

# A Systems Modeling Approach to Support Environmentally Sustainable Business Development in Manufacturing SMEs

Manuel Seidel, Rainer Seidel, Des Tedford, Richard Cross and Logan Wait

**Abstract**—Small and Medium Sized Enterprises (SMEs) play an important role in many economies. In New Zealand, for example, 97% of all manufacturing companies employ less than 100 staff, and generate the predominant part of this industry sector's economic output. Manufacturing SMEs as a group also have a significant impact on the environment. This situation is similar in many developed economies, including the European Union. Sustainable economic development therefore needs to strongly consider the role of manufacturing SMEs, who generally find it challenging to move towards more environmentally friendly business practices.

This paper presents a systems thinking approach to modelling and understanding the factors which have an influence on the successful uptake of environmental practices in small and medium sized manufacturing companies. It presents a number of causal loop diagrams which have been developed based on primary action research, and a thorough understanding of the literature in this area. The systems thinking model provides the basis for further development of a strategic framework for the successful uptake of environmental innovation in manufacturing SMEs.

**Keywords**—Environmentally benign manufacturing, SMEs, Systems modeling.

## I. INTRODUCTION

In the last few years sustainable economic development has come in the mainstream of public perception in most industrialised countries, and there has been a clear increase in consumer understanding and affinity to global environmental issues such as climate change and oil depletion. With this raised awareness in the market, has come a steady increase in the demand for environmentally friendly products. This trend is particularly prominent in European countries where environmental criteria for products are quickly becoming order qualifying factors [1]. In addition, environmental legislation in the European Union is the strictest in the world, and is now covering all aspects of manufacturing.

Environmental design and manufacturing principles are already well established in many European companies, whereas in some other parts of the developed world, manufacturers are

lagging behind, as the main external drivers towards sustainability are not as strong [2, 3]. However, given the global trend to sustainability thinking, it seems only a matter of time before markets in more developed countries follow the lead of Europe in their demand for environmentally benign products.

This paper presents systems models of the factors that affect sustainable business development in Small and Medium sized Enterprises (SMEs). The aim of this ongoing research is to enable the development of a practical strategic roadmap to enable these companies to overcome the barriers they face due to their intrinsic lack of investment and skill resources.

## II. RESEARCH STRUCTURE AND METHODOLOGY

The overall aim of this research is to develop a practical strategic 'roadmap' for successfully overcoming the barriers that small and medium sized manufacturers face in adopting environmental design and manufacturing practices and moving towards sustainable business development. As seen in the schematic in Figure 1, the research is based on a triangulation methodology which includes Action Research [4] in a case study SME, a broader qualitative investigation in a number of case companies, and model development based on a comprehensive analysis of the existing scientific literature.

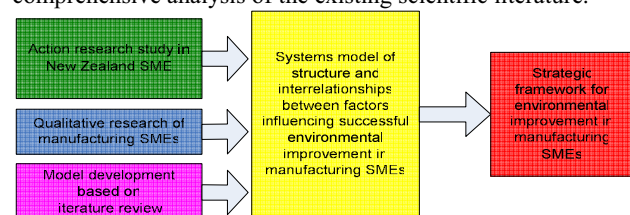


Fig 1: Schematic of research methodology

At this stage, the first of two Action Research cycles have been completed along with an initial review of the relevant literature. The following sections summarise the findings of this initial research and subsequently summarise a number of causal loop models linking the significant influencing factors in the successful uptake of environmental practices and innovation in manufacturing SMEs.

## III. NEW ZEALAND MANUFACTURING SECTOR

Over the last five years the New Zealand business environment for manufacturers has become increasingly

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difficult to operate in. Manufacturers catering for the domestic market are coming under pressure to create competitive advantage over foreign companies importing products at low cost from Asia. New Zealand's overvalued exchange rate and the attraction of low labour and operating costs in third world countries have both contributed to the recent trend of high-profile manufacturers moving their operations offshore. A number of business experts are already predicting the gradual decline of the manufacturing sector in this country.

Most manufacturers operating in New Zealand fall under the category of Small and Medium sized Enterprises (SMEs). Figures from Statistics New Zealand show that there were 23,095 manufacturing enterprises in this country [5]. Of this sector, the vast majority fall into the SME category of 100 or less employees (Figure 2).

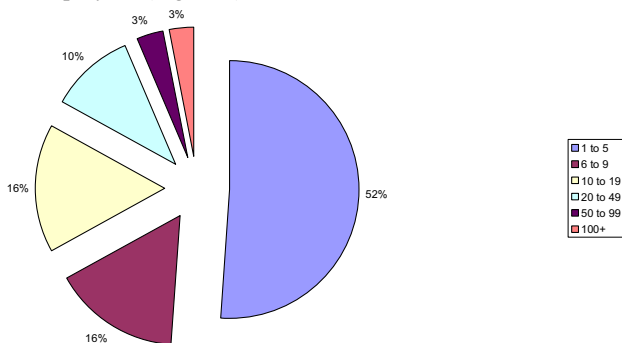


Fig. 2: Breakdown of the New Zealand manufacturing sector in terms of employee numbers

Small and medium sized manufacturing companies clearly play an important role in New Zealand and globally in both developing and OECD economies. Finding suitable practical approaches to introduce and integrate environmental sustainability in these companies can, therefore, significantly contribute to the global quest towards sustainable economic development.

#### IV. SYSTEMS THINKING AND ENVIRONMENTALLY SUSTAINABLE BUSINESS DEVELOPMENT

The successful adoption of environmental design and manufacturing innovation requires substantial organisational change – and organisational change in SMEs is complex. Many variables, both internal and external, have an influence on driving and obstructing successful change.

Internal factors include management structure, organisational culture and politics, leadership capabilities, shared vision, financial position, management and strategic processes, etc. These internal influencing factors are interrelated and dynamic, as opposed to controlled and static, which traditional research methods use as an assumption.

In addition to the internal organisational factors, an SME is also influenced by its external business environment. External factors that have an influence on SME organisational change and innovation can include: changing market requirements, competitive pressures, legislation, etc. It is thus quite clear that in the SME context nothing is 'black and white'; decisions are often made based on what the decision maker believes to be

the best means by which the company can remain in business from one day to the next.

Systems thinking seems an obvious method to capture this complex scenario and develop possible pathways to overcoming the barriers to the adoption of environmental product and process innovation in SMEs. As opposed to other methods, systems thinking acknowledges the 'messiness' of the world and sees the problems in the context of their internal and external environments [6]. Without an explicit understanding of the underlying causes of barriers and events related to environmental issues within an organisation or community, any solution will often create another event, and an endless stream of cause-and-effect relationships will develop [7]. Solutions that seem sound in the short term, may in fact amplify or merely shift the problem elsewhere, costing an organisation significantly more in the longer term [8]. Systems thinking is an approach to research which views individual component parts of a system in the context of relationships with other systems rather than in isolation. This enables a more holistic understanding of the impact that a solution may have on the organisation in the short and longer term.

It has become clear that in the change process toward sustainable business development no single factor has an overarching influence on success. For example, the development and implementation of an Environmental Management System (EMS) certified to ISO14001 standard does not necessarily mean that an organisation will make effective continuous improvements in the environmental context. However, on the other hand, it would be wrong to say that the existence of an EMS does not have an effect on successful change. The point is that an EMS will most likely not be effective without for example the complementary existence of an organisational culture which is open and conducive to environmental innovation.

To develop effective mechanisms and methods for successfully overcoming the barriers towards sustainable business development in SMEs, it is therefore important that we sufficiently understand and model the various factors (and their interrelationships) that have an influence. Systems thinking, for example through the application of causal loop models, captures the relationships and feedback between various influencing factors, and has been found to be effective in understanding and solving complex problems in the organisational context [6, 9].

In his book 'The fifth discipline', Senge describes five disciplines necessary for cultivating successful organisational learning [8]. The five disciplines described by Senge are personal mastery, mental models, shared vision, team learning, and systems thinking. Systems thinking is seen as the cornerstone which fuses the other disciplines into developing a holistic and coherent body of knowledge and practice. Senge argues that in the organisational context, managers often focus on solutions that are closely related to the problem and that seem to create immediate short term (usually financial) benefits. However, when these short term solutions are viewed in the systems context, they can often be seen to be the cause of significant long term costs.

SMEs in particular are well known for their short-term 'fire fighting' focus on day to day survival, and often put few resources into the development and direction of the business in a strategic sense [10, 11].

This paper describes the findings of our research into the structural factors that have an impact on successfully developing sustainable business practices in manufacturing SMEs. A systems thinking approach which models the organisational factors that affect the success of environmental innovation in manufacturing SMEs is presented. It is based on our extensive review of the available literature, a range of surveys and studies of SMEs in New Zealand and, and the initial results of a longitudinal action research study of a 'typical' manufacturing SME in New Zealand.

## V. DISTINCTIVE CHARACTERISTICS OF SMEs

In developing the initial systems thinking model it was clear that a comprehensive understanding of the special characteristics of SMEs and their operating environments was required. SMEs are not simply 'smaller large companies' as their characteristics make the process of successfully implementing environmental innovation different compared with larger organisations [3, 12]. In the context of this research, SMEs are defined by their firm characteristics; the following paragraphs discuss the organisational traits which the literature describes as 'typical' of SMEs. The behaviour of these organisations is largely dictated by these structural characteristics rather than by their staff numbers. The important characteristics of SMEs have been built into the causal loop models described later in the paper.

SMEs are usually privately owned businesses that are managed by their owner/entrepreneur. In larger organisations, the 'power base' is more evenly distributed amongst the managers of various departments, whereas in SMEs, the owner generally has a major influence on most strategic decisions. The background, character, values, beliefs and education of their manager will thus have a significant impact on the strategic direction of the firm [13, 14].

Another characteristic of SMEs that makes them different from larger companies is in their general organisational structure. In SMEs, job descriptions are often not as well defined and there can be a significant overlap in responsibilities with staff members taking on a number of different roles [15]. The accountability of individuals is therefore often lower than in larger firms, and initiatives sometimes 'tend to fizzle out'. In addition to this, SMEs often have fewer, less structured procedures in place for strategic development, and the communication and information flows are usually less formalised. This means that details regarding strategic initiatives are sometimes inclined to lack follow-up and can 'fall through the cracks' [11].

The majority of SMEs serve their local markets as opposed to exporting significantly (although with increasing globalisation, there is a trend toward more export). They are therefore less exposed to international pressures and trends when compared with larger multinational corporations, as local markets may not represent market expectations overseas in terms of legislation and public perception.

Another important characteristic of SMEs is their general focus on day-to-day activities. This is due mainly as a result of inherent limitations in financial and staff resources, and SMEs thus often concentrate on short-term problem solving and 'making ends meet', as opposed to taking a longer-term strategic approach [16].

In summary:

- Owner managers in SMEs have a strong influence on the direction of the organisation
- SMEs often have a short term focus with little thought for strategic initiatives
- Communication flows are often not well developed
- SMEs are strongly influenced by external conditions

## VI. BARRIERS TO MANUFACTURING SME ADOPTION OF SUSTAINABLE BUSINESS PRACTICES

In order to effectively model the system of environmental innovation uptake in SMEs, it is fundamental to understand the drivers and barriers that have an influence of the system in addition to the specific characteristics and operating conditions of these organisations. It is the combination of the characteristics of SMEs and influences from their operating environment (introduced in the previous section) which cause barriers to the implementation of environmental innovation. The process of moving towards environmentally benign design and manufacturing and the development of sustainable business practices is thus inherently complex [17].

Previous research has identified some of the difficulties that SMEs typically face when aiming at implementing environmentally friendly and sustainable business practices. The major impediments to the successful adoption of environmentally benign manufacturing for SMEs are summarised in Table 1 and analysed and discussed in further detail below.

An important barrier to improving environmental performance in SMEs is their undeveloped organisational culture with regard to environmental issues [20]. This becomes a particular problem in economies which, at present, have limited external drivers pushing SMEs towards making environmental improvements, such as legislation, public pressure or market requirements. In this situation, companies are effectively forced to develop their own internal drive for environmental innovation activities. Without an organisation-wide affinity for environmental issues (but in particular from a top management perspective), companies will most likely make very limited progress in this area [35].

As mentioned earlier, the vast majority of enterprises operating around the world are SMEs, and their cumulative impact makes them very significant contributors to the world's environmental problems [31]. While there are no quantifiable figures available, it has been estimated that SMEs contribute up to 70% of global pollution [25]. However, a survey into the environmental practices of SMEs in the United Kingdom has revealed that the vast majority of SMEs are ignorant of their own environmental impacts [22]. For example in 2002, 86% of SMEs questioned in the survey believed that their activities did not have a harmful impact on the environment. Past surveys by

the UK organisation Envirowise even highlight an increasing level of 'head in the sand' attitudes by SMEs: 22%, 33%, and 48% of the businesses questioned in 1995, 1998, and 2000 respectively, felt that they did not have a negative impact on the environment [36]. A similar trend is evident from the follow-up survey to the 2002 NetRegs study, which revealed that in 2005 only 7% of the surveyed UK businesses thought that they performed activities that could cause harm to the environment [23]. It is obvious that this misjudgement by SMEs of their environmental impact does not bode well as a driver for increasing their level of environmental performance.

Owner-managers of SMEs typically have very limited 'ecoliteracy' or in other words, knowledge and understanding of environmental issues and how they relate to their company [27]. This is a major concern, because as previously mentioned, owner-managers in small firms typically have significant power and influence, and thus are the source of most strategic initiatives and decisions. In cases where this lack of knowledge with regard to environmental issues exists, owner-managers are unlikely to put into place systems or initiatives to make improvements.

Recent studies have shown that effective environmental legislation is one of the most important reasons why SMEs invest in environmental developments [37, 38]. SMEs will often state that they will not invest in environmental improvements unless they are forced to by law [37, 39]. In SMEs in countries like New Zealand, there is an apparent lack of awareness of the international trends in legislation and markets with regard to the environmental aspects to business [31]. It is true that with the onset of information technology and globalisation, SMEs now have increased exposure to international business influences, opportunities, threats, and imperatives [40]. However, it seems that even in the 21st century, many SMEs (especially in less developed economies) struggle to use the available information to respond quickly to the competitive pressures from abroad [41].

This inability by SMEs to be flexible and responsive to the increased importance of environmental issues in the market, is likely caused by their general lack of available financial and time resources. SMEs will usually not consider investment that does not present a significant short-term financial benefit [20]. This is a particular problem in countries without stringent environmental legislation, which effectively rely on manufacturing companies to voluntarily adopt environmental practices.

Table 1: Barriers faced by SMEs to adopting sustainable business practices

Barrier faced by SMEs	Examples of literature references
Undeveloped organisational environmental culture.	[18-20]
Ignorance of own environmental impacts	[21-24]
Lack of knowledge and experience with environmental issues	[15, 20, 25-28]
Absence of effective environmental legislation	[20, 29]
Lack of awareness of trends or not believing that sustainability will benefit the company	[25, 30, 31]
Limited financial and staff resources available for environmental projects	[2, 15, 20, 26, 27, 30],
Perceived conflicts between environmentally friendly practices and other business objectives	[1, 32]
Tools, business case, measurements, and verification procedures so far are primarily aimed at large businesses	[15, 33, 34]

## VII. DRIVERS FOR MANUFACTURING SME ADOPTION OF SUSTAINABLE BUSINESS PRACTICES

In the past, environmental concerns in business have generally centred on large manufacturing organisations, whereas small and medium sized firms have been largely neglected [20]. It has been said that this is because

*"... small businesses are written off as a group that is too expensive to reach, while attention is concentrated on the easier to reach large businesses" [29].*

Another reason why more progress in the area of sustainability has been achieved with larger companies is due to the public pressure historically put on large manufacturing enterprises, which is based on the belief that they were the major contributors to environmental degradation [27].

Previous studies have provided extensive analysis of the drivers of corporate social responsibility [42-44]. Bansal and Roth list three categories that motivate firms to take on ecologically responsive initiatives:

1. Legitimation – the desire to improve suitability of the firm's actions within an established set of regulations, norms and values [45].
2. Moral responsibility – the desire that stems from the concerns a firm has for its social obligations arising from its self-perception as a functional entity within the macro economic, social and natural environments [46].
3. Competitiveness – the desire to improve the potential for profitability through developing resources and capabilities that are difficult to imitate [47, 48].

Table 2 summarises the SME drivers for the adoption of environmental innovations in products and production processes.

Drivers and pressures for SME adoption of environmental practices	Examples of literature references
Customer pressure	[26, 49, 50]
Business to business pressure from larger organisations	[3]
Managing existing and future legislative requirements	[3, 27, 29, 49-52]
Cost reductions	[3]
Pressure from other external stakeholders (banks, insurance etc.)	[3, 15]
Potential new market opportunities	[53]
Owner values or employee aspirations	[35, 50]

Exactly how seriously a firm considers sustainability amongst its set of competitive objectives depends on the specific market, industry and society that the firm operates in [54]. In recent years, there has been a general increase in the external pressures placed upon smaller companies to think about the environmental impacts of their operations. This trend is particularly apparent in many countries in Europe, where it has mainly been driven by the introduction of more stringent environmental legislation, a developing understanding in industry of the financial cost of waste, and the increase in consumer awareness and pressure with regard to environmental issues [20, 55]. In Europe, environmentally benign manufacturing and care for the environment is thus fast becoming an order-qualifying factor. This means that customers are less inclined to consider purchasing products from manufacturing organisations that do not take an active role in improving and promoting the sustainability of their operations [1].

While environmentally benign manufacturing is already ranked highly amongst the competitive objectives of most European companies, many firms in other parts of the world, in particular in Asia, South America and Australasia, are lagging behind, as the main external drivers towards sustainability are still relatively weak [2, 3, 13]. In many of these economies, care for the environment does not yet carry enough weight in the market, and there is also often an absence of effective environmental legislation.

While many of the barriers and drivers identified in these sections are generic and in line with the barriers and drivers faced by SMEs in other countries, New Zealand is in a somewhat unique position in that it is geographically isolated from its major trading partners and has traditionally held a 'clean and green image'. These factors have an influence on the extent to which the drivers and barriers identified affect a given organisation in this country, and thus the rate at which environmental sustainability initiatives are adopted by industry.

#### VIII. SYSTEMS THINKING MODEL FOR MOVING TOWARDS ENVIRONMENTALLY SUSTAINABLE BUSINESS PRACTICES

The previous sections summarised the specific characteristics of SMEs and the barriers and drivers which influence their progress towards environmentally sustainable business practices. Based on this extensive research of the existing academic literature, two causal loop models have been developed to capture and understand the significant interrelationships.

One of the most important characteristics of SMEs outlined in the previous sections is the significance of the owner on the decision making process. It is clear from the literature and in our experience with case companies that owner/manager support for environmental programmes are fundamental to their long term success (Figure 3).

One of the main drivers for environmental initiatives in countries like New Zealand, where legislation and market forces are not as developed as in Europe, is cost savings. Eco-efficiency programmes around the world over the last few decades have shown that significant savings can be achieved by implementing waste efficiency initiatives. These cost savings lead to increased owner manager support for environmental initiatives. Given the significant influence of owner/manager on decisions in SMEs, increased support leads to an increase in the availability of resources for sustainability initiatives. This increased availability of staff and financial resources leads to an increase in eco efficiency initiatives and thus further cost savings.

The second significant loop is the 'Environmental culture development loop'. This loop is again strongly influenced by owner/manager support for environmental initiatives. Our action research experience shows that the motivation of employees is strongly linked to the level of owner/manager support. An increase in motivation of employees leads to an increase in the effectiveness of the organisational environmental culture. An increase in effective environmental culture leads in an increase in "environmental competence", or in other words the ability of employees to unconsciously implement environmental efficient practices. An increase in this type of environmental competence will usually lead to an increase in cost reductions.

The most significant balancing loop (counteracting the positive feedback loops) is the 'Eco-efficiency cost loop'. Given the general lack of financial and staff resources available in manufacturing SMEs, the cost of implementing eco-efficient manufacturing initiatives are a significant barrier. Owner/manager support for environmental initiatives is negatively affected by the cost of sustainability. In order to overcome this barrier, there may be scope for prioritising eco-efficiency projects which have short term cost saving potential as well as reduced environmental impact. As time goes by, the influence of this loop will decrease, after having made the required initial investments and overcome the perception of insurmountable costs.

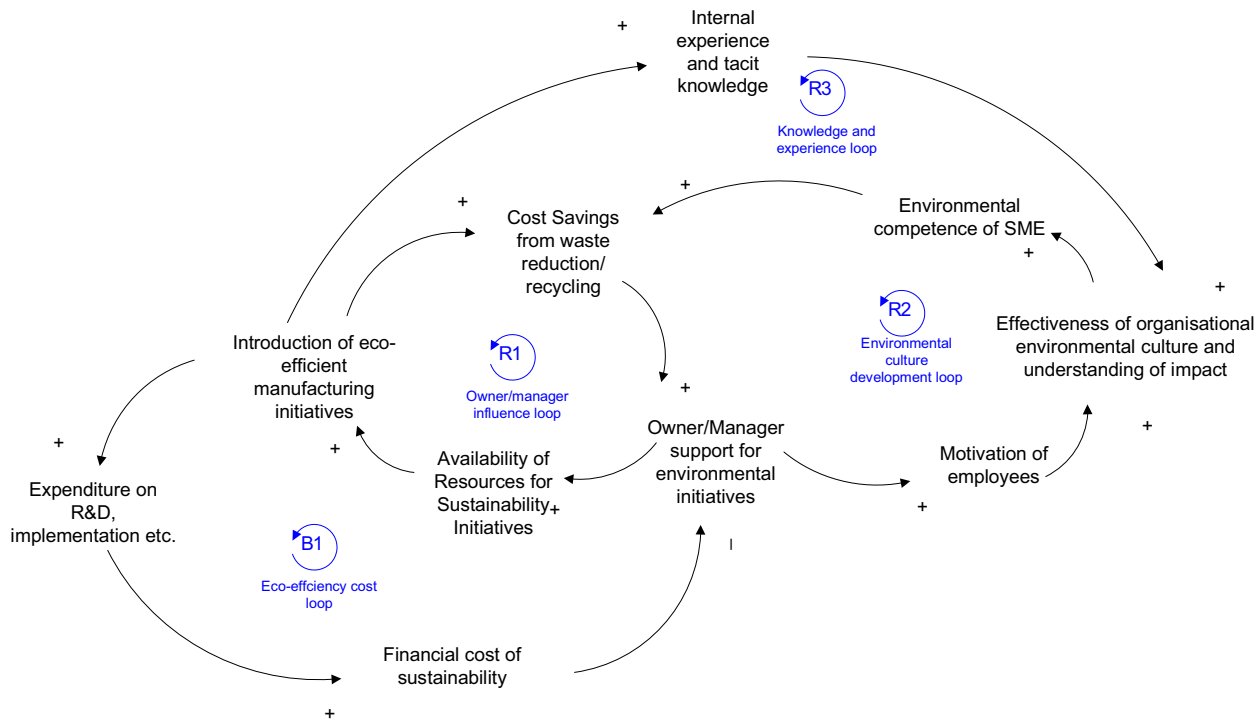


Figure 3: Owner/Manager influence on success of environmental practices

With increased introduction of eco-efficient manufacturing initiatives comes an increase in the experience and tacit knowledge of the SME with environmental issues (R3). This can lead to an improvement in the effectiveness of the organisational environmental culture and understanding of the SME environmental impact. As outlined earlier lack of experience and knowledge is a significant barrier to environmental improvement in SMEs. Because every company is different the best way to gain knowledge is most likely through 'learning by doing'.

As the market and legislation drivers for environmentally sustainable products develop the dynamics of the system change (Figure 4). The owner/manager of the SME increasingly becomes aware of these external pressures and requirements for implementing environmental initiatives. While previously the environmental initiatives focused on eco-efficiency in manufacturing (where short term financial savings were the main driver), the owner support for environmental initiatives now extend to the design of the products themselves.

The Market Expansion loop (R4) has a more strategic significance when compared to those described previously. By introducing eco product design features the SME's products will increasingly become compliant with environmental legislation and standards. This compliance will increasingly qualify the SME's product into those overseas markets with stringent legislation, increasing the potential market share and, over time, increase the number of sales.

By introducing eco product design features, products will become eligible for eco-labels and legitimate "green marketing" (R5). With increased expenditure on marketing, customer awareness of the products' environmental credentials will improve, which will eventually lead to an increase in sales and profit.

The counteracting loops (B2 and B3) are not as significant in this situation as the market and legislation is now demanding environmentally sustainable products.

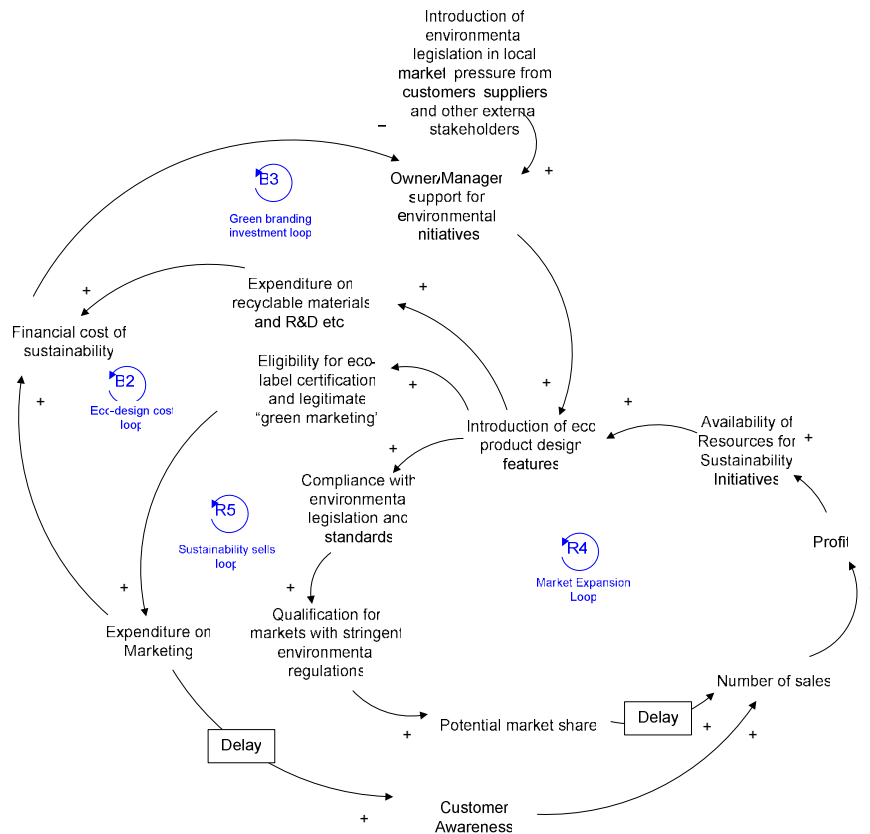


Fig. 4: Market and legislation drivers exist

## IX. DISCUSSION AND CONCLUSIONS

Pressure on industry to become environmentally conscious is increasing in the developed world. SMEs have an important role to play in this context as they make up a significant proportion of industry in industrialised economies.

The systems model presented in this paper has emphasised the significance of the owner on strategic direction of the SME and on the motivation of staff – which both impact the success of moving towards environmentally sustainable development. This modelling of the SME organisational setting in relation to environmental practices is continuing in a longitudinal research project. In order to ensure that future environmental improvement tools for SMEs are simple, applicable, understandable and cost effective, they need to take into consideration the special characteristics of these organisations.

Another cycle of action research, and further data collection from surveys and the recent scientific literature will develop and verify the causal loop models. The systems relationships and related insights will then be used as a basis for the development of a framework for the successful implementation of environmental practices in SMEs.

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