SCIENTIFIC PROBLEMS
OF MACHINES OPERATION
AND MAINTENANCE
2 (158) 2009

PRZEMYSŁAW KURCZEWSKI*

Life Cycle Management as a concept for industrial application

Key words

Management, life cycle, quality, environment, cost.

Słowa kluczowe

Zarządzanie, cykl życia, jakość, środowisko, koszt.

Summary

In the paper, LCM (Life Cycle Management) is defined as the application of life cycle thinking concept to modern business practice, with the aim to manage the total life cycle of products and services towards more sustainable production and consumption. Relevant systems, methods and tools connected with LCM concept are presented, specially: TQM, ISO 9000, ISO 14000, ecodesign. There is indicated that the application of various elements of management system may differ due to different purposes and different interested parties. While quality management systems deal with customer needs, environmental management systems address the needs of a broad range of interested parties and evolving needs of society for environmental protection.

The problem of introduction of LCM is of key importance for small and medium enterprises (SME), because they constitute, in Western World, almost 2/3 of the private sector and represent a major source of growth in employment, through new business start-ups. Thus, the SME sector becomes an important target for growth of competitiveness, innovation and environmental policies and practices but reveals low awareness of environmental issues.

* Poznań University of Technology, Faculty of Working Machines and Transportation, Institute of Working Machines and Transportation Piotrowo 3 St., 60-965 Poznań, Poland.

1. Introduction

Among main the directions of organization development is minimizing of generated environmental impacts connected with economic cost minimizing. Some companies undertake various efforts to reduce the impact of their products or services on the environment. Sometimes, even the entire "life" of products or services are considered to meet requirements of sustainable development and to create an environmental image of the organization. Life Cycle Management (LCM) can support various activities oriented to environmental improvements. Although LCM is still rather a concept then the consequently structured regulation, it has the chance to be formed in the future in the shape of integrated tool. Some tools or solutions of another nature, which could assist LCM implementation in companies, are analysed in this paper.

2. Scope of lcm concept

Environmental burden generated by products results from the interrelated decisions made at various stages of a product's life. Therefore, it is necessary to support the products' creation with different tools and methodologies that enable an assessment of the environmental consequences in each stage. But at the beginning, to create an environment friendly product, life cycle thinking should be a common phenomenon in organization, because of the following:

- It expands the traditional focus on products and manufacturing processes to incorporate economic, environmental and social aspects associated with a product over its entire life cycle.
- It is oriented to reduce resource use from the environment and emissions to the environment and to improve the social performance in various stages of a product's life.
- Achieved results of life cycle thinking combine different and very important for the companies, results, since cleaner products and processes, provide a competitive advantage to products and the company [1].

Although life cycle thinking is called the best way to environmental improvements, the practical solutions to achieve environmentally oriented goals are established in the concept of Life Cycle Management. LCM is defined in the following ways:

- LCM is the application of life cycle thinking to modern business practice with the aim to manage the total life cycle of an organization's products and services towards more sustainable consumption and production.
- LCM is systematic integration of sustainability, e.g. in company strategy and planning, product design and development, purchasing decisions and communication programs,

- LCM is integrated management framework of concepts, techniques and procedures incorporating environmental, economic, and social aspects of products, processes and organizations.
- LCM is voluntary and can be gradually adapted to the specific needs and characteristics of individual organizations [1].
- LCM is a dynamic process; organizations may begin with small goals with the resources they have and get more ambitious ones over time [2].

Generally, LCM can be established as a practical approach to optimization focused on minimizing the environmental burdens associated with products and services over their entire "life" through better, environmentally oriented, decision making. LCM should attract the developed companies in Poland and other CEE countries, as a support tool on their way to improve their environmental image [3]. The basis for LCM incorporation to organizations in CEE countries should be focused on introducing in organizations the rules of Total Quality Management and the regulations of such standards as ISO 9001 (Quality systems – Model for quality assurance in design, development, production, installation and servicing) and ISO 14001 (Environmental management systems – Specification with guidance for use).

Typology of the strategies, systems, concepts, and different tools is presented in the Table 1.

Table 1. Strategies, systems, concepts, and tools useful in LCM [1]
Tabela 1. Strategie, systemy, koncepcje i narzędzia użyteczne w LCM [1]

Policies/Strategies	Sustainable Development, Integrated Product Policy, Cleaner Production, Eco-efficiency, etc.
Systems/Processes	TQM, EFQM model, Integrated and Environmental Management Systems, e.g. ISO 9000/14000, EMAS, Extended Producer Responsibility, Environmental Communication, etc.
Concepts/Programs	Design for Environment, Supply Chain Management, Public Green Procurement, Green Accounting, Supplier Evaluation, etc.
Tools/Techniques	Analytical: LCA, MFA, SFA, I/O, LCC, etc. Procedural: Audits, Checklists, Labelling, etc. Supportive: Weighting, Uncertainty, etc.
Data/Information/ Model	Data: Databases, Controlling Information, Best Practice Benchmarks, References

3. LCM connections with TQM

Some methods useful for LCM applications are coming from the TQM area. They could be applied at the different levels of economy, being especially suitable in the organizations [4]. TQM as a way of organization management, which is characterized by system approach, orientation on strategic goals, ability to continuous and for ever improvement, includes close contacts from one side with suppliers and customers from the other side. It should allow for easier

negotiations with them on environmental topics. Practically, the steps of formalization and implementation of TQM may include:

- Establishing, by organization board, the team in charge of TQM policy implementation,
- Self-evaluation of managerial staff,
- Training of all employees on TQM policy,
- Training of all employees on psychological and social work environment,
- Internal and external promotion of TQM policy,
- Self evaluation of the company,
- Rendering the source materials to all supervisors,
- Contest for the most interesting solution within TQM, and
- Establishing quality circles and developing their methodology.

The above mentioned aspects indicate the crucial role of TQM in the process of LCM implementation. The reason is that LCM should become part of an organization's policies, so that its importance encompasses all levels of the organization. LCM policies should be visionary and long-range, while also being realistic and concrete, parallel to its types of goals. There are at least three different types of features common for TQM and LCM:

- Internal readiness and commitment to continuous improvements,
- The desire for life cycle improvement of products, and
- The desire to take the complex characteristics of products a step further by reporting and marketing activities and thereby create general organizational successes.

Additionally, the natural consequence of TQM can be common participation of range of employees who ensure that the LCM initiatives will be deeply rooted in the organization and that the focus will be on concrete improvements to a product. Furthermore, broad participation in LCM activities ensures that the LCM program does not die if a key employee involved leaves the organization [1].

4. LCM connections with ISO 9001

The ISO 9001 is one of international standards dealing with quality system requirements that can be used for external quality assurance purposes. The quality assurance model encompasses: design, development, production, installation, and servicing. There are several elements of this model which include the activities influencing the environment:

- Management responsibility – managers shall define and document their policy for quality, which shall be relevant to the expectations and needs of customers (initiation of actions to prevent the occurrence of any nonconformities related to the product, process and quality system, also connected with environment);
- Design control – establishing and maintaining of documented procedures to control and verify the design of the product in order to ensure that the specified

requirements are met (design input requirements reacting to the product, including environmentally related items);
- Purchasing – establishing and maintaining the procedures ensuring that the purchased product conforms to specific requirements (the supplier shall evaluate and select subcontractors on the basis of their ability to meet subcontract requirements including the environment influences);
- Process control – identification and planning the production, installation and service processes, which directly affect quality (environment) and shall ensure that these processes are carried out under controlled conditions;
- Inspection and testing – establishing and maintaining of documented procedures for inspection and testing activities in order to verify that the specified requirements for the product are met (the supplier shall ensure that incoming product is not processed until it has been inspected of otherwise verified as conforming to environment requirements); and,
- Corrective and preventive action – establishing and maintaining documented procedures for implementing corrective and preventive action appropriate to the magnitude of problems.

In practice, a system based on an international standard ISO 9001 can help the organization to address strategic planning, overall management, product and process development, procurement, production, distribution, marketing, communication and other functions in a more systematic and comprehensive approach. The organization will typically, in the beginning, focus on what is going on at the site and those inputs and outputs connected to its own activities. After achieving the easy improvements of quality the organization will have to expand its focus [1].

5. LCM connections with ISO 14001

International standards covering environmental management (e.g. ISO 14001) are intended to provide organizations with the elements of an effective environmental management system, which can be integrated with other management requirements, to assist organizations to achieve environmental and economic goals [5]. The ISO 14001 standard specifies the requirements of such an environmental system, which could be applicable to all types and sizes of organizations and to accommodate diverse geographical, cultural and social conditions. A system of this kind enables an organization to establish and assess the effectiveness of procedures to set an environmental policy and objectives, achieve conformance with them, and demonstrate such conformance to others. The overall aim of this standard is to support environmental protection and prevention of pollution in balance with socio-economic needs. Many of the requirements may be addressed concurrently or revisited at any time.

In the ISO 14001 standard requirements for an environmental management system are specified, to enable an organization to formulate policy and objectives taking into account legislative requirements and information about significant environmental impacts. It applies to those environmental aspects, which the organization can control and over which it can be expected to have an influence.

The organization shall establish and maintain an environmental management system, the requirements of which are in following fields:

- Environmental policy,
- Objectives and targets,
- Planning,
- Legal and other requirements,
- Environmental management programs,
- Implementation and operation,
- Operational control,
- Emergency preparedness and response, and
- Monitoring and measurement.

The ISO standards on environmental management systems and tools can assist in the process, but common sense is still needed, e.g. do not to implement one or the other side alone, but use the synergy of combining by product-oriented environmental management systems. Product oriented environmental management overlaps with the concept of LCM or corresponds to the environmental dimension of LCM. An examples from Netherlands and Denmark show, good practice in product-oriented environmental management means:

- A link between organization environmental initiatives and the market,
- Complemental environmental studies with market studies and analysis of interested parties expectations,
- Direct integration of environmental requirements into the product development,
- Common and continuous analysis, improvement objectives setting, networking and evaluation activities, and
- Knowledge building [1].

On the base of above-mentioned information, it is easy to indicate that success of product oriented management systems implementation in companies depends on the stage of specific organization in the ecodesign and formalized environmental (and quality) management learning curves.

6. LCM connections with Design

LCM plays a special role in product design oriented also on environmental goals. It is called design for environment (DfE) or eco-design. DfE is defined as “the systematic process by which companies design products and processes in an

environmentally conscious way" [6, 7]. The scope of DfE encompasses many disciplines, including environmental risk management, product safety, occupational health and safety, pollution prevention, ecology, resource conservation, accident prevention, and waste management [8]. The topic of DfE is especially important in the connection with the environmentally oriented assessment of the designed product. It is worth remembering that early assessment of environmental aspects incorporated to the designing phase can lead to effective design improvement and to improve the environmental image of the product. On the base of [9], the place of design in the new product development process is presented on the Figure 1.

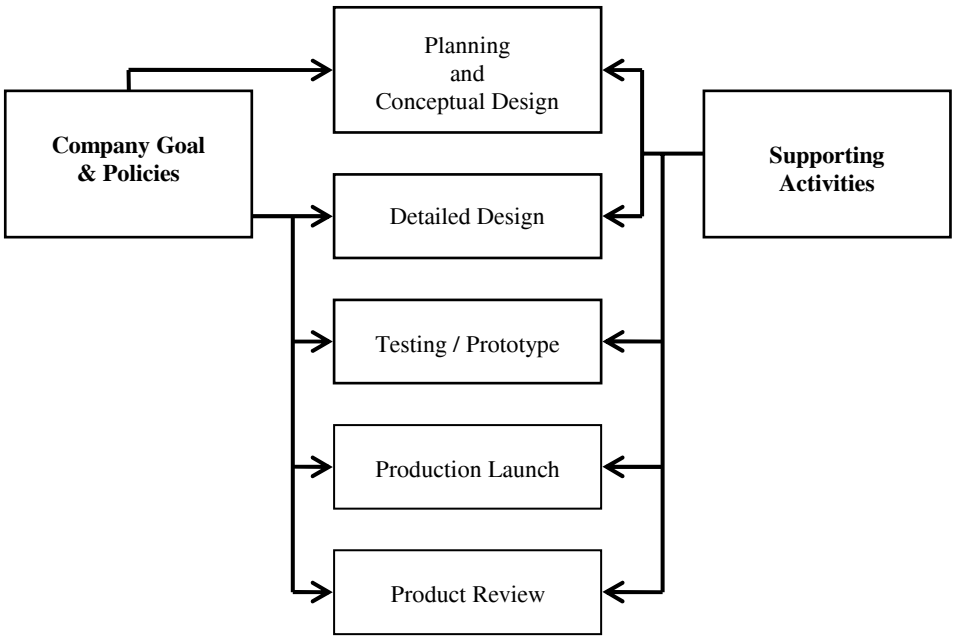

Fig. 1. New product development process
Rys. 1. Proces rozwoju nowego produktu

Design seems to be commonly treated as the crucial phase, which has an influence on the environmental image of the final product. The reason is that design determines:

- 70–80% of the total project life cycle costs, and
- Most of the total life cycle environmental impacts.

Additionally, it is worth remembering that early assessment of environmental aspects incorporated into the designing phase can lead to effective design improvement and to improve the environmental image of the product. The following steps of DfE can be distinguished [1]:

- Link the significant environmental parameters to relevant environmental strategies.
- Identify relevant implementation measures for the improvement of the environmental parameters belonging to a certain environmental strategy.
- Develop redesign tasks for the chosen implementation.
- Develop product specification, and it should consists of fixed and desired specifications.
- Identify the function of the reference product and then add a new function and/or modify an existing function based on the product specification.
- Generate ideas to realize the function.
- Generate variants – assembling idea corresponding to each function of the newly improved product generates the variants.
- Develop a product concept by selecting variant – variants are evaluated against criteria such as economic, technical, social, and environmental ones.
- Continuing detailed embodiment design, layout, testing, prototype, production and market launch.

7. The case of refrigerators

As an example of advanced LCM application connected with ecodesign project, the case study of refrigerator optimization is presented in this paper. Realized stages of the project included:

- Ecodesign team formation,
- Goal definition,
- Object of reference specification (LCA, LCC and LCWE),
- Target definition, and
- Designing and testing.

The first goal of the study was to determine the general guidelines and principles of environmental improvements of refrigerators. Also, economical and social aspects were analysed from the perspective of refrigerator life cycle. Results of the first stage of the study were focused on different aspects, important for the design processes. Particularly, a matrix of information about the environmental view of different components' compositions of refrigerators have been created. Such data were concentrated on the following issues, which should be helpful for designers and product managers: life cycle conscious decision making, risk information approaches, on-line monitoring of degradation processes of the materials and components, and prediction models and verification of remaining lifetime.

In this stage, it was necessary to answer the following questions:

- Can changes in the used materials improve the environmental image of the refrigerator's life cycle?

- Can changes in the production processes be reflected in the decrease of the environmental impacts?
- What activities should be implemented in the project to minimize environmental burdens in the life cycle of refrigerator?

Further stages of the case study (conceptual design, detailed design and research) has also been carried out by the team of experts. Analysed variants of the changes in the construction of refrigerators are specified in the Table 2.

Table 2. Ecodesign tasks and ways of their execution [10]
Tabela 2. Zadania ekoprojektowe i ich wykonanie [10]

Ecodesign task	Way of execution	Number of variant
Energy consumption reduction to the level of 218 kWh/year	Substitution of existing aggregate for more efficient aggregate	1
	Application of one aggregate (instead of two aggregates)	2
	Application of more energy efficient refrigerant	3
	Improvement of thermal insulation	4
	Replacement of traditional (electrical) aggregate by magnetic aggregate	5
Reduction of noise level to 38 dB (A)	Application of materials minimizing acoustic vibration of aggregate	6
	Replacement of traditional (electrical) aggregate by magnetic aggregate	5
	Substitution of aggregate	1
	Application of one aggregate (instead of two aggregates)	2
	Improvement of thermal and acoustic insulation	4
Reduction of number of harmful substances by 25%	Application of more environment friendly (incl. energy efficient) refrigerant	3
	Elimination of chloroparaffins	7
Reduction of disassembly time to 30 minutes	Reduction of the number of permanent joints by 10%	8
	Reduction of number of used materials by 5%	9
	Application of one aggregate (instead of two aggregates)	2
Reduction of refrigerator mass	Application of one aggregate (instead of two aggregates)	2
	Reduction of number of used materials by 5%	9
	Reduction of the packaging mass	10
Assurance of recovery index on the level of 80%	Reduction of number of used materials by 5%	9
	Application of more environment friendly refrigerant	3

The final results of the project are improved refrigerators. Some innovative solutions have been applied in consequence of ecodesign and LCM detailed studies. They were worked out in the following areas [10]:

- The application of one modern aggregate (16% better result of LCA and 11% better result of LCC),
- The application of more energy efficient refrigerant (8% better result of LCA and 3% better result of LCC), and
- The improvement of thermal and acoustic insulation (6% better result of LCA and 5% better result of LCC).

7. Conclusions

Life Cycle Management suggested in this paper includes a lot of systems, methods and tools, but the most important nowadays are DfE or eco-design and other product life cycle based concepts. Companies with a Life Cycle Management system in place will have increased possibilities to comply with such product-related legislation, because early integration of environmental and social concerns into the design and development cycle is expected to reduce costs, promote innovation, facilitate supply chain integration and assure greening initiatives.

Observed factors limiting implementation of LCM are [1]:

1) The form of the perspective of product development process:
   - Environmental criteria, which are not always included in the design process,
   - The lack of environmental information flow between companies and suppliers,
   - A diverse level of environmental understanding,
   - A lack of a system of reviewing environmental design alternatives, and
   - No need of environmental product design specification.
2) The form of the perspective of useful tools:
   - Limited environmental design abilities (methodology, checklist for design, software, etc.),
   - The lack of list of environmentally preferred materials for product design,
   - A very limited practice of reporting of environmental improvements to the product,
   - LCA studies for any product, which are not carried out, and
   - A lack of performance indicators in design processes.
3) The form of the perspective of life cycle thinking:
   - No need of product design for disassembly or recycling for example,
   - No need of easy servicing – this is not always a requirement,
   - The use phase, which is not typically considered with respect to the environmental requirements, especially energy consumption, and
   - No plan to have a remanufacturing facility.
4) The form of the perspective of managing aspects:

- The lack of formal and structured educational and training programme,
- The lack of design involvement in the environmental policy in the company, and
- A limited responsibility for the products throughout the life-cycle.

The problem of the introduction of LCM is of key importance for small and medium enterprises (SME), which are an important target for competitiveness, innovation and environmental policies and practices, but reveals low awareness of environmental issues. The fields that should be strongly developed in practice are environmental life-cycle assessment and life-cycle costing. They should change the image of design practice to be a driving wheel for LCM implementation in the future.

References

[1] Jensen A. A., Remmen A.: *UNEP guide to Life Cycle Management – a bridge to sustainable products,* Background report for a United Nations Environment Programme, 2005.
[2] Hunkeler D. et al.: *Life cycle management,* SETAC, Brussels 2003.
[3] Kurczewski P., Kłos Z.: *Proceedings of the conference: Design methods for practice*, Zielona Góra 2006.
[4] Kłos Z.: *Introduction of TQM strategy to Polish enterprises – analysis of conditions.* Organizacja I Kierowanie, 1996, nr 1.
[5] Kłos Z.: *Introduction of Life Cycle Management to companies, supported by TQM and ISO standards,* in: Proceedings of 1st International Conference on Life Cycle Management, Copenhagen 2001.
[6] Lenox M., Jordan B., Ehrenfeld J.: *The diffusion of design for environment: a survey for current practice,* in: International Symposium on Electronics and the Environment, Dallas 1996.
[7] Zhang H. C., Kuo T. C., Lu H., Huang S. H.: *Environmentally conscious design and manufacturing*: A state-of-the-art survey, Journal of Manufacturing Systems, 1997, vol. 16, nr 5.
[8] *Environmental Consciousness: A strategic competitiveness issues for the electronics and computer industry,* Comprehensive report: Analysis and synthesis, task force reports and appendices, Microelectronics and Computer Technology Corporation, 1993.
[9] ISO/TR: 14062: 2003, Environmental management – Integrating environmental aspects into product design and development, Geneva 2003.
[10] Kurczewski P., Lewandowska A. e al.: *Rules of environmental designing of technical object for the need of their life cycle management*, KMB Druk, Poznań 2008.

Manuscript received by Editorial Board, December 01st, 2008

Zarządzanie cyklem życia jako koncepcja do stosowania w przemyśle

S t r e s z c z e n i e

W artykule zdefiniowano zagadnienie LCM (zarządzania cyklem życia) jako sposób zastosowania koncepcji myślenia kategoriami cyklu życia w nowoczesnej praktyce biznesowej, z ukierunkowaniem na zarządzanie całym cyklem życia produktów lub usług, by osiągać bardziej zrównoważoną produkcję i konsumpcję. Zaprezentowano odpowiednie systemy, metody i narzędzia związane z koncepcją LCM, w tym szczególnie TQM, ISO 9000, ISO 14000, ekoprojektowanie. Wskazano, że wprowadzenie poszczególnych składowych systemu zarządzania

może zależeć od różnych celów i poszczególnych zainteresowanych stron. Podczas gdy systemy zarządzania jakością ukierunkowane są na oczekiwania klientów, systemy zarządzania środowiskiem uwzględniają potrzeby szerszej grupy zainteresowanych stron, rozszerzając oczekiwania społeczne o aspekty ochrony środowiska.

Problematyka wdrażania LCM ma kluczowe znaczenie dla małych i średnich przedsiębiorstw (MŚP), ponieważ w „krajach zachodnich" kształtują one blisko 2/3 prywatnego sektora gospodarki i są głównym źródłem wzrostu zatrudnienia poprzez uruchamianie nowych przedsięwzięć gospodarczych. Z tego powodu sektor MŚP staje się ważnym obszarem wzrostu konkurencyjności, innowacyjności oraz kształtowania polityki i działalności środowiskowej, jednak ujawnia się w nim niska świadomość problemów środowiskowych.