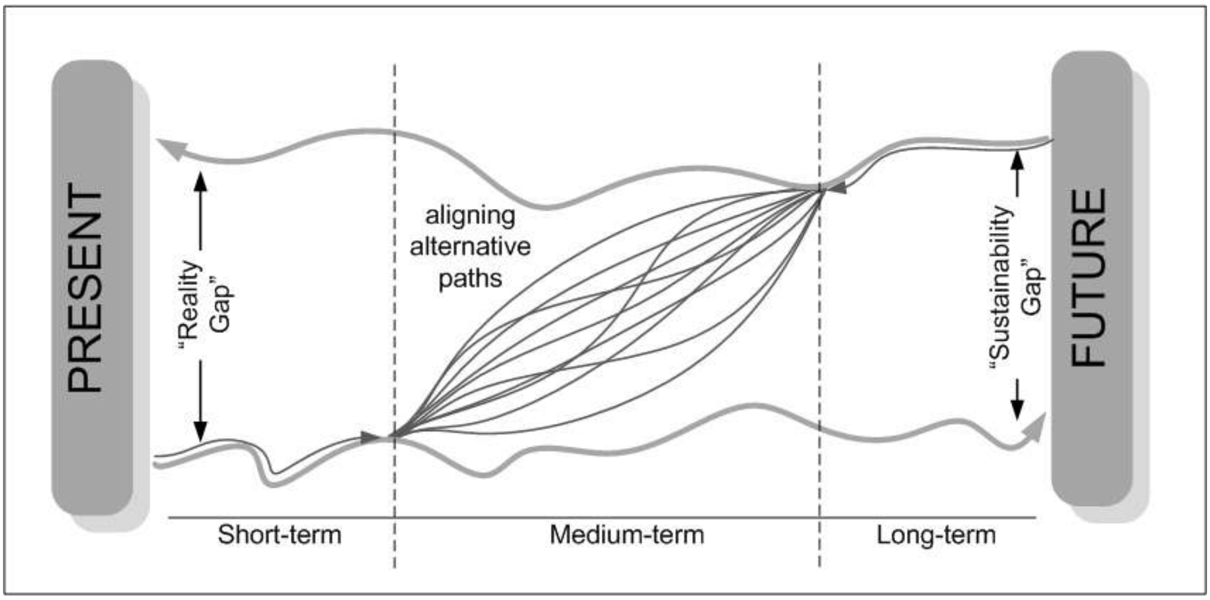

Figure 33. Criterion 4

First, CAS are non-linear, demonstrate emergent behaviour, self-organisation, continuous change, sensitivity to initial conditions, learning, irreducible uncertainty, and contextuality (see Chapter 2, Section 2.3). As a result of these characteristics, the future of any CAS becomes unpredictable, indeterminate and emergent (Section 4.3). Therefore, present-time choices of system elements determine the future of the system yet are unable to accurately identify what those future changes will be. For this reason, starting only from the future may result in not being able to acknowledge lock-ins which need to be overcome and which are embedded in the present socio-technical system. On the contrary, following only a forward flow of strict causality may limit multiplicity of paths or even the possibility of developing a path for periods longer than medium term. Within the socio-technical domain, cause-effect relationships are difficult to ascertain. Socio-technical problems are characterised by complexity - there are multiple causes, or more appropriately, 'influences' which may affect the likelihood of an event occurring. In the socio-technical domain, causality is not deterministic as applied to physical phenomena, but instead, it is probabilistic and almost every 'effect' is a cause for the following events. Also, starting only from the present may result in not being able to achieve the transformation needed at system level for the society to be sustainable.

In addition, scenarios can be predictive, explorative and normative (see Section 4.2.2). In the context of system innovation, both exploratory scenarios, which try to explore what can happen under some anticipated circumstances and, normative scenarios, which provide the transformation knowledge required to achieve a desired target are equally important to break from the lock-ins prevailing in the present state while at the same time aligning the exercise of breaking the lock-ins with the vision of a sustainable society.

The second reason which justifies the suggestion to follow a double-flow approach relates to the specific focus of this research. Since companies individually do not have too much agency to change the entire system (unlike well-planned top-down policy interventions) anticipating alternative innovation paths linking the present of companies to possible and desirable futures at societal level is crucial to overcome barriers, identify short-term opportunities and thus, to empower and encourage companies to actively take part in change towards system innovation.

Criterion 5 (SR1, SR2, CR2, CR3, CR5): The scenario method should have a layered risk approach in order to identify implications of overarching sustainability risks on companies' businesses as contextual risks. This way, sustainability can be internalised in companies' organizational and product development strategies and active participation of companies in setting sustainability visions at societal level can be enabled (Figure 34).

Based on the critical review of sustainability assessments (Section 2.5), and the critical review of the MLP theory and model (Section 6.2), a layered risk model was proposed and juxtaposed on the MLP model to develop a risk-based MLP model (Figure 20 in Section 6.2.3). According to the risk-based MLP model, sustainability risks influence change within the socio-technical regime. These changes pose risks to business and these risks will be mitigated by regime actors through creation and/or realisation of niches at the niche level. When a niche is capable of mitigating/ managing/adapting to one or more risks, a business opportunity is identified. The decision of whether to develop that niche or not will be made after evaluating the niche's implications on other risks. This way a systemic approach is brought to niche development which also potentially might help avoiding rebound effects.

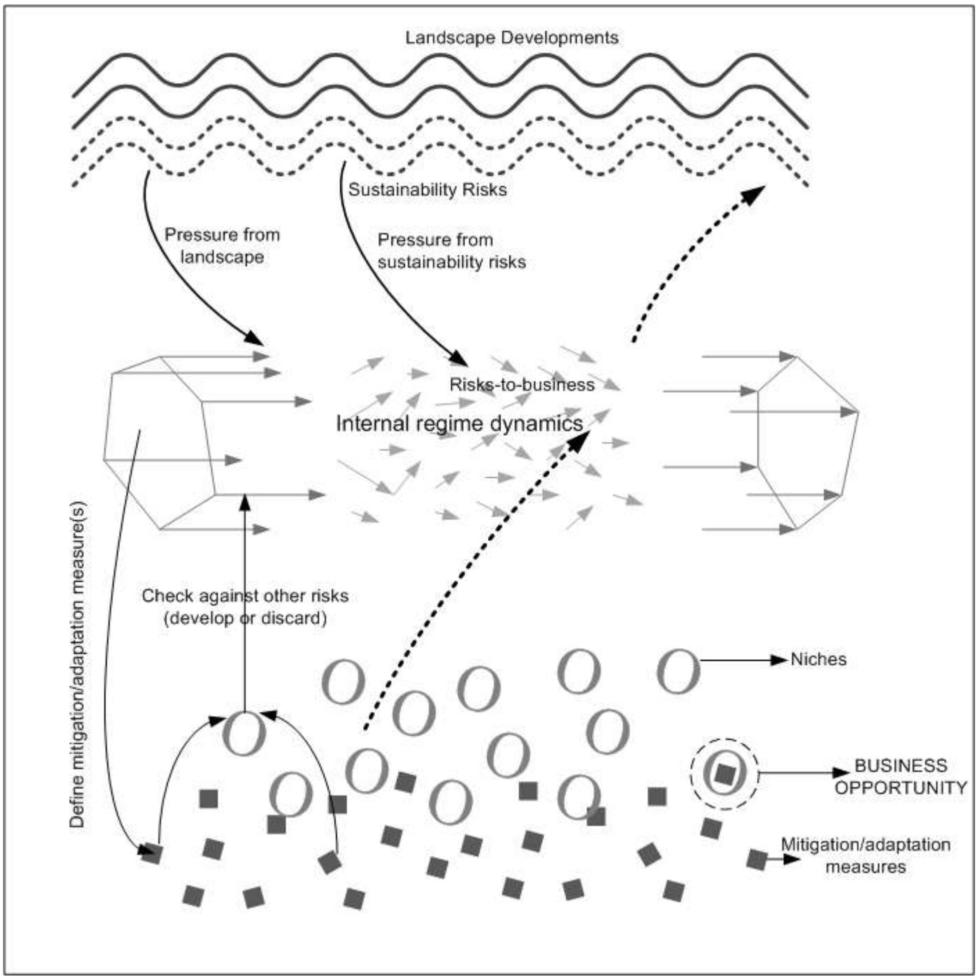

Figure 34. Criterion 5

7.2.2. Outline of the Scenario Method

Based on the criteria explained in the previous section, a scenario method for the use of product development teams was developed. Figure 35 provides an outline of the scenario method which has three phases: preparation phase, scenario development phase and completion phase.

There is only one task to be carried out as part of preparation. This task covers identification of sustainability risks and their influences on the business of the organisation. During this task, dynamic relationships between risks need to be analysed as well in order not to reinforce one while mitigating other(s).

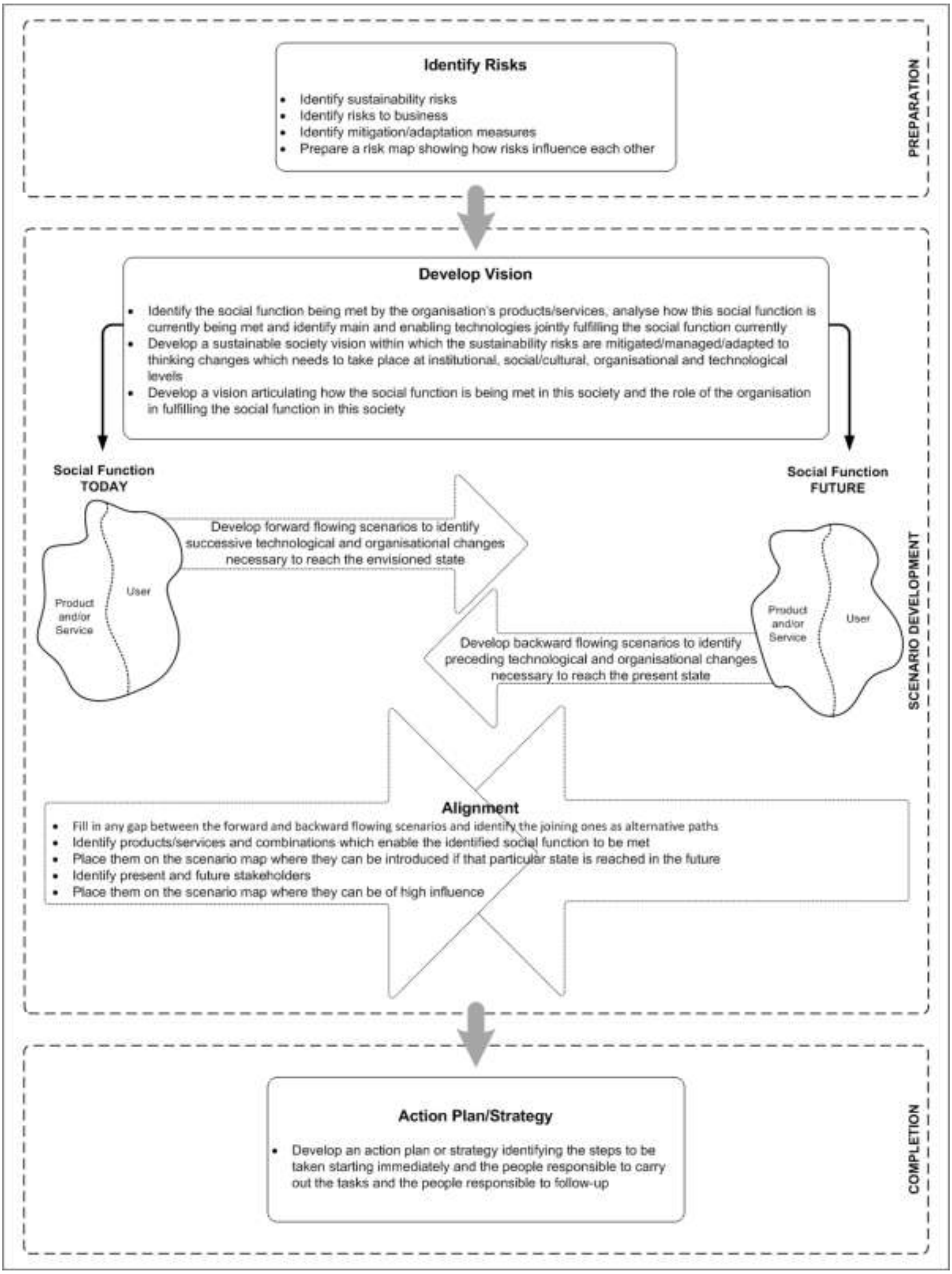

Figure 35. Outline of the scenario method

In the scenario development phase the first task is visioning. In this task, initially, the product development team identifies and analyses the social function being met by the products/services of the organisation in detail. The critique of the MLP theory and model (6.2.1) highlighted the difficulty of identifying socio-technical regimes and pointed out the interdependencies between regimes. The refinements brought to the MLP theory and model proposed focusing on social function rather than a specific regime in order to represent regime interdependencies at product development level. By identifying and analysing the social function, the all socio-technical regimes having a role in fulfilling that function can be taken into consideration. Analysis of social function can also help the product development team to gain an understanding about the institutional and social/cultural as well as organisational dynamics which have a role in fulfilling that function and which can be used as leverage points towards system innovation (Section 6.5).

Following identification of the social function, the product development team develops a sustainable society vision articulating institutional, social/cultural, technological aspects and the characteristics of the individual people living in this society. Then, considering the organisation (i.e. company) as part of this sustainable society, the product development team initially details the role of their organisation in this society in order to identify organisational changes necessary to take place for the company to survive. Following this, the team details how the social function is being met in this society. This way, the vision of a sustainable society and the means of meeting the social function are systemically aligned to each other. Once the vision on how the social function is being met in the envisioned sustainable society is completed, forward flowing scenarios starting from present are developed to identify successive organisational and technological changes necessary towards the envisioned society. After developing forward flowing scenarios, backward flowing scenarios starting from the envisioned sustainable society are developed to identify preceding organisational and technological changes necessary to reach towards present. The aligning sets of forward and backward flows are identified as alternative innovation paths which can be exploited by the organisation.

The double-flow of scenarios allows dealing with current issues in line with the prevailing dynamics in the socio-technical system through forward flowing of analytical scenarios while pulling technology development paths towards sustainability through the backward flowing of normative scenarios. The normative scenarios are future state(s) in which identified sustainability risks and risks to business are mitigated. The identified future states should not be accepted as ultimate ‘sustainable states’ but rather as guidelines pulling scenarios towards sustainability. The reason for following a backward resolution is not to identify how those future states can be achieved but, rather, to open the paths for the forward flow of scenarios.

At the end of the alignment exercise, the events layer of the scenario map is completed and two additional layers are laid over the scenarios. The first layer is the stakeholders layer. Initially, stakeholders of the organisation are identified. Then, the future changes the organisation anticipates and the stakeholders which can influence those changes are matched. The second layer is the products/services layer. Innovative product and service ideas are generated and placed on the map where they can be developed by the organisation if those particular anticipated future changes happen.

In the final phase, an action plan or strategy is formulated. This action plan/strategy articulates the steps to be taken by the organisation to follow the identified innovation paths. For each step identified, execution and follow-up responsibility should be allocated.

7.3. THE OPERATIONAL FRAMEWORK OF THE SCENARIO METHOD

The operational framework presents the workshop process designed as the operational tool of the scenario method to implement the methodical steps identified in the outline of the scenario method. List (2005) developed an extensive set of generic design criteria which need to be met by futures inquiry methods. To guide the design of the workshop, the criteria developed by List (2005) needed to be expanded in order to address the specific characteristics of the scenario method developed in this research. The characteristics of the scenario method relevant to the design of its operational tool were:

- a specific normative end-point, i.e. a sustainable society;
- a specific purpose, i.e. to help product development teams to align their actions and decisions with the long-term, systemic, societal transformation that needs to take place to achieve sustainability;
- a specific approach to assessing sustainability, i.e. a layered risk approach, and;
- a specific positioning of the organisation using the scenario method, i.e. systemically linking the product development teams, companies and society.

Table 9 shows the design criteria followed in designing the workshop. These criteria cover both the criteria developed by List (2005) and the additional criteria developed in this research considering the above listed characteristics of the scenario method.

Table 9. The design criteria followed in designing the workshop (the ones in italics were developed by the researcher)

No.	Criteria
1	All stakeholder groups are included in the workshop
2	The workshop enables a reflective process with efficient use of time
3	The workshop should be quick, efficient and nimble
4	The workshop participants gain more detailed perceptions of future possibilities
5	The workshop should integrate a wide range of methods, approaches, and data types
6	The workshop should include wide diversity of viewpoints and range of scenarios
7	The workshop should probe behind the issues, focusing on underlying drivers
8	The workshop should extend the focus beyond the short-term future
9	The workshop should include a means of anticipating discontinuities
10	The workshop should consider how technological and social aspects may interact
11	The workshop should use a morphological approach in development of scenarios to ensure comprehensiveness
12	The workshop should include narratives to describe change processes
13	The workshop output should be readily understandable by all concerned
14	The anticipations should be expressed in a way to enable tracking and confirmation
15	The workshop should focus on the situation of the entity in its changing environment
16	The format of workshop output should enable re-analysis and expansion of detail as needed
17	*The workshop should enable the participants understand the hierarchical irreversible relationships between the environment, society and economy and between their organisation and these three sub-systems*
18	*The workshop should enable the participants understand the issues threatening the sustainability of the society (i.e. risks to sustainability of the society), the dynamic relationships among these issues and the implications of these on their business*
19	*The workshop should enable the participants to generate normative long-term societal visions within which the risks to sustainability are mitigated/managed/adapted to by the society through a combination of institutional, social/cultural, organisational and technological changes*
20	*The workshop should enable the participants to develop scenarios linking the present of their organisation and products/services to the normative vision of a sustainable society*

The workshop is designed to take place over two full days, ideally one week apart from each other to enable reflection. Table 10 provides the outline of the first version of the workshop design and briefly explains the activities in and the expected outcome from each module.

Table 10. Outline of the workshop

Day	Module	Activities	Expected Outcome
Day 1	**Introduction**	Welcome, check-in and warm-up	Checked-in people, ready to start the day
	Risks	Identification of sustainability risks relevant to the company, brainstorming to analyse the implications of sustainability risks on company business; development of dynamic risk maps using simplified causal-loop diagrams.	A dynamic risk map; the group understands how long-term wider-scale sustainability risks which threaten the society do and will affect the company's business/products.
	Forward Flowing Scenarios	Identification of social function and development of forward flowing scenarios mitigating the sustainability risks and the risks to business identified in the previous session.	Forward flowing, explorative scenarios.
	Backward Flowing Scenarios	Introduction of generic visions of a sustainable society; developing risk mitigating societal visions followed by organisational and social function visions for each societal vision. Development of backward flowing from the vision directing towards present.	Backward flowing, normative scenarios
	Wrap-up and Closure	Evaluation of the day Learnings Orientation for the second day	
Day 2	**Introduction-Knitting the Knots**	Welcome and check-in; summarising the outcomes of the first day; warm-up for the day.	Checked-in people, everyone understands where the work of the group is ready to start the day
	Alignment	Alignment exercise in the medium term to align backward and forward scenarios; identification of alternative innovation paths; generation of product concepts. Identification of stakeholders and development of a stakeholder map.	Scenarios for multiple alternative innovation paths, product/service concepts and stakeholders mapped on the scenario map
	Action Plan/Strategy	Identification of technical and human capacity development requirements; Development of a strategy outline.	A strategy/action plan
	Wrap-up and Closure	Evaluation of the day Learnings/Outcome	

The main processes used in the workshop design (i.e. brainstorming, visioning and decision making) are adaptations of existing generic processes used by facilitators of futures inquiry workshops (see, for example, Justice & Jamieson, 2006, p. 180; Michalko, 2006, p. 311). However, for two activities in the workshop design, i.e. development of dynamic risk maps and scenario development, generic and commonly used processes - suitable for a scenario method based on CAS and system innovation theory - were not available. Therefore, the process used for developing the dynamic risk maps was designed by the researcher. The scenario development process was adapted from a recent contribution to the scenario development literature.

For the process which involves generation of dynamic risk maps, a simplified version of causal-loop diagrams is used. Causal-loop diagrams are used in analysing systems to visually represent dynamic interactions and interrelationships between system components (Hjorth & Bagheri, 2006). The dynamics in a system can be represented by positive and negative feedback loops. Positive feedback loops reinforce while negative feedback loops counteract change (Sterman, 2001). The interrelationships between the sustainability risks relevant to an organisation can be analysed by using causal-loop diagrams. By articulating the dynamic relationships between sustainability risks, the overall potential of a product/service concept to mitigate/manage/adapt to those risks can be assessed. Based on this assessment, decisions on whether to develop or discard a product/service concept can be made in a way to avoid amplifying a sustainability risk while mitigating another. Figure 36 provides an example of a dynamic risk map.

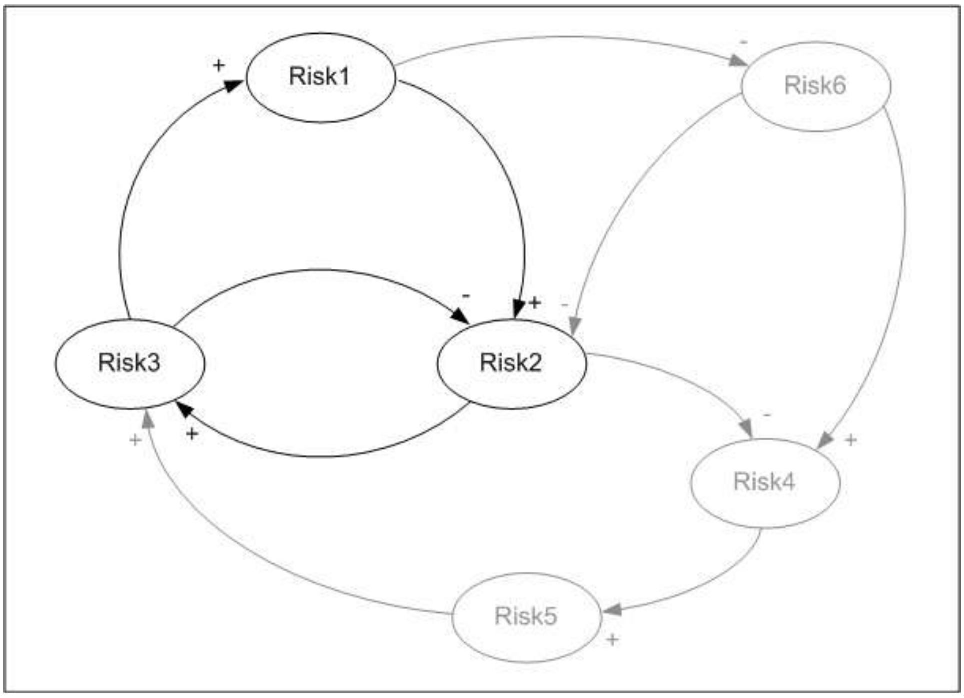

Figure 36. An example dynamic risk map

In this dynamic risk map, developed as a simple causal-loop diagram, Risk 1 increases the occurrence/likeliness of Risk 2, Risk 2 increases the occurrence/likeliness of Risk 3 and Risk 3 increases the occurrence/likeliness of Risk 1, however; Risk 3 decreases the occurrence/likeliness of Risk 2. Therefore, while there is a reinforcing dynamic relationship between Risk 1, Risk 2 and Risk 3, the relationship between Risk 2 and Risk 3 is a balancing dynamic. If there were only these three risks, mitigating Risk 1 would initially result in Risk 2 to decrease. A decrease in Risk 2 would increasingly result in a less increase and thus a gradual decline and possibly diminishing of Risk 3. Therefore, a decision to focus on mitigating Risk 1 would mitigate all of these three risks. However, when Risk 4, Risk 5 and Risk 6 are considered, it becomes clear that focusing solely on mitigation of Risk 1 is not likely to achieve any significant improvement in the system. An analysis of the causal-loop diagram suggests that a combination of risks needs to be targeted at the same time and more than one combination can provide satisfactory overall risk mitigation in the system. Once the dynamic risk map is developed and analysed, product/service concepts can be evaluated based on their potential to bring high leverage to risk mitigation in the system.

For the scenario development process, the event-tree approach is used. The event-tree approach was conceived by List (2005) in order to address the multiplicity and non-linearity of influences resulting in a particular event (an event can be a situation or a process). This approach was also found helpful by participants of futures inquiry workshops in generating backcasting scenarios which involves thinking backwards from a desired future state (personal communication, D. List, July 7, 2007).

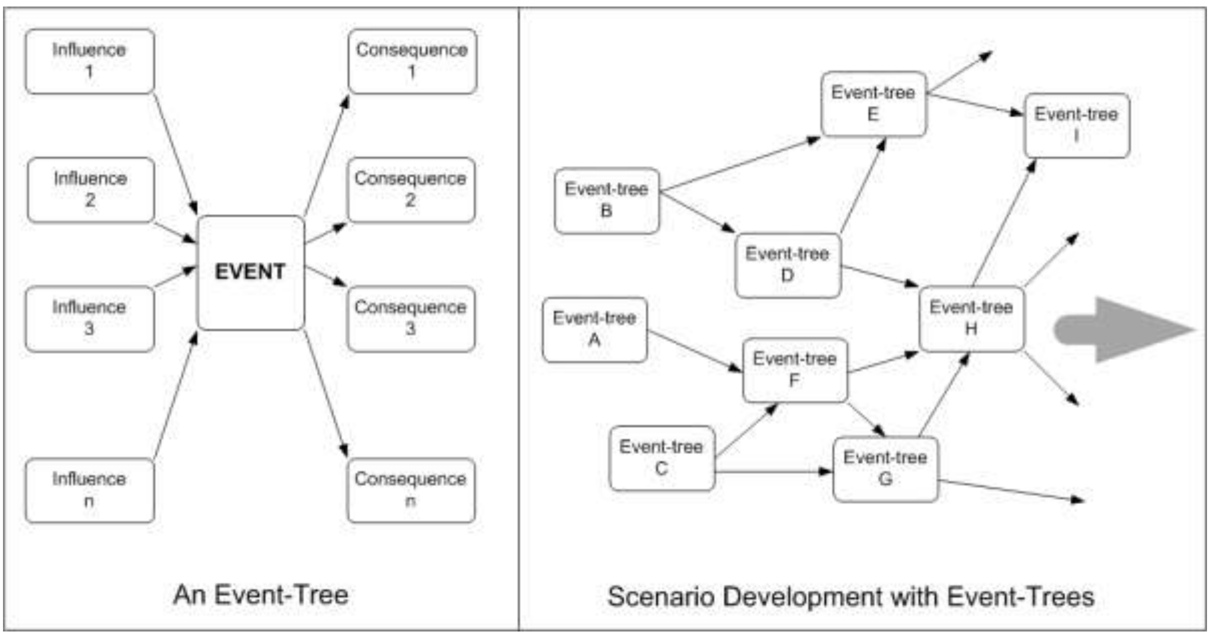

Figure 37. Scenario development with event-trees

The event-tree approach involves generating event-trees through brainstorming and developing a scenario map by chronologically ordering event-trees (see Figure 37). The core event of the event-tree or any of the outcomes of an event becomes an influence for other event trees. Using event-trees in developing scenarios enables the resulting scenarios to be extended indefinitely. The capability to indefinitely extend the scenarios has several benefits. First, it generates flowing scenarios rather than snapshot scenarios. This characteristic enables linking present and future in a realistic way and identification of alternative innovation paths (see the Criterion 4 articulated under Section 7.2.1). Second, the scenario map can be detailed extensively over the time period covered and, if desired, the time period covered can be extended towards the future. Therefore, the scenario map can be regularly revisited and, easily, quickly, and thus, inexpensively altered to include new (emergent) developments which were not foreseen when the map was first developed. Third, the scenario map can be detailed extensively at any point of the time period covered. This enables detailed analysis of the influences and consequences of certain events of high importance. Fourth, the resulting scenario maps can be linked to other scenario maps in a systemic way. As a result, an organisation can later link the scenario map to other relevant scenario maps such as sectoral, industrial or regional development scenarios or stakeholders' scenarios.

7.4. SUMMARY OF THIS CHAPTER

This chapter presented the conceptual and operational frameworks of the scenario method. The conceptual framework was developed based on the theoretical framework presented in Chapter 6. It consists of the criteria that the scenario method needs to meet and the outline of the methodical steps which need to be taken to meet those criteria. The operational framework presented the operational tool of the scenario method (i.e. a workshop process) developed based on the conceptual framework.

The criteria developed as part of the conceptual framework are:

1. The scenario method should link the planning periods applicable to companies (operational and strategic) to the long-term planning period (visionary) in order to enable companies to address long-term societal visions in their strategies and effectively implement these strategies in product development;
2. The scenario method should aid companies in identifying not only technology development requirements but also organisational/human development requirements;

3. The scenario method should aid companies in developing integrated business strategies aligned with societal level sustainability visions and day-to-day business activities and should facilitate integration of all business functions in line with the company strategy;
4. The scenario method should have a double-flow approach in order to link present and future in a realistic way and enable identification of alternative innovation paths which are possible from a technological point of view, acceptable from a social/cultural point of view and desirable from a sustainability point of view, and;
5. The scenario method should have a layered risk approach in order to identify implications of overarching sustainability risks on companies' businesses as contextual risks. This way, sustainability can be internalised in companies' organizational and product development strategies and active participation of companies in setting sustainability visions at societal level can be enabled.

The outline of the scenario method consists of three phases: preparation, scenario development and completion. The preparation phase involves identification and analysis of sustainability risks and implications of them on the business of the organisation. In the scenario development phase initially the social function being met by the products/services of the organisation is identified and analysed. Then, vision(s) of a sustainable society, within which the sustainability risks are mitigated, is developed. In this vision of a sustainable society, the role of the organisation and how the social function is being met are articulated. The vision development task is followed by development of scenarios. The forward flowing scenarios start from the present and flow towards the vision and the backward flowing scenarios start from the vision and flow towards present. The aligning sets of forward and backward flowing scenarios are identified as alternative innovation paths towards sustainability. At the end of the alignment exercise, the events layer of the scenario map is completed. In order to complete the scenario development phase, two additional layers (i.e. the stakeholders layer and the products/services layer) are laid over the scenarios. In the completion phase, an action plan/strategy is formulated which articulates the steps to be taken by the organisation and allocates the responsibilities to take and follow-up the identified actions.

The workshop design was based on the design criteria for futures inquiry methods developed by List (2005). The majority of the processes included in the workshop design are based on generic group facilitation processes. However, for three of the modules; i.e. forward flowing scenario development, backward flowing scenario development and risks module, two non-generic processes are proposed.

In the risks module, a process specifically designed for this research which uses a simplified version of causal-loop analysis is used. This process enables the participants to develop an understanding of the dynamic interrelationships between the sustainability risks which need to be mitigated. Only after such understanding is achieved can the participants make sound decisions on which product/service concepts to develop, based on the real capacity of those concepts to mitigate/manage/adapt to the sustainability risks in overall.

In both of the scenario development modules, in line with the requirement of addressing non-linearity and multiplicity of influences jointly resulting in an event, the event-tree approach, which was developed by List (2005), is used. The use of event-tree approach in scenario development enables the resulting scenarios to be linked to other scenarios relevant to the organisation in a systemic way. Event-trees also enable the resulting scenario map to be re-addressed and changed easily as time progresses and future unfolds.

8. FIELD WORK: RESEARCH METHODOLOGY AND DESIGN

8.1. INTRODUCTION

The previous chapter provided the conceptual framework of the scenario method which was developed by integrating findings and insights gathered through the review of literature and the theory or models developed as part of this research. Based on the conceptual framework of the scenario method, a workshop process consisting of several modules was designed as the operational tool of the scenario method.

It is possible to develop theory without empirical approaches; however, a method developed solely through desktop research will be prone to failure in its first use. In addition, since this research has a specific aim of embedding the research outcome into real-life, the scenario method needed to be tried in real-life settings and, if necessary, needed to be improved. Also, since the main theoretical basis of the scenario method developed in this research (i.e. system innovation theory) is quite new and still emerging, any method based on this emerging theory needed to be evaluated in terms of its potential to aid in managing system innovations. For these reasons, it was decided to include an empirical approach in this research. This empirical approach consisted of field work which aimed to test, improve, and evaluate the conceptual framework and the operational tool (i.e. the workshop process) of the scenario method. This chapter reports the details of the research methodology and research design followed to carry out the field work.

8.2. METHODOLOGICAL AND DESIGN CONSIDERATIONS OF THE FIELD WORK

Below is a list of the methodological and design considerations which guided selection of the research methodology and designing the field work:

- The research methodology needed to be suitable to be used in real-life experiments and with human participants since the field work had to incorporate running workshops following the workshop process developed as the operational tool of the scenario method;
- The research design needed to be suitable to generate feedback to improve both the conceptual and the operational frameworks of the scenario method in conjunction to each other;

- The research methodology needed to be suitable for qualitative research since a quantitative (i.e. statistically proven) approach was beyond the time and budget limitations of this research as it would require running around 200 workshops;
- The research methodology and research design needed to be suitable for formative evaluation since a summative evaluation is not applicable for a newly developing method (and also since there is not an absolute criterion to be used as the basis of a comparison in order to make a conclusive decision that the scenario method is good or bad) (List, 2005);
- The research methodology needed to be suitable for evidence-based research since a hypothesis-based research was not possible (In hypothesis-based research, a hypothesis is formed based on preliminary findings, variables are identified and the hypothesis is tested one variable at a time by keeping the other variables constant and/or using a control sample. In cases when establishing a hypothesis to be tested is not possible either because the research area is new, and therefore, the researcher does not have sufficient experience with the research context to generate a hypothesis or when the variables to be tested cannot be kept constant for a reason (e.g. in real-life experiments researcher cannot have control over all variables influencing a situation) evidence is gathered, analysed in detail and a conclusion is reached);
- The research design needed to be suitable for accommodating multiple case studies of different characteristics since a single case study was not appropriate for this research. (A single case study would not provide sufficient data for the purposes of producing generalisations. In addition, a multiple case study approach would provide contingency and fast recovery if one or more case(s) fail(ed). Also, using only one case study would either require the scenario process to take much longer or, the data generated would not be sufficient to support this research.);
- The research methodology and research design needed to be suitable for sequential case studies since if the studies were carried out simultaneously there would not be a basis for comparing the improvement achieved;
- The research methodology and research design needed to be suitable for an iterative research process since using sequential case studies would require an iterative process enabling comparison between the previous case and the following one giving an indication of improvement achieved.

Since the field work was going to take place in real-life, and since it required using a formative and evidence-based approach and sequential studies with iterative cycles, the most suitable methodology to be followed was a form of action research methodology. The next section briefly explains the historical, theoretical and conceptual underpinnings of action research methodology and provides justification for its use in this research. This is followed by a detailed explanation of the research design developed based on the selected research methodology.

8.3. FIELD WORK METHODOLOGY: ACTION RESEARCH

Action research as a term was initially coined and articulated by Lewin (1946). Since then, several variations of action research for different purposes have been proposed and used (see, e.g., Peters & Robinson, 1984; Dash, 1999; Reason & Bradbury, 2008). The different areas action research has been used in are education, health, social work, organisational development, urban planning/architecture, economic development, issues related to inner-city and rural poverty, disability and domestic violence (Stringer, 1996; Gray, 2004) and product development (for example, Van der Lugt, 2008).

The three characteristics found to be common in all variations of action research are change-agenda and problem-focus, cyclic/iterative and reflective process, and participatory/collaborative research design (Peters & Robinson, 1984, Gray 2004). Action-research is one of the few suitable methodologies of knowledge transfer in research which cross-cuts several disciplinary boundaries and involves stakeholders into the research process with the aim of solving complex, real-life problems (Pohl & Hirsh-Hadorn, 2008). Also, complex societal issues are systemic in character, and therefore, they require consideration of different perspectives of the actors involved and necessitate alignment and integration of these perspectives for a commonly shared understanding and an agreed solution (Loorbach, 2007). Action research enables this through the use of an iterative process which not only helps integration of different perspectives (which could be achieved by survey research) but also enables alignment through mutual learning.

These characteristics of action research were aligned with the characteristics and aims of this research. First, this research had a change agenda and a problem focus. It aimed to be a stepping stone in the transformation towards a sustainable society by meeting a real-life need, i.e. the lack of methods and tools to link activities and decisions of product development teams to the long-term and systemic transformation which needs to take place in the society. Instead of generalising findings on the basis of standardised conditions, this research aimed at validating abstract models in real-life situations in order to provide a solution for a socially-relevant, urgent and complex problem. The field work required an iterative and reflective research process since it was undertaken to test and improve the scenario method and since a survey-type, quantitative approach was not found feasible for this purpose. Since this was a research undertaken to qualify for a Ph.D. degree, which requires the research to be undertaken by the researcher individually, a collaborative approach was not possible. Nevertheless, in order to enable the research outcome (i.e. the scenario method) to be adopted by and usable for the product development teams, the actual potential users of the scenario method needed to be involved in the research as participants. A participatory approach was also necessary in order to include different perspectives of industry and academic experts, who are working in the joint area of sustainability and innovation, in improving the theoretical basis and conceptual framework of the scenario method.

8.4. FIELD WORK DESIGN

8.4.1. THE TWO COMPONENTS OF FIELD WORK: EXPERT CONSULTATION AND WORKSHOPS

The field work consisted of two components: expert consultations and workshops (see Figure 38). The expert consultations involved receiving feedback from experts on the conceptual framework of the scenario method through one to one consultation sessions. The second part involved receiving feedback on the workshop design from potential members of product development teams through running workshops based on the workshop design presented in Chapter 7 as the operational tool of the scenario method. The details of selection of research participants (i.e. sampling), the procedure followed (i.e. the method) and the data collection and management strategies are explained in the following sections.

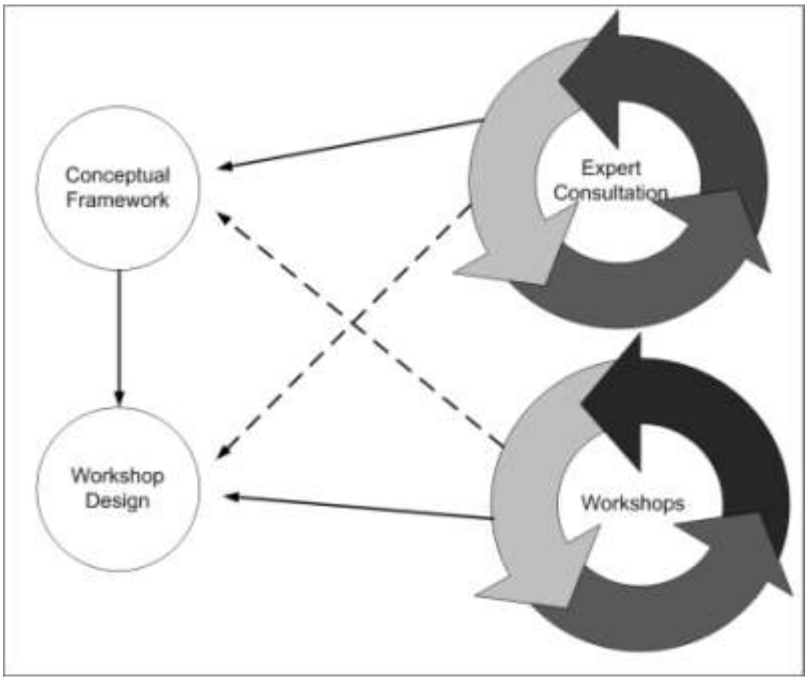

Figure 38. The two components of the field research

There are four main reasons for designing the fieldwork to incorporate two components. First, the scenario method is based on the recently emerging system innovation theory (Chapter 6). This theory cannot be empirically tested neither can it be fully disproved (no sustainable system innovations are completed so far to empirically test the theory and it is impossible to measure all different dimensions of a transition exactly) (Loorbach, 2007). Expert consultation is a commonly used qualitative method if the research area is novel and there is not much known about it (Gray, 2004). Therefore, in order to improve the theoretical underpinnings of the conceptual framework expert consultation was used.

Second, in order to enable the uptake of the scenario method by companies, it was necessary to ground the method in the current reality and framework of businesses. However, a direct feedback from businesses carried a risk of diverging from the theoretical background that the conceptual framework was based on since the concepts and requirements which are put forward are currently hard to understand and challenging to meet by most of the businesses. In this regard, the expert consultation played a buffer role by enabling improvement of the scenario method without compromising from the requirements identified through theoretical findings in a way understandable and usable by businesses.

The third reason for designing the field work to incorporate two components was to integrate the different perspectives prevailing in the area of sustainability and innovation into the scenario method. This would not be possible only through the workshops, First, because workshop participants were not necessarily knowledgeable in the area of innovation and sustainability and, Second, since the data collected through the workshops would mainly be through observation to investigate whether the processes were successful or not. Different perspectives were integrated into the scenario method by consulting experts from different localities and who have a range of different specific expertise relevant to the joint area of innovation and sustainability.

The fourth reason was related to the aim of providing a research output which would be readily usable in real-life. The expert consultations were aimed at improving the theoretical underpinnings of the conceptual framework. The workshops, on the other hand, were designed to be real-life experiments to improve the workshop design.

8.4.2. The Samples

For the two components of the fieldwork, two different sets of participants were sampled. For the expert consultation component potential expert users of the method were sampled. A potential expert user of the method was defined as any person who has expertise in providing advice/consultancy to businesses in the joint area of sustainability and innovation and/or any person who has expertise in facilitating group processes. For the workshops component, groups representing product development teams of companies were sampled. Product development teams consist of members who either actively take part in design and development of products and services a company develops or who are actively involved in strategic decision making regarding the product development function of companies. Therefore, a potential member of the second sample set was identified as anyone with a professional qualification of product/service design, design engineering, innovation management, strategy development, environmental/ sustainability management, and sales and marketing who provides input to the team during product design/development phase.

Expert users are not the end-users but potentially the intermediary users of the scenario method who can introduce the method to businesses and lead/facilitate workshops with product development teams. Product development teams of companies are the intended end-users of the method. Any member in these teams can assume the role of a change agent and lead/facilitate a workshop or a workshop can be delivered to these teams by external change agents (which are represented by the potential expert users).

Expert Consultation

For the expert consultation component of the field work, eight local and five overseas experts participated in the research. The five overseas experts had design and research experiences in different socio-cultural contexts covering the USA, the EU, Hong Kong/China and bottom-of-the-pyramid contexts such as Cambodia and Vietnam.

Table 11 shows the place of origin, self-claimed expertise and the sectoral positioning of experts who participated in this research and provided feedback for the improvement of the scenario method. Appendix I provides more details on the expertise and experience of these experts.

Table 11. Experts consulted

Participant Code/ Place of Origin	**Sector**	**Self-Claimed Expertise**
Expert1 New Zealand	Industry	engineering design (general), industrial design (general and sustainability specific), design research (general and sustainability specific), marketing (general), business strategy development (sustainability specific), environmental management, LCA of products
Expert 2 New Zealand	Industry	business strategy development (general and sustainability specific), environmental management
Expert3 Netherlands	Academic/ Industry	engineering design (sustainability specific), industrial design (sustainability specific), design research (sustainability specific), business strategy development (sustainability specific)
Expert4 New Zealand	Industry	business strategy development (general), group facilitation
Expert5 New Zealand	Industry	group facilitation
Expert6 New Zealand	Industry	marketing (general and sustainability specific), business strategy development (general and sustainability specific), futures studies
Expert7 New Zealand	Industry	industrial design (sustainability specific), design research (sustainability specific), marketing (sustainability specific), business strategy development (sustainability specific), environmental management, LCA of products
Expert8 USA	Academic/ Industry	engineering design (general and sustainability specific), industrial design (general and sustainability specific), design research (general and sustainability specific), marketing (general and sustainability specific), business strategy development (general and sustainability specific), environmental management, LCA of products, business risk assessment (specifically regarding CO_2 issues), futures studies, group facilitation, industrial ecology
Expert9 Hong-Kong/China	Academic/ Industry	industrial design (general and sustainability specific), user research, product identity building, lifestyle design research
Expert10 New Zealand	Industry	engineering design (sustainability specific), business strategy development (sustainability specific), environmental management
Expert11 UK	Industry	engineering design (sustainability specific), industrial design (sustainability specific), design research (sustainability specific), marketing (sustainability specific)
Expert12 New Zealand	Local Government/ Industry	business strategy development (sustainability specific), environmental management, resource efficiency
Expert13 Netherlands	Academic/ Industry	futures studies, sustainable system innovation, transitions, technology and society, constructive technology assessment

Table 12 shows the breakdown of consulted experts in terms of their self-claimed expertise. Most of the experts claimed more than one expertise. As a result the sufficient representation of different expertise was achieved with a small sample size. The most frequently claimed expertise within the sample was sustainability specific business strategy development.

Table 12. Breakdown of consulted experts in terms of self-claimed expertise

Self-claimed Expertise	**Number of Self-claiming Experts**
Engineering design (general)	2
Industrial design (general)	3
Design research (general)	2
Marketing (general)	3
Business strategy development (general)	4
Engineering design (sustainability specific)	4
Industrial design (sustainability specific)	6
Design research (sustainability specific)	5
Marketing (sustainability specific)	4
Business strategy development (sustainability specific)	8
Environmental management	6
LCA of products	3
Business risk assessment	1
Futures studies	3
Group facilitation	3

Workshops

Sample workshop groups (henceforth, WG) representing product development teams could either be from the same company and designing and developing products/services or could consist of a group of individuals, each of whom meeting the definition given at the beginning of this section, gathered specifically to undertake a workshop. Three workshops were held with three sample WG representing product development teams. Each WG together with their respective company constituted three case studies, which, henceforth will be referred to as Case Study 1, Case Study 2 and Case Study 3 (respectively for WG1, WG2, WG3).

<u>Case Study 1</u>

Case Study 1 was a small size, established (16 years old) company based in New Zealand providing facilitation and facilitation training services. The company did not have an official product development team but everyone was involved in proposing new service ideas, developing new services and making strategic decisions about new service introductions. There were four participants consisting of managers, employees and associates. The core business of the company was not explicitly related to innovation for sustainability, however; the company had a commitment to become a sustainable organisation in 2002 and developed an action plan to achieve this. The action plan articulated steps the company needed to take including decreasing the environmental impact of their operations. Nevertheless, as a result of being a small service company, the company considered its major potential in influencing the society towards sustainability to be the services and training provided in relation to co-operative working and collective decision making.

There were four participants in the workshop who attended all of the sessions. The stakeholders represented in the WG1 were managers (one), employees (one) and associates (two).

Case Study 2

Case Study 2 was a start-up company at the initial phases of establishment based in the Netherlands. This company was a for-profit spin-off of a not-for-profit organisation (i.e. a foundation). The foundation defined itself as 'innovators in sustainability' and its mission was 'to inspire and involve young entrepreneurial people to co-operate on profitable solutions for environmental and social issues'. The foundation was dependent on external funding to fund its projects. Nevertheless, even though once in the incubation phase it was relatively easy to find funding for the projects coming out of the foundation, it was difficult to find funds/sponsors for the earlier, feasibility and pre-start phases of projects. In order to be able to support more projects at earlier phases financially, the foundation wanted to generate its own funding. However, due to the nature of not-for-profit organisations, there was a need for a commercial entity which could legitimately operate for profit. As a result, the foundation decided to establish a company and accepted participating in the research to investigate possible innovation paths for this start-up company towards system innovation for sustainability.

The number of participants in the WG2 varied between six and ten. Six of the participants attended the entire workshop. The stakeholders represented in this workshop were managers (one to three), associates (one), employees (two to three) and volunteers (three). The volunteers are students, young professionals and some experts who take part in the activities and projects of the foundation by allocating time and sharing knowledge. Their role in the foundation ranges from operational (assisting in organising an event) to strategic (sounding board for management). The volunteers who participated in the WG2 were an industrial designer, a knowledge management intern and a postgraduate student researching about scenario methods.

This was the only case study among three which had innovation for sustainability at the core of its business. Even though the expected outcomes from the business of this company included new innovative technologies/products, the company would not be directly involved in developing these new products/technologies but rather would be providing services to facilitate such innovation. This was also the only case study within which the scenario method was tried by a start-up company.

Case Study 3

The members of WG3 were not from the same organisation but were individuals who were brought together only for the workshop. Therefore, the company in Case Study 3 was a fictitious company conceived for the purpose of providing the organisational context for WG3. This fictitious company designed and manufactured plastic educational toys for primary school children. It was an established, medium-sized company. There was an emerging interest in sustainability within the company but it was not a strategic priority yet. The company had an official product development team. The headquarters and design office was in Turkey but the manufacturing plant was in Romania.

WG3 consisted of ten participants. Three of the participants were practicing industrial designers and the rest were postgraduate students in the industrial design departments of two Turkish universities. The postgraduate students had bachelor degrees from different disciplines covering economy, industrial engineering, architecture, interior design and industrial design. The representation of stakeholders was done through role playing. Two of the participants who had children volunteered to represent the customers of the company. The rest of the participants played the roles of managers (two) and employees (six) in the product development team.

This was the only case study which took place in a developing economy (as opposed to New Zealand and the Netherlands which are classified as advanced economies according to IMF (2009)). This was also the only case study in which the subject company was a fictitious one and the members of the WG were not from the same organisation. This case study enabled testing and improving of the scenario method in relation to its applicability to a group of individuals coming from different organisations. The applicability of the method to such groups is important since being through a workshop constitutes experiential learning and is crucial to transfer the knowledge of the scenario method to internal change agents and increase the influence potential of the scenario method.

These case studies enabled a variety of detailed input to be provided with a minimum number of workshops. To summarise:

- Each case study was located in a different country and represented different socio-cultural and values perspectives;
- The sizes of companies in each case study ranged from small to medium;
- The type of innovation generated by the companies included products and services;
- The level of integration of sustainability as a strategic priority into the company business ranged from low to high.

8.4.3. The Method

The Schedule and Use of Action Research Cycles in the Field Work

The phases of the cyclic process of action research were conceived originally by Lewin (1946) as planning, action and reflection. As noted by List (2005), there is an implicit phase of observation between action and reflection. As Figure 39 shows, in this research there were five distinguishable action research cycles (henceforth ARC). These five iterations resulted in the sixth version of the scenario method.

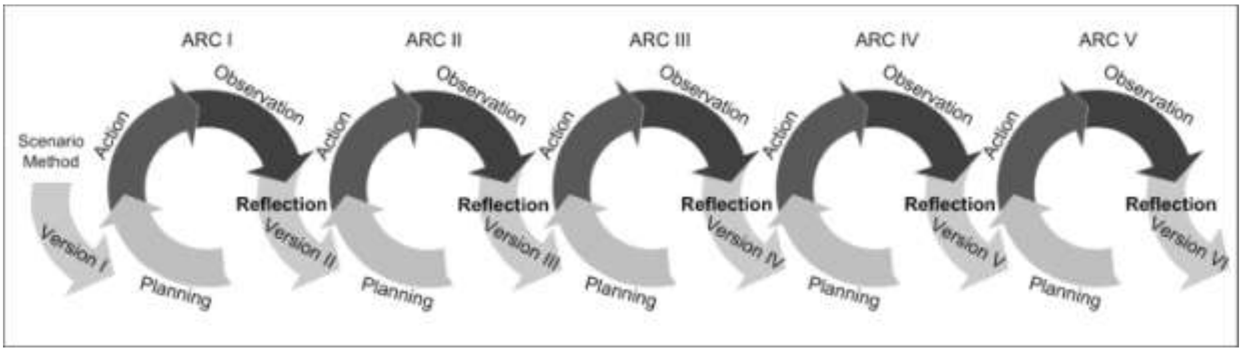

Figure 39. The ARC of the field work

The five ARC of the field work were spread over six months. In action research, it is not possible to know when an ARC will be finalised at the beginning of that ARC. Also, the outcome of the preceding ARC determines whether there is going to be another ARC. Therefore, it was not possible to set a fixed schedule for the field work before it started. As McNiff, Lomax and Whitehead (1996) point out, action research cycles are ways of disciplining the research process rather than representing the research itself. An action research project dynamically evolves and a whole project may indeed be a cycle of cycles or a spiral of spirals with a potential to continue indefinitely. In this field work, an ARC was accepted to be complete once both the conceptual framework and the workshop design were improved mutually to result in a new version of the scenario method. In the beginning of the field work, it was decided to include three case studies in the field work to test and improve the scenario method through real-life experiments. It was also decided that these case studies should have different characteristics (i.e. socio-economic and cultural context, company sizes and strategic approaches to sustainability) to enable inclusion of diverse perspectives. However, planning for Case Study 2 and Case Study 3 started after the field work started. The timing of these case studies were left towards the (expected) end of the field work in order to make sure all changes made to the scenario method were tried in a real-life experiment. The field work was going to be accepted as completed after all of the case studies were finalised and when there were no significant changes brought to the scenario method at the end of an ARC.

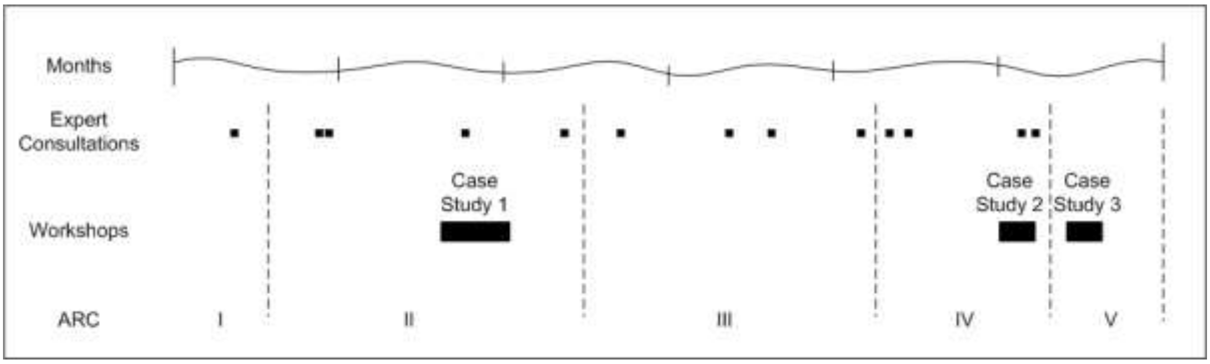

Figure 40. The schedule of the field work

Figure 40 shows the scheduling of expert consultations as well as workshops relative to each other and to each ARC over the total duration of the field work. As seen, ARC successively became shorter indicating a progressive decrease in the new information generated in each ARC. At the end of the fifth ARC, no significant changes were brought to the scenario method. Therefore, the field work was deemed to be complete.

Since there were only five overseas experts in the expert sample compared to eight local experts, a strategy was needed to counter the dominance of local experts and to avoid local perspectives domineering the feedback and improvement mechanism. For this aim, effort was put in to ensure that in each ARC at least one overseas expert was consulted, except the first consultation which immediately resulted in the Version 2 of the scenario method.

The Procedure Followed for Expert Consultations

For the expert consultation part of the field work, initially a list of local and overseas experts who work in the joint area of sustainability and innovation was prepared. These experts were invited to participate in the research via e-mail. Those who responded positively were scheduled for one hour appointments. Two slightly different procedures were followed for consulting local and overseas experts.

<u>Consulting Local Experts</u>

At the meeting with each expert, the expert was presented with the conceptual framework and the workshop outline of the version current at that time with the aid of a laptop computer. Notes were read in order to make sure that the same message was presented to all experts for the same version of the method. Also, to keep visual distraction and bias which might have risen from differing visual preferences of experts to a minimum and to keep the focus on the content and ideas to be evaluated, the presentation was designed in black and white. The final version of these presentations (i.e. Version 4) with notes as read to the participating experts can be found in Appendix II.

After the presentation, if there were any, the expert's questions were answered. Once all of the questions were answered, an open-ended evaluation questionnaire was given to the expert to complete (this questionnaire can be found at Appendix III). The questionnaire was added to the other questionnaires completed by the other experts consulted in that cycle. All of these questionnaires were analysed at the end of each cycle and following reflection on the results of this analysis, and combining the results from the workshops if there was any in that cycle, the scenario method was improved.

<u>Consulting Overseas Experts</u>

In order to receive feedback from the overseas experts, the first step was to upload a slidecast (i.e. a slide presentation with background audio) of the current version of the scenario method to a web site which allows presentations to be shared, viewed and downloaded by users (see Slideshare, 2009). The presentation accompanying the slidecast was identical to the presentation used in meetings with local experts in that cycle. Similarly, the audio accompanying the slidecast was identical to the notes which were read to the local experts during presentation of the same cycle. On the day of the scheduled appointment, the link of the slidecast was sent to the overseas expert via e-mail. The expert was instructed to send any questions he/she might have via e-mail after viewing the presentation. Once all questions of the expert were answered, the evaluation questionnaire was sent to the expert to complete and return via e-mail. All of the questionnaires were analysed at the end of each cycle and using the results of this analysis, combined with the results from any workshops in that cycle, the scenario method was improved.

The Procedure Followed for Workshops

Initially, a list of companies which might be interested in participating in the research by attending a workshop was prepared. E-mails were sent to the companies to explain the research and request their participation. The response was not high. Only one company responded and showed interest but found the duration of the workshop (a total of two days) too long. Finally a facilitation and facilitation training company, which had not been contacted to request participation, heard about the search for companies to try a scenario method and volunteered to undertake a workshop. This company fulfilled the local case study (Case Study 1) which was being searched for.

In order to expose the scenario method to different socio-cultural and socio-economic contexts, it was decided to carry out workshops in other countries. For this aim, an organisation in the Netherlands which was known as highly proactive in the area of sustainability and innovation was contacted. This organisation agreed to participate in the research to try the method for a start-up company they had been planning to establish (Case Study 2). It was also decided to try the method in a developing country in order to gather insights about the potential of the scenario method and to improve the method to be suitable for developing (industrial) contexts as well as developed (post-industrial) contexts. For this purpose, Turkey was selected since it is the home country of the researcher, and therefore, the researcher had established networks there which enabled formulating a case study suitable for the field work. A workshop was organised at the Industrial Design Department of Middle East Technical University, Ankara, Turkey (Case Study 3). This workshop targeted post-graduate students and young professionals who represented potential members of product development teams (see the definition given in 8.4.2).

The procedure followed slightly differed between the first two and the last case studies due to the different characteristics of the last case study from the first two. However, in all of the case studies there were three main phases: preparation, workshop and feedback/evaluation.

Phase 1: Preparation

For Case Study 1 and Case Study 2, (phone, e-mail or online video) conversations were held with the person from the company who acted as the initiator/coordinator within his/her organisation and who arranged the schedule and organised other participants. These conversations clarified what the workshop would involve, what the purpose of the workshop was and what the expectations of the company from the workshop were. The distinction between the purpose of holding a workshop for the researcher (i.e. to test and improve the scenario method developed as part of the Ph.D. research) and for the company (i.e. to identify alternative innovation paths for [The Company] towards system innovation for sustainability) was made clear since this was highlighted as a common confusion among the participants by List (2005) from his experience. Once the schedule was set and participants were shortlisted, each participant were contacted individually, personally invited to the workshop and informed about the purpose of the workshop by the researcher. The agenda of the workshop was also sent to the participants via e-mail. In these correspondences each participant was encouraged to ask any questions they might have regarding the workshop and the research. If there were any questions, they were answered.

For Case Study 3, since it was not a company but a group of individuals together representing a product development team, there was no one to act as a coordinator. Therefore, each participant was directly contacted in the first place by the researcher and briefed about the research and the purpose of the workshop in relation to the research. They were sent an agenda and, if there were any, their questions were answered. From each participant, information about their background and the reasons of being interested to participate in the workshop was requested in order to ensure diversity of professional backgrounds in the group and to be able to align the group members on common expectations from the workshop. On the first day, before starting the first session of the workshop, the group members were briefed about the characteristics of the fictitious company they would 'work for' during the workshop and allocations of stakeholder roles were made.

The purpose of any group work and common acknowledgement of it by the group members plays a crucial role for the success of the group work (Hunter, Bailey & Taylor, 1999; List, 2005). Therefore, the purpose was not only communicated to the participants before the workshop, i.e. during the preparation phase, but also was written on an A3 size paper and hung in the workshop venue for all of the three case studies.

The venue for the first case study was set to be the office of the company in Auckland, New Zealand. For the second case study, it was again the office of the company which was in Rotterdam, the Netherlands. The venue for the third case study was allocated to be the studio of post-graduate students in the Department of Industrial Design, Middle East Technical University, in Ankara, Turkey.

Phase 2: Workshops

The researcher facilitated all three of the workshops. Throughout the entire process the group was observed and field notes were taken to be used during reflection phase of the ARC when necessary (details of data collection strategies are given under 8.4.4). The Case Study 1 workshop took place in four half day sessions over two weeks. The workshops for Case Study 2 and Case Study 3 were spread over two full day sessions within one week.

Phase 3: Feedback/Evaluation

With all three WG, at the end of each day of workshops, a brief discussion about the day was held. Workshop modules held on that day were evaluated by the participants. At the end of the workshop, questionnaires (Appendix III) were given to each participant to be completed for an overall evaluation of the workshop.

8.4.4. Data Collection and Management Strategies

In executing the ARC, interwoven strategies of data collection and management were used. These strategies were observing the participants, keeping a research journal which also was used to write facilitator's notes and reflections down during preparation, execution and after completion of the workshops and having participants complete an open-ended questionnaire at the end of both expert consultation sessions and workshops.

Open-Ended Questionnaire for Direct Feedback

In order to receive feedback from the research participants for both of the field work components (i.e. expert consultations and workshops) and to improve the scenario method, open-ended evaluation questionnaires were used. Questionnaires were preferred over interviews in order to:

- avoid the risk of interviewer bias (the researcher who was also the developer of the scenario method could have prejudgements on how to improve it and this might have influenced the interviewing process);

- ensure anonymity of the responses of the workshop participants (even though full anonymity could not be assured due to the nature of the group work, the responses of participants would remain as anonymous within that group) and;
- provide space free from psychological pressure for expert participants (as a result of the nature of the consultation, i.e. to receive expert feedback, anonymity was not required for expert responses, however, the presence of the developer of the scenario method as the interviewer might have influenced the interviewing process).

An open-ended questionnaire format with few questions was preferred rather than a highly structured format with many closed-ended questions in order to:

- ensure consistency in data collection (since the aim of the field work was to test and improve the method, if closed questions about specific parts of the method were used, the questions would have to be altered every time the method was improved, i.e. at the end of each action research cycle);
- avoid the risk of imposing the view of the researcher on what the participants need to be looking at when evaluating the scenario method;
- allow emergence of responses in relation to elements which had not been anticipated beforehand but which could potentially be of high significance in improving the scenario method;
- provide the necessary reflective space to the participants.

The evaluation questionnaires given to the consulted experts and to the workshop participants were only slightly different. In addition to the evaluation questionnaires, professional information was collected from participating experts using a separate questionnaire. The questionnaires used in the field work can be found in Appendix III.

Observation

Observation, i.e. systematically watching what is happening, was used during workshops. While questionnaires reflected the perspective of the participants on their experience with the method, observation enabled the researcher to understand how the group and individual participants responded to certain elements of the workshop design. The whole group was observed to assess how well each workshop module worked as a process. Using the participant feedback in conjunction with observations enabled cross-checking and established the validity of observations.

Observations in relation to the content of the workshop for each module which, later, informed the reflections from each action research cycle, were recorded. In order to systematise the use of reflection, a set of questions was prepared to be answered for each workshop and answers were recorded. These questions were:

1. What is the expected outcome (the expected outcomes from each module are given in Table 10 under Section 7.3) from this module (if it has been achieved, analyse the following module; if it has not been achieved, continue with the following questions)?
2. What has happened? Why has it happened?
3. How could the identified issues be resolved?
4. Has the proposed solution resolved the issue?

The fourth question was investigated in the following action research cycle.

Answers to these questions were integrated with feedback from expert consultation process which took place within that cycle. Following this a new version of the scenario method to be used in the next ARC was prepared.

Research Journal

The observations were recorded in the research journal during the workshops as soon as they were observed as suggested by Bailey (2007) (at quiet times when the group was engaged in a task). During the short group discussions at the end of each day, notes were taken to be considered during reflection. All of the details not related to the content of the workshop but which could have influenced the outcome and which would help in comparing the case studies were also logged. These details included:

- The list of participants;
- Attendance to each workshop module;
- The starting and ending times of each day and each module;
- Brief description of the physical environment; and
- Any significant incident which took place during the workshops (e.g. conflict between two or more participants, etc.).

After each workshop, the notes in the journal were reviewed and reflections and improvement ideas were written down. A summary of these reflections can be found in the next chapter where the results of the field research are reported.

Review of Journal Paper

With one of the consulted overseas experts, the process diverged from the standard expert consultation method applied (i.e., make a presentation about the conceptual framework and the workshop design and receive feedback through a questionnaire in the course of an hour). This expert provided feedback intermittently over the course of four months reviewing a draft journal paper which saw Version 3 and Version 4 of the scenario method developed through this research. The feedback provided by this expert through this extensive review process is incorporated in the improvement of the scenario method.

8.5. SUMMARY OF THIS CHAPTER

This chapter reported the research methodology and design followed in carrying out the field work aim of which was to test and improve the scenario method. As a result of the methodological decisions taken and in line with the specific aim of embedding the outcome of this research into real-life, action research was identified as the most suitable methodology to test and improve the scenario method. The field work was designed to consist of two interwoven components; expert consultations and workshops. In order to collect, manage and analyse data, a range of interwoven strategies were used covering observation, open ended evaluation questionnaires, and research journal.

For the expert consultation component of the fieldwork, eight local and five overseas experts provided feedback on the scenario method. The experts consulted had varying degrees of expertise in areas relevant to sustainability and innovation. They also had varying degrees of working experiences in different socio-cultural contexts. Three workshops were held with three case studies representing product development teams. Two of these case studies were located in developed (post-industrial) and one of the case studies was located in a developing (industrial) country. The case studies included an established, a start-up and a fictitious company. The diversity in the expertise and experience of the consulted experts and the characteristics of the case studies used in workshops were aimed to enable diversity in the views and perspectives which were used to improve the scenario method.

The field work took place over a six months period and covered five action research cycles at the end of which the sixth version of the scenario method was released. The next chapter reports the results of the field work.

9. FIELD WORK RESULTS

9.1. INTRODUCTION

The field work consisted of five ARC and was undertaken under an action research methodology framework based on the research design explained in Chapter 8. The gathering and analysis of data was a continuous process spread over the duration of the field work (i.e. six months) due to the iterative nature of action research methodology. In each ARC data had to be collated from different activities involved in that particular ARC (i.e. observation, expert feedback, workshop participant feedback), analysed, reflections/insights were noted down. Based on these reflections/insights, modifications were brought to the scenario method in order to improve it and a new version of the scenario method was released. This new version of the scenario method was tested and improved if necessary in the following ARC. The first section of this chapter reports the consolidated results of ARC and provides the final version of the scenario method. As much as reporting the final outcome (i.e. final version of the scenario method) of the field work was important to establish contribution of this research, documenting the entire iterative process (i.e. the reflections/insights and modifications from each ARC) was important to establish the validity of the chain of logic which resulted in the final outcome. Therefore, the detailed documentation of results of each ARC is provided in Appendix IV.

The results of the ARC, in addition to the conceptual framework the scenario method is based on and the workshop design as the method's operational tool, enabled improvement of a third aspect associated with the scenario method: the facilitation of the workshop process. The feedback of workshop participants on facilitation and learnings obtained from facilitating these workshops are incorporated in the Facilitators' Guide (Appendix V).

The second part of this chapter provides the summary of the results of the evaluation of the scenario method to support the argument that it is a valuable method to link the product development level to the societal level in system innovation for sustainability. The detailed results of this evaluation are provided in Appendix VI.

9.2. Testing and Improving the Scenario Method

9.2.1. Summary of ARC Results: Changes to the Criteria and Workshop Design

Table 13 shows the final criteria establishing the conceptual framework and the workshop modules corresponding to these criteria. Figure 41 provides a timeline of ARC to show when each modification was made with respect to the ARC.

Table 13. The final criteria establishing the conceptual framework of the scenario method and the corresponding workshop modules

Code	Criteria	Code	Corresponding Workshop Module(s)
Crit 1	The scenario method should be based on the strong sustainability model.	Mod A	We are a System
Crit 2	The scenario method should enable businesses to model themselves within the strong sustainability model.		
Crit 3	The scenario method should link the planning periods applicable to companies (operational and strategic) to the long-term planning period (visionary) in order to enable companies to address long-term societal visions in their strategies and effectively implement these strategies in product development.	Mod B	Visions
		Mod C	Social Function
Crit 4	The scenario method should aid companies in identifying not only technology development requirements but also organisational/human development requirements.	Mod D	Products/Services
		Mod E	Stakeholders
		Mod F	Action Plan
Crit 5	The scenario method should aid companies in developing integrated business strategies aligned with societal level sustainability visions and day-to-day business activities and should facilitate integration of all business functions in line with the company strategy.	Mod B	Visions
		Mod G	Scenario Development
Crit 6	The scenario method should have a double-flow approach in order to link present and future in a realistic way and enable identification of alternative innovation paths which are possible from a technological point of view, acceptable from a social/cultural point of view and desirable from a sustainability point of view.	Mod G	Scenario Development
Crit 7	The scenario method should have a layered risk approach in order to identify implications of overarching sustainability risks on the companies' business as contextual risks. This way, sustainability can be internalised in the companies' organizational and product development strategy and active participation of companies in setting sustainability visions at societal level can be enabled.	Mod H	Risks to Sustainability and Implications

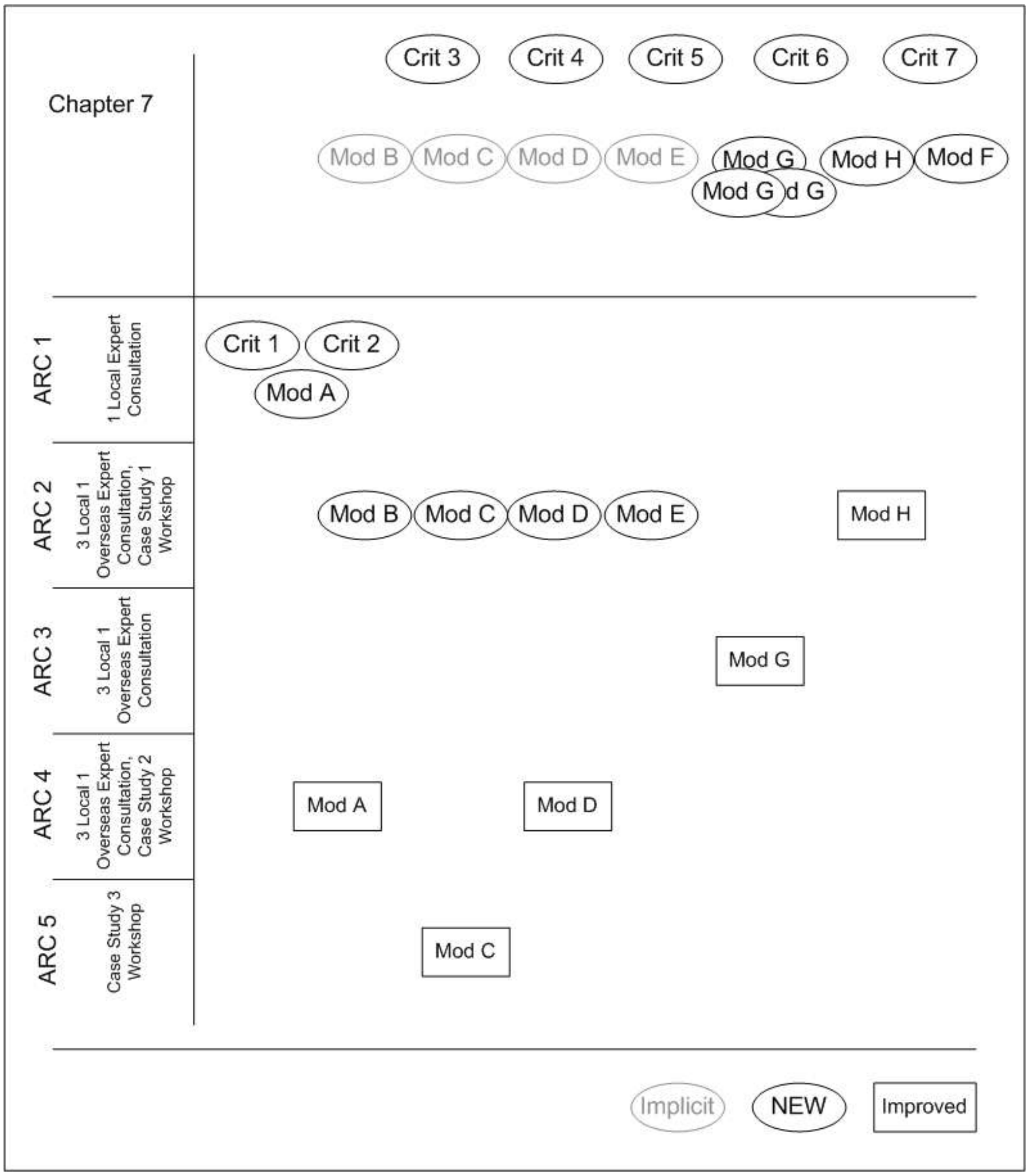

Figure 41. Timeline of modifications brought to the scenario method

ARC 1 saw a rapid maturation. Only one expert consultation was carried out during this cycle. At the end of this consultation both the conceptual framework and the workshop design were changed, therefore, the cycle was completed. At the end of this cycle two new criteria were added to the conceptual framework of the scenario method and based on these criteria a new module (i.e. 'We are a System') was developed and included in the workshop design.

ARC 2 consisted of consulting one overseas and three local experts and holding a workshop with Case Study 1. This case study provided the opportunity to try the scenario method with a service company. No evidence was encountered to disprove that the method could be used for service innovation. Since originally the method used the concept of social function to break mental models based on the characteristics of present products and services, and since a function can be met by a service as well as a product no specific changes were identified to be necessary to render the scenario method applicable by service companies. This ARC provided input mainly to improve the workshop design. At the end of this cycle, four new modules (i.e. visioning, social function, products/services, and stakeholders) which were implicit in the original workshop design were made explicit and identified as separate modules. The risks module was improved to make sure that the workshop participants do not overlook any sustainability risks relevant to the business of the company.

ARC 3 consisted of one overseas and three local expert consultations. It provided input mainly in relation to the conceptual framework of the scenario method. During this cycle the scope of application of the scenario method was further clarified. The expert consultations which took place in this ARC highlighted that the workshop process might not be readily adoptable by organisations which had not committed to achieving sustainability since the precondition was the will of the organisations to try the method. Therefore, the method was not likely influence companies at all levels of awareness/commitment towards sustainability unless an internal change agent actively undertook the mission of convincing a group of people to participate in a workshop. Eventually, without the commitment of the upper management, change would not take place. However, the non-commitment at managerial level in the earlier phases of a change project did not necessarily determine the outcome as negative since the momentum to change might develop in the organisation and a group of pro-change people could later convince the managers. The scenario method could help a group of innovative people in an organisation in building a business case to present to the management. This emphasised the importance of initially targeting internal change agents for the adoption of the scenario method. Internal change agents can be anyone and anywhere in the organisation; they can be board members, CEOs, executives, managers but also any member of the staff (Dunphy, Griffiths, & Benn, 2007). Therefore, since the scenario method was originally planned to be used by a product development team in a company, in order to transfer the knowledge of the scenario method to internal change agents, the workshop design should also be applicable in groups of individuals from different organisations. As a result, a variation of the workshop design has been formulated to suit to a group of individuals coming from different organisations in order to transfer the knowledge of the scenario method to potential internal change agents. This variation was tested later in ARC 5 with Case Study 3. ARC 3 also revealed that three separate modules for scenario development activity (i.e. forward scenarios, backward scenarios and alignment modules) were not necessary. Given the group is large enough, developing backward and forward scenarios simultaneously as two sub-groups and cross-fertilising these two sub-groups by exchanging members generates automatic alignment of two flows.

ARC 4 consisted of consulting one overseas and three local experts and a workshop with Case Study 2. This case study provided the opportunity to try the scenario method with a start-up company. No evidence was encountered to disprove that the method could be used for start-up companies. This case study, similar to Case Study 1 was a service company. Therefore, this case study strengthened the claim that the scenario method is suitable to be used by service companies. This was also the only case study among three which had innovation for sustainability at the core of its business. No evidence was encountered to indicate that the scenario method is more suitable to be used by companies with higher proactivity in relation to sustainability. This ARC provided input mainly in relation to the workshop design and helped to further clarify the scope of application of the scenario method. At the end of this ARC, improvements were brought to two modules (i.e. 'We are a System' and Products/Services). The expected outcome of the 'We are a System' was changed from a model strictly portraying three concentric circles to one which demonstrates an understanding of the hierarchical relationships and interdependencies between the environment, society and economy. A process to evaluate ideas was incorporated in the Products/Services module of the workshop design. This process was not seen as an essential element for the scenario method; therefore, it was identified as optional and could be used in groups which chose to undertake such evaluation. The process would only focus on the evaluation of short-term ideas in order not to jeopardise premature dismissal of product/service ideas for the longer term. Also, this process should not involve deletion of any of the ideas from the scenario map even if they were voted off during the evaluation as these ideas might prove useful later.

ARC 5 consisted of one workshop with Case Study 3. In this ARC the variation of the workshop design developed at the end of ARC 3 was tested for its applicability to a group of individuals coming from different organisations. The differences in this workshop design covered formulating a fictitious company and presenting it to the workshop participants to work on during the workshop. In addition, since this was a group consisting of unrelated individuals worked on a fictitious company, the stakeholder and action plan modules were not held but the group was briefed about how to run these two modules. With this group, the social function and visioning modules were quite challenging. The participants had problems with identifying a social function which everybody agreed upon. The participants did not have a difficulty in developing societal level visions mitigating the risks identified as threats to the sustainability of society. However, the generation of visions regarding how the social function is being met in that society had been challenging since they had to imagine how the social function (which they had difficulty in identifying) was being met in the long term. The discussions with the participants indicated that the problem arose because the group was not a real team and was working on a fictitious company/product scenario. The participants' responses were not based on real life experience with the company/product and they were not familiar with the characteristics of the fictitious company which was their scenario for the purposes of the workshop.

Case Study 3 was the only manufacturing company case included in the field work. Even though the scenario development module was successful, the product/service ideas generated were not path breaking. In manufacturing companies, defining the social function based on the current product(s) the company is producing might be counterproductive for two reasons. First, as experienced in Case Study 3, for a very specific product, participants might find it hard to formulate a social function which will remain unchanged in the long term. Second, the social function of a product might be useful in developing forward flowing explorative scenarios to start thinking at the conceptual level and generate innovation ideas based on the current product and technologies. But, when developing backward flowing scenarios, since future opportunities may be completely different from the activities the company conducts currently, the more effective approach might be focusing on the societal vision of sustainability and the core competencies of the company. This way innovation ideas based on opportunities which are likely to rise on the way to achieve sustainability might be generated (J. McLaren, personal communication, November 30, 2009) and the innovation paths can be directed towards fulfilling societal needs. Following these reflections, changes were brought to how social function was used in the scenario development module. The workshop design was changed to use social function only during the development of explorative scenarios in order to exploit the emerging opportunities. In developing the backward flowing scenarios, the focus would be on achieving the societal level vision of sustainability and core competencies of the company. The changes brought to the workshop design would only apply to the workshops undertaken by manufacturing companies since, with service companies, social function proved to be conceptual enough and worked equally successfully in development of both forward and backward flowing scenarios.

Case Study 3 was the only case study which took place in a developing (i.e. industrial) economy. No evidence was encountered to disprove that the method could be used for companies in developing economies.

9.2.2. Consolidated Results: The Final Version of the Scenario Method

Based on the changes and improvements brought to the criteria, the outline of the scenario method has changed. Figure 42 provides the final version of the scenario method outline.

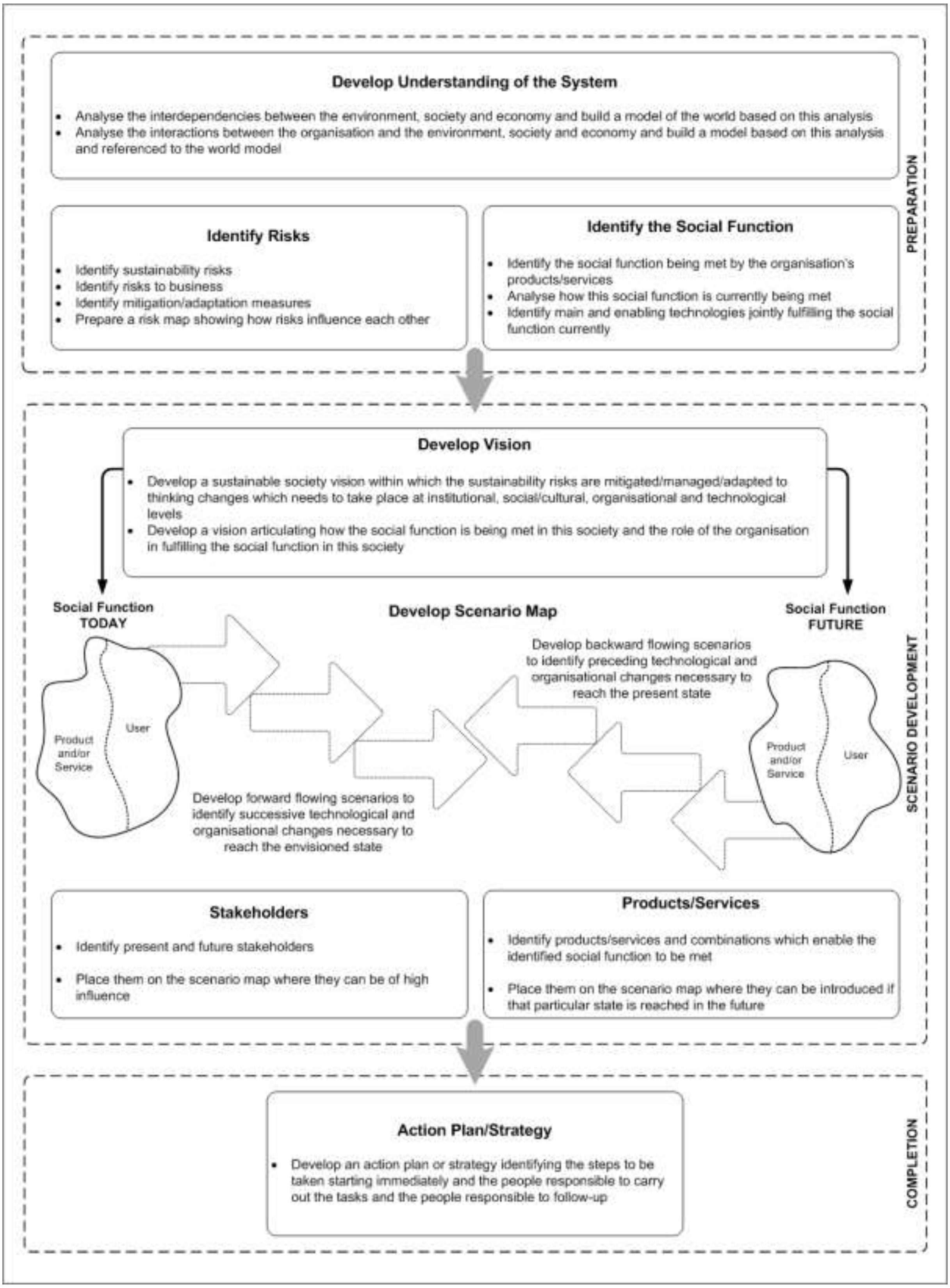

Figure 42. The final version of the scenario method outline

The workshop design has changed based on the improvements/changes brought to the criteria and the outline. Table 14 shows the progression of the workshop modules along with brief explanations of what the module involves and what are the expected outcomes. This table also provides indicative times for completion of each module. Details of the workshop schedule and design are provided in the Facilitator's Guide (Appendix V).

Table 14. The progression, outcomes and indicative minimum required duration for the completion of workshop modules

	Minimum Duration	Module	Activity	Outcome/Deliverable
1st Half-Day	45 mins.	0. Introduction	1. The participants check-in; 2. The facilitator briefs the group about the purpose and agenda of the workshop and gives a short presentation clarifying the concepts used.	**Outcome:** Everybody checked-in, common understanding of the purpose of the workshop and the concepts used, group ready to start.
	40 mins.	1. We are a system	1. The group builds a world model showing the interrelationships between the environment, society and economy; 2. The participants position their organisation on this world model and articulate the interactions taking place between each sub-system and their organisation; 3. (Optional) The participants draw a life-cycle map of one of their organisation's product/service.	**Outcome:** Participants understand the irreversible, hierarchical relationships between the environment, society and economy. The participants understand the major interactions taking place and dependencies between their organisation and the environment, society and economy. **Deliverable:** A world model based on the hierarchical interdependencies between the environment, society and economy showing the interactions taking place between the organisation and the environment, society and economy.
	80 mins.	2. Risks	1. The group prepares a list of risks to sustainability; 2. The facilitator checks this list against a pre-prepared list compiled from different resources (e.g. Kates et al., 2001; MEA, 2005; IPPC, 2007; UNEP, 2009b) and makes suggestions to expand the list if any risk relevant to the organisation is missing; 3. These risks are mapped on the world model the group built in the previous module and the dynamic relationships between them are identified; 4. The participants	**Outcome:** The group understands how long-term wider-scale sustainability risks which threaten the society do and will affect the organisation's business and products/services it delivers. **Deliverable:** A list of risks to sustainability; a risk map (mapped on the world model developed in the previous module) showing dynamic relationships between risks; a list of implications of risks to sustainability on the

			identify implications of the risks to sustainability to the business of their organisation.	organisation and the products/services it delivers.
2nd Half-Day	60 mins.	3. Social Function	1. The group identifies the social function fulfilled by the products/services offered by the organisation	**Outcome:** The group starts to think conceptually and is able to shift the existential focus of the organisation from itself to the wider context of society. **Deliverable:** Written expression of social function.
	105 min.	4. Visions	1. The group develops a normative vision for a sustainable society within which the risks identified in the previous section are mitigated/ managed/adapted to; 2. The group develops an organisational vision (can be referenced to the social function the organisation would like to fulfil) compatible with the vision of a sustainable society.	**Outcome:** The group involves in development of societal visions for sustainability and understands the systemic relations between the future of the society and their organisation. The group understands how institutional and social/cultural changes need to go in parallel with organisational and technological innovations to achieve sustainability. **Deliverable:** Vision(s) of a sustainable society documented on paper in written form (can be accompanied with imagery).
3rd Half-Day	130 mins.	5. Scenario Development	1. The group is divided into two sub-groups; 2. One group develops forward flowing, explorative scenarios; 3. The other group develops backward flowing, normative scenarios; 4. Some group members switch between groups to cross-fertilise each flow; 5. Two groups share their work with each other; 6. Aligning paths are identified and further work can be done to help some other paths to align.	**Outcome:** The group gains an understanding on the availability and characteristics of the possible innovation paths the organisation can use towards system innovation. **Deliverable:** A scenario map
4th Half-Day	50 mins.	6. Products/ Services	1. The group brainstorms to generate product/service ideas which can be introduced if particular events anticipated happen; 2. These ideas are mapped on the scenario map; 3. (Optional) The product/service ideas are evaluated.	**Outcome:** The group gains an understanding on the availability and characteristics of products/services that can be introduced along the innovation paths developed in the previous module. **Deliverable:** A scenario map with the products/services layer added onto it.

50 mins.	7. Stakeholders	1. The group prepares a list of stakeholders; 2. The group maps the stakeholders on the two-axis stakeholder model; 3. The group maps the stakeholders on the event trees or connections of the scenario map where they are likely to be most influential.	**Outcome:** The group gains an understanding of the current and future stakeholders, their intentions and possible influences along the innovation paths identified. **Deliverable:** A list of stakeholders, a stakeholder map and a scenario map with the products/services and stakeholders layers added onto it.
50 mins.	8. Action Plan	1. The group reviews the scenario map; 2. The group identifies actions to be taken in the following week, month, year; 3. For each action identified, a responsible person is allocated; 4. A follow-up meeting to review the scenario map is scheduled in a year's time.	**Outcome:** The group identifies the immediate steps needed to be taken to realise the innovation paths towards system innovation for sustainability and commitment is established to the action plan developed. **Deliverable:** An action plan agreed upon by the participants and documented in written form.

9.3. Evaluation of the Scenario Method

9.3.1. Participant Evaluation

This section reports the evaluation of the scenario method by the research participants. The results reported here are based on the evaluation questionnaires (Appendix III) completed by the participants either after an expert consultation session or a workshop. This section does not report the recommendations made by the participants to improve the method since these were already addressed in the previous section (and in detail in Appendix IV) and used to improve the method.

Expert Consultation

Table 15 provides a summary of the responses given by the participating experts to the two closed evaluation questions asked in the evaluation questionnaire. All of the 13 experts consulted stated that, in an overall assessment, the scenario method can aid product development teams to incorporate sustainability issues into their decision making in an effective way. Eleven of the experts stated that, in an overall assessment, the scenario method can influence the business transformation which needs to take place as part of the societal transformation to achieve sustainability. Two of the experts stated that they did not know if the scenario method could achieve such business transformation.

Table 15. Summary of the evaluation of the scenario method by the expert participants

Question	Response	No. of Experts
In an overall assessment, do you think the scenario method can aid product development teams to incorporate sustainability issues into their decision making in an effective way?	Yes	13
	No	0
	Don't know	0
In an overall assessment, do you think the scenario method can influence the business transformation which needs to take place as part of the societal transformation to achieve sustainability?	Yes	11
	No	0
	Don't know	2

The most commonly cited useful or interesting part of the scenario method by the participating experts was the double-flow approach to scenario development. Seven out of 13 experts explicitly stated the double-flow approach as useful and interesting in their responses. The main reason given by all of these seven experts was that linking present and long-term using a double-flow approach to scenario development and aiming for alignment in the middle would render the process meaningful for businesses and would increase the likeliness of business adoption of the scenario method. There was no commonly cited least useful/interesting part of the method by the experts.

Workshops

Table 16 provides a summary of the responses given by the workshop participants to the three closed evaluation questions asked in the evaluation questionnaire. Even though in total 24 people participated in the workshops, as a result of the replacements in Case Study 2, only 20 people have participated through the entire process. Therefore, six participants have not responded to the overall assessment questions. All of the 20 participants who participated in the entire workshop stated that, in an overall assessment, the scenario method can aid product development teams to incorporate sustainability issues into their decision making in an effective way. Sixteen of the participants stated that, in an overall assessment, the scenario method can influence the business transformation which needs to take place as part of the societal transformation to achieve sustainability. Three of the participants stated that they did not know if the scenario method could achieve such business transformation. One participant stated that she/he does not think the scenario method can influence such business transformation. The third question in the questionnaires was answered only by participants of Case Study 1 and Case Study 2 and since it was not applicable to Case Study 3. This question inquired whether the participants thought the activity was worthwhile for the company.

Since this question was not applicable to Case Study 3, only ten participants of Case Study 1 and Case Study 2 who had been though the entire workshop responded this question and all of them stated that in an overall assessment the activity was worthwhile for their company.

Table 16. Summary of the evaluation of the scenario method by the workshop participants

Question	Response	No. of Particip.
In an overall assessment, do you think the scenario method can aid product development teams to incorporate sustainability issues into their decision making in an effective way?	Yes	20 out of 20
	No	0
	Don't know	0
In an overall assessment, do you think the scenario method can influence the business transformation which needs to take place as part of the societal transformation to achieve sustainability?	Yes	16 out of 20
	No	1 out of 20
	Don't know	3 out of 20
In an overall assessment, do you think the activity was worthwhile for the company?	Yes	10 out of 10
	No	0
	Don't know	0

The most commonly cited useful/interesting part of the scenario method by the workshop participants was the forward-backward scenario development part. Fourteen participants explicitly stated that developing explorative and backcasting scenarios was (one of) the best parts of the entire process since it opened up possibilities and demonstrated how a vision can be achieved in a step-by-step manner. For these participants, the scenario development module was the one which made all of the other modules meaningful. This module is cited as one of the most useful/interesting parts of the scenario method by participants of all three case studies. The other module which was cited by all three case studies as one of the most useful/interesting parts was the 'We are a System' module. Participants reported that this module gave them new insights about how businesses relate to the bigger picture of the society and to the environment.

There was no cross-case correlation in relation to the least useful/least interesting part of the scenario method; however, there was internal consistency within the case studies. The participants in Case Study 1 did not identify any specific module as least interesting or least useful. For five participants in Case Study 2, the stakeholder module was stated as the least interesting/useful module. Three of these participants stated that preparing a list of the stakeholders was useful but trying to place them on the provided stakeholder map which has supply/power axes was frustrating. For Case Study 3, the part which was found by the majority of the participants (six) as the least useful/interesting was the second part of the visions module where the participants were supposed to develop an organisational vision articulating how their social function is being met in the societal level vision and what the characteristics of their organisation in this society were.

9.3.2. EVALUATION OF THE SCENARIO METHOD AGAINST EFFECTIVENESS CRITERIA FOR FUTURES WORK

This section evaluates the effectiveness of the scenario method as a futures work. The evaluation is based on the outcomes of the workshops carried out with three case studies. For the evaluation, the effectiveness model and criteria developed by List (2005) to evaluate futures work are used with some modifications to fit this research.

Table 17 shows the effectiveness model for futures work. As seen, there are three levels of this model, implementation, influence and application. The first level, implementation, assesses whether the activity took place as planned and stands as a prerequisite for the rest of the evaluation since if the process did not go ahead as planned or did not happen at all evaluation cannot take place. The second level of the model, influence, assesses the influence of the process on the participants and the third level, application, assesses the effectiveness of the application of the process.

Table 17. The effectiveness of futures work model by List (2005)

Level	Label	Description of the effectiveness label
1	Implementation	The process goes ahead as planned without practical problems in execution.
2	Influence	The process influences participants to change their thinking and perceptions.
3	Application	The participants are able to use the output of the process and such use contributes to their entity's achievement of goals.

List's (2005) focus was on organisations and his research was not related to sustainability. In addition, he was not aiming to link organisations to the rest of the socio-technical system in a systemic way. Therefore, the effectiveness model developed by him focused only on the entities undertaking the process and success was defined in line with the goals of the entity regardless of the impacts of those goals on the environment and the society. For the purposes of this research, there was a need to clarify and/or alter the definitions of effectiveness labels so that they would be aligned with the overall objective of the research. Table 18 shows the modified effectiveness model.

Table 18. The effectiveness of futures work for sustainability model

Level	Label	Description of the effectiveness label
1	Implementation	The process goes ahead as planned without practical problems in execution.
2	Influence	The process influences participants to change their thinking and perceptions about the future, their entity and how their entity relates to the rest of the socio-technical system in achieving sustainability.
3	Application	The participants are able to use the output of the process and such use contributes to their entity's achievement of goals towards system innovation for sustainability.

List (2005) developed evaluation criteria to be used in conjunction with the effectiveness model. Table 19 lists these criteria at each effectiveness level. The first nine of these criteria need to be assessed during the field work; before, during or right after the workshops. The last three criteria need to be assessed during follow-up after a sufficiently long period of time to compare the situations before and after the organisation has been through the futures inquiry process. The fifth criterion can only be assessed partially during implementation (i.e. 'anticipations are expressed specifically') and full assessment (i.e. 'anticipations can be tracked and confirmed') can only be carried out during follow-up. Further research is necessary to fully assess the fifth and the last three criteria as these require sufficient time for implementation and application of the process, which was beyond the scope and capability of this research.

Table 19. Evaluation criteria developed by List (2005) for each effectiveness level

Effectiveness Level	Criterion
Implementation	1. The purpose of the futures work is made explicit to all involved.
	2. Participants' initial assumptions are challenged, focus broadened, and their perceptions reframed.
	3. Each possibility is explored with equal attention, not neglecting any that seem awkward or inconvenient.
	4. Workshop participants include all major stakeholder groups, covering all likely impinging systems.
	5. Anticipations are expressed specifically enough that they can be tracked and confirmed.
Influence	6. Participants are satisfied with the process, feeling the activity was worthwhile.
	7. Participants gain more detailed perceptions of future possibilities. The process creates 'future memory' to help prepare for later action.
	8. Participants feel empowered and stimulated to act.
Application	9. The output is directly usable by the entity.
	10. As a result of the process, the entity becomes more future-oriented, more open to divergent thinking, and more adaptable to change.
	11. The broad situation is successfully anticipated.
	12. The process results in action for change: in the entity, or in participants' behaviour.

The criteria to be used for assessment in this research need to be modified to reflect the changes made to the effectiveness model. Table 20 shows the evaluation criteria derived from the criteria of List (2005) to reflect the changes made to the effectiveness model and where the evidence for each criterion can be found.

Table 20. The evaluation criteria used to assess the effectiveness of the scenario method developed in this research and the sources of evidence

Effectiveness Level	**Criterion**	**Source of Evidence**
Implementation	1. The purpose of the futures work is made explicit to all involved.	Agenda, e-mails, facilitator's notes and participant feedback
	2. Participants' initial assumptions are challenged, focus broadened, and their perceptions reframed both about the future of their entity and how their entity relates to the rest of the socio-technical system.	Participant feedback, facilitator's notes from 'We are a System' and 'Social Function' modules.
	3. Each possibility leading towards the developed vision is explored with equal attention, not neglecting any that seem awkward or inconvenient.	Participant feedback, facilitator's notes
	4. Workshop participants include all major stakeholder groups, covering all likely impinging systems.	Attendance data, stakeholder map
	5. Anticipations are expressed specifically enough that they can be tracked.	Analysis of the final scenario map
Influence	6. Participants are satisfied with the process, feeling the activity was worthwhile.	Attendance data, participant feedback
	7. Participants gain more detailed perceptions of future possibilities. The process creates 'future memory' to help prepare for later action.	Participant feedback
	8. Participants feel empowered and stimulated to act to move their entity and activities towards system innovation for sustainability.	Participants feedback, action plan
Application	9. The output is directly usable by the entity to achieve its goals towards system innovation for sustainability.	Participant feedback, entity managers' feedback

Table 21 provides an overall summary of the evaluations for all case studies based on these criteria (detailed documentation of evaluation of each case study against effectiveness criteria can be found in Appendix VI). As seen, the evaluation provided supporting evidence that the scenario method developed in this research is effective as a futures work for sustainability.

Table 21. Evaluation of the effectiveness of the scenario method for all case studies: summary

Criterion	Case Study 1	Case Study 2	Case Study 3
1.	Fulfilled	Fulfilled	Fulfilled
2.	Fulfilled	Fulfilled	Fulfilled
3.	Fulfilled	Fulfilled	Fulfilled
4.	Partially fulfilled	Partially fulfilled	Not applicable
5.	Fulfilled	Fulfilled	Fulfilled
6.	Fulfilled	Fulfilled	Partially fulfilled
7.	Fulfilled	Partially fulfilled	Fulfilled
8.	Fulfilled	Fulfilled	Fulfilled
9.	Fulfilled	Fulfilled	Not applicable

9.3.3. Evaluation of the Potential of the Scenario Method to Aid in Achieving System Innovation for Sustainability

This section provides evaluation of the potential of the scenario method to aid product development teams in their involvement in system innovation for sustainability. The assessment is based on the outcomes of the workshops carried out with three case studies. The evaluation provides supporting evidence for the general claim that the scenario method developed in this research is a valuable method.

Considering specific characteristic of this research, four design criteria were developed to guide the design of the operational tool of the scenario method in conjunction with List's (2005) design criteria and were presented in Section 7.3 (see Table 9). Based on those four design criteria, criteria were developed to evaluate the scenario method in terms of its potential to aid in system innovation for sustainability. These evaluation criteria were:

1. The participants understand the hierarchical irreversible relationships between the environment, society and economy and between their organisation and these three sub-systems;
2. The participants understand the issues threatening the sustainability of the society (i.e. risks to sustainability of the society), the dynamic relationships among these issues and the implications of these on their business;

3. The participants are able to generate normative long-term societal visions within which the risks to sustainability are mitigated/managed/adapted to by the society through a combination of institutional, social/cultural, organisational and technological changes, and;
4. The participants are able to develop a scenario map linking the present of their organisation and products/services to the normative vision of a sustainable society.

Table 22. The modules outcomes of which provided evidence to evaluate the scenario method in terms of its potential to aid towards system innovation for sustainability

Criterion	Corresponding Module	Sources of evidence
1.	We are a System	Models drawn by the participants in the 'We are a System' Module, facilitator's notes on the discussion which took place during group work
2.	Risks	The lists of sustainability risks and dynamic risk maps prepared by the participants, the facilitator's notes on the discussion which took place during group work
3.	Visions	The visions developed by the participants, the facilitator's notes on the discussion which took place during group work
4.	Scenario Development	The scenario maps developed by the participants

The workshop modules providing evidence to evaluate the scenario method against the criteria listed above and the sources of that evidence in the corresponding modules are shown in Table 22. Below an overall summary of the evaluation for all case studies against each criterion is provided (detailed documentation of evaluation of each case study against evaluation criteria can be found in Appendix VI).

Criterion 1: Have the participants understood the hierarchical irreversible relationships between the environment, society and economy and between their organisation and these three sub-systems?

This criterion was fulfilled in all three of the case studies. Figure 43 shows the models drawn by WG of each case study in 'We are a System' modules. All of the models - both world and organisational – developed and the group discussions which took place during each of the 'We are a System' modules clearly demonstrated that all three of the WG understood the hierarchical, irreversible relationships between the environment, society and economy and between these systems and their respective organisation.

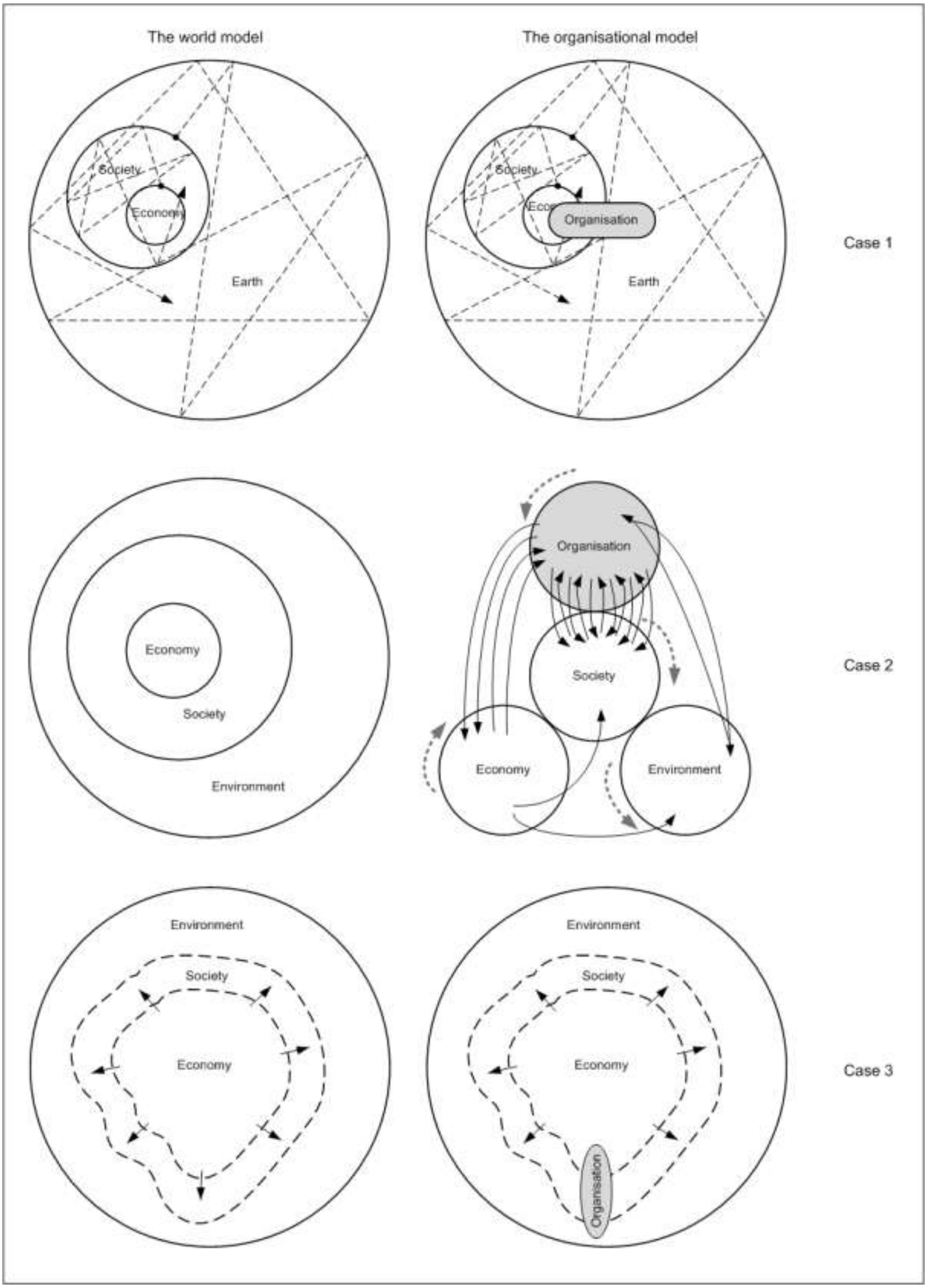

Figure 43. The models drawn by WG in ‘We are a System’ modules of Case Study 1, Case Study 2 and Case Study 3 workshops

Criterion 2: Have the participants understood the issues threatening the sustainability of the society (i.e. risks to sustainability of the society), the dynamic relationships among these issues and the implications of these on the business or their organisation?

This criterion was partially fulfilled in all three of the case studies. The evidence (i.e. lists of sustainability risks prepared by each WG) indicated that for all three of the WG, the participants were able to identify the implications of risks to sustainability on their business however they were bound by their preconceived ideas on what those implications were and how they can respond to them. Nevertheless, this difficulty is not an inherent shortcoming of the scenario method. It can be overcome by carrying out preparatory research before the workshop about the probabilities and consequences of the sustainability risks. This preparatory research can either be done by the facilitator or, if they are willing to, by the participants. Another strategy to overcome this difficulty may be inviting an expert to the workshop.

Even though the different perspectives influenced the outcome in relation to the perceived priorities, the participants were still able to come up with a comprehensive list or were able to articulate verbally indicating that they understood the issues threatening the sustainability of society. They were also able to show how those risks dynamically influenced each other after being introduced to developing simple diagrams to demonstrate dynamic relationships between system parameters. Figure 44 shows a segment of the dynamic map developed by WG2 in Case Study 2 workshop as an example.

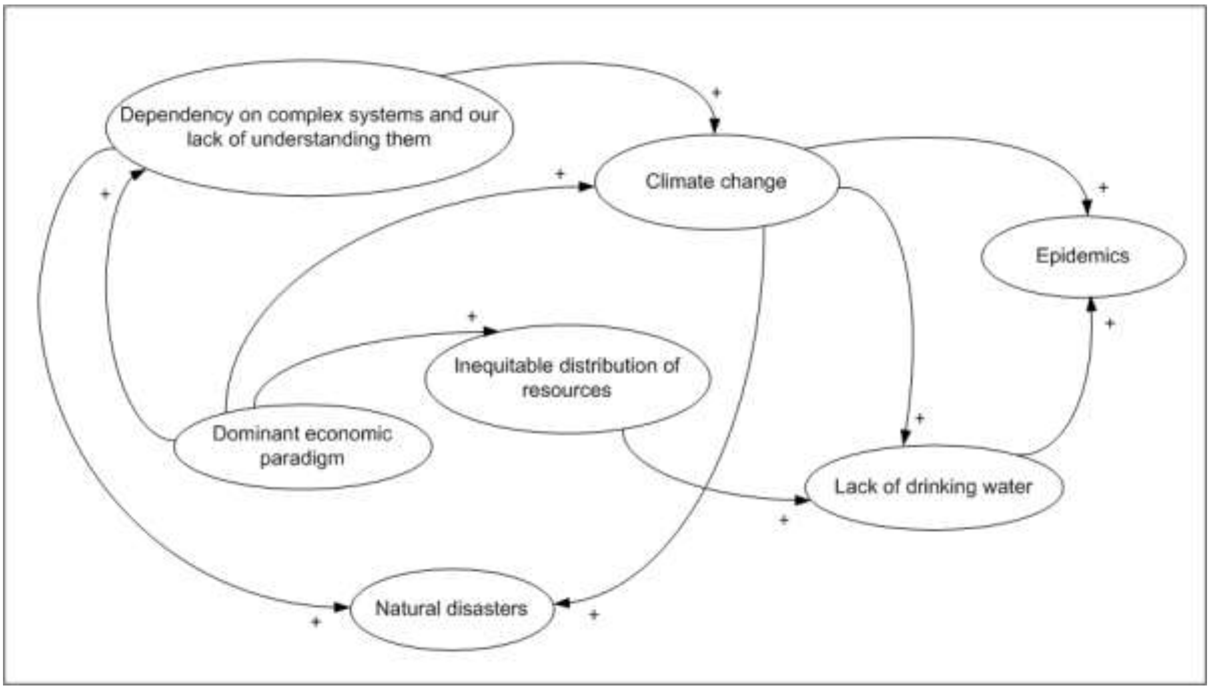

Figure 44. Segment of the dynamic risk map developed in Case Study 2 workshop

Criterion 3: Were the participants able to generate normative long-term societal visions within which the risks to sustainability were mitigated/managed/adapted to by the society through a combination of institutional, social/cultural, organisational and technological changes?

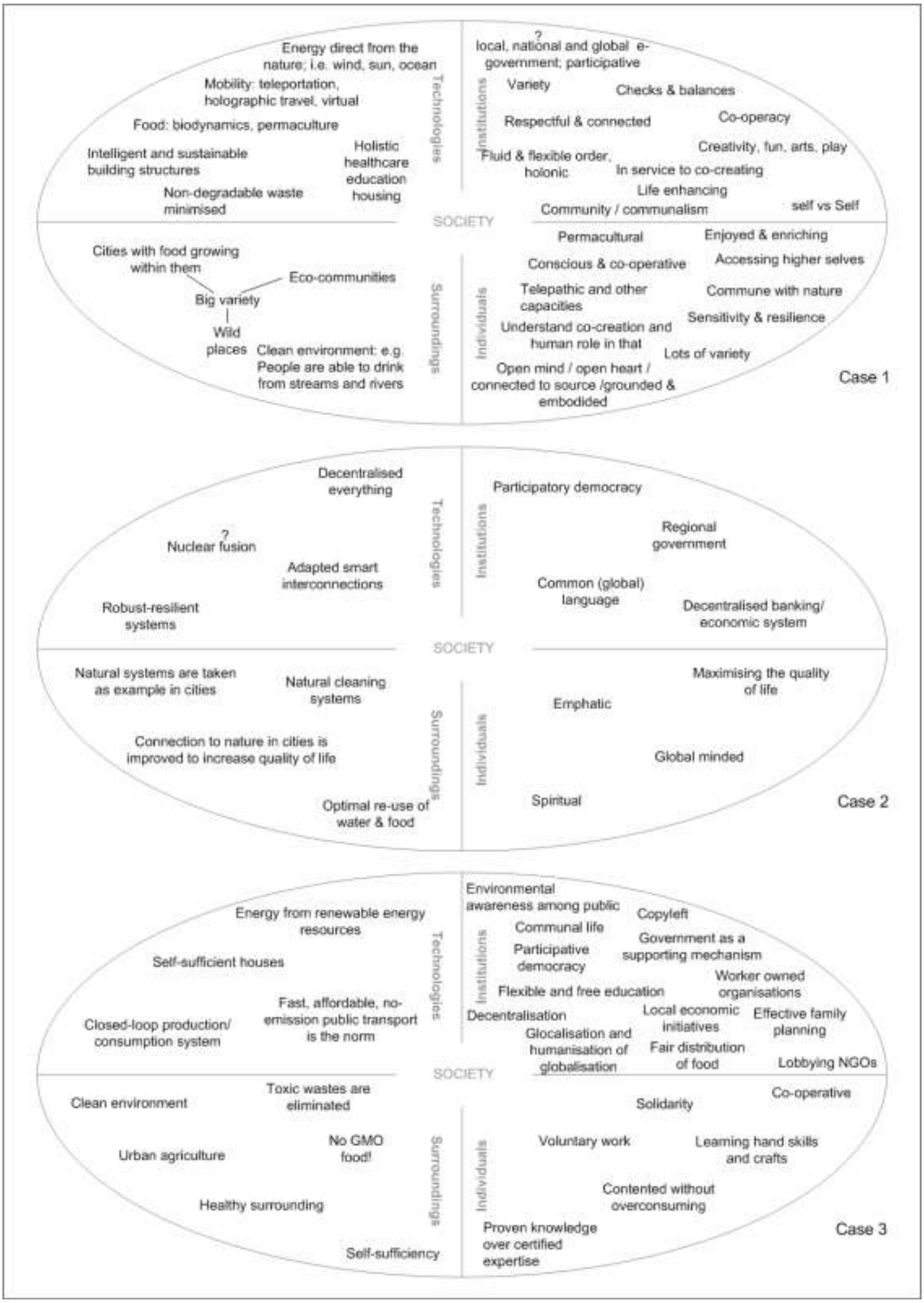

Figure 45. Sustainable society visions developed by WG in the visions module of Case Study 1, Case Study 2 and Case Study 3 workshops

Figure 45 shows the normative visions of sustainable societies developed by WGs in all three case studies. Based on the evidence found in the normative visions developed by all three WGs and the discussions which took place during the group work it was concluded that this criterion was fulfilled by WG1 and WG3 and only partially fulfilled by WG2.

The normative vision developed by WG1 addressed all of the high priority risks they identified and some risks not identified as high priority risks. This WG generated some technological breakthrough ideas as well as institutional and behavioural changes which potentially mitigate/manage the risks to sustainability they identified in the risks module.

Even though the risks identified by WG2 demonstrated a high-level understanding of sustainability issues, the resulting vision addressed those risks only to a certain extent. One reason of not achieving development of a long-term vision might be the group's preoccupation with generating solutions for sustainability issues presently. Since the group already put a lot of thought and had preconceived ideas on how to achieve innovation for sustainability, they had difficulty in focusing on long term or seeing their present activities in the context of long term. In facilitating this workshop it was assumed that there would be no need to explain the reasons behind using a 50-plus years time frame since the core business of the group was innovation for sustainability and this case study was based in the Netherlands; i.e. the country where system innovation theory and related projects were initiated and mainly coming from currently. In facilitating the other two workshops, the reasons behind the selection of 50-plus years time frame were explained and no similar problems were encountered. Therefore, the difficulty experienced with this group does not indicate a short-coming from the perspective of evaluating the scenario method but rather a short-coming of the facilitation of this module in this case study.

The vision developed by WG3 addressed all of the risks identified as high-priority by the group as well as many of the risks not identified as high-priority through a combination of institutional, social/cultural, organisational and technological changes. Nevertheless, the majority of the solutions anticipated by the group were focused on behavioural and cultural change.

Criterion 4: Were the scenario maps developed by the participants able to link present to the long-term future visions of a sustainable society they developed enabling alternative innovation paths to be identified?

This criterion was fulfilled in all three of the case studies. Figure 46 shows the general structure of the maps produced which was achieved with all three case studies with varying degrees of detail of innovation paths. The degree of detail of innovation paths was directly proportional to the number of event trees generated by the participants. The number of event trees was directly proportional to the number of participants and the time allocated to the task of scenario development. However, the scenario maps developed by all three WGs were able to link present to the long-term future visions of a sustainable society and enabled identification of alternative innovation paths.

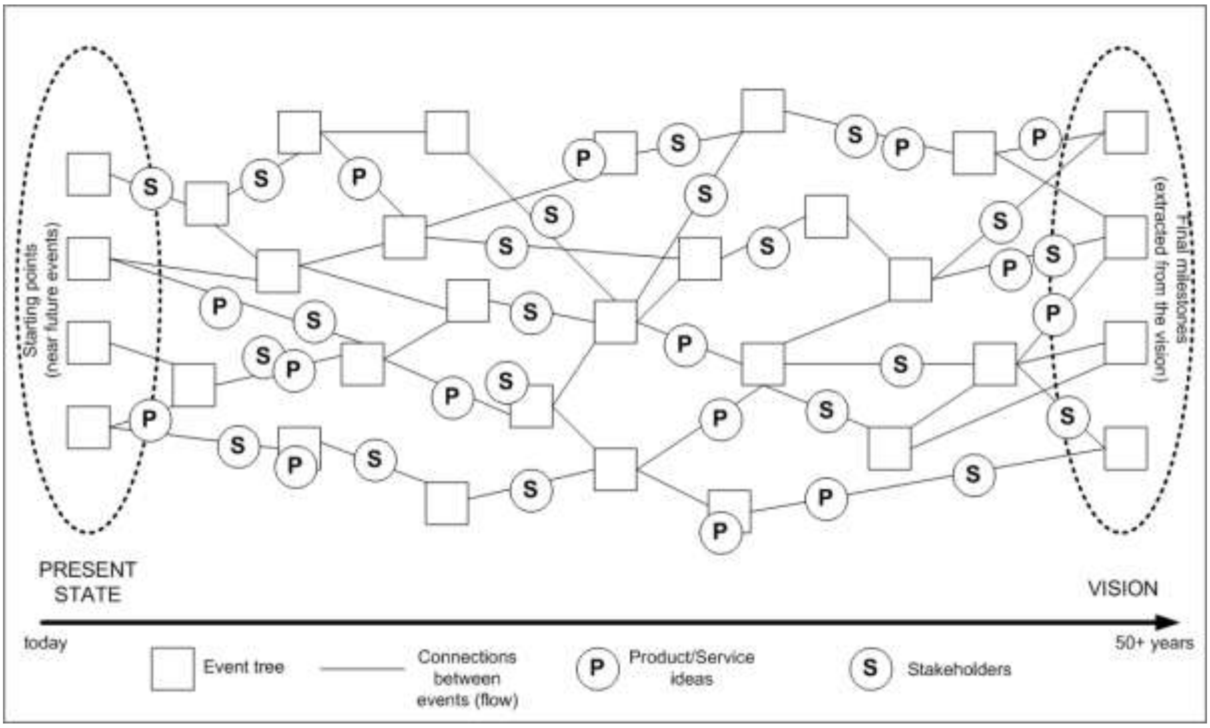

Figure 46. The generic structure of scenario maps generated during the workshops

9.4. Outstanding Issues Related to the Scenario Method

9.4.1. Trade-off: Time/Cost Efficiency versus Depth

Despite the overall success of the scenario method, there are some outstanding issues related to specific features of the method which need to be acknowledged. The first of these issues is the trade-off between the amount of time allocated to the workshops and the amount of detail which can be achieved in the outcomes (i.e. risk analysis, visions, scenario map). The efficient use of time was identified as a design criterion in designing the workshop (see Section 7.3 for details). This is also required to keep the man-hour costs of running a workshop down. However, the two-day schedule, also depending on the pace of the group progress, remains insufficient to generate a sufficiently detailed scenario map. Any module in the workshop can be expanded to generate more detailed outcomes. For example, the products/services module can be expanded to a full day to enable accommodation of processes specifically developed for generating breakthrough product/service concepts (for example The Slingshot process developed by Orban and Miller (2007)). There are several parameters influencing the time required for completion of each module and the workshop. These parameters will be different for each workshop group. Some of these parameters are the quantity of people in the group, internal group dynamics, the cognitive abilities and knowledge of the group members relevant to the content of modules, quality of facilitation, quality of the environment within which the workshop takes place and, most importantly, the amount of detail of the outcome desired to be achieved by the group from each module. It is certain that an exact amount of time which should be allocated to specific modules and to the overall workshop cannot be prescribed by this research.

9.4.2. Time Horizon Used

Another outstanding issue is the time horizon used by the scenario method. Some of the people experienced in strategy development for businesses who were consulted about the research commented on the unfeasibility of using a 50 years time frame considering the time frames currently used by businesses. Previously it was acknowledged that the 50 years is very unconventional in business planning (see Section 6.4). Even though currently long-term planning periods of businesses do not generally cover periods longer than 10 years, there are increasingly good reasons for looking into the future longer than what businesses are conventionally used to. The quest towards sustainability will require the humanity to develop strategies to mitigate/adapt to long-term sustainability issues and to transform many -if not all- conventions and constructs the society is currently operating under. The sustainability issues will have direct and indirect implications on the businesses and they will need to play a significant role in mitigation/adaptation strategies.

In addition, the findings of a survey carried out among futurists to find out about the time horizons these futurists are using provides some supportive evidence justifying the time frames required to be used by the scenario method (Brier, 2005). For example, according to the results of this survey a well-known consulting futurist stated that the interest in longer-term futures in business world is increasing and that he had 60 corporate clients in years 1999-2000 demanding to look at 20 to 30 years ahead. Another corporate futurist stated that, the time frame used by his clients vary depending on the scope of the exercise. For example, the often used time frame is between three to five years which applies for the projects run by the companies. If the focus of the study is a function; e.g. future of R&D in the company, future of labour force etc., the time frame used becomes ten years. These clients look into terms longer than ten years very rarely, only if the scope of the futures exercise is wide such as a whole industry. This study, besides researching about the time frames used by corporate futurists, also surveyed the time-frames used by academic futurists who are dealing with social futures; i.e. futures of the society. The time-frames used by futurists looking into broad social futures generally varied between 20 and 100 years since 20 years is the minimum amount of time (which equates to one generation) needed to bring changes to the society. These findings highlight the requirement to adopt longer terms as the system, future of which is being inquired into, gets bigger (i.e. as the scope of the futures inquiry gets wider). This justifies the time-frame prescribed by the scenario method developed in this research. Then, the issue is to convince the companies to get interested in their role and stake in the future of the society. This is fundamental for the success of the scenario method since it will determine the uptake of the scenario method by businesses; however, developing strategies to convince the businesses to be interested in the futures of the society and their role and stake in it is beyond the immediate scope of this research.

9.4.3. Unproven and Potential Application Scope

The results of the workshops carried out with the three case studies demonstrated overall success indicating that the method can be used in different socio-technical contexts, both by established and start-up and both small and medium size companies. The scenario method was not tried in a large company. Therefore, there is no indication on whether the scenario method can effectively be applied in large companies. However, during the field work no evidence was encountered suggesting that the size of the organisation played a significant role in the effective application of the method. The difficulty foreseen in relation to large companies is not related to applying the method by running a workshop with dedicated and enthusiastic employees but related to the effective dissemination of the outcomes of the workshop and enabling adoption of the strategy/action plan developed by the wider organisation.

The results of the field work indicated that the scenario method can effectively be applied by companies. However, the discussions carried out with consulted experts and some other professionals working in governmental agencies highlighted that the application scope of scenario method may not be limited to businesses and any organisational entity delivering products and services to the community potentially could benefit from the scenario method. For example, a senior officer from a local council recently identified two ways the council he is working for can use the scenario method. One is using the method internally to identify service innovations the council can develop in serving the community towards a sustainable future; i.e. to align the council strategy with the long term visions of a sustainable society. The other is using the method externally to deliver workshops for the local organisations to help them in aligning their own innovation paths and strategies with the long term visions of a sustainable society.

Referring back to the objective of the research (i.e. to effectively link the activities/decisions at product development (micro-innovation) level in companies with the transformation which needs to take place at the societal (macro-innovation) level to achieve sustainability), it can be concluded that the application scope (i.e. companies) originally targeted in developing the scenario method has been achieved. Even though not tested, the scenario method can also potentially be used by any type of organisation delivering products and services to the community in addition to the companies.

9.5. Summary of this Chapter

This chapter (along with Appendices IV, V and VI) reported the results of the field work which was undertaken to test and improve the scenario method using an action research methodology. Based on the results of the field work, an evaluation of the scenario method was carried out to evaluate the scenario method from the perspective of research participants, as a futures inquiry tool and in terms of its potential to aid product development teams in planning for system level innovation for sustainability.

The field work consisted of five ARC. The first and third ARC mainly improved the conceptual framework of the method whereas second and fourth ARC mainly improved the workshop design. These two ARC indeed have inner cycles through which the expert consultations in the beginning of the cycles informed the design of the workshops which took place towards the end of the relevant cycles. The third ARC witnessed intense input informing the conceptual framework with implications on the workshop design which was then tried in the fourth ARC after incorporating the expert consultation input from the beginning of that ARC. The fifth ARC did not involve any expert consultation but the results of the workshop informed the conceptual framework as well as the workshop design.

The evaluation of the scenario method indicated that the research participants thought that the scenario method can aid product development teams to incorporate sustainability issues into their decision making in an effective way. The majority of them also thought that the scenario method can influence the business transformation which needs to take place as part of the societal transformation to achieve sustainability. All of the workshop participants of the real company case studies who participated to the entire process found the activity worthwhile for their company. The detailed evaluation of the effectiveness of the scenario method as a futures work and the potential of it to aid in system innovation for sustainability provided supportive evidence for the claim that the scenario method is a valuable and a viable method.

Three outstanding issues related to the scenario method remain as potential areas for improvement and/or further research. The first of these issues is the trade-off between the time/cost efficiency of the scenario method and the depth of the output which can be achieved using it. The second issue is the conflict between the time horizon prescribed to be used by the scenario method and the planning periods conventionally used by businesses which is only a fraction of the time required to transform socio-technical systems. The third issue is about the application scope of the scenario method. The case studies in this research did not include a large company. Therefore the applicability of the scenario method to large companies is not verified. However, the results of the case studies did not indicate the size of the organisation to be a success factor in the effective applicability of the scenario method. The scenario method was tried only with companies and the results indicated that the scenario method can effectively be applied by companies. Potentially, any organisational entity delivering products and services to the community can benefit from the scenario method. Verification of this potential application requires further research.

PART III

COMPLETION: REVIEW, DISCUSSION AND CONCLUSIONS

10. REVIEW AND DISCUSSION OF THE RESEARCH

10.1. CONTRIBUTIONS OF THE RESEARCH

10.1.1. THE SCENARIO METHOD COMPARED TO THE PREVIOUS METHODS USED IN SYSTEM INNOVATION PROJECTS

The scenario method developed as a result of this research brought improvements to the existing scenario methods in multiple ways. The problems identified in relation to existing scenario methods used in system innovation projects can be grouped under three titles: 1. Methodological; 2. Theoretical, and; 3. Those resulting from the underlying, generally implicit and under-acknowledged politics of these methods. These problems have been discussed in detail in earlier chapters. Table 23 serves for a summary.

Table 23. Summary of problems identified in relation to scenario methods previously used in system innovation projects

Methodological problems	Steps of the method are not clear and transparent enough for others to use the method (STS) Scenarios developed either without a guiding vision, starting from present and developed towards an unknown future state (STS), or, starting from a desired envisioned state and present state was not considered (STD and derivatives) Suitable for policy analysis and development in relation to large socio-technical systems such as food, housing etc. and not for micro-scale of innovation (product/service) or smaller operational contexts (e.g. companies)
Theoretical problems	Co-evolutionary approach to innovation was weak (STD and derivatives) Sustainability measure was either insufficient to address sustainability issues (STD and derivatives) or there was none (STS) Causality understanding not aligned with CAS; linear and deterministic, therefore, not suitable to deal with uncertainty and emergence (all)
Underlying politics	Western worldview (all) Techno-centric and technologically-optimistic approach to innovation (all) Used only in the North European socio-cultural and socio-economic context (i.e. democratic, pluralistic, distributed power, high-income, post-industrial) (all) Scenario development and analysis by an expert –who can be also referred to as the ‘transition manager’ (STS) Scenario development (ideally) participatory, analysis by expert (STD and derivatives)

This research addressed these problems in the following ways:

- A theoretical framework was developed in order to guide the development of the scenario method. This theoretical framework:
    - has its roots in CAS and system innovation theory and articulates how product development level relates to the co-evolutionary dynamics existing in the socio-technical system;
    - covers a risk-based MLP model developed in order to enable mitigation of/adaptation to sustainability risks to be the focus of any innovation activity;
    - covers theory and models developed with the specific aim to align activities and decisions at product development level with the required change at the level the socio-technical system;
    - proposes a typology of different socio-technical contexts to enable envisioning a variety of possible sustainable societies so that innovation paths which are not techno-centric can be opened;
- The scenario method combined exploratory (forward flowing) scenarios with normative (backward flowing) scenarios in order to link the unsustainable present (reality) and the desired sustainable future (vision) in an effective way;
- The event-tree approach used in the scenario method allows generation of map-like scenarios flowing through time. This enables linking present and future in an effective way and identification of several innovation paths as strategic alternatives. A map-like, flowing structure also helps addressing emergence and uncertainty inherent in inquiring into the future of CAS by allowing regular, quick and inexpensive alterations to and detailing of the scenario maps. The scenario maps developed by and/or for an organisation can also be systemically linked to scenarios developed for larger systems such as industrial sectors, regions, etc.;
- The operational framework of the scenario method was articulated through designing (and testing/improving) a workshop process and presenting it in detail in order to guide the implementation of the methodical steps of the scenario method;
- The scenario method is not developed to be used under supervision/facilitation of scenario development experts or policy analysts. Instead, it is, complete with its operational framework, developed to be facilitated and used by the members of product development teams. This aims to achieve two things. First, in the lack of a vision of a sustainable society prescribed by an expert or an authority of some sort such as a government policy etc., the participants can inquire into and develop their own vision of a desired sustainable future and indirectly but proactively take part in the broader societal transformation required. Second, scenario

development can also be used by groups which do not have access to a lot of resources such as SMEs, or companies in developing and underdeveloped economic contexts;

- The scenario method, through conceptualising social function fulfilment in the wider context of the socio-technical system, encourages investigating the necessary organisational and behavioural changes as well as technological solutions in order to avoid a techno-centrism and technologically optimist approach to innovation for sustainability, and;
- The scenario method is tested and verified in three different socio-technical contexts all of which with different socio-cultural and socio-economic characteristics.

A recent development in the literature, which took place after the completion of this research, needs to be acknowledged here. Morales (2009) combined backcasting with STS to develop a new method for evaluation of carbon-free hydrogen and battery electric transport scenarios in the Netherlands. The outcome of his critical review of backcasting and STS has quite similar points to the outcome of the critical review carried out as part of this research (reported in Gaziulusoy & Boyle, 2008 and in Chapter 5 under Section 5.5 of this thesis). As a result of his critical analysis, he integrated backcasting with STS for the same reason a double-flow approach to scenarios was developed in this research; i.e. to effectively link present to a normative and radically different future. Even though there are similarities in the methods developed in both of the research projects, Morales' (2009) work is significantly different from this research in terms of its particular aim; i.e. guiding technology development policy. As a result, the scenario method he developed does not intend to link the societal sustainability visions to activities and decisions of product development teams. Also, Morales' (2009) method deals with promotion/evaluation of technologies already acknowledged as (more) sustainable, the method does not provide a means to conceiving sustainable technologies. On the other hand, the scenario method developed in this research helps the product development teams to map alternative innovation paths between the present state and the envisioned future state of a sustainable society which include identification of new product/service and technology concepts fulfilling the social function of concern.

10.1.2. The Contributions of the Research to Its Parent Fields

It was stated earlier that any genuine attempt in the industry towards achieving sustainability should be based on the knowledge provided by sustainability science which focuses on the dynamic interactions between the nature and the society (e.g. Kates et al., 2001; Clark & Dickson, 2003). In order to address sustainability problems more effectively several authors emphasised the need for widening the scope of engineering practice and education curriculum (e.g. Vanderburg, 1999; Boyle

& Coates, 2005; Fenner, Ainger, Cruickshank & Guthrie, 2006; Cruickshank & Fenner, 2007; Davidson et al., 2007; Onwueme & Borsari, 2007). As a response to this need, recently, sustainability engineering has been emerging as a meta-discipline (Mihelcic et al., 2003). This new meta-discipline integrates engineering disciplines in providing solutions for sustainability problems. Since social, environmental and economic systems are interdependent, this new meta-discipline also collaborates with other fields outside of engineering in solving these complex, real-life problems. It is typical of sustainability and systems related research projects to be integrative and problem oriented (e.g. Carew, 2004; Wickson, Carew & Russell, 2006; Hirsch Hadorn, Bradley, Pohl, Rist & Wiesmann, 2006; Zierhofer & Burger, 2007; Hirsch Hadorn et al., 2008; Späth, 2008). Similarly, this research also integrated theories and models from different fields and built on them with the aim to solve a socially relevant problem.

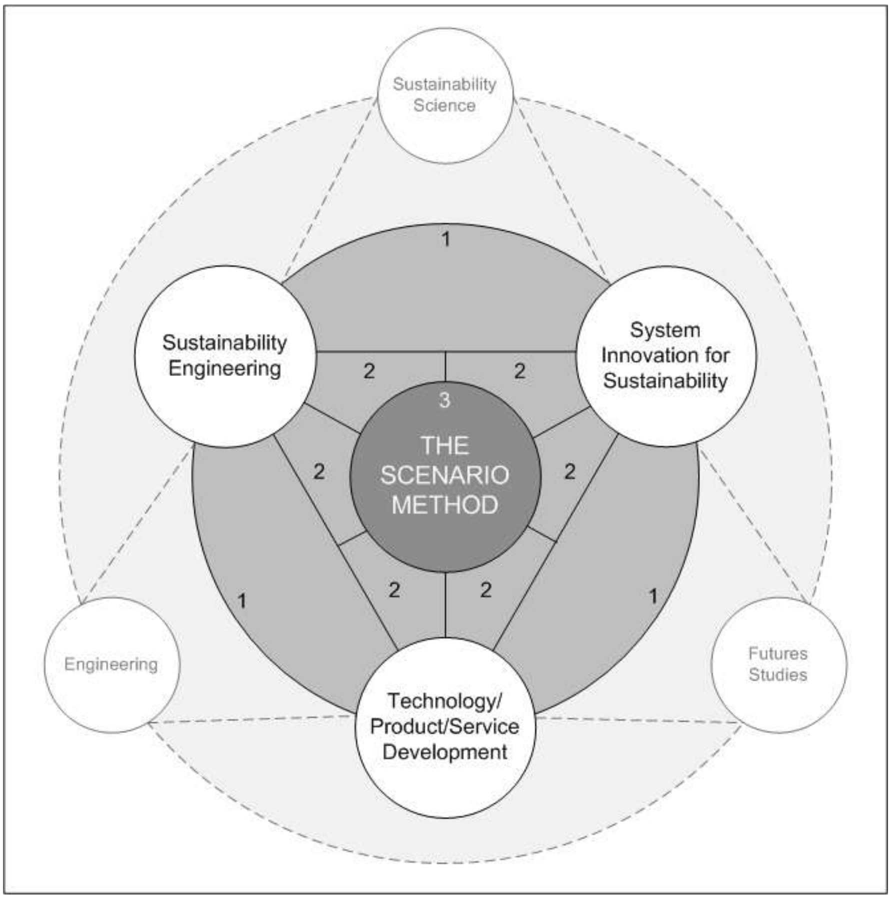

Figure 47. Positioning the research outcomes in relation to its parent fields

Figure 47 shows the positioning of the outcomes of this research in relation to its parent fields. This research advanced the knowledge in all of these areas. However, since the research was integrative, it is not possible to isolate research contributions and assign them to individual parent fields. The specific contributions of this research were:

1. A broad and integrative review of literature related to sustainability and innovation (Chapter 2, 3, 4 and 5) covering the areas of sustainability science, futures studies and system innovation;
2. Development of a theory and conceptual models about system innovation for sustainability at product development level through integration of insights and findings gathered as a result of the literature review. Specifically:
    - Refining the MLP model through addition of a horizontal empirical layer to represent regime dependencies (Chapter 6, Section 6.2.3);
    - Development of a risk-based MLP model (Chapter 6, Section 6.2.3);
    - A model to link product development function to system level innovation (Chapter 6, Section 6.4);
    - System innovation model from the perspective of product development (Chapter 6, Section 6.5);
    - A suggestive and generic typology of different socio-technical contexts (Chapter 6, Section 6.6), and;
3. Development, testing, improvement and evaluation of a scenario method and its operational tool (i.e. a workshop process) which is systemically linking the activities and strategic decisions of product development teams to the long term transformation which needs to take place at the level of socio-technical systems to achieve a sustainable society (Chapter 7, 8 and 9).

The types of knowledge generated in research aiming to solve socially-relevant complex real-life problems are analytical, anticipatory, normative and action-guiding knowledge (Wiek, 2007). According to this classification, the knowledge generated through this research are analytical (integration of discourses and development of conceptual models/frameworks) and action-guiding knowledge (the scenario method). The scenario method is an aid in development of anticipatory and normative types of knowledge and in the scope of this research were developed by the workshop groups during the field work.

10.1.3. The Contributions of the Research to the Broader Society

In terms of research output, since research of this type aims to solve socially relevant problems, it is necessary to position the research output both scientifically and socially (e.g., Pohl & Hirsch Hadorn, 2007; Walter, Helgenberger, Wiek & Scholz, 2007; Merkx, van der Weijden, Oostveen, van den Besselaar & Spaapen, 2007). For the purposes of positioning research in terms of social contribution, Pohl and Hirsch Hadorn (2007) suggest articulating the implications of the research in three different areas which are private sector, civil society and public agencies. Figure 48 shows positioning of the research outcomes in the context of society.

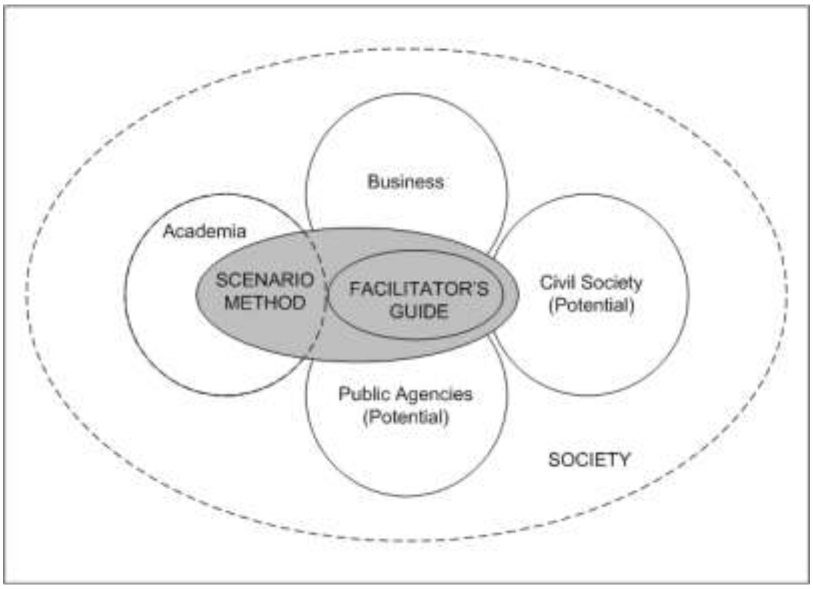

Figure 48. Positioning of the research outcome in the social context

In addition to contributing in the academic body of knowledge (which is explained in the previous section), the scenario method has implications for businesses and potentially for the civil society and public agencies. With its systemic approach, the scenario method links components of the socio-technical system across scales and time-frames. As a result, the scenario method puts the entity and the activity of concern in the focus of planning for sustainable futures for the entire system the entity resides and the activity takes place in. This systemic approach, therefore, enables placing longer time frames and changes/risks/opportunities associated with these time frames in the perspective of the entity during decision making. This is especially important for transforming the private sector since conventionally private sector entities (i.e. companies) have been only concerned about their own – generally short-term- viability. The evaluation of the scenario method both by the research participants (i.e. potential users) and by the researcher indicated that the scenario method can influence the business transformation which needs to take place as part of the societal transformation to achieve sustainability.

In addition to businesses, the scenario method is potentially useful for the public sector and the civil society. The entities in these sectors - such as governmental organisations and NGOs - can also use the scenario method to plan for system innovation for sustainability. The ongoing conversations with representatives of these sectors indicate that the scenario method for the entities of these sectors can be used both internally and externally. The scenario method can help these entities to identify product/service innovations they can develop in serving the community towards a sustainable future. Alternatively, the scenario method can be added to the toolbox of these entities to be delivered as a service to the organisations they work with. This means that the scenario method can also have a synergistic affect and can potentially enable identification of collaborative innovation projects. The real potential and capabilities of the scenario method in public and civil sectors needs to be researched.

In order to socially embed the outcome of this research and maximise its adoption and use in private, public and civil sectors a Facilitator's Guide (Appendix V) has been prepared. As a means to enable the real-life adoption of the scenario method, the Facilitator's Guide is distributed initially to all of the research participants and some interested stakeholders, peers and colleagues. The further dissemination of the guide is planned to be done through making it available online. In order to enable second order dissemination of improved and adapted versions of the scenario method, and to render the tracking of these newer versions possible, the Facilitator's Guide is licensed under Creative Commons Attribution-Noncommercial-Share Alike 3.0 Unported License (Creative Commons, 2010) which allows non-commercial use and sharing of the work and its derivatives as long as attribution to the original work is made. This license, therefore, enables open innovation and potentially increases the social embedding of the scenario method.

10.2. REVISITING THE RESEARCH OBJECTIVE AND AIMS: HAVE THEY BEEN ACHIEVED?

The overall objective of this Ph.D. research was to effectively link the activities/decisions at product development (micro-innovation) level in companies with the transformation which needs to take place at the societal (macro-innovation) level to achieve sustainability. In line with this objective, initially a theoretical framework was developed articulating how activities and decisions at product development level can be linked to the long term and structural changes required at the socio-technical system level to achieve sustainability. Based on this theoretical framework, a scenario method was developed. The scenario method was then tested and improved via field work.

To conclude that the research objective has been achieved, two intertwined conditions needed to be met:

1. The intended users of the scenario method needed to find the scenario method valuable so that it would be used;

2. The use of the scenario method should generate results which aid product development teams towards achieving system innovation for sustainability.

The results of the evaluation of the scenario method by the research participants (for details refer to Sections 9.3.1, 9.3.2 and Appendix VI) provided evidence that the research participants, who are also potential users/facilitators of the scenario method, found the scenario method to be:

1. An effective way to aid product development teams to incorporate sustainability issues into their decision making;
2. Able to influence the business transformation which needs to take place as part of the societal transformation to achieve sustainability, and;
3. A worthwhile activity for their respective companies.

The results of the evaluation of the scenario method (for details refer to Section 9.3.3 and Appendix VI) provided evidence that the scenario method effectively assists product development teams in:

1. Understanding the hierarchical irreversible relationships between the environment, society and economy and between their organisation and these three sub-systems;
2. Understanding the issues threatening the sustainability of the society (i.e. risks to sustainability of the society), the dynamic relationships among these issues and the implications of these on the business or their organisation;
3. Generating normative long-term societal visions within which the risks to sustainability were mitigated/managed/adapted to by the society through a combination of institutional, social/cultural, organisational and technological changes, and;
4. Developing scenario maps to link present to the long-term future visions of a sustainable society they developed enabling alternative innovation paths to be identified.

These results indicate that, both of the conditions are met and the scenario method can now be used in real life projects where product development teams would like to align their activities and decisions with longer-term wider-context requirements of sustainability. Therefore, it is concluded that the overall objective of the research has been achieved at the end of the research.

Since the research aims which guided the three distinguishable phases of the research progressively enabled achieving the overall research objective, in an overall assessment it can be claimed that all of these aims were achieved as well.

11. CONCLUSIONS

11.1. SUMMARY OF THE RESEARCH

The overall objective of this research was to effectively link the activities/decisions at product development (micro-innovation) level in companies with the transformation which needs to take place at the societal (macro-innovation) level to achieve sustainability. In order to achieve this objective, the research took place in three consecutive phases. These phases were:

1. A broad and critical review of literature in areas relevant to the research objective:
   - sustainability and elements of sustainability science;
   - characteristics of innovation for sustainability and theory of system innovation;
   - the relationship between futures studies, sustainability and system innovation;
   - the role of industry in achieving sustainability;
2. Development of a scenario method consisting of:
   - a theoretical framework explaining how product development level relates to system innovation for sustainability;
   - a conceptual framework articulating the criteria which needs to be met by the scenario method and the outline of the method;
   - an operational framework articulating the criteria which needs to be met by the operational tool of the scenario method and a workshop process;
3. Conducting field work which:
   - aimed to receive feedback from the potential users to test, improve and evaluate the scenario method;
   - followed an action research methodology;
   - interweaved consultations with eight local and five overseas experts and workshops with three case studies in New Zealand, in the Netherlands and in Turkey over five action research cycles.

11.2. CONCLUSIONS

Currently, the humanity is at a very important turning point in its short evolutionary history. Simply put, it has to ensure a sustainable human presence on this world. A sustainable human presence on this world requires transformation of the entire socio-technical system which is referred to as system innovation. System innovation requires structural changes to take place within the society. These structural changes cannot happen without the support of stakeholders of the assumed/proposed changes. This thesis focused on industry as one of these major stakeholders in system innovation.

Innovation at system level requires companies to start aligning their products/services, strategies and business models with the society's long-term sustainability visions in a systemic way. Recently there has been increasing interest and promising developments in research addressing sustainability issues in innovation. However, a critical review of this literature concluded that the existing tools and approaches have not been sufficient to guide the industry towards system level innovation. There was also a lack of theory enabling alignment of innovation efforts at product development (micro-innovation) level to the changes which has to take place at societal (macro-innovation) level. This research addressed these needs by first developing one such theory and, based on this theory, a scenario method which can be used by product development teams in planning for system innovation.

The scenario method developed in this research is the first method to address the question of how to link activities and decisions of product development teams to the societal transformation which needs to take place for us to achieve sustainability while targeting product development teams themselves as the users of the scenario method. It is based on a state-of-the-art understanding of system innovation theory and sustainability science. It effectively links present to a radically different future and enables simultaneous leveraging of technological and behavioural changes. It effectively and systemically links the large scale (society) to small scale (product development teams) and challenges the current business mind-set to enable transformation.

To conclude, the author would like to acknowledge the limitations and the short-comings of the scenario method which are discussed in detail in Chapter 9 and Appendices IV and VI. Even though it is concluded that the scenario method developed in this research is the first method linking activities and decisions of product development teams to the required societal level change, it is by no means perfect. Neither does it meet all needs of product development teams to plan and act for system innovation. From a systems thinking perspective, the scenario method developed in this research, the methods critically reviewed as part of this research and the methods to be developed in the future, can potentially provide more effective strategies towards sustainable futures if used in a paradigm of collaboration rather than a competitive one by addressing different levels in the socio-technical system and dealing with the transformation in more detail at their relevant focus. The scenario method developed in this research can be used as a meta-tool to oversee the product development activity in the broader context of the entire socio-technical system and during a long time period over which, theoretically, system innovation should start, mature and finalise.

11.3. CONTRIBUTIONS OF THE RESEARCH

Below is a summary of contributions this research made:

1. A broad, critical and integrative review of literature related to sustainability and innovation covering the areas of sustainability science, futures studies and system innovation;
2. Development of a theory and conceptual models about system innovation for sustainability at product development level through integration of insights and findings gathered as a result of the literature review. Specifically:
    - Refining the MLP model through addition of a horizontal empirical layer to represent regime dependencies;
    - Development of a risk-based MLP model;
    - A model to link product development function to system level innovation;
    - System innovation model from the perspective of product development;
    - A suggestive and generic typology of different socio-technical contexts;
3. Development, testing, improvement and evaluation of a scenario method and its operational tool (i.e. a workshop process) which is systemically linking the activities and strategic decisions of product development teams to the long term transformation which needs to take place at the level of socio-technical systems to achieve a sustainable society, and;
4. Preparation and distribution of a Facilitator's Guide to enable and increase the real-life adoption and impact of the scenario method (i.e. to socially embed the research outcomes).

11.4. RECOMMENDATIONS FOR FURTHER RESEARCH

Based on the results of the field work, the discussion and review of the research and the issues/limitations identified, below is a list of recommendations for future research:

1. Even though the conversations held with consulted experts and some other professionals working in governmental agencies highlighted that the potential organisational use scope of the

scenario method can be wider and any organisational entity delivering products and services to the community can benefit from the scenario method, this is yet to be verified. The organisational use scope of the scenario method needs to be further clarified by testing (and altering if necessary) it in organisations other than companies;

2. Even though the scenario method has successfully been implemented in three different socio-cultural contexts, it has not yet been tested in a bottom-of-the-pyramid context. The application scope of the scenario method needs to be further clarified by testing (and altering if necessary) it in socio-cultural contexts other than the ones the three case studies represented;
3. Even though the scenario method is unique in linking the societal transformation needed to achieve sustainability to the actions/decisions taken at product development level (i.e. linking the different scales and time-frames relevant to system innovation) in a systemic way, it is by no means a stand-alone method capable to aid in generating all of the knowledge necessary to understand and transform the socio-technical systems. Further research needs to be done to investigate how the method can synergistically interact with other available tools and methods relevant for product development level;
4. In depth research about creativity methods suitable for generating breakthrough product/service ideas needs to be carried out and the outcomes needs to be added as a toolbox to the workshop design;
5. Even though in order to socially embed the outcomes of the research and to enable further improvement of the scenario method a Facilitator's Guide is prepared and distributed to potential change agents, it is not certain if the workshop can effectively be facilitated with the aid of this guide by people with no special facilitation training or no expert knowledge in the areas the scenario method is based on (i.e. sustainability science, systems thinking). This needs to be further investigated and the guide needs to be improved if necessary. However, the significant research potential lies in developing a quick and effective method for training facilitators to run workshops;
6. An indirectly relevant but interesting outcome of the workshops was the sustainability models (and organisational models based on these) developed by participants (see Section 9.3.3 and Appendix VI). All of these models demonstrated an innate understanding of hierarchical and irreversible relationships between the environment, society and economy by the participants none of whom previously came across the two models of sustainability (discussed in Chapter, Section 2.2). Further research in order to test this phenomenon more widely could yield to essential knowledge for leveraging transformative projects.

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Personal Communications

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Allan, Tim	Mr.	Product Designer Founder and CEO of Locus Research, A New Zealand based design research company.
Elmore, Mark	Mr.	Head of Design, Fisher & Paykel Appliances Ltd., A New Zealand based appliances company.
Geels, Frank	Prof.	University of Sussex, Science and Technology Policy Research Unit, Co-developer of Socio-technical Scenarios, Multi-Level Perspective of System Innovations (Geels).
Gianni, Christian	Mr.	Vice President Engineering, Fisher & Paykel Appliances Ltd., A New Zealand based appliances company.
Kamphorst, Eva	Dr.	Communication Manager, Dutch Knowledge Network for System Innovations and Transitions.
List, Dennis	Dr.	Former of Audience Dialogue Consultancy, Adelaide, Australia, (http://wwwaudiencedialogue.net), Futurist, Developer of Scenario Network Mapping.
McLaren, Jake	Mr.	Principal Consultant with PE-Australasia, a subsidiary of PE-International, global experts in corporate and product sustainability
Quist, Jaco	Assis. Prof.	Delft University of Technology. Faculty of Technology, Policy, Management, Backcasting expert.
Weaver, Paul.	Dr.	Partner in Methods and Tools for Integrated Sustainability Assessment (MATISSE) Project, April 1st, 2005 - March 31st, 2008. Co-author of Sustainable Technology Development (Weaver et al., 2000).

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APPENDIX I:
CREDENTIALS OF THE EXPERTS CONSULTED DURING FIELD WORK

Expert 1 **New Zealand**

Expert 1 is the founder and principal director of a New Zealand based design research company specialised in sustainability and innovation and life cycle thinking in product development. The company was established in 2002. Prior to establishing the company, Expert 1 led a team of designers at a leading furniture maker of New Zealand for 5 years undertaking a diverse range of product research, development and design. Expert 1 has 15 years of experience in sustainable product development in the commercial domain leading technology oriented product development projects and diversified design teams.

Expert 2 **New Zealand**

Expert 2 is the founder and CEO of a New Zealand based organisation which is promoting sustainable business practices and helping businesses willing to undertake sustainability as a strategic priority. This organisation was established in 2002. Prior to establishing this organisation Expert 2 worked in projects related to school education, environmental management systems, The Natural Step, and sustainable design. Expert 2 has been a board member of three businesses all of which has sustainability as their core business focus. Expert 2 has sixteen years of experience in sustainability and innovation area.

Expert 3 **The Netherlands**

Expert 3 is an Assistant Professor in the Faculty of Industrial Design Engineering, Design for Sustainability Program, at the Delft University of Technology, the Netherlands. Previously, Expert 3 ran a small ecodesign consultancy between the years 1994-1996. Expert 3 is currently leading ecodesign/sustainable design projects internationally as well as teaching in these areas for the past twelve years.

Expert 4 **New Zealand**

Expert 4 has been working as a transformational coach, trainer and facilitator for eight years, working in leadership, personal, team and organizational development. Expert 4 is the co-founder and associate director of a small company based in New Zealand providing facilitation, coaching, mediation, personal health and development services. Expert 4 is also an associate of another New Zealand based company providing facilitation, coaching and mediation services as well as training in these areas.

Expert 5 **New Zealand**

Expert 5 has more than thirty years of experience as a group facilitator. In addition to facilitation, Expert 5 is a coach, author and researcher. Expert 5 is a co-founder and director of a New Zealand-based company providing facilitation, mediation, and coaching services to government, business and community sectors since sixteen years. Expert 5 received a Ph.D. degree in 2003 and specialised in facilitation of sustainable co-operative processes in organisations. Expert 5 is a member of the Generative Change Community, Asia, a sustaining member of the International Association of Facilitators, a former board member as Vice Chair International (2001-2007) and was instrumental in the development of the International Association of Facilitators Code of Ethics for Group Facilitators.

Expert 6 **New Zealand**

Expert 6 is currently the director of a New Zealand based company helping businesses and non-profit organisations to establish a sustainability strategy encompassing economic, social, cultural and environmental aspects. Expert 6 has twenty years of experience in media and consumer research (in Nielsen Media Research) and in the past five years directed this expertise to the areas of sustainability and social responsibility. Prior to working for this company, Expert 6 established and ran his own consultancy for more than two years. Expert 6 is involved in a number of industry working and advisory groups related to sustainable business and the development of the community and voluntary sector.

Expert 7 **New Zealand**

Expert 7 is Principal Consultant with a subsidiary of an international consultancy on corporate and product sustainability. Currently Expert 7 is consulting in the areas of Life Cycle Management, Life Cycle Assessment and Design for Environment to clients in private and public sector. Expert 7 has over fifteen years of experience in Life Cycle Management, Life Cycle Assessment and Design for Environment within consultancy, corporate and academic environments.

Expert 8 **USA**

Expert 8 has been the associate director of The Center for Sustainable Enterprise, which is under the Stuart School of Business at the Illinois Institute of Technology, USA, for ten years. Expert 8 is teaching as an adjunct professor within the school's Environmental Management Program as well as at the Institute of Design. Since 1998, Expert 8 is the founder and has been president a consultancy providing business development strategies dedicated to eliminating or reducing the negative environmental consequences of business and commerce. Clients of this consultancy include businesses, non-government organizations, and academic institutions. Formerly, for sixteen years, Expert 8 was Director of Product Development with a company developing award-winning products, services, and programs related to the management of materials for resource recovery. In addition to directing the company's Product Development Group, Expert 8 founded and directed the company's model Product Stewardship Program. Expert 8 served on the US EPA Peer Review Group for its Product Life Cycle Assessment Project and was an invited technical expert to the Canadian Standards Association's (CSA) Environmental Labeling, Design for the Environment Guidelines and The Strategic Advisory Group on the Environment (SAGE) the precursor group to the ISO-14000 Environmental Management Standards. Expert 8 was subsequently a member of the US Contingent in the development of the ISO 14000 General Guidelines.

Expert 9 **Hong Kong SAR/China**

Expert 9 is an Assistant Professor in the Department of Industrial and Product Design, at the School of Design of Hong Kong Polytechnic University, Hong Kong, for 14 years. Under the School of Design, Expert 9 established and became the leader of Asian Lifestyle Design Research Lab three years ago. Before joining the Hong Kong Polytechnic University, Expert 9 has participated in several visionary and innovative projects with companies such as JVC (Japan), Philips (the Netherlands), Hewlett Packard (France) and Alessi (Italy). Expert 9 also has joined O2 Sustainable Design Network as a corporate liaison, and as one of the team leaders of the 'sustainable design' initiative within Philip Design. Together with a professor of Milan Polytechnic University, Italy, Expert 9 has co-founded the Chinese Network on Design for Sustainability in China in 2000. Expert 9 has published a book, papers, and articles particularly about design for sustainability. Expert 9 has been invited as the regional advisor and contributor of the two UNEP sponsored publications on Product-Services Systems and Sustainable Design.

Expert 10 **New Zealand**

Expert 10 has been the Environmental Manager of a medium-size office furniture company operating in New Zealand, for four years. As part of this role, Expert 10 is responsible for managing the company's environmental aspects, controlling its environmental management system, and developing its environmental strategy. In 2008 Expert 9 was a founding member of a company which provides consultancy for companies to move towards environmentally sound practices throughout their organisation.

Expert 11 **UK**

Expert 11 has been working as Head of Innovation for six years for a UK based, independent, non-profit organisation with a mission to promote sustainable development by helping businesses and public organisations to understand and manage the risks and to find new opportunities towards a sustainable society. Before working for this organisation, Expert 11 provided consultancy on sustainable innovation and ecodesign for companies like Electrolux and Philips.

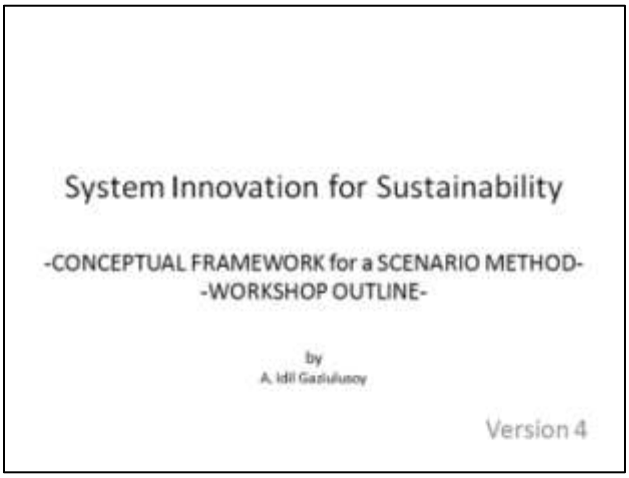
Expert 12 **New Zealand**

Expert 12 has been working as a Sustainable Business Facilitator for a Regional Council in New Zealand for two years. There are three main components of this role. These are implementing corporate sustainability initiatives and strategy for the council, facilitating regional and cross regional groups to drive corporate sustainability and regional waste minimisation outcomes and, co-ordinating a resource efficiency programme for SME's. Previous experience of Expert 12 involves managing contaminated site assessment and remediation projects, and providing consultancy to a local council in Australia in relation to community oriented sustainability initiatives.

Expert 13 **The Netherlands**

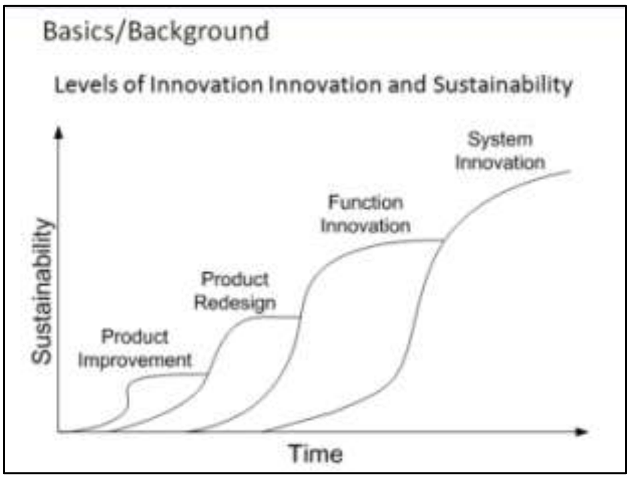
Expert 13 is an Assistant Professor in the Faculty of Technology, Policy and Management, at Delft University of Technology, the Netherlands. Expert 13 has been teaching and researching on sustainable foresight, scenarios, backcasting and sustainable (system) innovation for ten years in this organisation. Previously, Expert 13 was employed as a Project Coordinator for the Dutch National Inter-Ministerial Programme for Sustainable Technology Development which took place between 1993 and 2001.

APPENDIX II: THE FINAL VERSION OF THE PRESENTATION USED DURING THE EXPERT CONSULTATIONS



The purpose of this meeting is to get your feedback about the scenario method as an expert working in the joint area of innovation and sustainability and as a potential user of the method. I'll first present the theoretical background this research is based on briefly and state the underlying assumptions. Then I'll present the framework of the method in the form of the criteria the method needs to meet. Finally I'll briefly talk about a workshop outline that I designed as a possible way of implementing the method. After the presentation, I'll give you time to ask the questions you might have. Once all your questions are answered, I'll give you an evaluation questionnaire to fill out.

This presentation is designed to keep visual distraction to a minimum in order to keep the focus on the content and ideas to be evaluated.



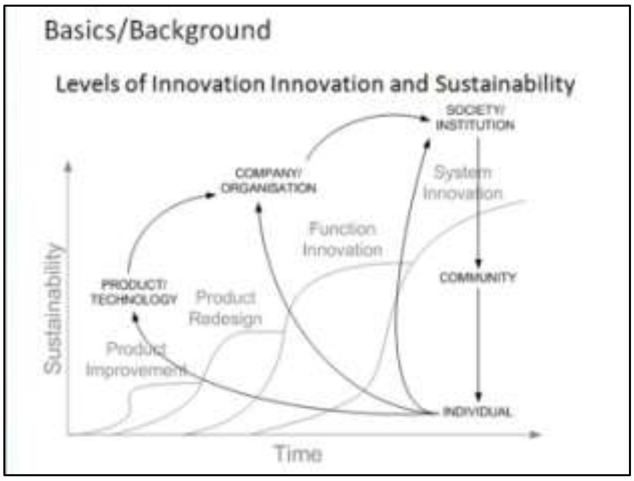
This graph shows the four levels of innovation and how they relate to sustainability.

The first level is product improvement. Product improvements are focused on reducing environmental impacts of existing products.

The second level is product redesign. In product redesign, product concept remains almost intact but either the product or its components are further developed or replaced. The first and second levels are where most of the efforts are focused at the moment, driven mainly by the regulatory push/push mechanisms. These first two levels have product focus and are performed within the realm of established technologies and social uptake of them.

The third level is function innovation. At this level, the innovation is not limited to existing product concepts but related to how the function is achieved. This level generally constitutes a transition between product focus and system focus. In function innovation, the social function of products or technologies is of concern and questioned. I'll talk about it a little bit in more detail later but social function is what exactly we aim to meet by a specific technology or product and whether there is another way of fulfilling that function. Currently, certain product-service-system applications fall into this category.

The fourth and final level of innovation is system innovation. At this level the whole socio-technical system is replaced by a new system. Some historical examples of system innovation are the transition from sailing ships to steam ships, the transition from horse-and-carriage to automobiles, and the transition from piston engine aircrafts to jetliners in American aviation. The older and much more profound system innovations are agricultural and industrial revolutions.



As you move towards the upper levels of innovation, the complexity of the problem increases. Since you move towards upper levels, the context of change required widens. At the first two levels, company is a sufficient entity for analysis and action. However, towards upper levels the change requires collaboration of many stakeholders, some of which are hardly counted as stakeholders today. At system level innovation we talk about innovation at institutional level, at the very fundamentals of society including every single aspect and element of the socio-technical system.

The primary assumption this research is based on is that in order to achieve sustainability, we need innovation at system level. I'd like to articulate on this a little bit.

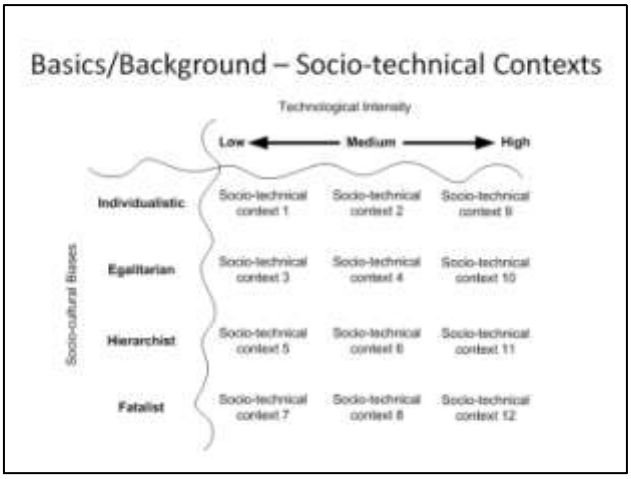
The 'System' we talk about here is the socio-technical system. Socio-technical system of course is all about the interrelationships between society, technology , economy and the environment. We focus on the socio-technical system because society and technology mutually shape each other and therefore both social and technological change should be considered together.

System innovation is radical change at system level. This means that there'll be a transition and at the end of this transition the resulting socio-technical system will be radically different from the one at the start. However, this doesn't necessarily mean that everything in the socio-technical system will radically change. Neither does it necessarily imply a rapid pace of change. Yet these are possibilities for some components or subsystems.

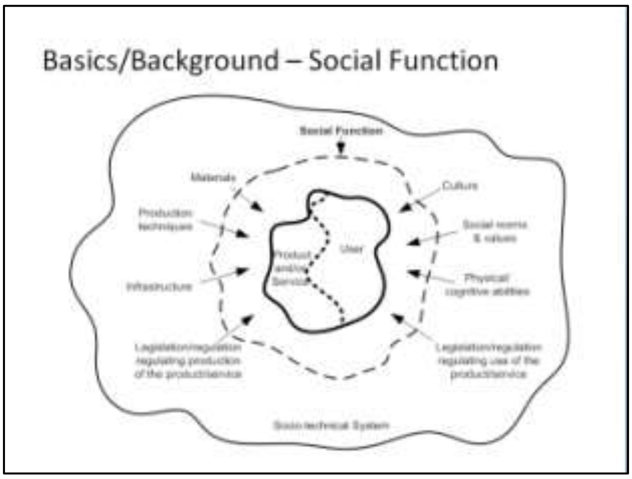
Technological optimism or techno-centricism has proven to be faulty. Technology will not save us. Therefore the focus of system innovation should not necessarily be new/smart/hi-tech technologies but rather technologies which are appropriate for the particular context they're meant to be used in.

Related to the previous point, when considering system innovation, care for the specific needs of the context must be given. Also, there is no one-size-fits-all solutions. Different contexts need different solutions not only for economic and technological, but also for cultural reasons.

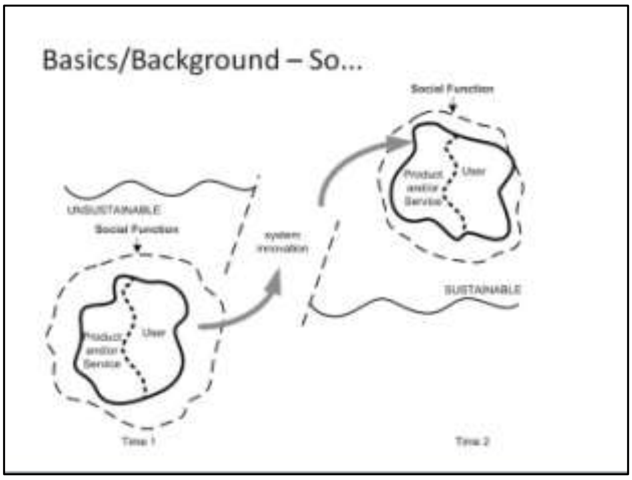
System innovation will not happen overnight. It requires long-term thinking and coordinated action. System innovation cannot be planned and enforced top-down but can only be steered at best. The entirety of all actors in the socio-technical system and their self-organisation will determine the path and success of any system innovation.



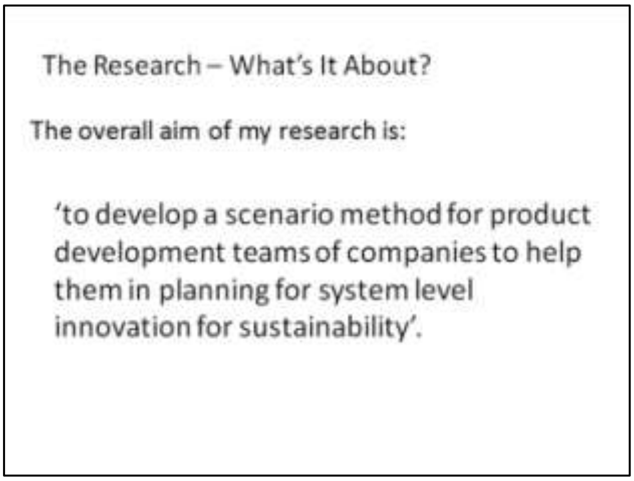
To determine a typology of socio-technical contexts this figure is based on anthropological work about socio-cultural biases. The four socio-cultural biases are matched with technological intensity of solutions appropriate in different contexts to generate twelve generic types of socio-technical contexts. It should be noted that the socio-cultural biases are ideal types and in reality there is a lot of fluidity among them. Similarly, the technological intensity row represents two opposite ends and the middle of a spectrum. Even though these twelve types are highly ideal, they serve sufficiently for the purposes of generating normative visions. In each socio-technical context shown in the figure, the same social function can be fulfilled by a different combination of technology/user.



Social function cannot solely be described technologically but it also has a social dimension. Social function fulfillment is therefore a function of materials, production techniques, infrastructure, etc which shape the product/service and the culture, social norms, and cognitive/physical abilities which define the user. It should be noted that, service provision also requires hardware so talking solely about service is not possible but we can talk about a system of products and services. At the interface between the physical aspects of the product and the experience of the user, lies the social function being met. In this sense, the product and user are co-dependent and meet each other at the function. Therefore, they need to be acknowledged individually yet considered simultaneously in system innovation as complementary to each other. It should be noted that the size of the physical sphere may vary independent of the function since a function can be met in multiple ways some of which will be more material intensive than the others.

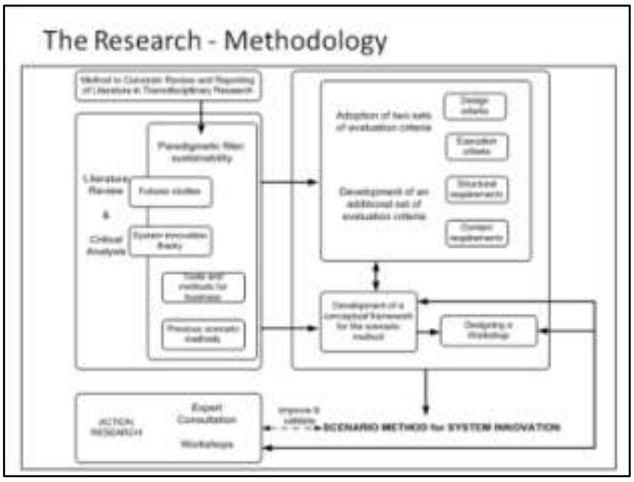


So, simply put, from the perspective of product development system innovation is to provide the same function in the future through a combination of innovations both at the technological and at the social sphere. This is a process a single company can have very limited control over. It will require companies to collaborate with other actors of the socio-technical system including other companies, NGOs, customers and government bodies and actively engage in the task of creating a sustainable society.



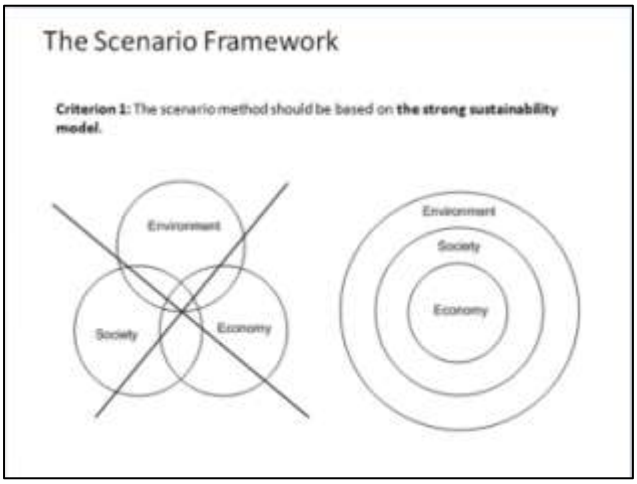
This brings us to the aim of my research. I, as an actor in the socio-technical system, would like my research to serve towards this much wider and longer-term vision of achieving a sustainable society too. I am particularly interested in empowering businesses and product development teams so that they can actively take part in system level innovation.

So, the overall aim of my research is to develop a scenario method for product development teams of companies to help them in planning for system level innovation for sustainability.



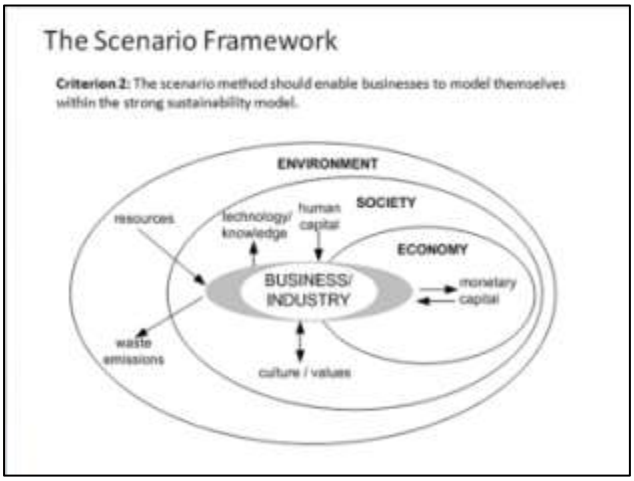
This is basically how I did my research. Of course the whole process wasn't as linear and straightforward as it looks here. As a result of following this methodology, I identified structural requirements and content requirements that the scenario method needs to meet for the particular aim of my research. These criteria establish the conceptual framework of the scenario method. I also designed a workshop process based on this conceptual framework. As part of the overall methodology, I'll use your feedback in an iterative process of improving the method if necessary.

Now, I'll present the conceptual framework of the scenario method.



In investigating and intervening in the role of businesses in achieving sustainability, the model currently being used is the weak sustainability model which is also the basis of triple bottom line approaches. The weak sustainability model assumes that either unlimited substitution among different kinds of capital is possible or that money is the universal substitute for anything. These assumptions often promote trade offs at the expense of the environment or create social injustice. Strong sustainability model represents the irreversible hierarchical dependencies between the environment, society and economy and emphasises that the different capitals subsumed by the environment, society and economy cannot be substituted and are complementary.

Therefore the first criterion is that the scenario method should be based on the strong sustainability model.

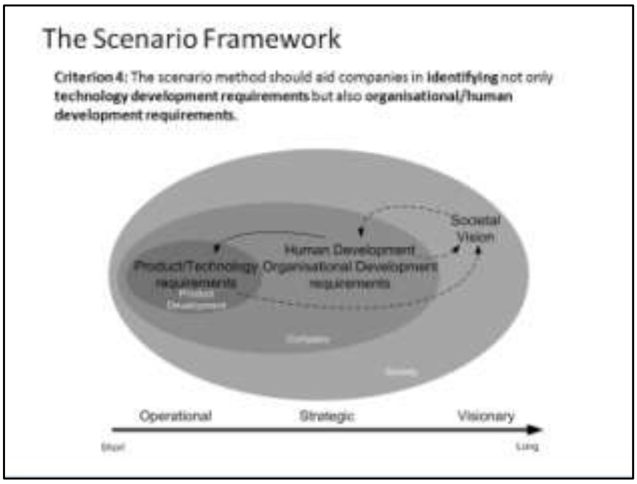


Businesses are one of the major causes of unsustainability, but they are also one of the most important agents of technological and social change. Businesses are not entities needing to be corrected but they are mirrors of the society they operate in. They'll either co-evolve with the society or become unsuccessful. It is important to emphasize that businesses are strictly subject to the irreversible hierarchy of the strong sustainability model and reference the interactions between the businesses and the environment, society and economy to this model.

Therefore the second criterion is that the scenario method should enable businesses to model themselves within the strong sustainability model.

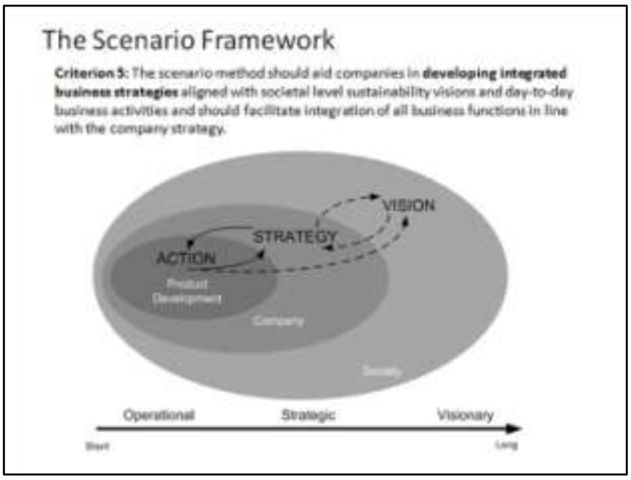
Individual companies have very limited agency to influence change at the systemic level. Nevertheless, companies are part of society. Therefore, their strategic goals should not be contradictory to visions of society and should be aligned with the goals desired at societal level to achieve sustainability.

So the third criterion is that the scenario method should link the planning periods applicable to companies (operational and strategic) to the long-term planning period (visionary) in order to enable companies to address long-term societal visions in their strategies and effectively implement these strategies in product development.



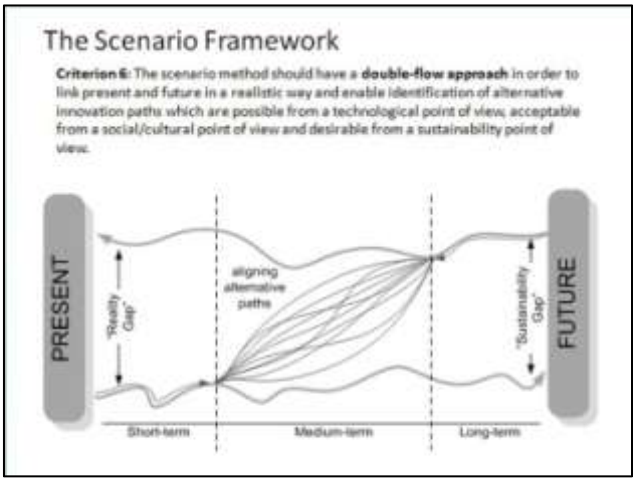
From an organisational point of view, sustainability is ensured by adaptation to external forces through management of internal change. In addition, the organisational context will determine the success of any technical activity since the capacity, knowledge and capability to innovate is generated, assessed, developed and used within the organisational context. Organisational innovations should cover a longer time span than technological innovations in order to be able to influence technological innovations towards sustainability. Organisational innovations are planned at the company level and within the strategic period.

So the fourth criterion is that the scenario method should aid companies in identifying not only technology development requirements but also organisational/human development requirements.



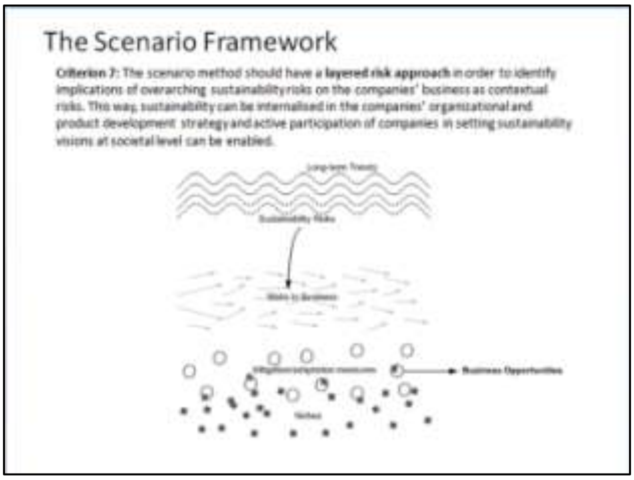
The implications of a normative sustainability vision needs to be integrated into day-to-day activities at product development level. This requires internalisation of sustainability into company strategy along with other business priorities. Since successful product development requires integration of all major business functions within a company and since company strategy needs to be referenced to future visions in order to guide product development towards system innovation, the scenario method should enable integration of business functions in line with the organisational/strategic plan. Therefore, construction and organisation of product development teams will play a very important role in any attempt for system level innovation to be successful. The organisational and technological barriers to integration of business functions need to be acknowledged along with possible facilitating mechanisms in developing a scenario method for the use of companies.

So the fifth criterion is that the scenario method should aid companies in developing an integrated business strategy aligned with societal level sustainability visions and day-to-day product development activities and should facilitate integration of all business functions in line with the company strategy.



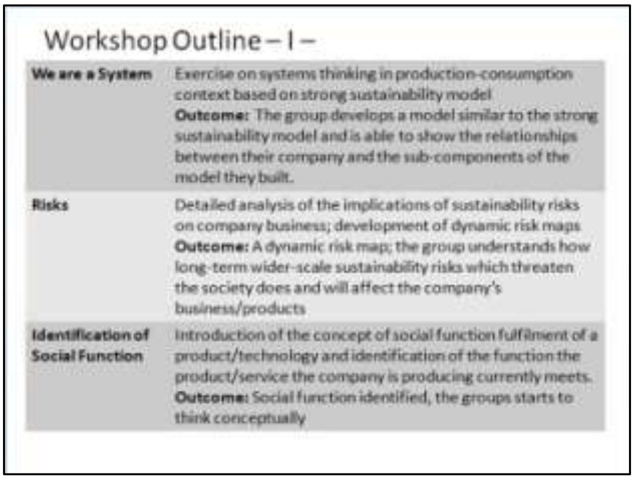
Some of the previous projects in the context of system innovation developed forward flowing, predictive or explorative scenarios which started from the present and flowed towards an undetermined future. Some other projects developed backward flowing, normative scenarios, starting from 50 years in the future towards a never-reached present. Starting only from the future may result in not being able to acknowledge the lock-ins needing to be overcome and which are embedded in the present socio-technical system. On the contrary, starting from present and developing scenarios based on strict causality may limit multiplicity of paths or even the possibility of developing a path for periods longer than medium term.

So the sixth criterion is that the scenario method should have a double-flow approach in order to link present and future in a realistic way and enable identification of alternative innovation paths which are possible from a technological point of view, acceptable from a social/cultural point of view and desirable from a sustainability point of view.



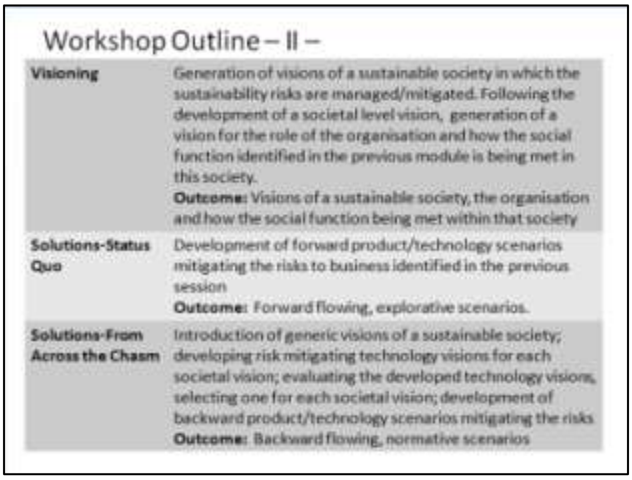
The seventh criterion is that the scenario method should have a layered risk approach in order to identify implications of overarching sustainability risks on the companies' business to render sustainability risks relevant to the companies' present businesses and to identify mitigation/ management measures as opportunities. This way, sustainability can be internalised in the companies' organizational and product development strategy and active participation of companies in setting sustainability visions at societal level can be enabled.

These seven criteria established the framework. Now I'll briefly present the workshop outline.

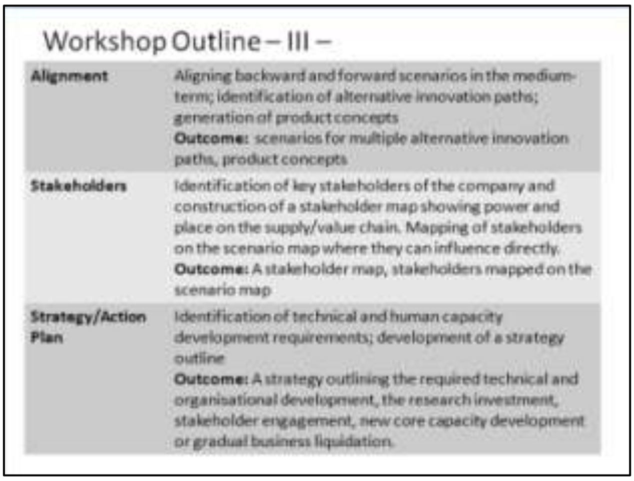


The workshop is designed to take place over either two full-days or four half-days even though it can take longer depending on how much detail the company would like to put into certain modules. Two days in total is the minimum time required to address all of the criteria set in the conceptual framework.

First half consists of six main modules which can either be undertaken over a full-day or can be divided over two half days. Initially the group undertakes an exercise on systems thinking in production consumption context based on the strong sustainability model. This is followed by detailed analysis of implications of sustainability risks on company business and development of dynamic risk maps. Following development of risk maps, the concept of social function is introduced to the group and the group identifies the social function their particular product or service is meeting currently.



After identification of social function, the group develops forward flowing, explorative scenarios. These scenarios start from the present and flow towards the future. On a step by step basis these scenarios identify how should the product evolve and how should the user behaviour change to fulfil the social function to mitigate the risks to business. Next module is generating backward flowing, normative scenarios starting from the future. In this module the group is introduced to generic visions of a sustainable society. These generic visions are also suggestive of current or future markets. The group develops risk mitigating technology visions through backcasting for each of or the selected generic sustainable society visions. If the group is large enough to be divided into two sub-groups, these two modules can be run at the same time each group working on one of the modules and sharing their scenarios in the end.



Workshop Outline – III –

Alignment	Aligning backward and forward scenarios in the medium-term; identification of alternative innovation paths; generation of product concepts **Outcome:** scenarios for multiple alternative innovation paths, product concepts
Stakeholders	Identification of key stakeholders of the company and construction of a stakeholder map showing power and place on the supply/value chain. Mapping of stakeholders on the scenario map where they can influence directly. **Outcome:** A stakeholder map, stakeholders mapped on the scenario map
Strategy/Action Plan	Identification of technical and human capacity development requirements; development of a strategy outline **Outcome:** A strategy outlining the required technical and organisational development, the research investment, stakeholder engagement, new core capacity development or gradual business liquidation.

The second half of the workshop has three main modules which can either be undertaken over a full-day or divided into two half days. In the first module, the explorative, forward flowing and normative, backward flowing scenarios are aligned in the middle. This way multiple alternative innovation paths are identified and some product concepts that the product development can start to develop may be generated. This module is followed by a short module in which a stakeholder map is developed considering the supply and power relationships. The stakeholders are mapped on the scenario map where they can be of most influence. This module is followed by the final module in which a strategy or an action plan is developed. In this module, the group engages in dialogue to make decisions and develop an outline strategy. The issues which can be discussed cover research investment, capacity development, stakeholder engagement, development of new core capacity, or gradual liquidation of the business.

Appendix III:
Questionnaires Given to the Research Participants

A. Evaluation questionnaire given to group participants

1. Which one of the below job titles describe your role in your company best? Please choose one.
   - Design Engineer
   - Product (Industrial) Designer
   - Business Strategist
   - Marketing Specialist
   - Environmental/Sustainability Manager
   - Other (please indicate).............................

2. In an overall assessment, do you think the scenario method can aid product development teams to incorporate sustainability issues into their decision making in an effective way?
   - Yes
   - No
   - Don’t know

3. In an overall assessment, do you think the scenario method can influence the business transformation which needs to take place as part of the societal transformation to achieve sustainability?
   - Yes
   - No
   - Don’t know

4. Have you ever been to any futures workshop before?
   - Yes (Where and when was this workshop? What was the specific aim of this workshop? Who/Which organisation did offer the workshop? *Please answer briefly to the space provided below for each of the futures workshops you have attended*)
   - No

5. In an overall assessment, do you think the activity was worthwhile for the company?
   - Yes
   - No
   - Don’t know

6. What did you think was the best, most useful, or most interesting part of the workshop - and why?

7. What did you think was the worst, least useful, or least interesting part - and why?

8. How do you think the process could have been improved?

9. Are there any other comments you would like to make?

B. Evaluation questionnaire given to individual workshop participants

Profession:

Job Title:

1. In an overall assessment, do you think the scenario method can aid product development teams to incorporate sustainability issues into their decision making in an effective way?
   - ☐Yes
   - ☐No
   - ☐Don't know

2. In an overall assessment, do you think the scenario method can influence the business transformation which needs to take place as part of the societal transformation to achieve sustainability?
   - ☐Yes
   - ☐No
   - ☐Don't know

3. Have you ever been to any futures workshop before?
   - ☐Yes (Where and when was this workshop? What was the specific aim of this workshop? Who/Which organisation did offer the workshop? *Please answer briefly to the space provided below for each of the futures workshops you have attended*)
   - ☐No

4. What do you think is the best, most useful, or most interesting part of the scenario method - and why?

5. What do you think is the worst, least useful, or least interesting part - and why?

6. How do you think the process could have been improved?

7. Are there any other comments you would like to make?

C. Evaluation questionnaire given to consulted experts

1. In an overall assessment, do you think the scenario method can aid product development teams to incorporate sustainability issues into their decision making in an effective way?
   - Yes
   - No
   - Don't know

1. In an overall assessment, do you think the scenario method can influence the business transformation which needs to take place as part of the societal transformation to achieve sustainability?
   - Yes
   - No
   - Don't know

1. What do you think is the best, most useful, or most interesting part of the scenario method - and why?

5. What do you think is the worst, least useful, or least interesting part - and why?

6. How do you think the process could have been improved?

7. Are there any other comments you would like to make?

D. Questionnaire used to collect professional information from the consulted experts

Name:
Surname:
Preferred Title: ☐Ms ☐Miss ☐Mrs ☐Mr ☐Dr

1. Which organisation are you currently working for?

2. What is your role in that organisation?

3. How long have you been working in that organisation?

4. Please briefly explain your work experience relevant to sustainability and innovation prior to working for this organisation.

5. In which one(s) of the below areas do you see yourself as an expert and/or provide consultancy to businesses?

    ☐Engineering design (general)
    ☐Industrial design (general)
    ☐Design research (general)
    ☐Marketing (general)
    ☐Business strategy development (general)
    ☐Engineering design (sustainability specific)
    ☐Industrial design (sustainability specific)
    ☐Design research (sustainability specific)
    ☐Marketing (sustainability specific)
    ☐Business strategy development (sustainability specific)
    ☐Environmental management
    ☐Life cycle assessment of products
    ☐Business risk assessment
    ☐Futures studies
    ☐Group facilitation
    ☐Other (Please state:..)

APPENDIX IV:
DETAILED RESULTS OF ACTION RESEARCH CYCLES

ARC 1

Background

This ARC saw a rapid maturation. Only one expert consultation was carried out during this cycle. At the end of this consultation both the conceptual framework and the workshop design was changed, therefore, the cycle was completed.

Reflections/Insights

The particular reflections which arose from this ARC were:

1. The conceptual framework should explicitly demonstrate that the method was based on the strong sustainability model. In its initial version, there was no explicit reference in the conceptual framework to the sustainability model adopted in developing the scenario method;
2. The method should enable product development teams to model themselves in the strong sustainability model, and;
3. The potential application area might be larger than originally anticipated; i.e. could be used for service innovation in addition to product innovation and could be used by any type of organisation (i.e. governmental organisations, NGOs, hybrid organisations) which would like to align their day to day actions with the societal transformation which needs to take place for humanity to become sustainable.

Changes/Improvements

Based on the reflections and insights gathered from this ARC, the following changes/ improvements were brought to the scenario method:

1. The conceptual framework was changed to explicitly demonstrate that the method is based on the strong sustainability model, and;
2. The workshop design was changed to include a module (called 'We are a system') consisting a group process to enable the group to investigate the relationships between the environment, the society and the economy and, to build a world model based on the understanding gained by

the participants from this investigation and then to place their organisation in the world model they built considering the relationships that their organisation has with these elements. The output of the process was identified as successful if the group built a world model similar to the strong sustainability model and, was able to position their organisation on this model identifying its relationships with the environment, society and economy.

ARC 2

Background

This ARC consisted of consulting one overseas and three local experts and holding a workshop with Case Study 1. This case study (following from the Reflection 3 of the previous ARC) provided the opportunity to try the scenario method with a service company. This ARC provided input mainly to improve the workshop design.

Reflections/Insights

The particular reflections which arose from this ARC were:

1. List (2005) identified enabling reflection with efficient use of time as a design criterion which needs to be met by a futures inquiry process. He designed and executed his workshops as four half-day sessions which were several days apart from each other. He did not try a different schedule (e.g. two full-days instead of four half-days or running the sessions without several days in between) to compare the results of which with the four half-day version in terms of accommodating reflection. Consequently, it was not clear that a workshop design enabling reflection should necessarily be spread over four weeks or longer. During the preparatory period of this field work when companies were contacted to request their participation in this research, they saw that the man-hours to be allocated to the workshops as a big commitment on their behalf and, as an indirect but unjustified expense. This was especially the case for those companies which had not used futures inquiry methods in their business before and/or which did not have sustainability among the organisation's strategic priorities. Therefore, it became obvious that if the scenario method was going to be used by change agents to initiate transformation in an organisation, it needed to happen with the least possible disturbance to the organisation. As a result, the initial workshop design favoured two full-days over four half-days without any specifications on the quantity of days in between the sessions since, in real life, change agents will have to go with whatever is convenient for the organisation and

participants unless there is a lot of enthusiasm within the organisation and therefore co-operation and commitment levels were high. Nevertheless, in the beginning of this ARC, two of the experts consulted highlighted that the process would be very challenging for businesses because it would force them to think radically differently than they were normally used to (i.e. work with new concepts and much longer planning periods), and therefore, the workshop participants might need a more reflective process than two full-days could accommodate;

2. Some of the terms overlap with terms commonly used in businesses (e.g. vision) but with slightly different meanings or scope. Some other terms are unfamiliar to businesses (e.g. social function). Therefore the terminology used might confuse participants and some clarification was required;
3. The module 'We are a system' which was added to the workshop process as a result of ARC I, worked successfully. When participants were given the instructions and three circles, even though all of them were familiar with the TBL approach, none of them came up with the weak sustainability model which is the basis of the TBL approach (for the detailed discussion on models of sustainability see Chapter 2, Section 2.2). All of the participants suggested models which indicated some interrelationships between the three components even though initially none of those models explicitly showed hierarchical dependencies. One participant drew a model similar to the strong sustainability model at his first attempt and, as soon as he explained his reasoning, all of the other participants aligned with his thinking. The experience of this group (later the other two groups also developed similar world models) was an indication that the weak sustainability model cannot be naturally conceptualised as a result of a logical process aiming to understand the relationships between the environment, society and economy. Following the initial model of three concentric circles, the group developed this model to a more dynamic one within which economy is defined as a connector between the environment and the society and engaged in discussion about the interactions between their organisation and the system elements. For the model developed by this group see Figure A 1;
4. The risks module achieved its aim of making the participants understand the dynamic interrelationships between risks to sustainability of the society and the implications of those risks on their business. However, the risks identified by the participants diverged from what was expected. The risks the participants identified were mainly related to human behaviour (such as 'greed') and not many risks were identified in relation to the physical limits of the Earth. 'Approaching tipping points' was identified as a risk which indicated that the participants had a certain level of awareness regarding physical limits, but according to them, those risks resulted from human behaviour and therefore they were not the core issues needing to be focused on.

Reflecting on the facts that this company was a very small company in the service industry with not much material input and output, and that their business revolved around interpersonal and group dynamics, the participants' focusing more on the risks related to human behaviour rather than risks associated with physical limits of the Earth is understandable. The focus on behavioural change in this group also echoes the spectrum of different approaches to achieving sustainability which is discussed in Chapter 3, Section 3.2. These different approaches range between the two extremes of behaviour-oriented and technology-oriented approaches, each of which represents a different worldview. Therefore, as a result of the core of their business and the worldview shared by the participants, this group did not articulate the sustainability risks associated with the physical limits of the Earth. If during the risk identification phase, the worldview of a group only enables articulation of certain type risks (e.g. only social or only environmental) then this may result in overlooking some risks that may have potential implications for an organisation's business or some potential niches that an organisation can fill;

5. The identification of the social function being met by the organisation and its products/services and visioning of a sustainable society as part of the forward scenario development module confused participants. Identification of social function and visioning processes being part of the forward scenario development module also deemphasised the importance of the social function and the vision for the entire process. However, the participants developed a vision of a sustainable society within which the risks they identified in the previous session would be mitigated/managed. They envisioned the possible new roles their organisation could fulfil in this (sustainable) society and how the identified social function would be met. The vision development required more time than anticipated;
6. Identification of social function was successful but the group needed more explanation on the meaning of social function than was provided. The concept made a lot of sense to the participants once they understood it, however; identifying a social function required a longer discussion than expected;
7. The development of forward scenarios was successful and the participants found it easy to develop the event trees;
8. The group had difficulty in developing backward scenarios. The participants seemed to have lost the track of time-frames in the backward scenario development process. In the second day of scenario development, the references to long term started to disappear until an intervention was made to bring the group back on track. In an earlier conversation, List pointed to the difficulty experienced by participants in thinking backwards. According to his experience, it was much easier for the participants to think chronologically and as a result he developed the event-

tree approach to identify events, the influences leading to them and the consequences resulting from them (D. List, personal communication, July 7, 2007). A backcasting expert stated that coming up with a backcasting narrative, even though possible in theory, was very challenging to achieve in real life (J. Quist, personal communication, November 3, 2009). The event-tree approach had been adopted for the scenario development process of the workshop design (for details see Chapter 7, Section 7.3), and therefore the difficulty experienced by the participants in this ARC did not rise from a difficulty inherent to the challenge of generating a backcasting narrative. The participants' feedback indicated a need to refer to and review the vision frequently at the beginning of each scenario development module and especially at the beginning of each day. The opinion of the above-mentioned backcasting expert was supportive of the participant feedback on the need to refer to the vision frequently. He stated that the success of the backcasting experiments was determined by the normative vision generated (J. Quist, personal communication, November 3, 2009);

9. There was no need for a separate alignment module since alignment emerged naturally as forward and backward scenarios were being developed;
10. The action plan module was successful. The participants generated several actions to take the week following the workshop and allocation of responsibility was done through volunteering. The group also generated actions to take within a year and identified responsibilities to follow-up;
11. Since there was no need for a separate module for alignment of the scenarios, the action plan module happened to be the module in which the group mapped the layer of product/service innovations on the scenario map. The ideas put forward for new products/services were generated earlier by the company and no new product/service ideas were generated in this session. There might be two reasons for this: either the company had already put a lot of thinking in new product/service innovations they could introduce so could not think of any more ideas or the process was not supportive of generating new ideas for new product/service concepts;
12. For the same reason that there was no need for a separate module for alignment of scenarios, the action plan module also happened to be the module within which a stakeholder map was prepared and the stakeholders were placed on the scenario map where they might have influence in the realisation of certain anticipated events (e.g. introduction of a new product/service, an organisational change program, etc.). The preparation of the stakeholder map worked well, however; in longer periods of the scenario map, rather than referring to present stakeholders individually, group names were found to be more appropriate by the

participants to leave room for new stakeholders to emerge. Referring to the present stakeholders individually was found very useful in the near-future part of the map since these stakeholders were seen crucial for the company to collaborate in breaking certain lock-ins and to open the identified innovation paths. The participants found it difficult to directly map the stakeholders on the map since this activity required both thinking about the stakeholders and their position on the map. More time was needed to develop the stakeholder map and place the stakeholders on the scenario map than expected;

13. Even though the workshop as an overall exercise worked well, as a result of the small number of participants the scenario development modules required longer time than allocated in order to be able to produce a sufficient quantity of event trees, and;
14. Following from Reflection 3 of ARC 1, in this cycle the method was tested using a service company as a case study. No evidence was encountered to disprove that the method could be used for service innovation. Since originally the method used the concept of social function to break mental models based on the characteristics of present products and services, and since a function can be met by a service as well as a product no specific changes were identified to be necessary to render the method applicable by service companies.

<u>Changes/Improvements</u>

Based on the reflections and insights gathered from this ARC, the following changes/improvements were brought to the scenario method:

1. In order to accommodate a more reflective process for the participants, a four half-day workshop agenda was developed as an option in addition to the two full-day agenda. The four half-day version was tested in this cycle (ARC 2). Overall, the process worked well, however; since the scenario development modules require a long time frame, the backward scenario development session was cut in the middle to complete in the next half-day session. This might have contributed to the group's losing the track between the vision and the scenarios in the backward scenario development module. Since each of the modules in the workshop requires a considerable amount of time, in the four half-day version of the workshop, there might be a requirement to cut a module in the middle and complete it in the next meeting. It was obvious that there was a trade-off between accommodating a more reflective process and running the process in a non-fragmented way. Therefore, it could not be concluded that the four half-day version was better than the two half-day version of the workshop but it was an option provided that the modules in a day will not remain incomplete and a vision check-in is run frequently;

2. In order to address the issues highlighted above under Reflection 2 (confusion regarding the use of similar terms with businesses with slightly different meaning/scope) and Reflection 6 (confusion about what social function meant) a brief presentation session was added to the 'Introduction' module of the workshop. This presentation should clarify the terminology and concepts used by the method. It should explain what vision and social function means as they are used in the scenario method and provide examples of social function to clarify the concept. This presentation should be easy to understand by the participants and easy to present by the facilitator;
3. In order to make sure that all sustainability risks relevant to the company's business were considered, a generic risk list of sustainability risks can be used as a reference by the facilitator. After the group prepares a list of risks to sustainability, the facilitator can compare the list prepared by the group to the reference list. If he/she identifies a sustainability risk potentially relevant to the business of the company is missed out he/she can suggest the group to include these risks. Also, if the company carried out LCA, environmental and/or social risk assessments, the outcome can be incorporated into this module. However, this will require some additional work during the preparation phase of the workshops to extract relevant information from these past studies and to effectively communicate it to the participants during the risks module;
4. The workshop design and schedule was changed to include two previously implicit activities as two new modules before the scenario mapping process starts. The first of these modules was the social function module. In this module, the social function provided by the organisation through its products/services is identified and the current means of meeting this social function are articulated. The second module introduced was the visioning module. In this module the group develops a vision of a sustainable society and articulates the role of their organisation and how the social function they identified for their product/service is being met in this society;
5. In order to address the issue related to product/service ideas highlighted under Reflection 11, a 'creativity' process was included to first generate product/service ideas before mapping these on the scenario map. The generation and mapping of product/service ideas was identified as a separate module;
6. In order to address the issue highlighted under Reflection 12, a brainstorming process was included to first identify stakeholders before mapping these on the stakeholder map. The identification of stakeholders, preparation of the stakeholder map and mapping of the stakeholders on the scenario map was identified as a separate module, and;
7. In order to address the requirement of more time for small number of participants, two full-days were identified as the minimum time required for the workshop rather than the optimum time.

ARC 3

Background

This ARC consisted of one overseas and three local expert consultations. It provided input mainly in relation to the conceptual framework. During this cycle the scope of application of the scenario method was further clarified.

Reflections/Insights

The particular reflections which arose from this ARC were:

1. The execution of both the backward and the forward scenario development modules required substantial time. The types of thinking required by these two activities were quite different; the process of forward (explorative) scenario development required participants to think logically following causal links between events, whereas, the backward (normative) scenario development required participants to think creatively and use their imagination. Participating in both of these modules might be exhausting for the participants. This possibility was supported by the previous workshop experience (in ARC 2) as well in which participants reported difficulty of keeping engaged with the process after extended timeframes;
2. The expert consultations which took place in this ARC highlighted that the workshop process might not be readily adoptable by organisations which had not committed to achieving sustainability since the precondition was the will of the organisations to try the method. Therefore the method was not likely influence companies at all levels of awareness/commitment towards sustainability unless an internal change agent actively undertook the mission of convincing a group of people to participate in a workshop. Eventually, without the commitment of the upper management, change would not take place. However, the non-commitment at managerial level in the earlier phases of a change project did not necessarily determine the outcome as negative since the momentum to change might develop in the organisation and a group of pro-change people could later convince the managers. The scenario method could help a group of innovative people in an organisation in building a business case to present to the management. This emphasised the importance of initially targeting internal change agents for the adoption of the scenario method. Internal change agents can be anyone and anywhere in the organisation; they can be board members, CEOs, executives, managers but also any member of the staff (Dunphy et al., 2007). Therefore, since the scenario method was originally planned to be used by a product development team in a

company, in order to transfer the knowledge of the scenario method to internal change agents, the workshop design should also be applicable in groups of individuals from different organisations, and;

3. List (2005) identified inclusion of all stakeholder groups in the workshop among design criteria for futures inquiry methods (see Chapter 8, Table 2 under Section 8.3) which were adopted in designing the workshop for the scenario method developed in this research. The futures studies and system innovation literature provides supportive evidence for the benefits of participation of stakeholders in workshops (for detailed reviews of literature on stakeholder participation, see e.g., List, 2005; Quist, 2007). However, inclusion of external stakeholders in workshops at company level requires a carefully handled process since in these workshops commercially sensitive outcomes are generated. Also, managing participation of external stakeholders requires additional effort from the facilitator and probably more resources from the company. Therefore, participation of external stakeholders can be encouraged and recommended but not mandated for a workshop for a company as this might result in the company withdrawing from the undertaking.

Changes/Improvements

Based on the reflections and insights gathered from this ARC, the following changes/improvements were brought to the scenario method:

1. The workshop design was changed to have a single scenario development module by combining the three modules associated to scenario development (i.e. forward flowing scenarios, backward flowing scenarios and alignment modules). In this single scenario development module, the group would be divided into two sub-groups. One of these sub-groups would develop backward flowing and the other sub-group would develop forwards flowing scenarios simultaneously. These two sub-groups would come back together towards the end of the module to share their scenarios with each other and to work together on alignment. During the group work, in order to enrich the discussion and to cross-fertilise both scenario flows, members of each group could be exchanged. Dividing the group into two cannot be done with small groups. The minimum number of participants in each sub-group should be three to enable fruitful discussion. This new design can help address the requirement of more time to develop visions and identify social function which was highlighted under Reflections 5 and 6 of ARC 2. The new design was tested in the following ARC (i.e. ARC 4);
2. Following Reflection 2, a variation of the workshop design has been formulated to suit to a group of individuals coming from different organisations in order to transfer the knowledge of

the scenario method to potential internal change agents. This variation was tested in ARC 5 with the workshop Case Study 3, and;

3. Since participation of external stakeholders was a criterion already adopted by the scenario method, no further changes were made in the conceptual framework or workshop design. However, in order to make sure that stakeholder participation would be considered by the companies which would potentially undertake the workshop, the a brief background about the benefits of stakeholder participation and a recommendation to include as many stakeholder groups as possible was included in the Facilitator's Guide (Appendix IV).

ARC 4

<u>Background</u>

This ARC consisted of consulting one overseas and three local experts and a workshop with Case Study 2. The unique attributes of this case study was that it was a start-up company and it had sustainability at the core of its business/innovation strategy. This ARC provided input mainly in relation to the workshop design and helped to further clarify the scope of application of the scenario method.

<u>Reflections/Insights</u>

The particular reflections rose from this ARC were:

1. The 'We are a System' module with the workshop group in this ARC lasted longer than the time allocated (which was sufficient in the previous workshop) and resulted in an unexpected outcome. This group as well came up with the strong sustainability model within the first five minutes of the session. However, when positioning their organisation on this model they started to think conceptually and came up with a very sophisticated model on the interactions taking place between their organisation and the environment, society and economy as well as on the mechanisms through which their business was improving the environment and society. The resulting model, deviated from the strong sustainability model in appearance (see Figure A 2), however; the model the group produced in the first five minutes and the discussions which took place during the entire module indicated that the group understood the hierarchical dependencies portrayed by the strong sustainability model. It was when the group was asked to place their organisation on the model, a model using three concentric circles was found to be limiting since the participants approached the task from a conceptual perspective rather than a

physical. The sophistication of the final model was probably because innovation for sustainability was the core business of the company and so the participants had already put a lot of thinking in the systemic relationships between their organisation and the environment, society and economy;

2. The new design of combining all scenario modules and dividing the group into two sub-groups to run two parallel scenario development sessions (forward and backward) as decided in ARC 3 worked effectively and saved time;
3. The stakeholder model used to develop the stakeholder map did not work well. Because the company was a service company, the participants did not think the supply axis was very relevant to the direction of the company's business. This indicates that the supply axis was interpreted as representing the supply of material goods into the company which then would only be highly relevant for manufacturing companies. Following clarification on the meaning of supply, i.e. stakeholders providing input to the company such as staff, confusion arose regarding the power axis. The participants had difficulty in placing the stakeholders they identified on a power axis. There could be two reasons for this. First, since the company was a start-up, the stakeholder relationships were not so clear and therefore placing them on a power axis was not easy. Second, since this company was a spin-off of a foundation and together they are part of a hybrid organisational model, the power relationships between stakeholders were too complicated to map linearly. Since the previous case study (Case Study 1) was also a service company but was able to develop the stakeholder map using the stakeholder model provided without any problems, the problems observed in this case study did not provide sufficient evidence that the stakeholder model used should be changed. Nevertheless, the observed problems hinted that in workshop groups in which there are difficulties in identifying and/or positioning the stakeholders, the supply/power structure of the stakeholder model may be unhelpful;
4. Two senior participants of the workshop, in post-evaluation, commented that, even though interesting and useful, the time-frame was too long for business planning since it was hard to imagine what would happen in 50-plus years time. One of these participants stated that the process planted a lot of seeds in their heads in relation to the start-up company and it would be better if the resources (i.e. time and people) were not equally allocated to development of both scenario flows but more detailed work was done on the forward flow to explore short-term opportunities. He suggested using the long-term vision as an anchor and the backward scenarios as a compass to pull the explorative forward scenarios towards the vision. From a business planning perspective, allocating more resources in detailing the short-term opportunities makes a lot of sense. However, focusing on the long-term societal-level vision and the backward flow of

scenarios is indispensible in order to identify innovation paths linking present to future. Any changes to the scenario method should not compromise the long-term vision for a short-term opportunity otherwise the application of the scenario method will not provide anything other than business-as-usual scenarios, and;

5. Neither the original workshop design had a process for evaluating product/service ideas nor did the improvements brought to the workshop design in the previous cycles include a process of evaluation for the product/service ideas generated by the group. The participants of the workshop in this cycle highlighted lack of an evaluation process as an issue and suggested improvement of the workshop design through inclusion of one. Even though the merit of carrying out an evaluation of product/service ideas was obvious in following decision making regarding directing research and development activities, capacity development, investment etc., the aim of this scenario method is to identify as many innovation paths as possible between present and a sustainable future in order to increase adaptability of the organisation to possible emergences along the way while ensuring that the path being followed is directed towards sustainability. Evaluating and selecting product/service ideas anticipated to be developed in the near future of the scenario map makes sense from a business planning perspective. However, it should be noted that if the ideas for products/services mapped on longer terms of the scenario map were evaluated and selected at this stage the process might result in a premature closing of an innovation path just because an idea was not found feasible/desirable at the time of the scenario development.

Changes/Improvements

Based on the reflections and insights gathered from this ARC, the following changes/improvements were brought into the scenario method:

1. Following from Reflection 1, the expected outcome of the 'We are a System' module has changed from a model strictly portraying three concentric circles to one which demonstrates an understanding of the hierarchical relationships and interdependencies between the environment, society and economy. The resulting model which was developed by positioning the company on the sustainability model should articulate the relationships and influence mechanisms between the organisation and the three components as in the previous version of this module;
2. Referring to Reflection 3, in cases where there are difficulties in identifying the stakeholders, the Stakeholders module can be skipped. In cases where there are difficulties in positioning the stakeholders on the two-axis model, the stakeholder list produced as a result of the initial

brainstorming can be used. As the details become more evident, the company can incorporate these on the scenario map during follow-up reviews, and;

3. Following Reflection 5, a process to evaluate ideas was incorporated in the Products/Services module of the workshop design. This process was not seen as an essential element for the scenario method; therefore, it was identified as optional and could be used in groups which chose to undertake such evaluation. The process would only focus on the evaluation of short-term ideas in order not to jeopardise premature dismissal of product/service ideas for the longer term. Also, this process should not involve deletion of any of the ideas from the scenario map even if they were voted off during the evaluation as these ideas might prove useful later.

ARC 5

<u>Background</u>

This ARC consisted of one workshop with Case Study 3. Following from Reflection 2 of ARC 3, this case study enabled testing and improving of the scenario method in relation to its applicability to a group of individuals coming from different organisations. Since this was a group consisting of unrelated individuals worked on a fictitious company, the stakeholder and action plan modules were not held but the group was briefed about how to run these two modules. This ARC provided input mainly for the workshop design.

<u>Reflections/Insights</u>

The particular reflections rose from this ARC were:

1. The ‘We are a system’ module was successful in this workshop as well. Similar to the previous two case studies, the group came up with the strong sustainability model. This case study built on the outcome of ‘We are a System’ module of Case Study 2 and provided evidence that strictly expecting a model of three concentric circles to demonstrate an understanding of systemic and hierarchical relationships would limit the participants. The world model created by this group eventually demonstrated an understanding that some socio-technical contexts have more impact on the environment while some others have less or no impact (Figure A 3). As an unexpected outcome, this was the only case study where participants pointed to the difference between the impact of the developing and developed country contexts on the environment. In further discussion about the model they developed, the participants referred to their country context (i.e. Turkey) as an example to argue that, even if the strong sustainability model

suggests the environment to be a priority, before addressing more urgent issues (of social nature like poverty, unemployment etc.) there would not be a possibility of addressing environmental problems. This reasoning can be used to explain why this particular group came up with a model considering different contexts; simply because social issues are on the daily agenda of these people and so they are sensitised to the fact that Turkey is a developing country;

2. In the risks module, the group identified several risks threatening the sustainability of society and nothing important or highly relevant was missed out. In the identification of risks to business, initially the group argued that there was a conflict between the societal good and the company good since, for example, when overconsumption is a risk for the sustainability of society, it meant increased profit for the company. This was an unexpected outcome since the participants demonstrated understanding of systemic relationships between their company and the environment, society and economy through the world model they developed in the 'We are a system' module. Perception of conflict between the societal good and company good despite the demonstrated understanding of systemic relationships indicated the lack of thinking in the context of time and that the focus of the group was on the short term. As an intervention, the group was reminded of the outcome of the 'We are a System' module and asked to reflect on longer-term implications of overconsumption. Following this intervention, the participants concluded that without the consideration of the longer term, there was a conflict between the societal good and the company good. Consideration of longer term put the outcome of the 'We are a System' module in perspective and joint consideration of the world model with the risks identified as threatening the sustainability of society enabled the group to understand the risks to society were also risks to the company;
3. With this group, the social function module was quite challenging. Initially, the participants had difficulty in thinking conceptually in relation to the social function of educational toys. Then, the participants had problems with identifying a social function everybody agreed upon. The session lasted twice as long as expected and as experienced with the two previous groups but a tentative social function was finally identified. In questioning whether the group was clear about what is meant by social function of a product, the responses showed the problem was not because the participants were not clear about the meaning of social function. Therefore, the problem arose probably because the group was not a real team and was working on a fictitious company/product scenario so the participants' responses were not based on real life experience with the company/product and they did not have any real connection to the scenario from their previous experiences either (i.e. none of the participants worked for a company designing and

manufacturing toys). As a result, all of the ideas were being generated during the workshop, making the process slower and cumbersome. A similar observation was made during the visioning session and supported this reasoning;

4. In the visioning module, societal level visions mitigating the risks identified as threats to the sustainability of society were developed by the participants with no difficulty. However, generation of visions regarding how the social function is being met in that society had been challenging. The group again had difficulty in thinking conceptually, this time even more so, since they had to imagine how the social function (which they had difficulty in identifying) was being met in the long term. The group was constantly developing product/service ideas before articulating how the social function was being met within that society. This would not necessarily be an issue if the group could come up with breakthrough ideas but none of the product/service ideas proposed could be classified as innovative; they were variations of currently existing educational toys. The tendency to generate product/service ideas might be a result of the participants' professional and academic background (i.e. industrial product design). However, not being able to envision how the social function was being met in the societal vision the group developed recalls the experience of the social function module and may be related to a combination of reasons in addition the participants' background in industrial product design. One of the reasons might be the low professional experience in the group. As stated previously, only three of the participants were practicing industrial designers and none of them were in a senior position. In support of this argument, three of the participants highlighted their lack of industrial experience as a potential reason for struggling with conceptualising social function and developing a vision for it in the long term. Another reason was because the fictitious company and product scenario were identified without consultation with the participants. One participant raised this as an issue and suggested consulting with the group in formulating a fictitious company scenario. A third reason might be directly related to the fictitious company and product scenario. It is possible that, using a very specific product scenario not only giving the type of the product (i.e. toy) but also detailing the material, aim and age group that product was being designed/manufactured (i.e. plastic, educational toy for primary school children), limited the group's imagination;
5. The scenario development session worked without any problems. This was the only case study in which alignment of two flows occurred easily. The two sub-groups identified the same events in the middle of the map. This was supporting evidence that cross-fertilisation between sub-groups by exchanging members throughout the process fulfilled its aim. This group mapped

product/service ideas on the scenario map as it emerged (most of these ideas were produced already during the visioning module), and;

6. Even though the scenario development module was successful, the product/service ideas generated were not path breaking. In manufacturing companies, defining the social function based on the current product(s) the company is producing might be counterproductive for two reasons. First, as experienced in Case Study 3, for a very specific product participants might find it hard to formulate a social function which will remain unchanged in the long term (In Chapter 6 under Section 6.5 it was concluded that system innovation from the perspective of product development was providing the same social function in the future through a combination of innovations both at the technological and at the social sphere). Second, the social function of a product might be useful in developing forward flowing explorative scenarios to start thinking at the conceptual level and generate innovation ideas based on the current product and technologies. But, when developing backward flowing scenarios, the more effective approach might be focusing on the societal vision of sustainability and the core competencies of the company to generate innovation ideas which use opportunities which are likely to rise on the way to achieve sustainability since future opportunities may be completely different from the activities the company conducts currently (J. McLaren, personal communication, November 30, 2009). This way the innovation paths can be directed towards fulfilling societal needs.

<u>Changes/Improvements</u>

Based on the reflections and insights gathered from this ARC, the following changes/improvements were brought to the scenario method:

1. While working with a group of unrelated individuals (potential change agents from different organisations) the participants should be involved in determining the company scenario. One way of involving participants in determining the company scenario they would work on could be preparation of some options in line with the professional backgrounds of the participants. The information on the professional background of the participants could easily be collected during the preparatory phase of the workshop. Once some company scenarios relevant to the professional backgrounds of the participants were identified, the participants might be requested to put these options in order of preference. The most commonly preferred option would be selected as the scenario to be worked on;
2. In order to maintain the link between 'We are a System' module and the risks module, the risks identified by participants can be placed on the world model they developed during the risks module, and;

3. Following from Reflection 6, in the scenario method, the emphasis on the social function in the scenario development module was changed to use the social function during the development of explorative scenarios in order to exploit the emerging opportunities. In developing the backward flowing scenarios, the focus would be on achieving the societal level vision of sustainability and core competencies of the company. The workshop design was changed accordingly, however, only to affect the manufacturing companies utilising the scenario method since, with service companies, social function proved to be conceptual enough and worked equally successfully in development of both forward and backward flowing scenarios.

APPENDIX V:
THE FACILITATOR'S GUIDE

APPENDIX VI:
DETAILED RESULTS OF THE EVALUATION OF THE SCENARIO METHOD

Evaluation of the Scenario Method against Effectiveness Criteria for Futures Work

Case Study 1

Table A 1. Evaluation of the effectiveness of the scenario method for Case Study 1

Criterion	Evaluation
1.	The purpose of the workshop was communicated to all participants via e-mails during preparation phase and the purpose was hung on a wall during the workshop. Since this group was familiar with the research, there was no need to explain the two intertwined purposes related to the workshop, one related to the research and the other their entity, in detail. The participants were clear about the purpose of the workshop from the beginning.
2.	This group of participants welcomed the challenges to their initial assumptions and showed no resistance. One potential reason might be the type of work they are involved in (i.e. group facilitation) which involves implementing processes or doing interventions to open up new possibilities for the groups. Even though the process did not challenge this group, during the workshop the participants were able to deepen their understanding about the future of their entity and how it relates to the rest of the socio-technical system. This group found articulating their social function and conditions of their entity to exist in a sustainable society particularly eye-opening. Since they are a service providing company, they did not pay too much attention to the sustainability related practices of their suppliers since they purchase a minimal amount of materials mainly to run their office (i.e. water, stationery, power, food, etc.). However, during the workshop, even though minimal for the company's sustainability related performance, they realised that auditing their suppliers and demanding certain standards to be met could bring improvements beyond and above their company since once the suppliers come across such demands, they will start to change their behaviour and also start negotiating terms with their own suppliers etc. Therefore, the workshop enabled the company to gain a more systemic understanding about their impact and influence.
3.	Yes. All of the paths leading towards and backwards from the developed vision were investigated to the extent of the maximum time allocated for developing the scenario map.
4.	This group prepared a very detailed stakeholder map identifying 48 stakeholders under 12 stakeholder categories covering all impinging systems. In the workshop only managers, employees and associates were represented. The high-power and/or high-influence stakeholder groups not represented in the workshop were regulators, peers/competitors and clients. Therefore, this criterion was only partially fulfilled.
5.	Yes, the anticipations were expressed specifically enough that they can be tracked. All events in the event trees are stated clearly so that in a follow-up meeting there would not be confusion on what a specific event tree was about.
6.	All of the participants thought that in an overall assessment the activity was worthwhile for the company. All four of the participants attended the entire process. Besides recommendations on possible improvements that can be brought to the scenario

	method, no negative comments were made demonstrating dissatisfaction.
7.	The participants stated that through articulating their social function and the conditions which need to be met for the company to still exist in a sustainable society, they were able to identify paths that the company can take towards achieving their desired future. One participants stated that, even though she was a big picture thinker and so the initial modules were the most enjoyable for her because they were about developing desirable future visions, the following modules were very useful to help addressing the specific steps which need to be taken to arrive at that future.
8.	As far as the empowerment of furthering the work is considered, this group covered major decision makers in the company so they were already empowered. They were very satisfied with the action plan. As far as the empowerment of the company to move towards system level innovation for sustainability is considered, the participants found articulating how their social function can be met in a sustainable society very empowering since it provided the basis for developing the innovation paths.
9.	Yes. The company is already using the outcome of the workshop in their strategic planning for the future and introducing new services and improving the existing ones.

Case Study2

Table A 2. Evaluation of the effectiveness of the scenario method for Case Study 2

Criterion	Evaluation
1.	The purpose of the workshop was communicated to all participants via e-mails during preparation phase and the purpose was hung on a wall during the workshop. During the preparation phase, the purpose of holding a workshop for the researcher (i.e. to test and improve the scenario method developed) and the purpose of the workshop for the group (to identify alternative innovation paths for [The Entity] towards system level innovation for sustainability) were clarified. None of the participants reported any confusion on the purpose of the workshop.
2.	The participants in this group saw themselves as pioneers in innovation for sustainability. Since achieving a sustainable society was the core vision guiding the activities of the foundation mothering this new enterprise, the participants were very clued-up about sustainability risks and have been exploiting the niches rising as innovation opportunities to mitigate/manage these risks since the establishment of the foundation. Therefore, similar to Case Study 1, this group did not demonstrate resistance against challenges to their initial assumptions. This group found positioning the company and articulating the social function within the broader system covering the environment, society and the economy very mind-opening. Their initial (mental) model of how the company improves the sustainability of the broader system was challenged during the workshop and the group developed a new (visual) model articulating the sub-systems and mechanisms the company was using to intervene in the broader system and influence change towards sustainability. Another aspect of the scenario method, i.e. the long-term focus, was found to be bringing a new filter to see their company through even though the senior participants thought the length of the period considered too long for business planning.
3.	Yes, all of the paths leading towards and backwards from the developed vision were investigated to the extent of the maximum time allocated for developing the scenario map. However, the participants in their feedback complained about not evaluating the paths and products/services in terms of their feasibility.
4.	This group identified 46 stakeholders, and later reported later that this covered only a portion of the stakeholders. Since the time during this module was spent on discussion about whether the power-supply axes of the stakeholder map apply to the company or

	not and the general consensus was that the stakeholder model did not really make sense for their case and also probably because this was a start-up company so there were a lot of uncertainties about the possible stakeholders resulted in an incomplete stakeholder list. Even though the list was incomplete, the general stakeholder categories –even though not explicitly- were identified on the map. The stakeholders represented in the workshop were managers, employees, volunteers and associates and the high-power and/or high-influence stakeholder groups which were not represented were regulators, clients, peers/competitors, and funders/investors. Therefore, for this group as well, it can be concluded that this criterion was only partially fulfilled.
5.	Yes, the anticipations were expressed specifically enough that they can be tracked. All events in the event trees are stated clearly so that in a follow-up meeting there would not be confusion on what a specific event tree was about.
6.	In total 12 people participated in different parts of the workshop. At all times there were eight to ten people present and six of the people have been through the entire process. The reason of discontinuity was the other commitments they had. The people who could only partially participated to the workshop were also given evaluation questionnaires to complete for the parts they participated in. None of these participants stated any dissatisfaction. All six of the participants who were present during the entire workshop stated that in an overall assessment the activity was worthwhile for the company. Besides recommendations on possible improvements that can be brought to the scenario method, no negative comments were made demonstrating dissatisfaction. At a later meeting with the senior employee who coordinated and organised the workshop, he stated that the process planted a lot of seeds in their minds about the start-up and the outcome of it gave them a basis to direct opportunities.
7.	The participants, especially junior ones enjoyed the challenge of trying to align backward and forward flows to realise the vision they developed. Two senior participants found the timeframe too long. One of them stated that it was useful to think in the long term but he suggested that it would be better if the two flows were not forced to align. He did not understand why specifically aiming for alignment was necessary. Therefore with this group, this criterion was only partially met.
8.	The company, having innovation for sustainability as its core business, was empowered to carry the work forward. One observation, although not checked with the participants involved, was that the process empowered employees to stand up against the management to demand for a clear plan about the start-up. The employees put a lot of emphasis on this issue during the preparation of the action plan. The more junior participants, even though not highly influential in the decisions taken in relation to the company, stated that they were inspired and stimulated to carry their own relevant work forward regardless of whether they would still be working with this company in the future or not.
9.	Yes. The use of the outcome for this company is two-fold. First, the outcome of the workshop is currently providing input to the establishment of the start-up and developing its business strategy. Second, the (improved) process itself is a tool that the company is considering to use in its projects.

Case Study 3

Table A 3. Evaluation of the effectiveness of the scenario method for Case Study 3

Criterion	Evaluation
1.	The purpose of the workshop was communicated to all participants via e-mails during preparation phase and the purpose was hung on a wall during the workshop. During the

	preparation phase, the purpose of holding a workshop for the researcher (i.e. to test and improve the scenario method developed) and the purpose of the workshop for the group (to identify alternative innovation paths for [The Entity] towards system level innovation for sustainability) were clarified. None of the participants reported any confusion on the purpose of the workshop.
2.	Even though this criterion is not applicable to this case study considering the company level (since there is no real company) at the level of the individual participants, the process definitely challenged the initial assumptions of the participants on how an entity relates to the broader socio-technical system in achieving a sustainable society. The participants in this group were used to think at product/service level and assumed that sustainability can be measured at the level of individual products/services. They reported that they never thought about the (upper-level) systems (i.e. the business, the industry and the socio-technical system in general) the products/services were part of and that it was very eye-opening to see the connections.
3.	Yes, all of the paths leading towards and backwards from the developed vision were investigated to the extent of the maximum time allocated for developing the scenario map.
4.	This criterion was not applicable. Since the company was a hypothetical one the stakeholder module was not held with this group.
5.	Yes, the anticipations were expressed specifically enough that they can be tracked. All events in the event trees are stated clearly so that in a follow-up meeting there would not be confusion on what a specific event tree was about.
6.	In this case study assessing whether the process was worthwhile for the company was not relevant since the company was a hypothetical one. However, the participants seemed to be satisfied with the process. All of the participants except one attended the entire workshop and the one who could not attend the second day for due to another commitment came back to be briefed about the outcome and attended the presentation made by the group at the end of the workshop to the Faculty (the workshop took place at the Architecture Faculty of Middle East Technical University and promoted among the 30th Anniversary of the establishment of the Industrial Design Department). None except one of the participants expressed dissatisfaction. One participant, even though stated that she found the workshop interesting and mind opening, was not sure why she was invited to participate even though she expressed interest in participating when the event was announced initially. She stated that she was a product designer and the process did not make sense to her since the outcome is not a design of a product and that she was expecting to develop story boards for product/service scenarios. It was obvious there was a language problem resulting from many different meanings of the word scenario. So probably her dissatisfaction was more related to her having totally different expectations than what was (tried to be) communicated during the preparation phase.
7.	Because alignment in this case study occurred so naturally, the participants reported that the process helped them to understand how a vision in the long term can be realised even though in the beginning of the process they thought the vision was very far-fetched and almost 'Flash Gordon'. Therefore with this case study this criterion was totally fulfilled.
8.	In this case study, since the group consisted of randomly gathered individuals, a group empowerment was not relevant. However, the participants stated that the process enabled them to carry their thinking about sustainability from being a system criticism to something that they actually can do something about. Two of the participants explicitly stated that they would like to introduce this method to the company they were/will be working for to initiate some change in the company towards considering sustainability.
9.	This criterion is not applicable to this case study since the company was a hypothetical

one. However, the participants stated that they could use the process in the future.

Evaluation of the Potential of the Scenario Method to Aid in Achieving System Innovation for Sustainability

Criterion 1: Have the participants understood the hierarchical irreversible relationships between the environment, society and economy and between their organisation and these three sub-systems?

Figure A 1 shows a reproduction of the models developed by the participants of the Case Study 1. As seen, the group generated a model very similar, yet more sophisticated, than the strong sustainability model. The participants replaced the given word 'environment' with the word 'earth' as the possible alternative meanings of the former confused them and by using the word 'earth' they differentiated between the built environment which was covered in the society circle and the natural environment which was represented by the earth circle. The dashed lines represented the dynamism in the entire system illustrating that neither the meta-system nor the subsystems were static; rather they were continuously changing and interacting with each other. The world model and the discussions clearly demonstrated that the group understood the hierarchical, irreversible relationships between the environment, society and economy.

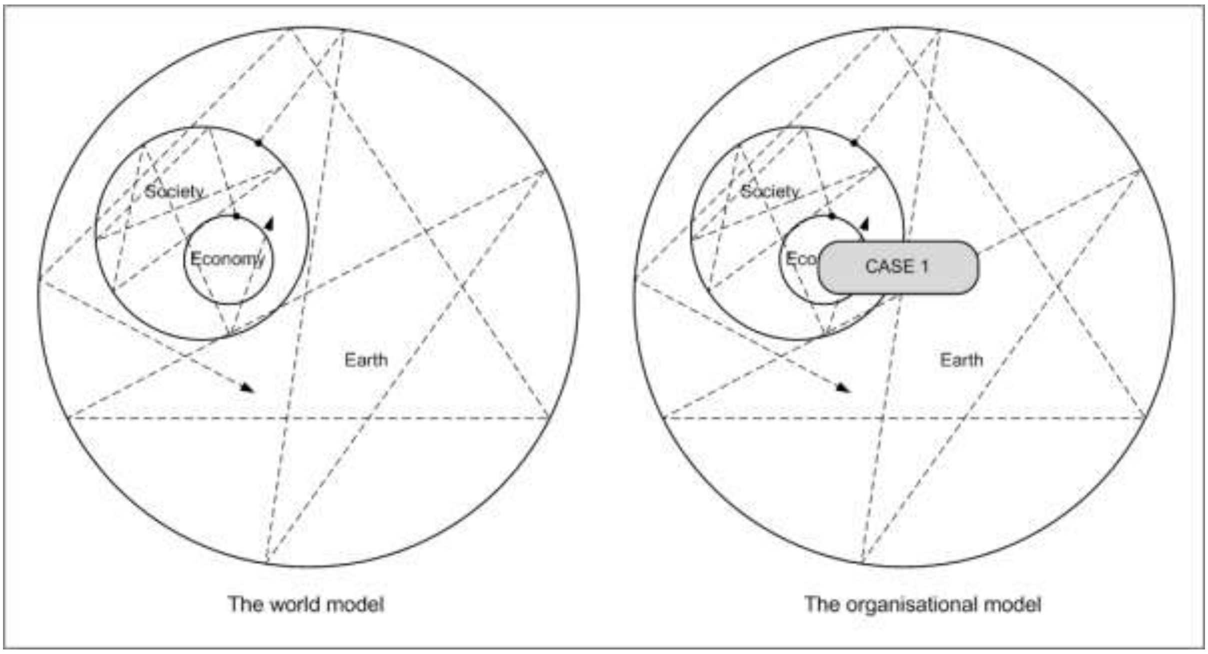


Figure A 1. The models developed by Case Study 1 in the 'We are a System' module

In the second half of the module, the group positioned their organisation in a way to cross-cut all three sub-systems. The participants identified interactions and exchanges taking place between their organisation and the three sub-systems. For this group, the majority of the interactions were taking place between the organisation and the society. Since the organisation was a small-scale service-providing company, there were not many interactions identified by the participants taking place between the organisation and the environment. However, the interactions identified by the group constituted a complete list.

Figure A 2 shows a reproduction of the models developed by the participants of the Case Study 2. The world model the group generated was identical to the strong sustainability model. The participants developed the model on the left in the first five minutes of the module and, in the rest of the time they developed the organisational model shown on the right. In developing the organisational model, their starting point was the world model. However, the world model limited them in terms of space and did not provide a structure which enabled them to explain their understanding of how the organisation related to the three sub-systems. Therefore, the group deconstructed the world model and, using the same components but a different structure, developed their organisational model. This model not only showed the interactions taking place between the organisation and the three sub-systems, but also demonstrated how the organisation influenced the entire system towards sustainability.

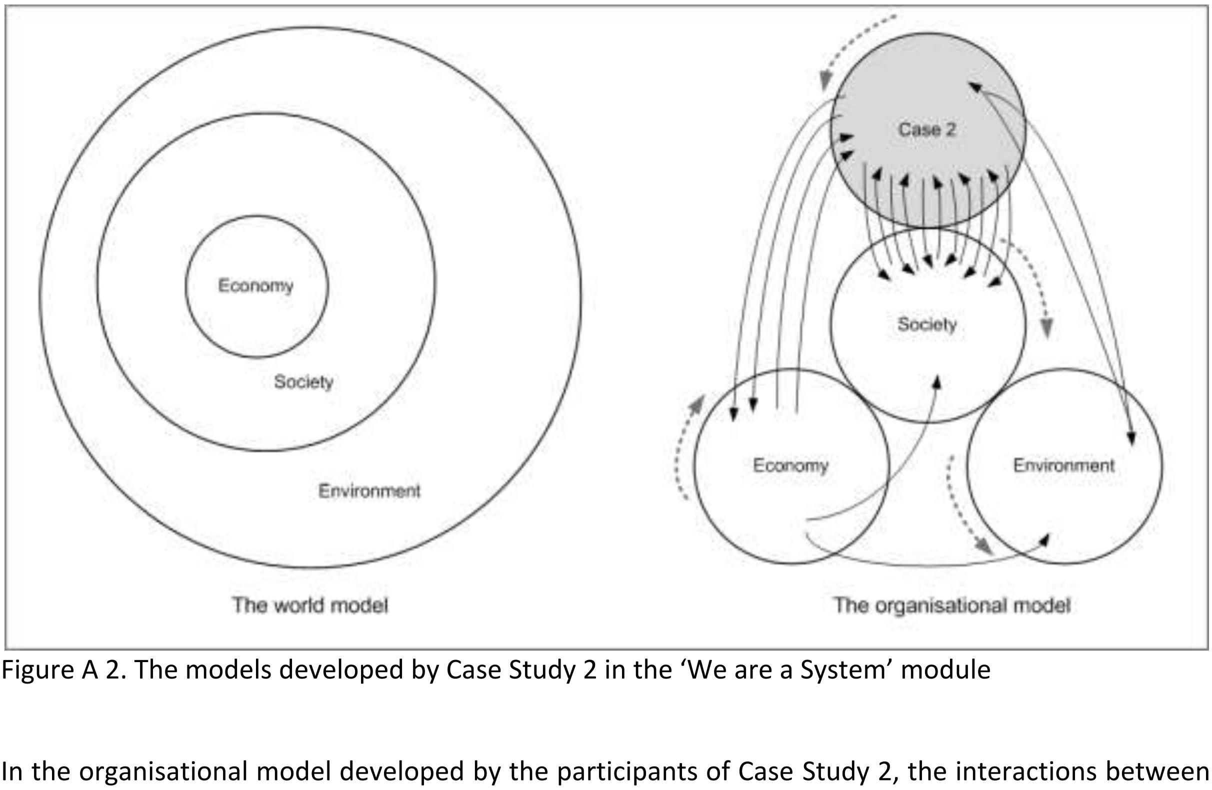


Figure A 2. The models developed by Case Study 2 in the 'We are a System' module

In the organisational model developed by the participants of Case Study 2, the interactions between the society, the economy and the environment were demonstrated by arrows which indicated the direction of the flow. The group did not articulate the interactions taking place between the organisation and the environment on the model and used two arrows to indicate what they take from the environment and what they give to the environment. They named this interaction simply as 'footprint'. Even though not articulated in the model, when asked, the participants were able to identify several inputs and outputs taking place between their organisation and the environment. However, the participants of Case Study 2 saw their main intervention point as the society. According to the participants, their organisation had a positive influence on the environment and helped the economic paradigm change through social innovation. The group, in developing the model, used a metaphor of gears for each sub-system and a machine for the meta-system. The gears did not have teeth so each gear could change its pace without being dictated by others and potentially causing a sudden shift in the entire system. The dark grey, dashed arrows in the model represent the turning directions of each gear and, by influencing change in the society, the organisation influences change in the other two sub-systems. This organisational model demonstrates understanding of systemic relationships between the organisation and the three sub-systems and the meta-system.

Figure A 3 shows a reproduction of the models developed by the participants of the Case Study 3. The world model the group developed was quite similar yet more sophisticated than the strong sustainability model. The sophisticatedness came from the acknowledgement and demonstration of different socio-technical contexts. The participants, instead of using the given circles, distorted two of the circles to represent different sizes of societies and economies and different amount of impact different societies have on the environment. The group made a differentiation between societies which are living within the carrying capacity of the world and those which are not. The group indicated that the economy was constantly growing, pushing the impact of society beyond what could be tolerated by the environment. In the model, the parts where the boundary of the society was closer to the boundary of the environment represent those socio-technical contexts with high impact. The participants placed their organisation at one of these 'high impact' areas since the organisation operated in an industrial context. The participants articulated the interactions taking place between their organisation and the three sub-systems, comprehensively covering all major input/output. The models developed by this group demonstrated an understanding of systemic, irreversible hierarchical relationships between the three sub-systems and between the sub-systems and their organisation.

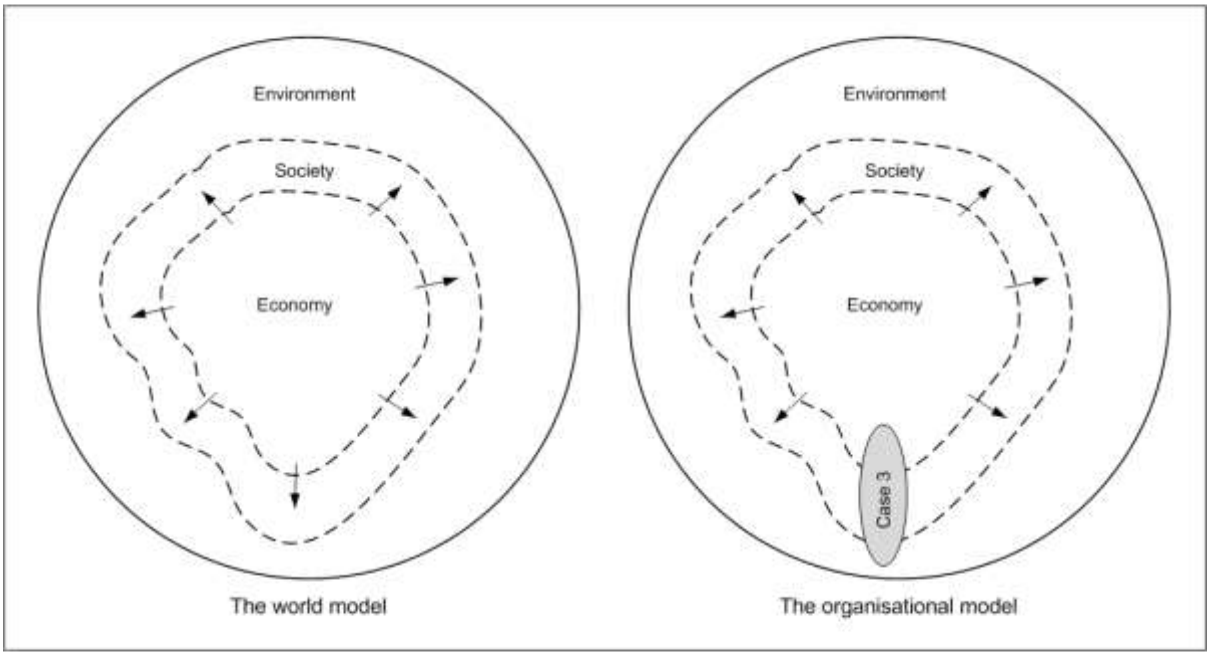


Figure A 3. The models developed by Case Study 3 in the 'We are a System' module

For all three case studies, the evidence provided was consistent and demonstrated that the scenario method enabled the participants to understand the hierarchical relationships between the environment, society and economy and the interactions between their organisation and the three sub-systems. Of course the models developed by participants did not indicate that the understanding of the participants was thorough and captured the complexity and dynamic relationships within the meta-system. Neither did they indicate that the participants became knowledgeable about the exact limits and the consequences of their actions. Nevertheless, participants' ability to develop these models and gain an understanding about the systemic relationships between the environment, society, economy and their organisation is the most important consequence. This understanding is the first and major stepping stone to shift the focus of an entity from its own success/survival to a realisation that the success/survival of their entity is dependent on success/survival of higher-order system components; i.e. the system components which govern the entity; first and foremost the environment and a functioning society.

Criterion 2: Have the participants understood the issues threatening the sustainability of the society (i.e. risks to sustainability of the society), the dynamic relationships among these issues and the implications of these on the business or their organisation?

Table A 4 shows the list of risks to sustainability of society prepared by the participants in all three case studies. The bold items indicate the ones identified as the most urgent risks by the participants. There are some interesting observations which can be made from these three lists. The identified risks, in all three case studies, cover environmental/ecological, social/cultural, and institutional topics. In all three case studies, the groups pointed to values and politics related risks as the core causes of environmental/ecological and social/cultural risks. Participants of Case Study 1 did not articulate environmental/ecological risks but identified generic risks such as destroying the viability of the environment and reaching tipping points. Even though the group did not articulate the environmental/ecological risks, the participants identified use of carbon based fuels and climate change separately as an urgent risk. The other risks this group identified were mainly social/cultural and institutional in nature. When asked, the participants verbally articulated how the viability of the environment was being destroyed or what tipping points were being reached. Their articulation covered all environmental/ecological risks identified by the other two groups, such as loss of biodiversity, increased risks of natural disasters, etc. However, for this group, these risks arise from more fundamental, institutional and/or social/cultural risks. Since their business was about group facilitation and facilitation training, the participants saw their major intervention possibility in changing institutional and social/cultural practices of the society and individuals therefore did not focus their effort on articulation of environmental/ecological risks. This is an indication that, even though theoretically there is a separation made between the risks to sustainability of the society and the implications of these on the business of the organisations, in reality groups bring their organisational perspective to the table from the beginning of risk identification. Similarly, in the case of Case Study 2, two perspectives, organisational and socio-cultural context, acted as filters in risk identification. As a result of the held organisational perspective, the risks identified as urgent are the areas the organisation has already done some business in relation to or areas which are already identified as opportunity points. The perspective related to the group's socio-cultural context (i.e. the Netherlands and the European Union) resulted in the group's identifying risks which are relevant for their immediate context, such as the ageing population and mass migration; two risks which were not identified by the other two case studies. In Case Study 3, since the group were not from a real company, the risk identification process was affected only by the socio-cultural context. For example this group identified genetically modified food as a risk which is, even though genetically modified organisms are accepted to pose some risk, a very specific item to include in the list of sustainability risks. The reason of this inclusion was because during the time the workshop was being held in Turkey, the government passed a law from the parliament initially indicating that the food containing genetically modified ingredients did not have to be labelled which resulted in public outcry. Consequently, this was a current, high-profile topic. Similarly, unemployment and poverty are only identified by this group since both of these are problems Turkey has been struggling with for a long time. The lack of an organisational perspective probably resulted in this group identifying the highest quantity of risks among all three case studies.

Table A 4. The lists of risks to sustainability prepared by the participants

	Case Study 1	Case Study 2	Case Study 3
Risks to Sustainability	• **Reaching tipping points** • **Destroying the viability of the environment** • Spread of nuclear/chemical weapons • **Use of carbon based fuels and climate change** • Disinformation from media • Political/religious dogma • Demonization of alternative systems • Entrenched views, attitudes, and obsolete systems • Slow uptake of alternatives • **Not using the available and emerging technologies/knowledge** • **Individualism** • Apathy/resignation • **Greed** • Overconsumption	• **Dependency on complex systems and our lack of understanding them** • **Inequitable distribution of resources** • Nuclear war • War • Epidemics • **Climate change and natural disasters** • Concentrated power • **Dominant economic paradigm** • Loss of cultural biodiversity • Loss of biodiversity • **Lack of drinking water** • Mass migration • Aging of the society • Growing population • Radicalisation	• Climate change • Genetically modified food • **Toxic waste** • War • Natural disasters • Desertification • Diminishing drinking water resources • **Diminishing natural resources** • Increasing crime rate • Unemployment • Poverty • Population increase • Greed • **Globalisation** • Unequal distribution of wealth • The current economic system • Injustice • Overconsumption • **Diminishing non-renewable energy resources and increasing energy demand** • Inappropriate urbanisation • Inequality (e.g. gender, social class etc.) • Hierarchical system • **Technophilia** • Individualism • Epidemics • Nationalistic fanatism • Global polarisation of power • Substance abuse

Another interesting observation is the possible influence of governmental policy on risk perception. All three case studies identified climate change as a risk to sustainability of society however; only two case studies identified it as an urgent risk. These two case studies were situated in New Zealand and the Netherlands, both of which are discussing the commitment they should make in relation to their responsibility rising from being parties to Kyoto Protocol. The third case study, which did not identify climate change as an urgent risk, was situated in Turkey. The Turkish government, even though signed and ratified the Protocol in 2009, has not made any greenhouse gas reduction commitments.

As a result of reluctance to commit decreasing greenhouse gas emissions at governmental level, there is not sufficient media focus on the issue. Even for those people interested, there is no clear explanation of the stance of Turkey in relation to Kyoto Protocol. For example, during the writing of this thesis, despite rigorous search on the web site of Turkey's Ministry for the Environment and Forestry, except a Turkish translation of the text of the Kyoto Protocol and a brief explanation of what it means in generic terms, no explanation was found on the particular stance and strategy Turkey has adopted in relation to climate change and to Kyoto Protocol.

From this analysis it can be concluded that the different perspectives groups bring to the table influence the sustainability risks identified. Since the workshop participants are not likely to be risk experts they may not be able to provide a realistic viewpoint of risks. Therefore, the risks module might require preparatory research about the probabilities and consequences of the sustainability risks which can be carried out either by the facilitator or, if they are willing to, by the participants. Another option can be inviting an expert to the workshop.

For the three case studies in this research the different perspectives influenced the outcome in relation to the perceived priorities, however, the participants were still able to come up with a comprehensive list or were able to articulate verbally indicating that they understood the issues threatening the sustainability of society. They were also able to show how those risks dynamically influenced each other after being introduced to developing simple diagrams to demonstrate dynamic relationships between system parameters. Figure A 4 shows a segment of the dynamic map developed by the participants of Case Study 2 as an example.

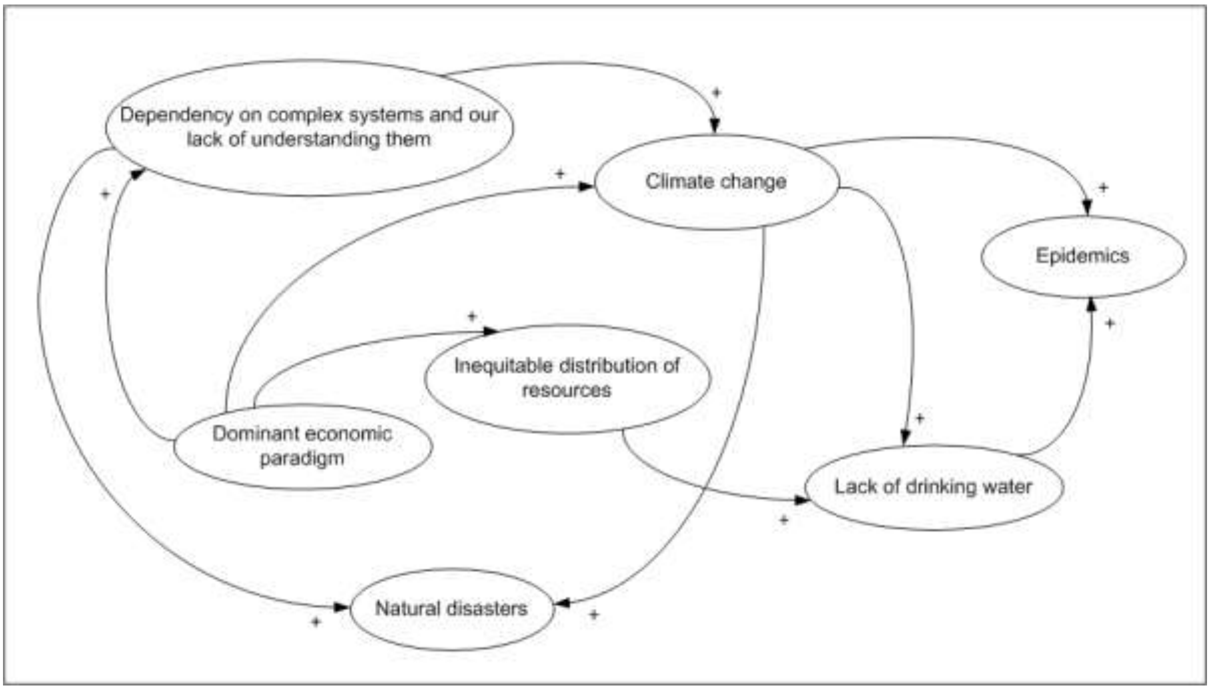


Figure A 4. Segment of the dynamic risk map developed by Case Study 2

The implications of the risks to sustainability on the businesses of organisations were being considered from the beginning of the exercise implicitly by employing organisational filters and only considering some risks to sustainability which were already relevant to the business of their organisation. The participants started the exercise with preconceived ideas on risks to sustainability and which one of those risks were relevant to their (current) business. However, the participants of Case Study 1, while preparing a comprehensive list of implications of the sustainability risks they identified, became aware of some business opportunities they had not thought of before.

In Case Study 2, breaking the barrier of preconceived ideas of the implications of risks to sustainability on their business was harder possibly because the core business of this case study was directly related to innovation for sustainability and the participants already had put a lot of thinking into sustainability issues and how their business could be a positive influence in the socio-technical system towards sustainability. Therefore, there was a resistance initially to accept any suggestions from the facilitator to expand their risks list and also they were convinced that thinking about generic, global risks was a waste of time since the connection to their work was not clear and the issues were too abstract to deal with. Nevertheless, the importance of this step became clear during the products/services module since the implications of risks to sustainability the group identified started to appear as opportunities or issues needing to be solved directly by the organisation itself.

Identification of implications of sustainability risks on the business of the company went the most smoothly and productively with Case Study 3. Probably because the group was working on a fictitious company and there were no vested interests in an established business, the group was able to think freely without the constraint of existing lock-ins. This group identified several implications of the risks to sustainability to the business of their organisation some of which marked opportunities and translated into product/service ideas in the later stages of the workshop.

In the light of the evidence provided above, it can be concluded that the participants were able to identify the implications of risks to sustainability on their business however were bound by their preconceived ideas on what those implications were and how they can respond to them. Nevertheless, this difficulty is not an inherent shortcoming of the scenario method and can be overcome with good facilitation skills.

Criterion 3: Were the participants able to generate normative long-term societal visions within which the risks to sustainability were mitigated/managed/adapted to by the society through a combination of institutional, social/cultural, organisational and technological changes?

Figure A5 shows the reproduction of the normative vision of a sustainable society developed by the participants of Case Study 1. Referring back to Table A 4, this group identified the following as high-priority risks:

1. Reaching tipping points;
2. Destroying the viability of the environment;
3. Use of carbon based fuels and climate change;
4. Not using the available and emerging technologies/knowledge;
5. Individualism, and;
6. Greed.

The normative vision developed by the participants clearly addresses all of these risks by elements in all four quadrants of Figure A5. For example, in order to address the first three risks listed above, the group envisions that in a sustainable society all energy will come from renewable resources; i.e. wind, sun and ocean. Here, an explanation is necessary. The group did not directly use the word renewable but instead used ‘directly from nature’. An energy resource directly from nature also covers non-renewable resources such as petroleum and coal, consumption of which results in greenhouse gas emissions. However, the conversations held with the group clarified that what the group meant was renewable and non-fossil energy resources.

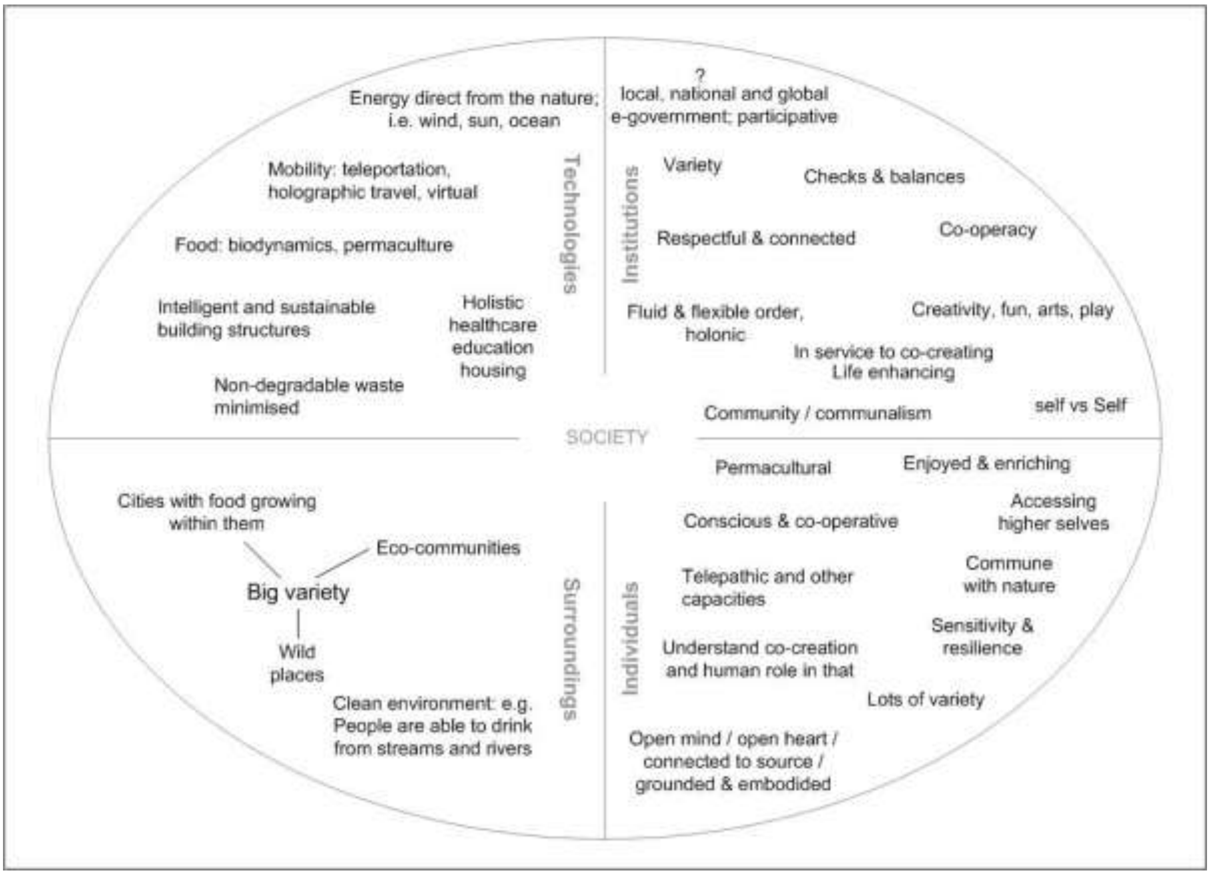


Figure A5. The normative vision of a sustainable society developed by the participants of Case Study 1

Other solutions the group envisioned in the technologies quadrant which address the same risks are related to mobility. The group envisioned that, in a sustainable society, mobility needs of people will be met through teleportation, holographic travel and virtual reality. All of these options currently seem technologically plausible even though a little bit further ahead. Teleportation of people and objects from one point to another is popularised by the science-fiction television series Star Trek in late 1960s. Davis (2004), in a report provides an in-depth review and status of theoretical and empirical maturation of available research in relation to teleportation. From this report it can be concluded that even though there is still a need for substantial theoretical and empirical advancement for a viable technology to come about, teleportation is far from being a science-fiction fad. According to a technological forecasting study carried out by the Institute of Defence Analysis of USA such teleportation will require major technological advancement which cannot be achieved in the next 50 years (Oliver, Balko, Seraphin, & Calhoun, 2002). Of course, it is not possible to determine whether transportation via teleportation is going to be a sustainable option of mobility and such assessment will need to be done when there is better understanding of the physics behind teleportation and when there is indeed a usable technology.

‘Holographic travel’ as used by the workshop participants corresponds to holographic image (and sound) transmission in scientific terms. Currently there is a lot of research going on in the field of holographic technologies and there are evidence that transmission of three-dimensional images and sound is possible (for example, see, Takano, Sato, Muto, & Wakabayashi, 2005). Currently, the common application of holography is static; i.e. holographic images are reproduced following a series of processes after the image has been recorded which means a delay time in capturing and being able to display the image. The real-time display and transmission of motion involving images will require some more time and research. However, with the advances in novel non-linear optical materials along with some advances in haptics in virtual reality in the not very far future, we might be able to, for example, have a virtual meeting as a product development team and try a prototype without being physically present together in a meeting room. Even though not based on holographic technology, a prototype for real-time three dimensional video display technology has already been developed (see, Matusik & Pfister, 2004) and three dimensional home televisions will be in the market in 2010 (Takenaka & Paul, 2010).

The WG of Case Study 1 identified several institutional and social-cultural changes both at the level of governance and of individuals. The vision they developed emphasised co-operation and community over individual to address the fifth and sixth risks they identified (i.e. individualism and greed).

In conclusion, the vision they developed addressed all of the high priority risks they identified and some risks not identified as high priority risks. Therefore, from the perspective of evaluating the scenario method, this workshop group generated some ideas which are associated with technological breakthroughs as well as institutional and behavioural changes which potentially mitigate/manage the risks to sustainability they identified in the risks module. The vision outcome from this workshop fulfilled the criterion.

Figure A 6 shows the reproduction of the normative vision of a sustainable society developed by the participants of Case Study 2. Referring back to Table A 4, this group identified the following as high-priority risks:

1. Dependency on complex systems and our lack of understanding them;
2. Inequitable distribution of resources;
3. Climate change and natural disasters;
4. Dominant economic paradigm, and;
5. Lack of drinking water.

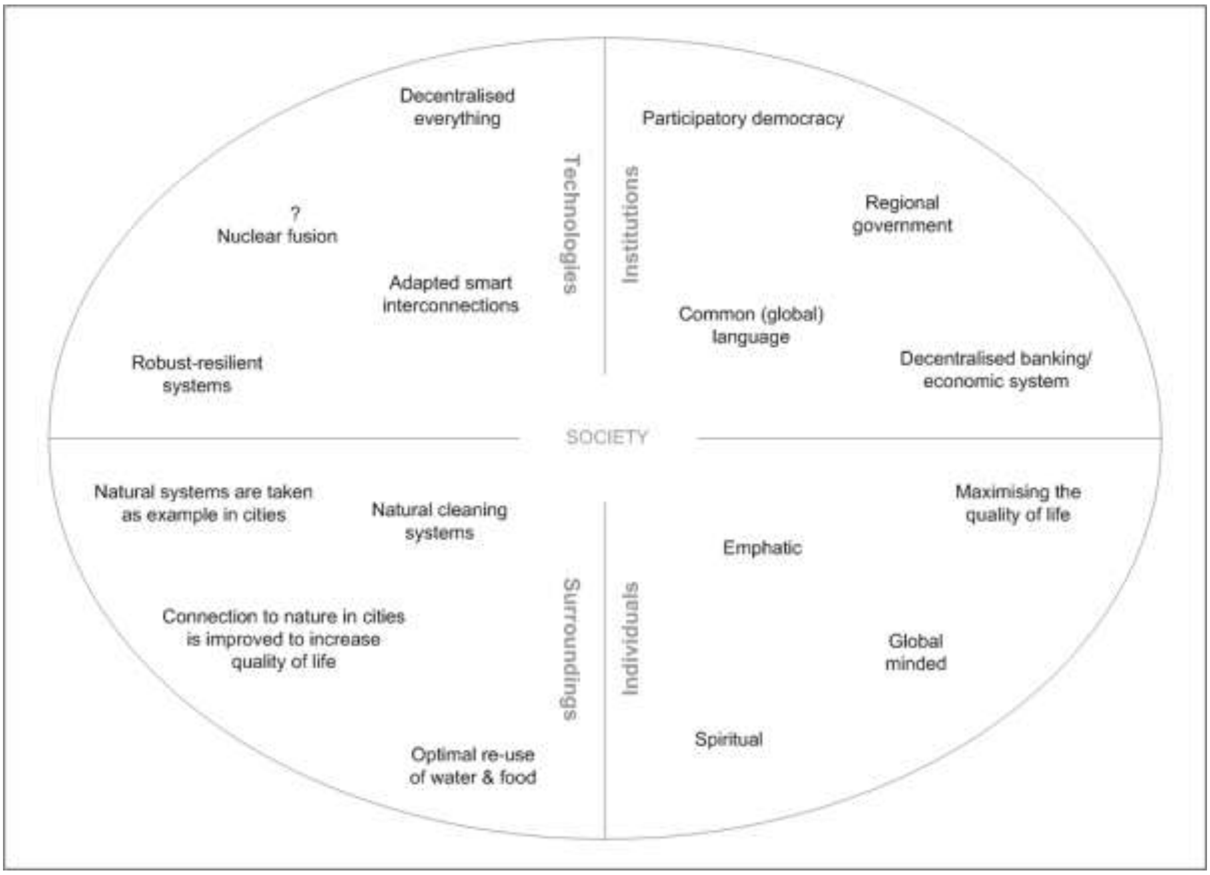


Figure A 6. The normative vision of a sustainable society developed by the participants of Case Study 2

The vision developed by participants of Case Study 2 address the high priority risks they identified to some extent; however, there are some problems associated with the vision rising from the lack of clarity and connection. Even though there are several aspects of the vision which are related to the risks identified, the direct connection is missing due to the level of abstraction in the vision. For example, in the technologies quadrant there is no clear technology vision (except nuclear fusion) but there are statements about the characteristics of future technologies such as 'robust and resilient systems' and 'adapted smart interconnections'. It is not clear how these characteristics are going to mitigate/manage the risks identified even though one can establish a connection between these characteristics and the first risk on the list (i.e. dependency on complex systems and our lack of understanding them) following some reasoning. The only clear technological concept is nuclear fusion which is attached to a question mark since not all of the participants were comfortable with the idea that nuclear fusion should be the way to meet the society's energy needs. Also, the vision does not seem to provide sufficient detail either. For example, dominant economic paradigm is identified as one of the high-priority risks by this group. This risk is central to the activities of the foundation from which the start-up company spun-off. In one of the meetings held with the founder and director of the foundation, he stated that whatever they do, their ultimate aim is to change the dominant economic paradigm. This indicates allocation of time and resources to mull-over this aim over a long period of time. However, the only aspect of the vision addressing this risk was the decentralised banking/economic system. One item in the institutions quadrant; i.e. common global language, is not connected to any of the risks identified by the group, neither the high-priority ones nor the rest of the list.

Despite the lack of connection and clarity of some aspects of the vision, there were aspects which were clearly defined and could be directly linked to the risks identified by the group. For example, the group identified lack of drinking water as a high-priority risk. Optimum (re)use of water and natural cleaning systems in the surroundings quadrant (even though more suitable for technologies quadrant) address this risk directly. The individuals in the individuals quadrant were identified as spiritual, emphatic and global minded. These attributes were seen by the group as essential to address equitable distribution of resources and creating a sustainable society in general. Even though, the 'common global language' does not have any direct connection to the risks identified by the group, a common language is likely to improve communication and may influence decision making at global level positively.

In conclusion, even though the risks identified by this group demonstrated a high-level understanding of sustainability issues, the resulting vision addressed those risks only to a certain extent as a result of lack of clarity. One reason of not achieving development of a long-term vision might be the group's preoccupation with generating solutions for sustainability issues presently. Since the group already put a lot of thought and had preconceived ideas on how to achieve innovation for sustainability, they had difficulty in focusing on long term or seeing their present activities in the context of long term. As mentioned earlier, one of the seniors in the group commented that 50-plus years time frame was too long and imagining what would happen in 50 years time was impossible even though 50 years was the time-period generally used in system innovation related projects (see Chapter 4 Section 4.5). In facilitating this workshop it was assumed that there would be no need to explain the reasons behind using a 50-plus years time frame since the core business of the group was innovation for sustainability and this case study was based in the Netherlands; i.e. the country where system innovation theory and related projects were initiated and mainly coming from currently. In facilitating the other two workshops, the reasons behind the selection of 50-plus years time frame were explained and no similar problems were encountered. Therefore, the difficulty experienced with this group does not indicate a short-coming from the perspective of evaluating the scenario method but rather a short-coming of the facilitation of this module in this case study.

Figure A 7 shows the reproduction of the normative vision of a sustainable society developed by the participants of Case Study 3. Referring back to Table A 4, this group identified the following as high-priority risks:

1. Toxic waste;
2. Diminishing natural resources;
3. Globalisation;
4. Diminishing non-renewable energy resources and increasing energy demand, and;
5. Technophilia (The WG used this word to refer to the techno-centric viewpoint which assumes that technological development is the key to achieving sustainability).

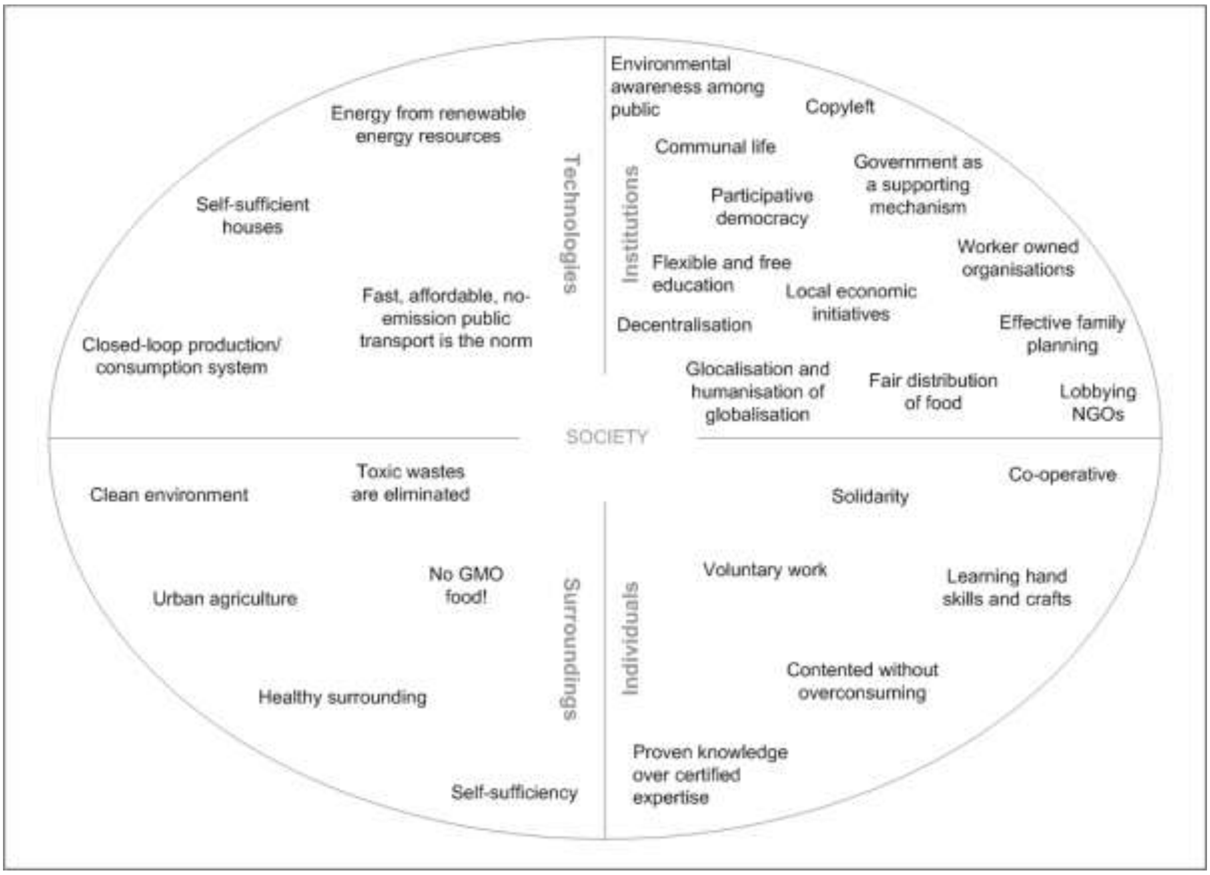


Figure A 7. The normative vision of a sustainable society developed by the participants of Case Study 3

The vision developed by the participants of Case Study 3 clearly addressed all of the risks identified as high-priority by the group as well as many of the risks not identified as high-priority by proposing changes in all four quadrants. For example, the first risk; i.e. toxic wastes, is clearly addressed in the surroundings quadrants and envisioned to be eliminated. The second risk; i.e. diminishing natural resources, is addressed in the technological quadrant by envisioning closed-loop production/consumption systems, in the institutions quadrant by envisioning an environmentally aware public and in the individuals quadrant by contentment without over-consuming.

In order to tackle the negative effects of globalisation, the group envisioned globalisation to be humanised by caring for the strength and resilience of local and regional economies. In these local and regional economies, people will not lose their jobs due to cheaper labour available elsewhere. Humanisation of globalisation was complemented by other changes in the institutional and individuals quadrants such as contentment with mostly consuming what is locally available.

The group envisioned the future to be fuelled by renewable resources to counter the undesired consequences of diminishing non-renewable energy resources and increasing energy demand. Relating to the expected population increase, this group did not see a viable future in individual car ownership and envisioned a super-fast, affordable, no-emission public transport mode to become the norm.

The risk identified as technophilia by the group corresponds to the stance that technological advancement does not per se solve our sustainability problems which is also held by the co-evolutionary paradigm to innovation discussed in Chapter 3 Section 3.2. In line with this stance the majority of the solutions anticipated by the group were under institutional and individuals quadrants; i.e. focused on behavioural and cultural change. For example, the group put a lot of emphasis on the requirement of communalism (similar to the participants of Case Study 1) and anticipated that, in a sustainable society, people should undertake voluntary work for the common good.

In the future vision developed by this group several risks not identified by the participants as high-priority were also addressed. However, a detailed account will not be given here and interested readers are encouraged to further analyse the sustainability risks list prepared by this group (Table A 4) and the vision developed (Figure A 7). For the purpose of evaluating the scenario method, sufficient evidence is provided here to demonstrate that the participants of Case Study 3 were able to generate normative, long-term, societal visions within which the risks to sustainability were mitigated/managed/adapted by the society through a combination of institutional, social/cultural, organisational and technological changes.

Criterion 4: Were the scenario maps developed by the participants able to link present to the long-term future visions of a sustainable society they developed enabling alternative innovation paths to be identified?

The process of scenario development was mediated by development of a vision for the social function identified by the group consistent with the vision of a sustainable society. The groups initially questioned if the social function they identified for their product/service still existed in a sustainable society. All three groups gave positive responses to this inquiry and developed a vision for their organisation and the social function of their product/service as a sub-set of the vision of a sustainable society, as a result systemically linked the two. From this second vision, specific to the organisation itself and the social function met by the organisation's product/service, the final event-trees were identified. Since the content of the organisational visions and scenarios are exclusive (for Case Study 1 and Case Study 2) and also not relevant to the evaluation of the scenario method, the maps are not going to be reproduced here. The important aspect of the scenario maps in the evaluation of the scenario method is the continuity of the flow between present and the future and identification of innovation paths providing the organisation with alternatives to choose from and to use if one path becomes unviable in the future. Figure A 8 shows the general structure of the maps produced.

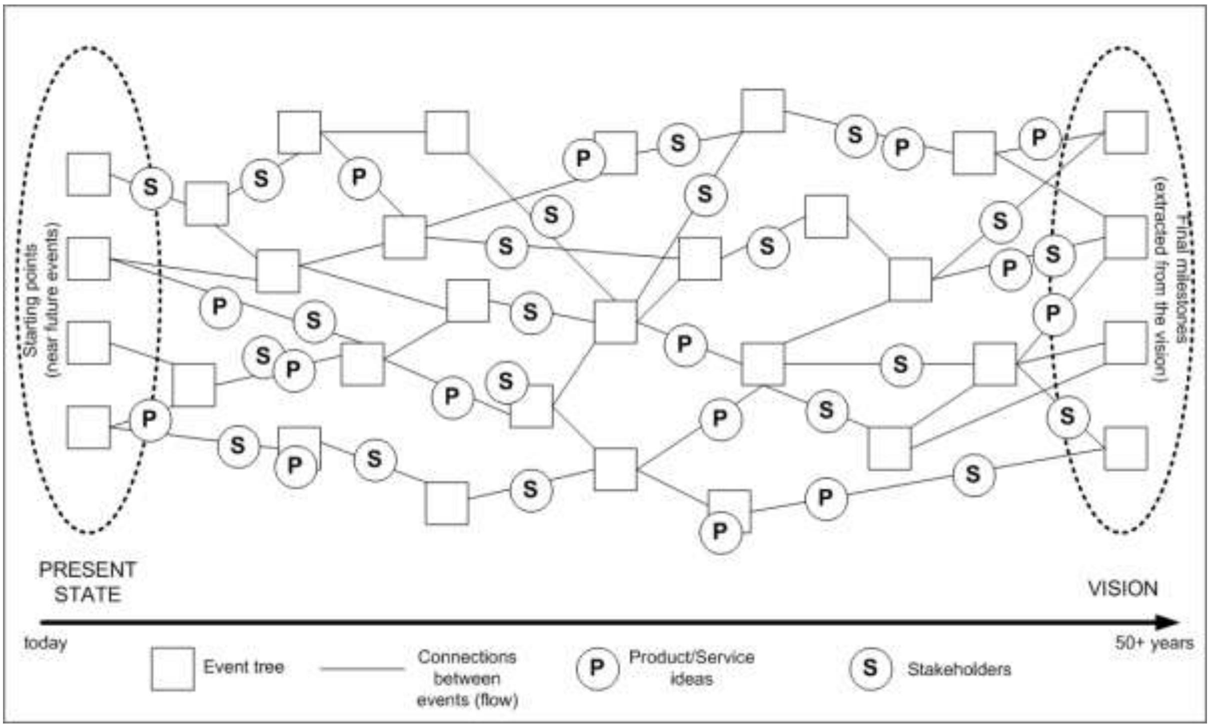


Figure A 8. The generic structure of scenario maps generated during the workshops

In the above figure on the left hand side there are events which are either happening currently or likely to happen in the very near future. These events can be events taking place in the organisation or in its immediate environment. Of course an organisation's immediate environment is not limited to physical immediacy but any event with potential high influence on the organisation's business needs to be considered here. On the right hand side, the events are directly extracted from the vision of a sustainable society and associated social function vision to mark the final milestones in achieving the vision. In the middle are events anticipated by the participants to take place in the future as well as some 'surprise' events which are not anticipated by the participants but introduced to the process by the facilitator (or a wild card) to increase diversity of innovation paths and to enable participants to think about not only likely but unlikely events and their consequences on the organisation. The events layer developed is a simpler version of the scenario network maps (List, 2005) however, they are not as detailed to cover an in-depth inquiry into the near past and intentions of stakeholders as a result of time limitations. Once the events are identified and flows are established, stakeholders are identified and mapped on the scenario map at places where they can be of high influence. Following the stakeholders layer, product/service concepts are identified and these are also mapped on the scenario map where they can be introduced.

This generic structure was achieved with all three case studies with varying degrees of detail of innovation paths. The degree of detail of innovation paths is directly proportional to the number of event trees generated by the participants. The number of event trees is directly proportional to the number of participants and the time allocated to the task of scenario development. Therefore, the degree of detail of innovation paths generated by Case Study 1 (only 4 participants) was not as high as the other two case studies. However, from the perspective of evaluating the scenario method, the scenario maps developed by the participants in all three case studies were able to link present to the long-term future visions of a sustainable society and enabled identification of alternative innovation paths.