A New Approach for Sustainable Product Development Using Scenario Network Mapping and Eco-design

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Abstract

The two most widely recognised ethics of sustainable development are equity between present and future people (intergenerational equity) and equity among currently living people (intra-generational equity); however, it is not always clear how to translate these principles into practice. This paper argues that at least two questions must first be addressed in order to bound sustainable development in space and time: (1) 'what is to be sustained?' and (2) 'sustained for how long?' In this paper, the system to be sustained is a business and the time horizon considered is 20 years. As a crucial role of any business is to meet needs within society, this paper presents a new framework for sustainable product and service development which combines both forward-looking strategy and measures that can be implemented in day-to-day product/service development. Once the framework is introduced, its application in the context of industrial electronics company Actronic Technologies is presented.

The strategic component of the framework uses a new scenario-building technique, scenario network mapping, to map trends within a business' core markets. By extending the business' planning horizon to several decades, it is possible to develop roadmaps for radically new technologies, products and/or services. However, as most products and services will undergo several major redesigns over this period, there is also room for both incremental change and flexibility at an operational level.

Even though the duration of a business' impacts upon society and the natural environment may well extend beyond 20 years, the long-term future is overwhelmingly uncertain and in most cases it will not be feasible for a business to study a time horizon of much more than this. In order to account for longer-term impacts, this framework requires that long-term risks be assessed by collaborative groups (e.g., universities and industry groups) and translated into implications that affect businesses in the short-term.

1 Background and introduction

In 1987, the World Commission on Environment and Development (WCED), chaired by former Norwegian Prime Minster Gro Harlem Brundtland, published its influential report *Our Common Future*. This document, commonly known as the *Brundtland Report*, provided what is now the most widely accepted general definition of sustainable development: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (WCED, 1987, p. 43)

Since the *Brundtland Report*, the concept of sustainable development has grown in popularity and is now accepted as a guiding principle of governments, corporations and other organisations around the world (Kates et al., 2005). Yet despite the slogans and policy statements, development remains far from sustainable (UNEP, 2007).

Many commentators frame the problem as a definitional one: we cannot measure what we cannot define therefore the solution is an operational definition to complement or replace the general Brundtland definition. However, as the current tally of definitions is likely to extend well into the thousands (Pezzey, 1997, p. 448), a universally accepted operational definition is unlikely. The challenge then becomes how to apply the principles of sustainable development elaborated by the Brundtland definition in the context of an organisation or other social group.

For businesses, a key concern is the impact of their products and services. Despite difficulties in making the Brundtland definition operational, there has been considerable progress made in assessing aspects of sustainability and developing products/services that are (or are expected to be) more sustainable than their predecessors. Environmental life cycle assessment (LCA), for example, allows businesses to assess the potential environmental impacts of their products from raw material extraction right through to their disposal, reuse or recycling (ISO, 2006). However, even though such techniques exist, their implementation in practice is often poor (see, e.g., Tukker et al., 2001 for a review of the implementation of eco-design in Europe).

In order to speed up implementation, it is tempting to develop a new tool; however, there is already too much emphasis on tool development and not enough emphasis on implementation and improvement of tools in practice (Baumann et al., 2002, p. 421). There is also too little emphasis on the connection between strategic (top-down) and operational (bottom-up) actions within business (Baumann et al., 2002, p. 421), yet the use of both approaches is essential for sustainable development (Simon, 1989, pp. 46-47; Faber et al., 2005, pp. 18-19).

The purpose of this paper is to take existing tools – in this case, eco-design (a bottom-up tool) and scenario network mapping (a top-down tool) – and discuss how they are used within a framework for new product development being applied at Actronic Technologies (Actronic). The next section questions sustainable development and outlines some preliminary responses. This is followed by discussions of innovation for sustainable product development and futures studies techniques that can be applied in long-term innovation projects. However, given that the future is uncertain, the challenge of assessing the sustainability of future options is then addressed. This leads to an overview of the sustainable product development framework, its application at Actronic and, finally, interim conclusions and the next steps that will be taken.

2 Questioning sustainable development

The inclusion of ‘development’ in ‘sustainable development’ can be regarded as the WCED’s attempt to place the principle of equity among today’s people (*intra*generational equity) alongside the principle of equity between present and future people (*inter*generational equity), which is implied by ‘sustainable’ (Redclift, 1993; Anand and Sen, 2000). However, in order to apply these principles in practice, two questions must first be addressed: ‘what is to be sustained?’ and ‘sustained for how long?’ (Costanza and Patten, 1995). While many further questions can be asked (see, e.g., Lélé, 1995), these two are perhaps the most fundamental as they define the scope of sustainable development in space and time. It is important to realise that any answers to these questions will be context specific (Norgaard, 1994, p. 22), so this section starts to sketch some preliminary responses at the level of global human society.

What is to be sustained? Fundamental to sustainable development is the survival of human life on Earth. *Our Common Future* discussed broad rules to ensure that this was possible at a global level (WCED, 1987, pp. 43-46), which were later extended by Daly (1991, pp. 44-45): (1) limit the scale of human activity to within the Earth’s carrying capacity; (2) ensure that technological progress is efficiency-increasing rather than throughput-increasing; (3) harvest rates of renewable resources should not exceed regeneration rates and waste emissions should not exceed the assimilative capacities of the receiving environment; and (4) non-renewable resources should be exploited no faster than the rate of creation of renewable substitutes.

These rules apply to human use of the natural environment, so are often considered as part of ecological or environmental sustainability. However, in order to make use of the resource base that is sustained, future people will also need appropriate knowledge and skills and some degree of social cohesion. These intangible assets, among others, are often referred to as social capital and bundled into the concept of social sustainability. Similarly, the concepts of economic capital and economic sustainability are used to refer to built infrastructure and other assets. However, it is important to note that the lines between ecological, social and economic sustainability are not always clear (see, e.g., Goodland and Daly, 1996).

Sustained for how long? One could argue that we should aim to preserve Earth's renewable resource base and life support services for as long as Earth itself is capable of supporting life. However, given the limits to human foresight over periods of decades (see, e.g., Wise, 1976; List, 2005, Appendix 1), it would be overambitious to consider a time horizon that may well be in the order of one billion years (Schröder and Smith, 2008). Furthermore, life supporting systems will change drastically over this time, so it makes little sense to attempt to sustain them in today's form. One alternative may be to use temporal scales that are consistent with the life span of the systems that actually support life: forests, fish populations, wetlands, etc. (Costanza and Patten, 1995, pp. 195-196). If these time scales are very long, it may be possible to instead consider the time duration over which stressors (e.g., the emission of sulfur dioxide into the atmosphere) are of concern.

3 Managing innovation for sustainable development

New product development must find a balance between many competing criteria, e.g., cost, aesthetics, usability and ease of manufacture. The umbrella term 'Design for X' is often applied to important criteria; for example, Design for Reliability and Design for Manufacture. With rising interest in sustainability, Design for Environment (also known as eco-design; see Brezet and van Hemel, 1997) and Design for Sustainability (also known as sustainable product design/development; see Crul and Diehl, 2006) have become increasingly popular.

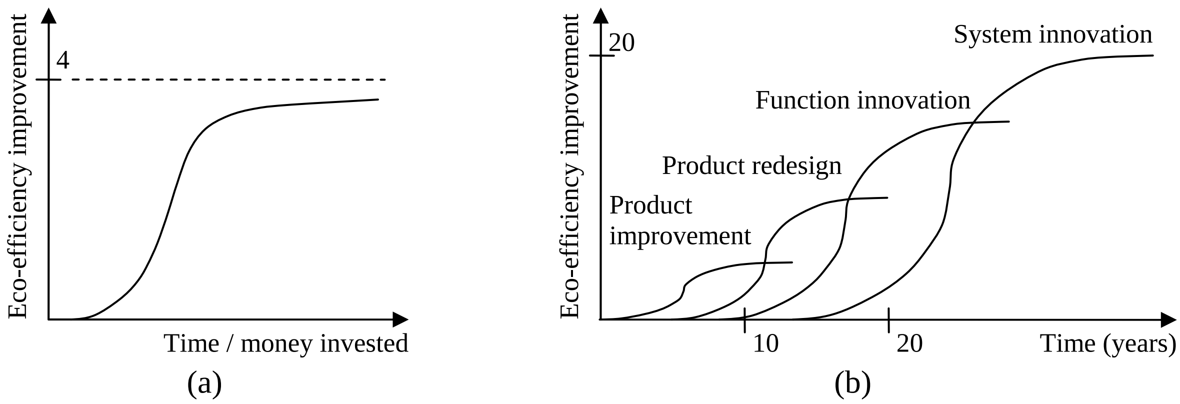

Figure 1: Eco-efficiency curves for a function that is fulfilled by (a) a single technology, or (b) different systems introduced over time as a result of innovation. (Adapted from Brezet, 1997)

Sustainable product development is broader than eco-design as it also considers social issues; however, both techniques primarily focus on ecological and economic issues. These issues may either be considered separately or together under the umbrella of eco-efficiency, a ratio between economic value and ecological impact (Huppes and Ishikawa, 2005). However, while the eco-efficiency of a technology (and the social systems that support it) can be improved, there will come a point where improvements become increasingly small and their cost can no longer be justified. For eco-efficiency, this limit is believed to be in the order of a four-fold improvement (Weaver et al., 2000, pp. 7-9), as is shown in Figure 1(a).

To go beyond this upper limit of improvement it is often necessary to enlarge the system of interest, as shown in Figure 1(b). So, for example, to reduce the emissions of a car, a designer could add a catalytic converter (product improvement), redesign the engine to be more fuel efficient (product redesign), design and promote ultra-efficient motorcycles as a better method of urban transport (function innovation), or go beyond the idea of personal transportation altogether (system innovation). This system innovation could be to make telecommuting a reality, to create a new mass public transport system that is both energy-efficient and highly effective at getting people from point A to point B, or some as yet unthought-of solution.

The last two stages may require firms to seek outside partners or even change the way that they do business. For this reason, the final stage is also known as a 'technological transition' or 'socio-technical transition'. The decades-long time horizon is based upon observations of how long it took for radical innovations, such as televisions and lasers, to be broadly adopted (Weaver et al., 2000, pp. 24, 54). However, both the time horizons and the level of eco-efficiency improvement possible will vary significantly from system to system so the numbers on the axes in Figure 1 are indicative only.

4 Scenario planning as a tool for sustainable development

As concern for the welfare of future people is fundamental to sustainable development (see section 2), it is crucial to consider what the future may bring so that there is sufficient time to mitigate risks and/or manage adaptation to large scale changes. While there are many ways to study the future, List (2005, pp. 10-11) discusses three broad categories that have emerged: intuitive, unscientific prediction; quantitative forecasting; and 'alternative futures' techniques, such as scenarios. Alternative futures developed in response to the inability of forecasting to make predictions with any accuracy more than a few years into the future (p. 19); in fact, in a review of 1556 technological forecasts that were made publicly by Americans between 1890 and 1940, Wise (1976) found that more than half were wrong and that experts were not significantly better at predicting the future than non-experts. Rather than try to accurately predict 'the future', alternative futures methods acknowledge that the future is inherently unpredictable and instead try to create a range of possible futures.

Scenarios are the most popular way to do this; however, they can be constructed in a number of different ways. List (2007a) discusses three widely used approaches:

1. *The expert method*, popularised by Royal Dutch/Shell Group, which uses skilled experts to identify key factors that are important to the future of an entity, ranks them by certainty and impact (the least certain and highest impact factors being the most important for scenarios) and then constructs a range of internally consistent scenarios;
2. *The standardised scenarios method*, which applies a selection of standard scenarios to an entity, e.g., continued growth, collapse, steady state and transformation; and
3. *The critical uncertainties method (also known as the double variable method; see Inayatullah, 2008)*, which typically identifies two variables that are both critical to the future of the entity and uncertain, and then combines two extreme values for each variable (e.g., small change vs. large change) to create four scenarios.

The expert method is poorly suited to small- and medium-sized enterprises (SMEs) as the process is time consuming (taking over a year at Shell; see Shell International, 2003, p. 23) and therefore expensive. Standardised and double variable scenarios are quicker and cheaper to construct, but consider only a small selection of the trends and other influences that may be relevant. Another difficulty with these methods is that scenarios are presented as different 'worlds' – the output is like a series of postcards or news clippings from the future describing how the world is at that time – and the connections between scenarios are often unclear (List, 2007a, pp. 3-4). An alternative technique, scenario network mapping (SNM), constructs scenarios that look more like roadmaps than postcards, as can be seen in the example in Figure 2. However, instead of towns and cities there are events, and instead of roads there are cause-and-effect links (which together form event trees) moving from the past into the future.

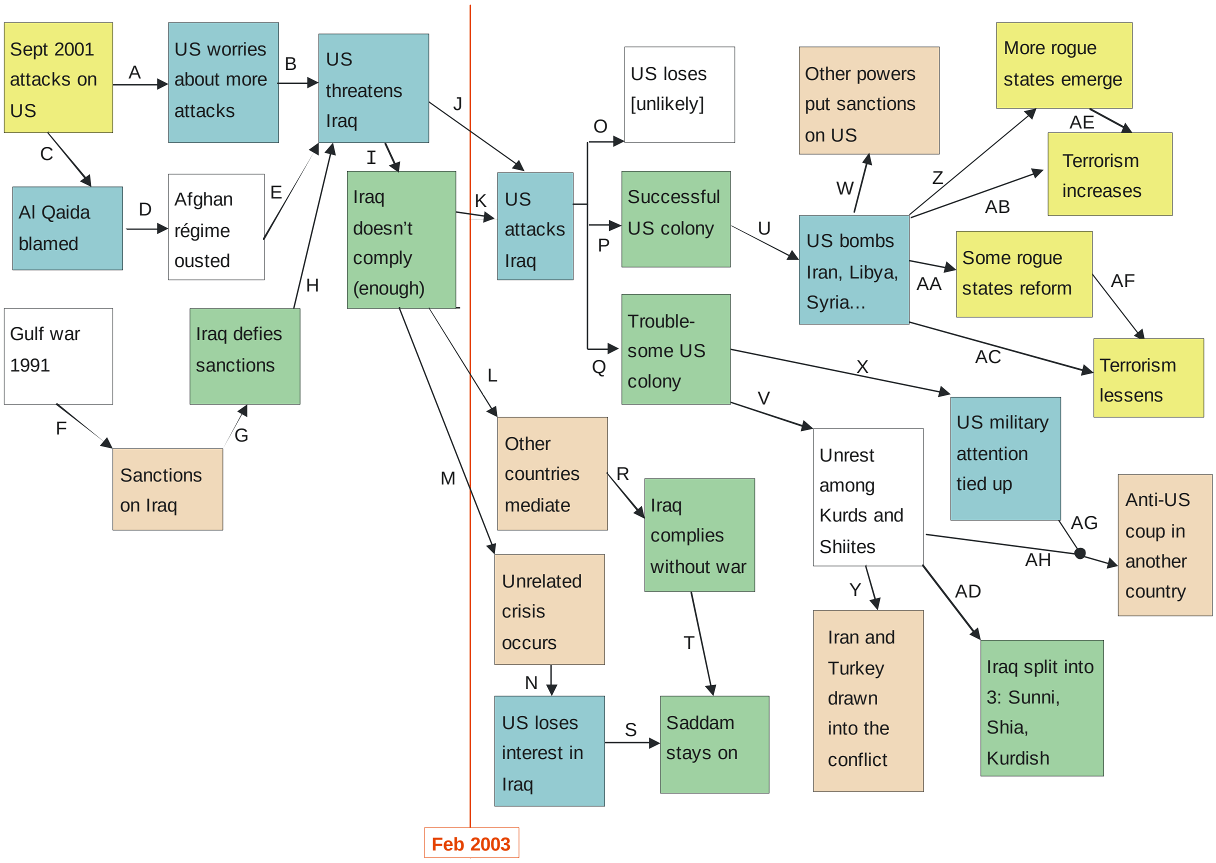

Figure 2: An example of a scenario network map for the US-led war in Iraq, constructed before it started. The past is on the left and possible futures are on the right. (Reproduced from List, 2007b, p. 88)

This approach has several advantages over conventional methods: (1) it is easier to identify leading indicators of change; (2) the underlying logic of the scenarios is made clear so they are easier to critique during development and revise in the future; and (3) scenarios lead more logically into action plans like product and technology roadmaps.

Unlike the expert method, scenario network maps are constructed by a diverse group of people that have a stake in the future under study (List, 2005, ch. 5). The reason for using stakeholders is that events within society are largely determined by people's actions, therefore the future of any group within society is largely determined by the actions of the people within that group (internal stakeholders) and the actions of the people that interact with the group (external stakeholders) (List, 2005, ch. 5).

In order to make any futures studies project manageable, a focus question with a clear scope must first be defined. List (2005) argues that any human futures project can be framed as "the futures of *[specified activity or concept]* among *[specified social group]* in *[specified location]* during *[specified time range]*" (p. 209, original emphasis). Broadly speaking, these first three variables can be combined as the 'the futures of *[what]*?', which is very similar to the question 'what is to be sustained?' from section 2. In a similar way, 'during *[specified* *time range]'* is comparable to 'sustained for how long?' In this respect, futures studies is well suited to address questions pertaining to sustainable development.

5 Assessing the future: which scenarios are sustainable?

Even LCA, one of the most detailed environmental assessment techniques, cannot definitively say that one product is 'better' than another. This is because LCA does not consider all relevant environmental impacts, there is uncertainty in inventory data, methodological decisions often involve value judgements, and impact models are an imperfect description of the real world (Finnveden, 2000). Furthermore, LCA does not account for social or economic factors, so it provides only a partial assessment of sustainability.

If it is not possible to make such an objective decision between two products, it seems highly unlikely that it will be possible to do so for two future scenario 'worlds', which will be much more complex. For this reason, it is crucial that the people who hold an interest in a social entity be involved in any decision over its future. However, stakeholder participation alone is insufficient for sustainable development – desirability does not ensure sustainability. While many groups have developed normative scenarios for sustainability, few have tried to assess whether these scenarios would be more or less sustainable than today's situation.

One study that did attempt this was the Sustainable Technology Development (STD) programme in the Netherlands during the 1990s (Weaver et al., 2000). The programme estimated a sustainable level of exploitation for a range of environmental concerns – depletion of oil, depletion of biodiversity, emission of carbon, etc. – and compared this with expected exploitation in 2040, assuming that each person lived a similar lifestyle to those in the developed world in 1990 (pp. 35-43). Identical living standards were used for all people to show the amount of improvement necessary if global society was to achieve equality by 2040. The findings showed that for many indicators, exploitation would need to be reduced by 10-, 20- or even 50-fold by 2040 (p. 41). These large numbers were used to prove that sustainable development requires radical innovation (pp. 7-8).

Using eco-efficiency as a yardstick helped to stimulate radical innovation; however, as with LCA, eco-efficiency can provide only a partial assessment of sustainability. Furthermore, for many ecological systems it will not be possible to estimate fixed limits to their ability to act as a source of resources or a sink for wastes (Norgaard, 1995), so the magnitudes of the eco-efficiency improvements that were calculated must be regarded as speculative. For these reasons, the remainder of this paper will assume that it is not possible to prove that one scenario is more sustainable than another. Scenarios will instead be used as a learning tool, a tool for risk mitigation, a tool for robust product development and a tool to assist adaptation.

6 Reconsidering sustainable product development

The four tier model in Figure 1 on page 3 presents four types of innovation with increasing influence upon eco-efficiency: product improvement, product redesign, function innovation and system innovation. In the final level – system innovation – individual organisations and individual products and services are no longer the focus for optimisation; instead the focus shifts to entire market sectors (e.g., transport). This is problematic for at least three reasons: (1) many scholars believe that the concepts of efficiency and optimisation, well suited to the running of a factory, are ill suited and even damaging when applied to society (Sachs, 1999; Princen, 2003); (2) as the time horizon considered is decades, multiple future scenarios must be developed to cope with uncertainty, yet it is unlikely that any one scenario can be proved 'more sustainable' than another (see section 5); and (3) while a successful system innovation is likely to be very lucrative for the firms that develop, market and support it, by shifting the focus away from individual organisations, the system innovation process can disempower these organisations. Thus, while system innovation is crucial for sustainable development, it will not be the focus of the framework for sustainable product development presented in this section. Instead, the focus will be on the lower levels of innovation that can be implemented by a single organisation: product improvement, product redesign and function innovation.

6.1 What is the system of interest?

Sustainable development can be applied to any social group, but in the context of sustainable product development, a business seems the logical choice. One challenge this poses is that a business' boundaries are constantly changing: staff may come and go and the entire business may be bought, sold or merged with another entity. Yet no matter how the boundaries are defined, a business must always meet a social need through its products and services (collectively 'products') in return for the income it receives. As every product requires raw materials and energy, all products have an impact upon the natural environment. Similarly, all products require human input – either directly through human labour or indirectly through the design and construction of machines to replace human labour – so all products have an impact upon society. As such, products affect the sustainability of the society in which the business is embedded and, therefore, products and the social-ecological systems that support them are an appropriate focus for research on sustainable development. However, as a product requires a market in which it can be traded, it is critical to understand what may happen to a product's markets in the future in order to understand what may happen to the product itself.

6.2 Over what time horizon should this system be studied?

It was argued in section 2 that the time horizon considered by a social group should be consistent with the life expectancies of the systems critical to its survival (e.g., the global climatic system), or, alternatively, consistent with the time horizon in which stresses imposed upon the system by the social group may have an effect (e.g., the duration that CO_2 remains in the atmosphere). However, the time horizon in both cases may be many decades, centuries, or millennia (consider, e.g., the half-lives of radioactive wastes). Such horizons are well outside 'long-term' strategic planning processes of businesses today. In surveys of strategic planning within UK firms, a study that included a high proportion of SMEs found that less than 3% of respondents considered a time horizon of greater than five years (Stonehouse and Pemberton, 2002, p. 857), while another study that included a high proportion of large enterprises found that 13% considered a time horizon of more than five years (Glaister and Falshaw, 1999, p. 109). In a survey of the strategic planning practices within multinational oil companies, Grant (2003) found that the longest strategic planning horizon – 20 years – was used by Shell.

The challenge with long time horizons is that the further into the future we look, the hazier the picture becomes. Shell, for example, have found that scenarios that look 20 years ahead are typically only valid for the next three to four years (Shell International, 2003, p. 87). Rather than expect all firms, including SMEs, to construct scenarios with time horizons of many decades, it seems more feasible to have larger social groups (e.g., industry associations, government agencies and associations of scientists) construct these scenarios and translate the long-term risks into measures with short-term implications. A current example is the impact that the Intergovernmental Panel on Climate Change (IPCC) has had on climate policy. Its reports have to a large extent led to the creation of carbon markets, such as the European Union Emission Trading Scheme, which assign a cost to carbon emissions and thereby make them a factor in present-day decisions. However, it should be noted that this privatisation of a public asset is not universally considered to be a 'good thing' (see, e.g., Lohmann, 2006).

Assuming that long-term (greater than 20 year) scenarios can and will be developed by broad social groups, not individual businesses, the time horizon for sustainable product development can be set firm by firm. For this paper, the time horizon will be approximately 20 years as:

1. It is close to the length of one human generation and is therefore the minimum time horizon necessary for a business to consider intergenerational equity directly;
2. This is sufficient time for function innovation (see Figure 1 on page 3), so it should be possible to make large improvements in environmental performance;
3. In most cases a product will undergo several major redesigns over a 20 year period, therefore potential future improvements can be mapped and phased in over time; and
4. Scenario network mapping is not designed for time horizons longer than 20 years as beyond this almost anything is possible (List, 2005, p. 2).

6.3 Combining 'top down' and 'bottom up' innovation within a business

Early work on the stimuli for innovation debated whether it was primarily driven from the demand side ('demand-pull') or the supply side ('supply-push'); however, it is now widely recognised that innovation is influenced both by demand-pull and supply-push, coupled with other regulatory and institutional factors (Mowery and Rosenberg, 1979; Cleff and Rennings, 1999). This should not come as much of a surprise: a product will not sell if there is no market, but for new innovations (e.g., microelectronics) there will not be a market unless potential customers see the benefits these innovations offer them. Likewise, regulatory and institutional factors provide the setting for the creation and diffusion of innovations.

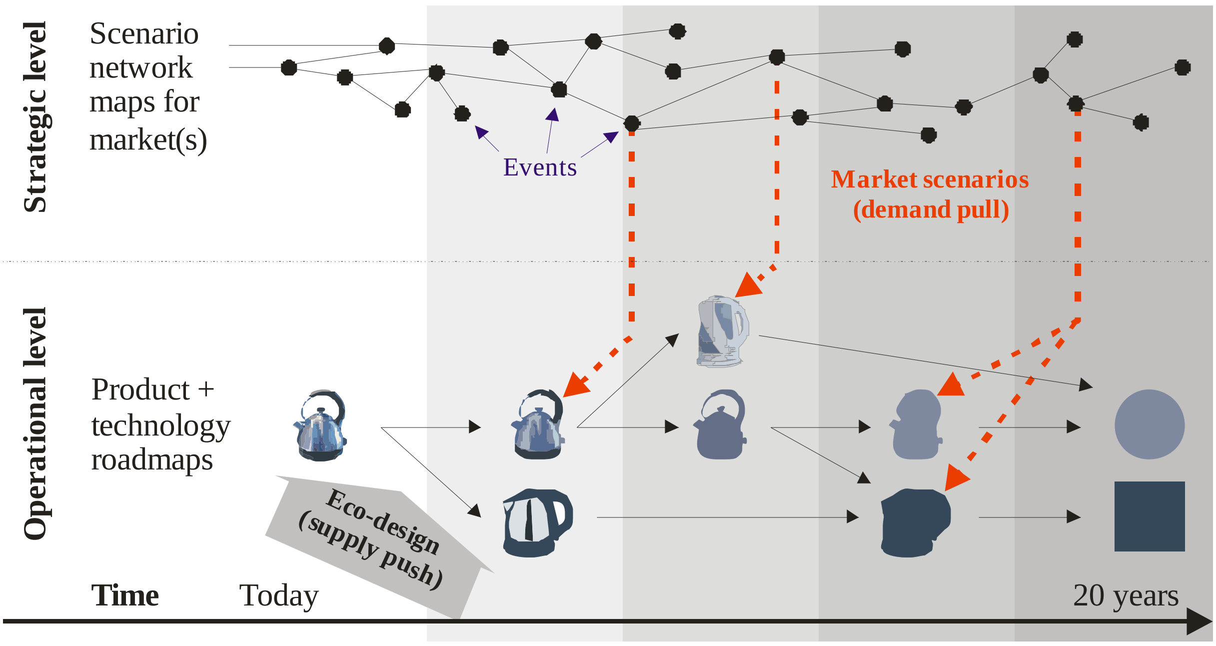

Figure 3: The links between scenario network maps for key markets (strategic level) and product and/or technology roadmaps which define solutions to fulfil these market needs (operational level).

Figure 3 provides a simple conceptual framework for sustainable product development that accounts for these factors and also accounts for the need to link strategic ('top-down') and operational ('bottom-up') initiatives within business, as discussed by Baumann et al. (2002, p. 421). In this case, supply-side and demand-side factors include all of the regulatory and institutional factors that influence the supply and demand of products and services, which is a broader interpretation than that generally used in economics. This framework suggests that businesses develop scenario network maps for their key market(s) over a time horizon of approximately 20 years. These maps set the context for future products and services and allow for robust strategy development. As the complexity of the real world makes it difficult to assess which scenarios are most likely, a robust strategy will be one that performs at least adequately under all scenarios at any given time (Schwartz, 1998, pp. xiii-xiv). Another important consideration for strategy development is flexibility. Scenarios do not predict 'the future' and as time passes, previously unforeseen events will spring up and certain chains of events will seem more plausible while others will seem less plausible. This 20 year time horizon is therefore better described as a sliding window; scenario-building is not a once-off exercise, rather it is an ongoing part of strategy development.

The scenarios and the strategies that flow from them can then be used to define operational paths for technology and product/service development. As a product or service is likely to undergo several redesigns over a 20 year period, designers (including engineers, supply chain managers, etc.) can seek to continuously improve its environmental and social performance.

7 Case study: An onboard weighing scale for heavy machinery

7.1 Introducing Actronic Technologies and Loadrite®

The case study for this paper is a Loadrite hydraulic weighing scale (see Figure 1), a system installed on industrial lifting machines, such as front-end loaders and excavators. It is designed and manufactured by Actronic Technologies, an industrial electronics company that employs approximately 70 staff worldwide. One common application for this product is to assist front-end loader operators in quarries to load road trucks accurately, thereby minimising both the number of truck trips needed to move a certain amount of material and the number of overload fines that truck operators receive.

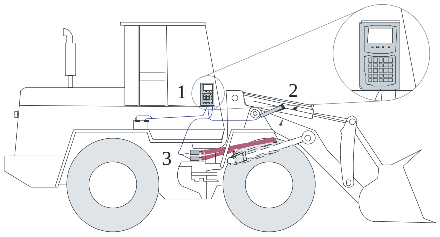

Figure 4: A Loadrite system installed on a front-end loader, consisting of: (1) indicator [processor, keypad and screen]; (2) trigger; and (3) pressure transducers.

7.2 'Top down' actions: scenario network mapping

7.2.1 Framing the futures question

Loadrite systems are sold into approximately 30 countries and within these countries they are used in a variety of applications (aggregates, mining, construction, agriculture, waste, etc.). Possible focus questions for scenario network mapping might include: 'the futures of the aggregates industry in the USA', 'the futures of hydraulic lifting systems in the mining industry' and/or 'the futures of wheel loaders in the Chinese aggregates industry'. But these questions are too specific as the future of onboard weighing scales is not solely dependent on a single market. However, the futures of these products are fully dependent on the machines into which they are installed, so the focus question has been refined as 'the futures of productivity systems for construction and mining equipment' (Figure 5). 'Productivity systems' has been used to reflect the broader industry of which weighing scales are a part.

Figure 5: Some examples of construction and mining equipment

However, in order to address this question it is first necessary to understand how the futures of construction and mining equipment may unfold. This in turn requires that the applications in which these machines are used be understood. Yet the stakeholders who should be invited to assess these futures are unlikely to be interested in a question as specific as ‘productivity systems for construction and mining equipment’. Instead, the broad question of ‘construction and mining equipment’ will be considered first and the output of this process will be fed into the input of the next. More specifically, the two questions to be addressed are: (1) ‘the futures of construction and mining equipment in the world up to 2030’; and (2) ‘the futures of productivity systems for construction and mining equipment in the world up to 2030’.

7.2.2 Extending and streamlining the scenario network mapping process

SNM is not designed to assess the futures of a global industry as too many stakeholders would need to be involved (List, 2005, p. 2). Furthermore, the standard scenario network mapping process involves four half-day workshops, each spaced approximately one week apart (List, 2007a, p. 4). Yet this project will study a global industry (construction and mining equipment) and given that a broad range of international stakeholders must be involved, four half-day workshops would be prohibitively expensive and difficult to coordinate. To this end, the SNM process found in List (2005, Appendix 5) has been streamlined as follows:

- The first workshop (“Influences from the past and present”) has been replaced by two questionnaires, the results of which will be compiled into a background document;
- The second and third workshops (“Generating possibilities” and “Mapping paths to the future”) have been combined and will be followed by discussion online; and
- The final workshop (“The future as layers”) remains largely unchanged.

The whole process will be repeated three times, with the first two iterations addressing ‘the futures of construction and mining equipment in the world up to 2030’ and the final iteration addressing ‘the futures of productivity systems for construction and mining equipment in the world up to 2030’. The first iteration will involve staff from Actronic only, each playing the role of an important stakeholder. It will be used as a test case to: (1) trial the revised scenario network mapping process; and (2) serve as a point of comparison with the second iteration so that the impact of broad stakeholder involvement can be assessed.

7.3 ‘Bottom up’ actions: eco-design

The first step for Actronic was to benchmark the environmental performance of its products. For this, the streamlined life cycle assessment tool eVerdEE was chosen as it had a large database (including electronic components), was easy to use and was capable of performing an LCA close to that of a comprehensive tool like GaBi (Vickers et al., 2008). The purpose of this LCA was to identify ‘hot spots’ of environmental impact along the product’s life cycle. The findings showed that use of the product was the most significant life cycle stage, followed by its distribution via airfreight and then pre-manufacture of its components and sub-assemblies. Final manufacture at Actronic had negligible impact (Vickers et al., 2008).

Starting with the next major revision to its product platform, Actronic will actively consider environmental criteria – such as recyclability, ease of disassembly, etc. – in new product development. As Actronic operates a stage-gate product development model, where new products must be reviewed at the end of each stage before being allowed to proceed through the gate to the next stage, these environmental criteria can be incorporated into the gate reviews to help ensure their implementation in practice.

As eVerdEE does not assess toxicity to humans or ecosystems, Actronic have also begun to phase out hazardous substances from their products. The first substances targeted were those listed in the European Union’s RoHS Directive (EU, 2003). Beyond this, Actronic will review Level A and Level B substances listed in the JIG-101 standard (EIA et al., 2005).

While the focus in this section has been on environmental impacts, attention can and should also be paid to social impacts. One way of incorporating this at an operational level is to audit suppliers’ workplaces; however, this may not be feasible for many small businesses.

8 Conclusions

The Brundtland definition illustrates two normative ethical principles that underlie sustainable development: inter- and intra-generational equity. However, in order to apply these principles in practice, some important questions need to be addressed, notably ‘what is to be sustained?’ and ‘sustained for how long?’ For sustainable product development, the system to be sustained is arguably a business. Products and services are a suitable focus for research into business sustainability as a business must have something to sell in order to survive. Yet products and services also require markets into which they can be sold, so to understand the future of a business it is crucial to understand the futures of its key market(s).

In order to address issues of intergenerational equity, the minimum timeframe that can be considered is that of one human generation, or approximately 20 to 30 years. However, over such a period the future becomes highly uncertain, so techniques that consider multiple futures are preferable to those that consider only one possibility. Scenario network mapping was chosen over other scenario-building techniques as: (1) it can be applied by an SME; (2) the resulting maps make it easier to identify leading indicators of change; (3) the logic of the scenarios is made clear so they can be critiqued during development and revised in the future; and (4) scenarios lead more logically into action plans like product and technology roadmaps.

One serious challenge for long-term sustainable product development is that it is not possible to determine which concepts are sustainable and which are not, as uncertainty is pervasive in social-ecological systems. While shared visions of the future are laudable, a desirable future is not necessarily the same as a sustainable future. Instead of trying to describe the future as it ought to be, the framework presented in this paper seeks to build a range of different future scenarios for a business’ markets and then to assess product/service concepts based upon their performance under all scenarios (i.e., their robustness) and their flexibility.

In order to account for long-lived anthropogenic impacts (i.e., those that exceed 20 years), one approach is to have other organisations – business associations, universities, government departments, etc. – translate these long-term risks into near-term measures. A current example of this is the influence that the IPCC has had on the development of carbon markets. The framework discussed in this paper relies on such measures, as it is unrealistic to expect every business in the world to adopt scenario-based planning that uses a time horizon of decades, centuries or millennia. Instead, the time horizon can be set on a firm-by-firm basis. In this paper, a horizon of 20 years is posited for the following reasons: (1) it is approximately the length of one human generation; (2) it is thought to be sufficient time for function innovation; (3) in most cases a product will undergo several major redesigns over a 20 year period, therefore potential future improvements can be mapped and phased in over time; and (4) the scenario technique to be used, scenario network mapping, is not designed for time horizons longer than 20 years as beyond this almost anything is possible (List, 2005, p. 2).

In order to effectively implement sustainable development within a business context, strategy development should be accompanied with tools that empower those involved in product and service development to take action on a day-to-day basis (Baumann et al., 2002, p. 421). In the case study of Actronic Technologies, the top-down strategic level considers ‘the futures of productivity systems for construction and mining equipment in the world up to 2030’, while the bottom-up operational level phases out hazardous substances and designs for disassembly and recycling, among other things. Implementation of these strategies is already underway within Actronic and the findings will be published once the study is completed in mid-2009.

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