An integrated LCM framework for manufacturing SMEs

Manuel Seidel[1], Rainer Seidel[2]*, Mehdi Shahbazpour[2], Helene Sterzik[3]

[1]KBS Sustainable Innovation Partners Ltd., Auckland, New Zealand

[2]The University of Auckland, Department of Mechanical Engineering, Auckland, New Zealand

[3]Massey University, Palmerston North, New Zealand

*rha.seidel@auckland.ac.nz

Abstract Many manufacturing SMEs are failing to adopt even the most basic requirements of environmentally sustainable manufacturing. This is partly caused by the lack of appropriate LCM approaches tailored towards the requirements of smaller organisations, coupled with their general lack of knowledge and resources required to make the necessary changes. Our three-stage LCM framework takes account of the specific characteristics of SMEs such as: Owner/manager influence, organisational culture, systems and processes, customers, markets and stakeholders. It provides SMEs with a practical strategic 'roadmap' to enable them to effectively establish, implement and take advantage of environmentally sustainable manufacturing practices, and facilitates the creation of an organisational culture which supports environmental sustainability innovation in smaller organisations.

1 Introduction

Small and Medium-sized Enterprises (SMEs) dominate most industrialised countries in terms of their sheer numbers, and as a combined group have a vast impact on the environment. However, in comparison to large organisations, these smaller companies find it particularly difficult to adapt to the growing demands for improved environmental performance. International research has found that many SMEs are failing to adopt even the most basic requirements of environmentally sustainable manufacturing and LCM [1-3].

A key contributing factor for this situation is that most existing LCM approaches require considerable experience, specialist knowledge and financial resources, and therefore are predominantly applied by larger organisations. However, together with a range of other factors, these requirements are significant barriers for SMEs who want to improve the environmental performance of their products and processes [4].

The research presented in this paper summarises a six-year longitudinal study of all aspects of sustainability and LCM in New Zealand manufacturing SMEs. In this research we applied a holistic approach, combining quantitative and qualitative methods, a thorough review of the international literature, industry surveys, participatory action research, case studies and systems engineering tools. Our aims were to fully understand the key factors that prevent SMEs from making more progress towards adopting environmentally benign business practices, and on this basis to develop the foundation for an LCM approach which suits the specific requirements of the SME environment.

One of the main outcomes of our research is a comprehensive LCM framework which integrates existing LCM approaches available to industry with new insights into the requirements and dynamics of the implementation of environmentally sustainable practices in SMEs. Our framework provides SMEs with a practical strategic 'roadmap' to enable them to effectively establish, implement and take advantage of environmentally sustainable business practices.

2 Characteristics of SMEs

When considering environmental issues with regard to SMEs, it is important to understand the special features and characteristics associated with these types of companies. SMEs cannot simply be seen as "smaller large companies." The specific characteristics of SMEs mean that the approaches they require for becoming environmentally responsible are different from those of larger organizations [5, 6]. Some of the key SME characteristics which distinguish them from larger organisations, and which have an impact on the companies' ability to move towards more sustainable practices, are [4, 7]:

- Owner/manager centric management style;
- Informal organisation structure and responsibilities;
- Lack of formal systems, procedures and processes;
- Limited staff and financial resources;
- Focus and dependence on local markets;
- Day-to-day orientation towards short term problem solving;

- Lack of relevant knowledge and experience;
- Lack of awareness of their environmental impacts;
- Lack of awareness of environmental trends;
- Underdeveloped organisational environmental culture;
- Perceived conflicts between environmentally sustainable practices and other key business objectives.

Our approach is specifically designed to take these factors and the associated barriers to the uptake and implementation of an LCM system into account. Our LCM framework is based on an incremental approach which provides SMEs with a practical strategic 'roadmap' to enable them to effectively establish, implement and take advantage of environmentally sustainable practices in a step by step fashion. The overall goal is to help organisations develop their own sustainability strategy, support them in defining long term targets and short term goals, and provide them with methods and tools that help them achieve these objectives.

The LCM framework involves three stages:

1. Baseline Assessment – an approach for identifying an organisation's current environmental position, establishing an organisational 'sustainability roadmap', and moving it from an indifferent or defensive perspective to a proactive approach to sustainability;
2. Strategising – formalising and communicating the roadmap through visual communication in order to facilitate the effective development of an organisational LCM system;
3. Integrating – using a web-based infrastructure to integrate sustainability into the culture of the company and to facilitate collaboration with external stakeholders.

The following sections describe briefly the research approach we applied to identify the requirements and to design the structure of our framework, followed by an overview of the concepts, methods and tools underlying its three main stages.

3 Understanding environmental sustainability in SMEs

Sustainability and LCM are complex issues; therefore it is not surprising that many SMEs have significant difficulties understanding them, identifying their own position and options, and knowing how to make a start towards more environmentally benign practices. Developing a full understanding of their situation is also important for researchers and environmental consultants who are trying to support SMEs. We used action research, case studies, literature research

and industry surveys to identify the barriers and other relevant factors that have an impact on SMEs' attitudes and behaviours with respect to LCM implementation.

For example, we realised that a significant number of SMEs do not yet experience sufficient external drivers such as legislation or market pressure to adopt environmentally sustainable practices. We concluded that any of their environmental initiatives must therefore be strongly influenced by their internal dynamics. In order to fully understand this situation and to establish the requirements of an LCM framework for this scenario, systems modelling techniques were used to identify and analyse the cause-effect relationships affecting the uptake of sustainable practices in such organisations [8, 9]. Our model illustrated the complex dynamic interactions between a number of 'causal loops' which either reinforce or counteract any organisational activities towards the implementation of LCM. A key factor is the influence of the owner/manager, whose increased support leads to an increase in the availability of resources for sustainability initiatives, and who also has a strong impact on the motivation of management and staff. This motivation in turn enhances the organisational environmental culture, which then leads to an increase in 'environmental competence', or in other words, in the ability of employees to instigate and implement environmental improvement practices. An increase in this type of environmental competence will usually lead to an increase in cost reductions.

Given the general lack of financial and staff resources available in SMEs, the perceived costs and uncertain financial returns of implementing eco-efficiency initiatives have also been recognised as one of the most significant barriers. The owner's perception of the 'affordability' of the implementation costs limits his/her early support for environmental initiatives. These major interrelationships also largely apply to other SMEs who already experience rising external market or legislative drivers, or whose owner has an inclination to adopt environmental practices for ethical or strategic reasons.

The dynamics revealed by our model explain why SMEs are often reluctant to make significant strides in the 'green' direction. These findings are in line with our case study and action research experience that many of the problems that companies have in getting started with environmentally sustainable manufacturing are due to initial attitudes and perceptions rather than insurmountable hurdles and barriers. This conclusion is also supported by the literature, for example by the results of a 2002 research project by the UK Department of Trade and Industry, which established that most of the barriers to the uptake of environmentally and socially responsible practices by SMEs were based on perceptions of unmanageable time and cost requirements. However, SMEs that have actually implemented environmentally friendly practices do not consider these issues as major barriers [10].

4 Baseline Assessment: Laying the foundation

As outlined above, our research has led us to the conclusion that many of the apparent barriers to environmentally benign manufacturing in SMEs can be attributed to attitudes and preconceptions of decision-makers, in general the owner/manager. While the investment capital and cost problems related to environmental projects cannot always be easily dealt with, there are significant opportunities to address the perceptions and concerns of decision-makers in SMEs to mitigate this situation.

On the basis of these considerations we identified a range of requirements for an LCM approach, and associated tools and methods to overcome the perception in SMEs that environmental improvement does not provide benefits to the organisation. In summary, we consider it critical that the tools and methods used

- address the concerns and perspectives of decision makers,
- are fast and easy to apply,
- require little specialist sustainability background knowledge,
- address specific SME barriers,
- express information in usable business terms, i.e. costs, etc.,
- require few financial resources,
- are complementary and provide multiple perspectives, and
- build on each other and generate a momentum.

Our LCM approach is structured into three distinct stages, which take account of these requirements and of the specific SME characteristics outlined above. The initial stage, Baseline Assessment, is a structured approach which considers in particular those factors which affect the initial uptake of environmental initiatives. As these are key factors for the success of an LCM programme in SMEs, we discuss our Baseline Assessment approach in more detail in this section.

It consists of a range of common business and environmental analysis tools, which are complementary and easy to apply. They generate an initial environmental profile of the organisation, and establish the foundation for the roadmap towards LCM. As shown in Figure 1, these basic tools can be used in sequence as a toolkit for overcoming some of the initial hurdles faced by SMEs wanting to implement LCM practices [7].

Fig.1: Baseline framework for uptake of LCM practices in manufacturing SMEs

Most of these tools have been effectively applied for analysis and optimisation of business processes around the world, but are as yet not widely used in the context of LCM. In particular in the case of those SMEs that have very little environmental experience, the tools should ideally be embedded in a process which is facilitated by an experienced external moderator. However, if an SME's environmental culture is already strong enough (in particular in respect of owner/manager support), the approach can also be completely driven from inside the organisation. The main aspects of the different tools in the context of our LCM approach are briefly introduced below [4].

- **Stakeholder analysis**

  Many SMEs have problems to identify and take advantage of market opportunities and relationships with external stakeholders, as SME owner/ managers generally have little time to scan the external business environment, collect information, interpret the situation and develop the necessary solutions. Given the significant influence of stakeholder relationships on achieving environmental improvements, it was deemed significant that SMEs have a means to easily and quickly understand and engage potential partners.

  Stakeholder analysis is beneficial in the LCM context for SMEs, as it can be used to identify the stakeholders that can be involved in, affected by or have an interest in the environmental performance of the product supply chain. Another important aspect is that networking is one of the simplest and most cost-effective ways for SMEs to overcome the problem of lack of adequate knowledge and experience with implementing LCM initiatives. Stakeholder analysis identifies the parties that could be involved in this network.

- **SWOT analysis**

  Our research has shown that SMEs are primarily concerned with the short-term financial implications when they are considering investment in environmental projects in their companies. However, the short term payback period of a particular project should not be the only factor in the capital investment decision-making process [11]. Strategic and technical factors are also very important, although these are sometimes difficult to quantify. For example, the strategic significance of improved vendor reputation obtained as a result of environmental improvements is substantial in the long term, but difficult to express in financial terms. SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis helps SMEs to identify strategic performance variables related to environmental projects. The data is categorised in the following four areas:

  Strengths: The attributes of the SME that will likely contribute to a positive outcome with regard to the company's environmental aspirations. For example, a company employee may have experience in environmental issues.

Weaknesses: The attributes of the SME that will likely have a negative effect on the success of the environmental project. For example, lack of resources of the company in any area would be identified here.

Opportunities: External factors that will likely result in a positive or value creating effect on or from the success of the project. For example, there may be a developing market for environmentally friendly products.

Threats: External factors that will likely have a negative effect on the success of the project. The threat may be a barrier, a constraint, or anything external that might cause problems. For example, the local Government may be planning to introduce stricter environmental legislation.

- **Life Cycle Inventory**

  Stakeholder and SWOT analysis tools provide information and insights relating to the business environment, potential partners and the drivers, benefits and opportunities etc., involved in implementing environmentally sustainable practices. Thus they help SMEs reach an improved understanding of their situation and be in a good position to start developing its environmental strategies and initiatives.

  Life Cycle Assessment (LCA) is a well established tool used to investigate and evaluate the environmental impact of a given product [12]. An LCA is a four-phase process which determines the input and output contributions of resources, waste, energy and emissions at the various stages of the product life cycle in order to get an accurate understanding of the environmental impact of a given product [13, 14]. LCA is the most comprehensive tool for environmental impact assessment for any type of organisation [11], and therefore an important component of sustainability initiatives in business organisations. However, a complete LCA is complex, expensive and time consuming, and generally exceeds the capabilities and resource availability of SMEs [15].

  Therefore our Baseline Assessment framework concentrates on the first two phases of LCA, namely the initial setting of the goals and the scope of the sustainability initiatives, followed by a Life Cycle Inventory (LCI). A basic, largely qualitative LCI, for example using a straightforward input-output approach [16], is a reasonably intuitive and relatively cost and time efficient means of developing a solid understanding of an SME's environmental aspects and impacts [4]. However, it should be noted that it generates a business-centred view which will not provide the SME with detailed information on the contribution of those environmental aspects to global warming or climate change, etc. It may not feasible at this initial stage of the LCM programme to extend the system boundaries for the environmental assessment beyond those of its own internal business processes. This being

said, the stakeholder analysis will already have provided the company with contacts up and down its value chain.

- **Prioritisation of projects**

  Prioritisation of projects, the final step of Baseline Assessment, is a key step for ensuring that the limited resources of an SME are used in the most effective way, and for optimising the potential return on investment of the crucial first improvement project activities. This is particularly important with respect to generating visible outcomes and 'buy-in' of top management and key staff in the organisation in order to overcome their above-mentioned concerns and perceptions. Our prioritisation criteria reflect our findings on the characteristics and the internal dynamics of SMEs, and of the barriers to the uptake of environmental initiatives outlined earlier (Table 1).

Table 1: Weighting scheme for identified environmental issues

Impact	Possible financial benefits	Quantity	Severity of consequence	Future trends
very high	10	5	5	5
high	8	4	4	4
moderate	6	3	3	3
low	4	2	2	2
very low	2	1	1	1
none	0	0	0	0

Consequently, the ranking scheme shown in Table 1 emphasises in particular 'Possible financial benefits' associated with a particular issue by allocating the highest weighting factor of 10. 'Quantitative impact' of an issue, e.g. the amount of a particular waste, is weighted second highest with a factor of 5. 'Severity of consequences' and 'Potential future trends', such as cost increases or legislative developments, have weighting factors of 3 each. While in particular the relatively low weighting of the consequences may not be in line with the thinking of environmental purists, this ranking reflects the prevalent thinking of decision makers in SMEs, which we have identified in our research.

The identification of relevant environmental issues an organisation is based on the understanding of their environmental aspects and impacts gained through the LCI, and through the two earlier steps of stakeholder and SWOT analysis. Table 2 demonstrates the use of the prioritisation tool in a furniture manufacturing SME, which served as case company for our research. In this case the first five issues were prioritised and provided with resources by company management at the start of the organisation's LCM programme.

Table 2: Prioritisation of environmental issues based on LCI findings

Environmental issues	Possible financial benefits	Quantity	Severity of consequence	Future trends	Total score (X/25)	Total score (X/100)
Off-cuts	10	5	3	3	21	84
Polystyrene	9	5	3	4	21	84
MDF dust	8	4	3	5	20	80
Vinyl	6	3	4	3	16	64
Chemicals	2	3	5	3	13	52
Rest waste	2	3	3	3	11	44
Crates / wood	4	2	1	1	8	32
Plastics	2	1	3	1	7	28
Waste air	0	3	3	1	7	28
Water	0	2	3	1	6	24
Cardboard	2	2	1	1	6	24
Noise	0	3	2	0	5	20
Heat	0	1	1	0	2	8

The validity and effectiveness of this approach is demonstrated by the fact that all resulting projects were highly successful. Apart from significant cost savings and reductions of waste, the company achieved a number of environmental awards as well as ISO 14001 certification. In particular, the success of these projects created a strong momentum and an environmental culture, which eventually entrenched LCM in all aspects of the company's operations.

5 Strategising: Communication and management of LCM

The Baseline Assessment stage of our LCM framework provides an SME with solid understanding of its position and its options with respect to LCM, and with an initial roadmap towards further progress. The key aim of the second stage of our framework is to develop and implement an organisational infrastructure for SMEs to formalize the LCM roadmap and to systematically manage progress. The ecoWheel® tool (Figure 2) was developed as a visual representation of LCM projects and objectives identified in the Baseline stage, which are categorized into eight programme themes. The visual tool facilitates a shared vision of the wider scope of sustainability in the organisation and generates a holistic view of LCM in the company [7]. While in the early stages of its LCM activities the SME will still likely focus on a limited scope, it is important that the specific short term projects and objectives are put into a wider context through their inclusion in thematic

programmes and through addition of longer term strategic targets. This allows the individual actors, functions and departments within the SME to understand how their activities fit into the organisation's overall LCM strategy. Thus the ecoWheel® generates communication mechanisms and facilitates shared understanding between management and staff. In addition to this it can be used as a basis for organizing LCM related documentation and record retention.

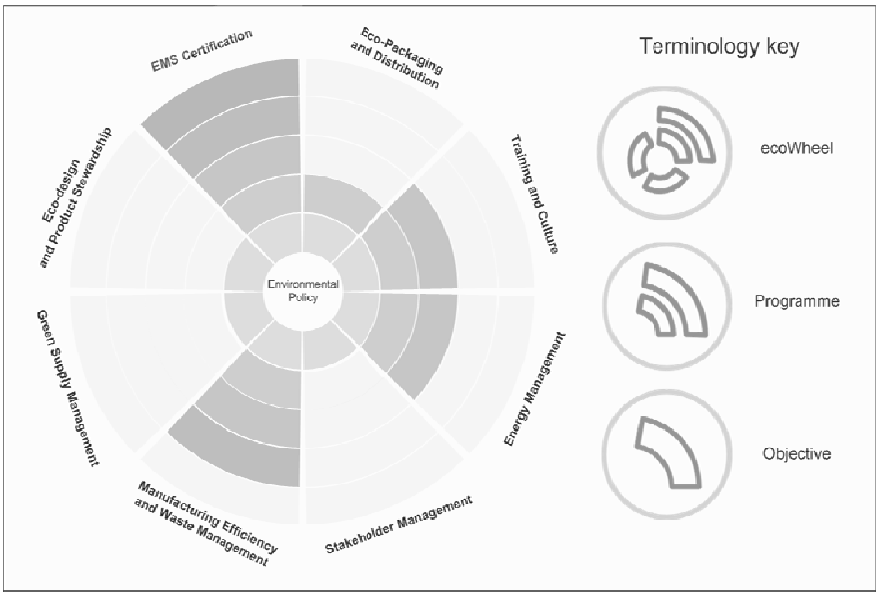

Fig.2: ecoWheel® communication and management tool

6 Integrating: Web-based LCM infrastructure

The final stage of our LCM framework is aimed at the full integration of LCM into the culture and processes of the company. In our case study research we identified a number of key criteria which an LCM system needs to satisfy in order to fully embed LCM into all aspects of the organisation. Our web based LCM system ecoPortal® [17] represents the core of the third stage of our LCM approach and provides the following functions and features:

- Communication between LCM team and organisation, including the ability to capture input from staff outside the core LCM team;
- Project management tools to assist the achievement of LCM objectives, including functions such as calendar reminders, responsibility designation, etc;

- Web based documentation and knowledge management to replace paper based systems and to facilitate the management of LCM knowledge;
- External accessibility to facilitate collaboration with external stakeholders. This includes sophisticated permissions functionality to limit access to internal and confidential information and documentation;
- Integration of critical elements of LCM, such as environmental policy, objectives and targets, relevant legislation, aspects and impacts, internal auditing, etc. This ensures accessibility and understanding, as well as meeting the requirements of ISO 14001.

7 Conclusions

The combined environmental impact of manufacturing SMEs around the world is significant. However, these companies face considerable challenges in progressing towards integrating LCM into their culture and their day-to-day activities.
The three-stage LCM framework described in this paper was developed under consideration of the specific characteristics of SMEs, and has been successfully applied in a number of case companies. The Baseline Assessment tools were found to specifically address the barriers SMEs face in the uptake of environmental improvement practices. The Strategising framework facilitates the development of a holistic and life cycle orientated environmental management strategy for the organisation. The ecoWheel® provides a visual representation of the organisation's LCM objectives, which can be easily communicated to staff and to supply chain stakeholders. The ecoPortal® was designed and developed to facilitate the integration of environmental management in manufacturing SMEs and their supply chains. The ecoPortal® uses the ecoWheel® strategy framework as the central interface. The accessibility and social networking features of the ecoPortal facilitate employee involvement and two way communication flows in advanced LCM projects with supply chain stakeholders.

References

[1] Anglada, M.L., *Small and medium-sized enterprises - perceptions of the environment: A study from Spain*, in *Small and Medium-Sized Enterprises and the Environment*, R. Hillary, Editor. 2000, Greenleaf Publishing: Sheffield. p. 62-74.

[2] Aiyub, K., et al., *Environmental Performance in Small and Medium Sized Enterprises (SMEs) Certified to ISO 14001 in the United Kingdom.* International Business Management, 2009. **3**(1): p. 7-14.
[3] Borga, F., et al., *Sustainability report in small enterprises: Case studies in Italian furniture companies.* Business Strategy and the Environment, 2006.
[4] Seidel, M., et al., *Overcoming Barriers to Implementing Environmentally Benign Manufacturing Practices: Strategic Tools for SMEs.* Environmental Quality Management, 2009. **18**(Spring 2009).
[5] Jenkins, H., *Corporate social responsibility – engaging SMEs in the debate*. 2004, Research Centre for Business Relationships, Accountability, Sustainability and Society.
[6] Williamson, D., G. Lynch-Wood, and J. Ramsay, *Drivers of environmental behaviour in manufacturing SMEs and the implications for CSR.* Journal of Business Ethics, 2006(67): p. 317–330.
[7] Seidel, M., *Towards Environmentally Sustainable Manufacturing: A Strategic Framework for Small and Medium sized Enterprises*, in *Department of Mechanical Engineering*. 2011, The University of Auckland: Auckland. p. 262.
[8] Seidel, M., et al., *A Systems Approach to the Implementation of Environmentally Benign Practices in Manufacturing SMEs*, in *15th CIRP International Conference on Life Cycle Engineering*. 2008: Sydney.
[9] Seidel, M., et al., *SME strategy framework for environmental sustainability*, in *16th CIRP International Conference on Life Cycle Engineering - Life Cycle Engineering in the Sustainability Age*. 2009: Cairo, Egypt.
[10] Castka, P., et al., *How can SMEs effectively implement the CSR agenda? A UK case study perspective.* Corporate Social Responsibility and Environmental Management, 2004. **11**: p. 140-149.
[11] Epstein, M.J. and M.-J. Roy, *Strategic evaluation of environmental projects in SMEs.* Environmental Quality Management, 2000: p. 37-47.
[12] Hauschild, M., J. Jeswietb, and L. Altinga, *From Life Cycle Assessment to Sustainable Production: Status and Perspectives.* CIRP Annals - Manufacturing Technology, 2005. **52**(2): p. 1-21.
[13] ISO 14040, *Environmental management - Life cycle assessment -Principles and framework.* 2006: International Organisation for Standardisation (ISO), Geneve.
[14] ISO 14044, *Environmental management - Life cycle assessment - Requirements and guidelines*. 2006: ,International Organisation for Standardisation (ISO), Geneve.
[15] Le Pochat, S., G. Bertoluci, and D. Froelich, *Integrating ecodesign by conducting changes in SMEs.* Journal of Cleaner Production, 2007. **15**: p. 671-680.
[16] Suh, S., and G. Huppes, *Methods for Life Cycle Inventory of a product*, Journal of Cleaner Production, Volume 13, Issue 7, 2005, p. 687-697
[17] <http://www.ecoportal.co.nz/home>, (Accessed 12.04.2011).