POLITECNICO DI MILANO

DEPARTMENT OF MANAGEMENT, ECONOMICS AND INDUSTRIAL ENGINEERING

THE ANALYSIS OF GLOBAL SUSTAINABLE MANUFACTURING IN RESEARCH

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Abstract

Environmental degradation, depletion of natural resources, and increased global warming and climate change have started to threaten the future of the world. The growing tension due to these environmental problems has fostered environmental awareness amongst the society. In addition to environmental awareness, increased prices of raw materials and energy and governmental interventions to control the degradation have forced manufacturing companies to find new ways to handle with these troubles. Therefore, *sustainable manufacturing* concept has emerged in reply to these troubles in order to satisfy the needs of today and future considering environmental, economic and social permanence.

The emergence of sustainable manufacturing has drawn attention among researchers and a significant number of articles related to the topic have been published. In this thesis, the evolution of sustainable manufacturing from 1999 to 2011 is examined. It is questioned whether the results of the evaluation support the actions that should be taken between 2011 and 2013 which intend to achieve the sustainable industry vision by the year 2020 defined in IMS2020 Action Roadmap, an EU project.

In the thesis, all the research -within the scope- that is conducted between 1999 and 2011 relevant to sustainable manufacturing concepts has been gathered and a well-grounded database has been created. Benefiting from the database, the evolution of sustainable manufacturing in this interval and what have been going until now in the literature have been examined. The definitions, milestones and the trends of sustainable manufacturing concepts within the scope have been determined in order to be used in the latter assessments.

Afterwards, the IMS2020 Action Roadmap is examined and the actions that intersect with the scope of the thesis are chosen. The chosen actions are utilized to comprehend what is expected in the development of sustainable industry in 2020 after taking these actions. Studies have been done to figure out if the progress in the literature in the last decade is going parallel with the actions that are needed to be taken between 2011 and 2013, since it is aimed to see whether the findings of this study underpin the actions defined in IMS2020 Action Roadmap.

In order to fulfill the requirements of sustainable industry vision by the year 2020, quick and concrete improvements, especially in technology should be done considering the progress that has been provided in the literature so far.

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1 Introduction

1.1 Motivation and background

Manufacturing has forced the environment to bear the burden of degradation, for the sake of the economic progress that it has provided for the industries and the countries. Environment suffers from depletion of natural resources due to their excessive and inadequate usage and increase of waste, pollution and toxicity as a result of not effectively utilized end of life options, and companies' preferences for controlling activities instead of preventing them. These factors have affected the environment in terms of increased global warming and climate change and started to threaten the security and health of the society, especially employees. The growing tension due to environmental problems has fostered environmental awareness amongst the stakeholders including customers, shareholders, employees, suppliers, and communities. The society's intent to conserve the world to have a sustainable future and the burden on the environment have forced governments and organizations to take precautions and to change the reaction of the progress from being only economically driven to sustainably driven. Governments have constructed many regulations and legislations which have obliged organizations to mitigate the adverse effects of manufacturing on the environment and society.

Sustainable world requires satisfying the needs of today without compromising the ability of future generations to satisfy their own needs as it is stated in Brundtland Report in 1987.[1] To satisfy the needs of sustainable world and development, three pillars of sustainability namely economic, environmental and social aspects should be taken into account at the same time. In order to mitigate the effects of manufacturing on the environment and ensure sustainable development without compromising any company objective, *sustainable manufacturing* concept has emerged which covers all the aspects of sustainability comprehensively. Lowell Centre of Sustainable Production defines the concept as "the creation of goods and services using processes and systems that are non-polluting, conserving of energy and natural resources, economically viable, safe and healthful for employees, communities, consumers and socially and creatively rewarding for all working people".[2]

From environmental perspective, sustainable manufacturing targets the consumption of less resources and generation of less hazardous materials in order to less jeopardize the environment by reducing global warming, climate changes and toxicity. From economic

[1] Report of the World Commission on Environment and Development: Our Common Future, (1987). United Nations General Assembly.
[2] Lowell Center for Sustainable Production. (1998). Sustainable Production: A Working Definition. Informal Meeting of the Committee Members.

perspective, the economic advantages of sustainable manufacturing can be acquired by minimizing the cost through less material, energy, resource, and time consumption. Last but not least, from social perspective, for better employment, well-being of the employees and livable communities; sustainable manufacturing considers workers' health and security with improved working conditions.

Nowadays, environmental challenges like climate changes, global warming, increasing pollution and waste, and excessive resource consumption are getting accelerated because of ongoing global industrialization, hence the importance of sustainable development and sustainable manufacturing has been growing universally. Manufacturing companies consider not only economic objectives such as cost, time and quality but also environmental objectives such as low emissions, waste minimization, and effective energy usage. Besides, although some issues are originally environmental driven, they have significant importance on economic issues. These issues might be listed as rising energy prices, penalties for violating the environmental regulations and certifications, and society's increased environmental awareness on global warming, climate change and excessive resource consumption that may affect corporate image and competitiveness positively or negatively.

1.2 Aim, scope and target

Not only for governments and organizations but also for academia sustainable manufacturing is on the agenda. There are many precious academic studies done about sustainable manufacturing and its concepts. This thesis also attempts to contribute to the research field with a sound database and a comprehensive state of the art analysis.

The scope of the thesis is defined as sustainable manufacturing concepts that

focus on

- ✓ manufacturing processes following the sequence from input through planning, manufacturing, control and evaluation to output in
- ✓ discrete manufacturing industries also considering
- ✓ endogenous and exogenous factors like environmental management systems and regulations that have a direct effect on the implementation of sustainable manufacturing practices

excluding

- ✓ process industries,
- ✓ products and services,
- ✓ supply chain management, eco-design concepts and

- ✓ supporting activities not directly related with manufacturing like green marketing, green purchasing, green packaging and green reporting.

In this thesis, it is aimed to gather all the research -within the scope- that is conducted between 1999 and 2011 relevant to sustainable manufacturing concepts and create a well-grounded database. The generated database is used to make general deductions by considering the interests and core concepts of the articles and the trends in the evolution of sustainable manufacturing practices in the literature are examined. Later, the IMS2020 Action Roadmap is examined and the actions that intersect with the scope of the thesis are chosen. The chosen actions are utilized to comprehend what is expected in the development of sustainable industry in 2020 after taking these actions. Hence, the gaps between currently researched topics and the actions that are defined in IMS2020 Action Roadmap and needed to be taken between 2011 and 2013 are attempted to be figured out.

The originality of this thesis is that it provides a sound database not only focusing on one concept of sustainable manufacturing but covering all the articles published in the selected scientific journals from a broader view for the researchers who intend to strike into any topic of sustainable manufacturing.

In order to achieve all the objectives above, the evolution of sustainable manufacturing from 1999 to 2011 should be examined. It is questioned whether the results of the evaluation support the actions that should be taken between 2011 and 2013 which intend to achieve the sustainable industry vision by the year 2020 defined in IMS2020 Action Roadmap, an EU project. The answers of the following questions are sought to guide the research and to reply the research question:

"How has the research in sustainable manufacturing evolved from 1999 to 2011 and are the developments in the last decade in research going parallel with the actions in IMS2020 Action Roadmap in order to realize the sustainable industry vision in 2020?"

- ✓ What is sustainable manufacturing?
- ✓ What is the linkage between sustainable manufacturing concepts namely lean, green and sustainable manufacturing?
- ✓ What has been done in the literature from 1999 till 2011 relevant to sustainable manufacturing concepts?

- ✓ Which trends are observable in the sustainable manufacturing concepts?
- ✓ What are the most and least popular topics in sustainable manufacturing concepts?
- ✓ Are the results of the research that is published between 1999 and 2011 parallel with the actions defined in IMS2020 Action Roadmap?
- ✓ What the gaps are between today's research and tomorrow's expectations? In which areas should developments be provided to narrow the gaps and catch up with the actions?

1.3 Structure

To gain knowledge that helps answer the research question a structured method is followed in the thesis.

Section 1 constitutes the introduction part of the thesis.

Section 2 is devoted to provide a background on the concepts that take place in the evolution of sustainable manufacturing which starts with lean manufacturing and reaches the current definition of sustainable manufacturing. General concepts are defined in order to form a base for the rest of the thesis.

Section 3 aims to inform the reader about the research methodology that is followed during the construction of the sound database required for the latter steps of the thesis. General concept research, defining keywords, collecting materials from peer-reviewed scientific journals, classification, analysis and evaluation of them are the main steps to reach a sound database and a conceptual framework and they are explained in this section thoroughly.

Section 4 includes classifying the articles based on the basic framework, mind mapping them to show the linkages between classes and fitting them into a conceptual framework. The classification of the articles is benefitted to facilitate the analysis phase. While the mind map examines the relationships between the classes, the conceptual framework fits all the classes into a three layered logical scheme.

Section 5 is doing the state of the art (SOTA) analysis, trying to figure out the trends in the data, and making deductions. In the SOTA analysis part quantitative and qualitative analysis support the deductions, and many charts visualize the results to make them more understandable.

Section 6 discusses the similarities and differences between current sustainable manufacturing implementations that are gathered from the SOTA analysis part of this thesis and the actions defined in IMS2020 Action Roadmap to achieve a sustainable industry in the future.

The thesis ends up in Section 7 with concluding remarks.

All the sections are visualized in the following figure (Figure 1).

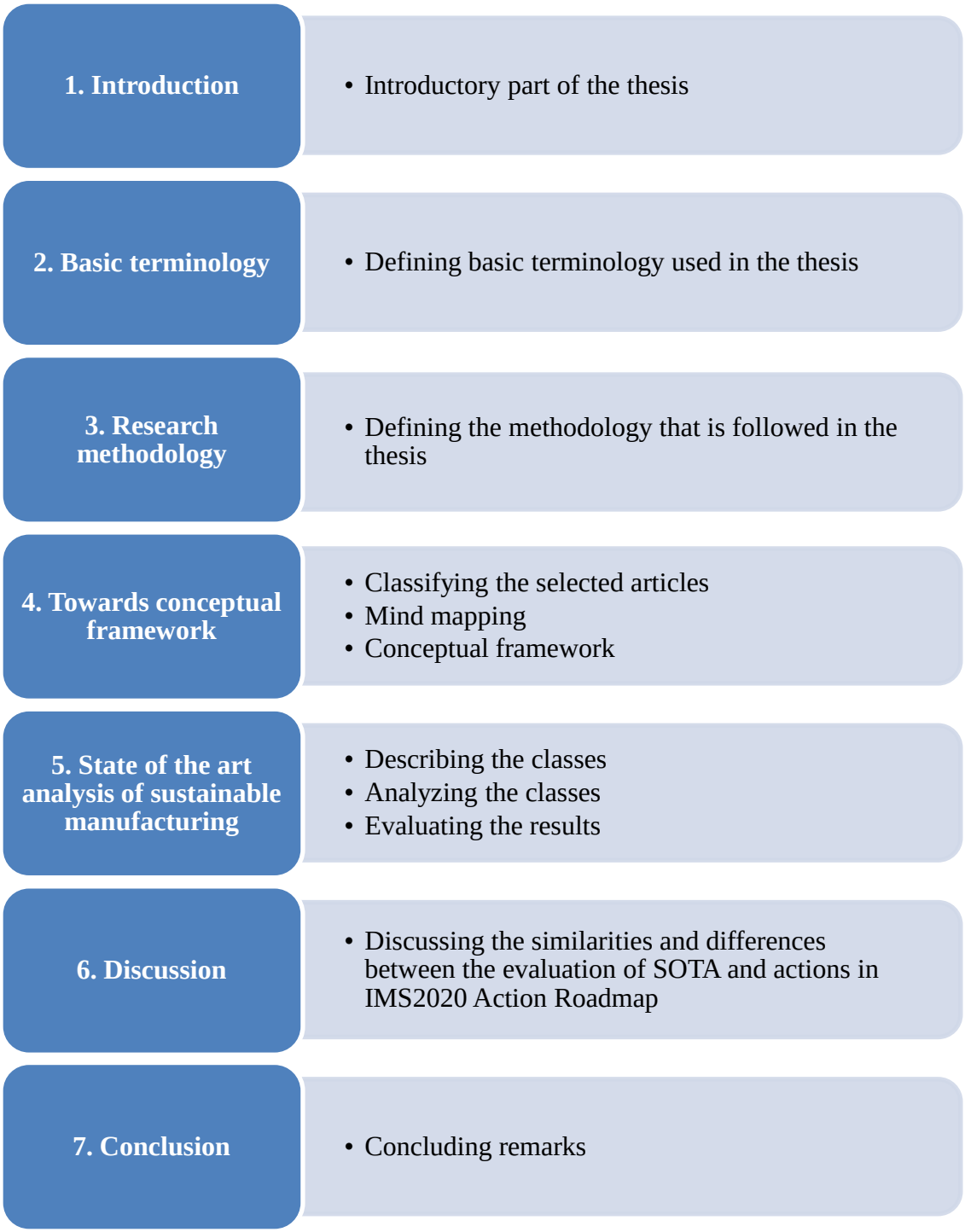

Figure 1 The sections of the thesis

2 Basic terminology

This section intends to describe the basic definitions of the concepts that are commonly used in the thesis. Instead of describing each term related with sustainable manufacturing, it focuses on the core concepts namely sustainability, manufacturing and manufacturing paradigms from lean manufacturing to sustainable manufacturing.

2.1 Sustainability

Sustain means "to cause or allow something to continue for a period of time"[3], which is the root of words such as sustainable, sustainability, sustaining etc. The first usage of this concept is in the form of "sustainable forestry and sustainable fisheries" in 1972 in UN Conference on the Human Environment in Stockholm. After 1980 the usage of the concept increases and appears in the form of "sustainable development". Generally sustainability and sustainable development are used as synonyms. In 1980 sustainable development is defined as "development that would allow ecosystem services and biodiversity to be sustained" by World Conservation Strategy produced by IUCN.[4] In 1987 a new definition for sustainable development is introduced by Brundtland Report like "development that meets the needs of present without compromising the ability of future generations to meet their own needs".[5] In 1992 Australia's National Strategy for Ecologically Sustainable Development shifts the meaning of *sustainability* to mean "using, conserving and enhancing the community's resources so that the ecological processes, on which life depends, are maintained and the total quality of life, now and the future, can be maintained".[6] A definition which considers different pillars is established by UN Conference on Environment and Development (UNCED) in 1992. According to UNCED *sustainability* equals the integration or balancing of environmental, social and economic issues or simultaneous progress in the environmental, social and economic domains, often in the context of strong programs of consultation and participation.[7] These three pillars are stated as "Environmental sustainability means the use of less energy resource, fewer hazards and emissions and is less toxic. The economic advantages of sustainability can be gained through manufacturing operations that take less time, have

[3] "sustain." Dictionary.Cambridge.org. 2011. Dictionary.cambrigde.org (6 July 2011).
[4] International Union for Conservation of Nature and Natural Resources. (1980). World Conservation Strategy Living Resource Conservation for sustainable Development
[5] Report of the World Commission on Environment and Development: Our Common Future, (1987). United Nations General Assembly.
[6] Government of Australia. (1992). National Strategy for Ecologically Sustainable Development
[7] Report of the World Commission on Environment and Development: Our Common Future, (1987). United Nations General Assembly.

high value added and are at minimum cost. Sustainability in society is seen in higher education levels, healthier life-styles and higher employment." [8]

2.2 Manufacturing

Manufacturing is defined as "the process of converting raw materials, components or parts into finished goods that meet a customer's expectations or specifications. Manufacturing commonly employs a man-machine setup with division of labor in a large scale production." [9]

Groover defines *manufacturing* in the first chapter of his book "Fundamentals of Manufacturing: Materials, Processes, and Systems" as follows:

> "The word ***manufacture*** is derived from two Latin words, ***manus*** (hand) and ***factus*** (make); the combination means "made by hand". The English word ***manufacture*** is several centuries old, and "made by hand" accurately described the manual methods used when the word was first coined. (As a noun, the word manufacture first appeared in English around 1567 AD. As a verb, it first appeared around 1683 AD.) Most modern manufacturing is accomplished by automated and computer-controlled machinery."[10]

Groover claims that manufacturing can be defined in two ways: one technologic and the other economic. From technologic aspect, manufacturing is the application of physical and chemical processes to alter the geometry, properties, and/or appearance of a starting material to make parts or products, manufacturing also includes assembly of multiple parts to make products. From economic aspect, manufacturing is transformation of materials into items of greater value by means of one or more processing and/or assembly operations. Manufacturing adds value to the material by changing its shape or properties, or by combining it with other materials.[11]

2.3 Lean manufacturing

Lean manufacturing's roots date back to the 1950's where Toyota Production System (TPS) was developed by Taiichi Ohno as a need to eliminate waste that is defined as "any human activity which absorbs resources but creates no value" from the production system to be able to recover from a war-torn economy. TPS is assumed as a major initiator of the more general

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[8] Pham, D., Ebrahim, Z., Shamsuddin, T., Barton, R., & Williams, O. (2008). Relationship Between Lean Manufacturing, Agile Engineering and Sustainability. Manufacturing Engineering Center, 9.

9 "Manufacturing." Businessdictictionary.com. 2011. http://www.businessdictionary.com (6 July 2011)

10 Groover, M. P. (2010). Fundamentals of Modern Manufacturing: Materials, Processes, Systems (4th edition b.). Hoboken: John Wiley & Sons, Inc.

[11] Groover, M. P. (2010). Fundamentals of Modern Manufacturing: Materials, Processes, Systems (4th edition b.). Hoboken: John Wiley & Sons, Inc.

term lean manufacturing. The occurrence of the term *lean manufacturing* takes the stage in the 1990's.[12] The term is coined to describe the leading manufacturing paradigm "where improving product quality, reducing productions costs, and being 'first to market' and quick to respond to customer needs are critical to competitiveness and success".[13] The transition from traditional to lean manufacturing results in reduced inventory, lead time, scrap and rework, and increased productivity. These enable the manufacturing companies to lower their costs to increase margins and/or decrease prices in a highly competitive, globalized market through elimination of non-value added activities. In addition, they allow meeting rapidly changing customer "just-in-time" demands without compromising quality, on the contrary producing goods of high and consistent quality.[14] Using Just-in-Time (JIT), Total Quality Management (TQM), Total Productive Maintenance (TPM), Kaizen, flow charts and workplace redesigning techniques in order to achieve leanness in the production system helps to realize and find the wastes and the root causes of them and the permanent solutions to prevent the occurrence of them. The eight deadly wastes of Lean Manufacturing can be seen in Table 1.

Form	Description
Overproduction	Producing more than is needed and/or used.
Human Resources	Not using people's minds and getting them involved.
Transportation	Moving tools/materials to the point of use.
Inventory	Materials or information. Includes WIP and finished goods.
Motion	Movement of people (walking, riding) as well as smaller movements.
Corrections	This includes rework or fixing products.
Over-Processing	Additional work above the requirements and/or needs.
Waiting	Time delays for materials, information or people.

Table 1 Eight forms of waste in lean manufacturing

2.4 Cleaner production

While the industries are striving to have their share in a market with shorter product life cycles, increasing product variety and production volume fluctuations, governments have started to elaborate their environmental policies using concepts such as pollution prevention, waste reduction and waste minimization. Therefore, in addition to economic objectives (e.g. cost, time, quality), environmental objectives (e.g. low CO_2 emissions) have become significantly important for manufacturing companies.

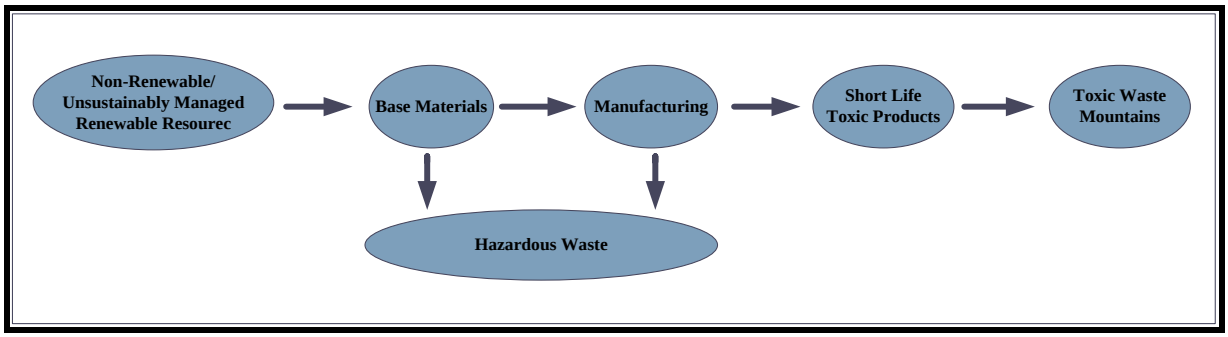
[12] Womack, J. P., Jones, D. T., & Roos, D. (1990). The machine that changed the world. Rawson Associates.
[13] EPA (2003) Lean Manufacturing and the Environment, Office of Solid Waste and Emergency Response, Washington, DC.
[14] EPA (2000) Pursuing Perfection: Case Studies Examining Lean Manufacturing Strategies, Pollution Prevention, and Environmental Regulatory Management Implications, Ross & Associates Environmental Consulting, Ltd., under contract to Industrial Economics, Inc.

The *pollution prevention* concept comes into the scene, before introducing the concept of *cleaner production* in 1988. The concept of pollution prevention is first developed and implemented by the Minnesota Mining and Manufacturing Company (3M) through a program they called 'Pollution Prevention Pays' (3P). The term is later defined as "eliminating the creation of pollution at the source and it also includes energy conservation, water conservation, and the protection of natural resources" by US EPA Centre for Environmental Research Information in 1995.[15] In addition to that concept, *waste reduction* is introduced as "in-plant practices, that reduce, avoid, or eliminate the generation of hazardous waste so as to reduce risks to health and environment" by US OTA in 1986, whereas *waste minimization* is presented as "the reduction, to the extent feasible, of hazardous waste that is generated or subsequently treated, stored or disposed of. It includes any source reduction or recycling activity undertaken by a generator that results in either the reduction of the total volume or quantity of hazardous waste, or the reduction of toxicity of hazardous waste, or both, so long as reduction is consistent with the goal of minimizing present and future threats to human health and the environment" by US EPA in 1986.[16]

As a new concept combining pollution prevention, waste reduction and waste minimization, *cleaner production* is coined as "continuous application of an integrated, preventive environmental strategy to both processes and products to reduce risks to humans and the environment" by UNEP in 1988, and then modified stating explicitly products and services are also included in cleaner production in 1996.[17]

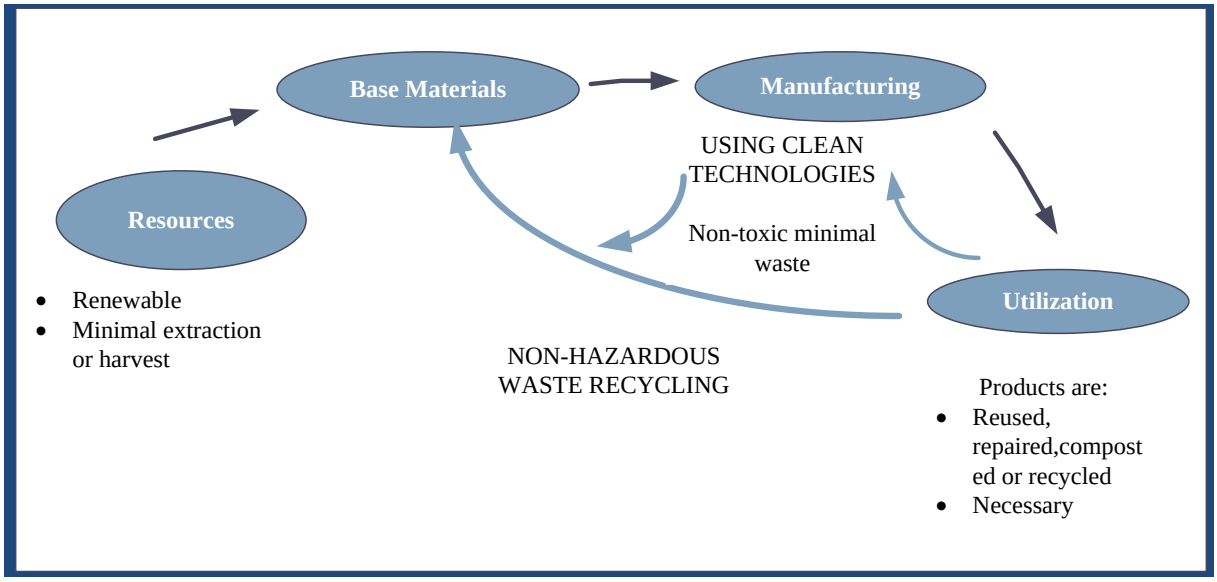
Different than the traditional production approaches, instead of first engineering the process and then engineering the treatment and disposal of waste streams, cleaner production minimizes waste generation at source which is more economical. Costly end-of-pipe pollution control systems are replaced by measures which reduce and avoid pollution and waste throughout the entire production cycle, "through efficient use of raw materials, energy and water[18]. The traditional industrial production and cleaner production differ from each other in some aspects that might be seen from Figure 1 and 2.

[15] U.S. EPA. (1995). Policy for Risk Characterization. From Carol Browner, Administrative, U.S. EPA, Washington, DC.
[16] U.S. EPA. (1986). Guidelines for Health Risk Assessment of Chemical Mixtures. Risk Assessment Forum, Washington, DC.
[17]Baas, L. W. (2005). Cleaner Production and Industrial Ecology. Delft, The Netherlands: Eburon Academic Publishers.
[18]Mullholland, K. L. (2006). Identification of Cleaner Production Improvement Opportunities. Hoboken: Wiley-Interscience; Schaltegger, S., Bennett, M., Burritt, R. L., & Jasch, C. M. (2008). Environmental Management Accounting for Cleaner Production. New York: Springer Science.



Source: Beverly Thorpe. (1999). Citizen's Guide to Clean Production

Figure 2 Conventional industrial production



Source: Beverly Thorpe. (1999). Citizen's Guide to Clean Production

Figure 3 Cleaner production

Cleaner production's main objectives might be listed as follows:

- ✓ Minimize the use, as well as optimize the reuse and recycling, of hazardous and non-hazardous materials,
- ✓ Use materials in the manufacturing process in a more efficient way, reducing the amount of inputs needed and the amount of non-desired outputs,
- ✓ Minimize risks and improve human capital through worker hygiene and safety programs,
- ✓ Improve monetary returns by minimizing energy consumption and reducing material and handling costs. This may often require capital investment.[19]

2.5 Environmentally benign manufacturing

In 2001, in WTEC Panel, *environmentally benign manufacturing* is defined as "manufacturing that does not compromise the environment, or the opportunities for development, for the next generation" which starts with the idea of enabling economic progress while minimizing

[19] Schaltegger, S., Bennett, M., Burritt, R. L., & Jasch, C. M. (2008). Environmental Management Accounting for Cleaner Production. New York: Springer Science.

pollution and waste and conserving resources, in other words integrating manufacturing into a sustainable society. The entire product life cycle including the design phase from raw materials production through the use phase of the product into its end-of-life treatment is considered in the manufacturing scope. The dilemma of maintaining a worldwide economy in a cost-effective manner while sustaining market share and providing gains for stakeholders without continuing to damage our environment is addressed by the movement of environmentally benign manufacturing.[20]

2.6 Environmentally conscious manufacturing

Environmentally conscious manufacturing aims at achieving optimal utilization of natural resources without harming the environment and without compromising the quality of the products, covering not only production process but also distribution, consumption and recovery and effective disposal of potential wastes. Environmentally conscious manufacturing is defined as "those processes that reduce harmful environmental impacts of manufacturing, including minimization of hazardous waste, reduction of energy consumption, improvement of materials utilization efficiency, and enhancement of operational safety.[21]

2.7 Green manufacturing

There exist several terms related to manufacturing concerned with environmental issues: green manufacturing, environmentally conscious manufacturing, and cleaner production. Though some differences can be found between the concepts, the bottom line is that concern for environmental issues is central to companies' manufacturing operations without compromising competitiveness. Embracing all of the environmental friendly manufacturing paradigms, green manufacturing is used as a representative concept.[22]

Green manufacturing encompasses all concepts that focus on environmental concerns in manufacturing by continuously integrating environmentally friendly industrial processes and products to mitigate air, water and land pollution, reducing waste at the source and minimizing risks posed to humans and other species. Green manufacturing consists of some practices: pollution prevention, toxic use reduction and design for environment.

[20]Gutowski, T. G., Murphy, C., Allen, D., Bauer, D., Bras, B., Piwonka, T., et al. (2001). Environmentally Benign Manufacturing. World Technology (WTEC) Division. Baltimore,Maryland: International Technology Research Institute; Kutz, M. (2007). Environmentally Conscious Manufacturing. Hoboken,New Jersey: John Wiley & Sons. Inc.
[21]Madu, C. N. (2007). Environmental Planning and Management. London: Imperical College Press.
[22]Johansson, G., Winroth, M. Lean vs. Green Manufacturing: Similarities and Differences. In: Proceedings of the Sixteenth International Annual European Operations Management Association Conference (EurOMA09), Goteborg, Sweeden.

Pollution prevention is achieved through source reduction related both to the process and the product and recycling. Means of source reduction might be listed as follows: [23]

- ✓ Product modifications by changing the shape and material composition of the product,
- ✓ Input substitutions by using less-polluting raw, adjunct materials and process auxiliaries (e.g. lubricants and coolants) with longer service lifetime,
- ✓ Technology modifications by improving the process automation, optimizing the process, redesigning of the equipment and changing the process,
- ✓ Good housekeeping by changing operational and management procedures to reduce or eliminate waste emissions with management and personnel practices etc.,
- ✓ On-site recycling by recovering or reusing waste materials.

Toxic use reduction focusing on chemical substances usage might be accepted as a subclass of pollution prevention. Last but not least, Design for Environment tries to integrate environmental performance into product development.[24]

In addition to reducing and eliminating hazardous inputs and outputs in all phases of product life cycle, i.e. design, synthesis, processing, packaging, transportation and product use in manufacturing industries, green manufacturing can result in lowering raw material costs through recycling wastes instead of purchasing virgin materials, increasing production efficiency through less energy and water usage, reducing environmental and occupational safety expenses due to smaller regulatory compliance and potential liabilities, and improving corporate image by decreasing perceived environmental impacts on the public. Moreover green manufacturing can be appraised as a tool to achieve competitive advantage for companies who are good at using their financial resources, technological knowledge, and operations to implement green manufacturing.[25]

2.8 Sustainable manufacturing

The roots of sustainable manufacturing date back to the 1980's where focus on waste reduction in production, in other words cleaner production came into the scene. Its main focus

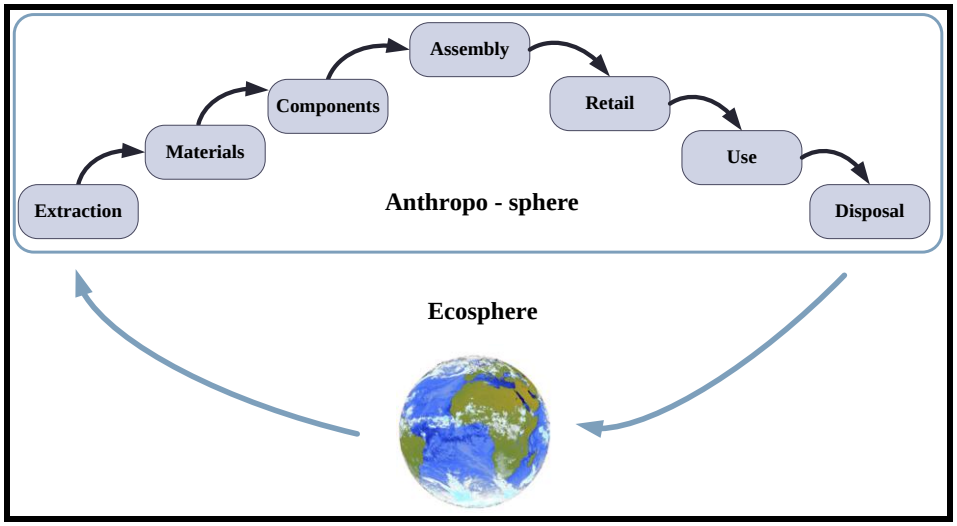
[23] Johansson, G., Winroth, M. Lean vs. Green Manufacturing: Similarities and Differences. In: Proceedings of the Sixteenth International Annual European Operations Management Association Conference (EurOMA09), Goteborg, Sweeden; Berkel van, R.; Willems, E.; Lafleur, M. (1997). The Relationship Between Cleaner Production and Industrial Ecology. Journal of Industrial Ecology, Vol. 1(1) pp. 51-66.

[24]Johansson, G.; Magnusson, T. (2006). Organising for Environmental Considerations in Complex Product Development Projects: Implications from Introducing a "Green" Sub-project. Journal of Cleaner Production, Vol. 14(15-16,) pp. 1368-1376.

[25]University of Alabama. (2006). Center for Green Manufacturing. 13 July 2007, http://bama.ua.edu/~cgm; Porter, M. E., & Van Der Linde, C. (1995). Toward a New Conception of the Environment-Competitiveness Relationship. Journal of Economic Perspective, Vol. 9 (4), 97-118; Barreto, L. V., Anderson, H., Anglin, A., Tomovic, C. (2010). Product Lifecycle Management in Support of Green Manufacturing: Addressing the Challenges of Global Climate Change. International Journal of Manufacturing Technology and Management, Vol. 19(3), pp. 294 - 305.

was environmental issues, and companies were forced to give importance to this concept due to environmental regulations, whereas nowadays there are many reasons to implement sustainable manufacturing activities in companies. Increasing raw material prices and energy costs, necessary investments for environmental technologies, potential penalties for lacking compliance with environmental regulations and regulative incentives, the introduction of CO_2 certificates, the rising public awareness on environmental issues causing challenges of maintaining corporate images for the companies are some examples that emphasize the economic significance of originally environmentally driven issues for companies, additionally to the idealistic vision and strive for sustainable manufacturing[26].

Sustainable manufacturing is coined and accepted as a guidebook for business and governments in achieving sustainable development in UNCED conference in Rio de Janeiro in 1992.[27] US Department of Commerce defines *sustainable manufacturing* as "the creation of manufactured products that use processes that minimize negative environmental impacts, conserve energy and natural resources, are safe for employees, communities, and consumers and are economically sound".[28] As another important definition of *sustainable manufacturing*, Institute of Manufacturing, University of Cambridge describes *sustainable manufacturing* as "developing technologies to transform materials without emission of greenhouse gases, use of non-renewable or toxic materials or generation of waste".[29]



Source: Allwood, J. (2005). What is Sustainable Manufacturing? In: sustainable Manufacturing Series, 16th February 2005

Figure 4 Sustainable manufacturing

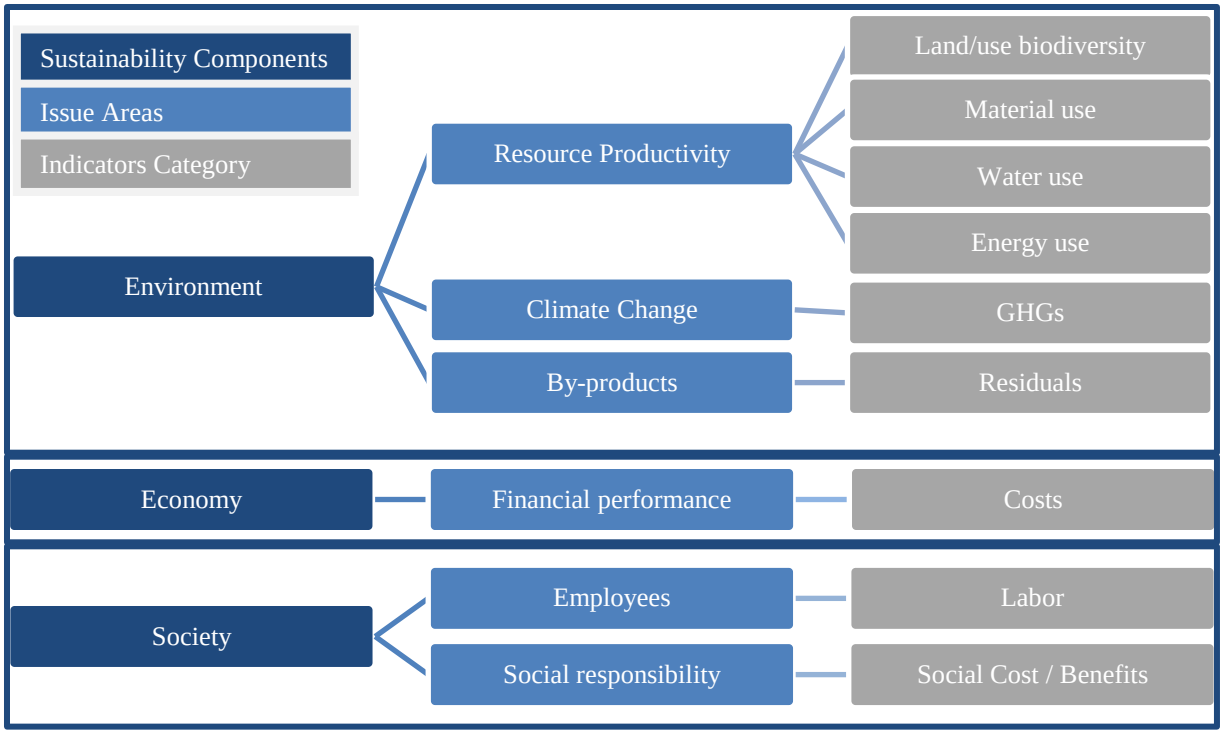
[26]Seliger, G., Kim, H.-J., Kernbaum, S., Zettl, M. (2008). Approaches to Sustainable Manufacturing. Int. J. Sustainable Manufacturing, Vol 1(1), pp. 58-77; Herrmann, C., Thiede, S., Stehr, J., Bergmann, L. (2008). An Environmental Perspective on Lean Production. In: The 41st CIRP Conference on Manufacturing Systems, Tokyo, Japan.

[27] Agenda 21 United Nations Conference on Environment & Development, Rio de Janerio, Brazil, 3-14 June 1992.

[28] http://www.trade.gov/competitiveness/sustainablemanufacturing/how_doc_defines_SM.asp

[29] Allwood, J. (2005). What is Sustainable Manufacturing? In: Sustainable Manufacturing Seminar Series, 16th February 2005.

To highlight the importance of the three pillars in the sustainability, Lowell Center for Sustainable Production defines *sustainable production* as "the creation of goods and services using processes and systems that are non-polluting, conserving of energy and natural resources, economically viable, safe and healthful for employees, communities and consumers, and socially and creatively rewarding for all working people".[30] This definition supports the main issues of sustainable development in environmental, economic and social aspects.



Source: Michael Bordt, The OECD sustainable manufacturing toolkit, Sustainability and US Competitiveness Summit, October 8, 2009, Directorate of Science, Technology and Industry, OECD, Paris www.oecd.org

Figure 5 The pillars of sustainable manufacturing

Sustainable manufacturing encompasses the manufacturing of sustainable products and sustainable manufacturing of all products by focusing on an innovation based 6R methodology to *recover*, *redesign*, and *remanufacture* broadening the former compass 'to *reduce*, *reuse*, and *recycle*'. In the 6R methodology, *reduce* focuses on usage of resources, energy and materials in the manufacturing phase, and waste in the use phase, *reuse* focuses on reuse of the product itself or its components after its first usage in order to decrease the usage or virgin raw materials, whereas *recycle* focuses on converting waste into new materials and products. *Recover* refers to collecting the used products, disassembling, sorting and cleaning to make them ready for reuse, *redesign* involves designing the products so that the post-use processes are simpler and the product is more sustainable, whereas *remanufacture* includes

[30] Lowell Center for Sustainable Production. (1998) Sustainable Production: A Working Definition. Informal Meeting of the Committee Members.

reprocessing of used products to transform them into their original states or a like-new form without loss of functionality.[31]

2.9 The linkage between lean, green and sustainable manufacturing

All the manufacturing paradigms, namely lean, green and sustainable manufacturing, are encompassed under the umbrella of sustainable manufacturing considering them as the different phases in the evolution of sustainable manufacturing. Lean manufacturing has emerged before all other sustainable manufacturing concepts with the focus on eliminating wastes in the companies that add no value to the system and ensuring leanness in all the activities, and thereby surpassing existent economic performance. Then, with the growing importance of environmental issues, green manufacturing paradigm has come into the scene in order to alleviate the adverse effects of manufacturing activities on the environment and improve environmental performances in the companies. Lastly, as the most comprehensive form of these paradigms, sustainable manufacturing has appeared to deal with all the three aspects of sustainable development, economic, environmental and social. If lean manufacturing is accepted as the initialization phase in the progress of sustainable manufacturing, green manufacturing can be admitted as the development phase, whereas sustainable manufacturing forms the maturity phase of the progress since it covers all the aspects of sustainable development comprehensively.

All these three paradigms are strongly related with each other, although their primary objectives are not alike. While lean manufacturing aims at improving economic performance of the companies by decreasing costs due to wastes, green manufacturing intends to better the environmental performance and mitigate the adverse effects of manufacturing on the environment. Moreover, sustainable manufacturing combines these two objectives and adds social concerns into its scope. However, all these three paradigms can result in similar outcomes.

There exist strong coherences between lean and green manufacturing regarding the perspective of waste elimination. Although their wastes were seen as "distinct set of solutions targeting different forms of waste", it has been proved that deadly wastes of lean manufacturing have also embodied environmental impacts.[32] The list of the deadly wastes and

31 U.S. Environmental Protection Agency. (2008). Municipal Solid Waste (MSW) – Reduce, Reuse, and Recycle; Joshi, K.; Venkatachalam, A.; Jawahir, I.S. (2006), A New Methodology for Transforming 3R Concept into 6R Concept for Improved Product Sustainability. In: Proceedings of the IV Global Conference on Sustainable Product Development and Life Cycle Engineering, Sa˜o Carlos, Brazil.

32 Bergmiller, G. G., & McCright, P. R. (2009). Lean Manufacturer's Transcendence to Green Manufacturing. Proceedings of the 2009 Industrial Engineering Research Conference.

their environmental impacts might be seen in Table 2. Therefore, eliminating these deadly wastes also serves the primary objective of green manufacturing by conforming to the strategy of environmental protection. The reciprocal relation between lean and green manufacturing shows itself in waste elimination. Lean manufacturing yields better environmental performances by achieving leanness in the activities and on the other hand, green manufacturing forces the companies to adopt lean manufacturing methods to decrease wastes in order to minimize the adverse environmental impacts of the processes. Therefore, it might be concluded that with the implementation of lean or green manufacturing practices, companies can ensure environmental sustainability.[33]

Possessing a lean system lays the groundwork for implementing green practices and achieving green results. Its techniques also help to create a culture in the companies for continuous improvement, waste minimization, and employee empowerment which fosters the adoption of environmental management systems and pollution prevention in the companies.[34]

Continuously focusing on reducing wastes in the activities, minimizing material, water and energy usage, and avoiding hazardous substances usage in lean and green manufacturing result in lowering costs, improving production lead times and increasing product quality. These activities bring the companies economic benefits, and help them to achieve economic sustainability and competitiveness in the long-term.[35]

Although their main objective is not ensuring social sustainability, lean and green manufacturing practices lead to improvements in working conditions and employee empowerment. Therefore, although they cannot fulfill the objective of social sustainability entirely, they make contributions to this component of sustainability.[36]

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[33] Miller, G., Pawloski, J., Standridge, C. (2010). A case study of lean, sustainable manufacturing. Journal of Industrial Engineering and Management, Vol. 3(1), pp. 11-32; Herrmann, C., Thiede, S., Stehr, J., Bergmann, L. (2008). An Environmental Perspective on Lean Production. Manufacturing Systems and Technologies for the New Frontier, Part 3, pp. 83-88.

[34] EPA. (2005). The lean and environment toolkit, version 1.0. The U.S. Environmental Protection Agency, Washington, DC.; Herrmann, C., Thiede, S., Stehr, J., Bergmann, L. (2008). An Environmental Perspective on Lean Production. Manufacturing Systems and Technologies for the New Frontier, Part 3, pp. 83-88; Venkat, K., Wakeland, W. (2006). Is Lean Necessarily Green? In: Proceedings of the 50th Annual Meeting of the ISSS.

[35] Barreto, L.V., Anderson, H., Anglin, A., Tomovic, C. (2010). Product Lifecycle Management in Support of Green Manufacturing: Addressing the Challenges of Global Climate. International Journal of Manufacturing Technology and Management, Vol. 19 (3), pp. 294 - 305.

[36] EPA (2000) Pursuing Perfection: Case Studies Examining Lean Manufacturing Strategies, Pollution Prevention, and Environmental Regulatory Management Implications, Ross & Associates Environmental Consulting, Ltd., under contract to Industrial Economics, Inc.

Waste Type	Environmental Impacts
Overproduction	✓ More raw materials and energy consumed in marking unnecessary products ✓ Extra product may spoil or become obsolete requiring disposal ✓ Extra hazardous materials used result in extra emissions, waste disposals, worker exposure, etc.
Inventory	✓ More packaging to store work-in-process (WIP) ✓ Waste from deterioration or damage to stored WIP ✓ More materials needed to replace damaged WIP ✓ More energy used to heat, cool and light inventory space
Transportation and Motion	✓ More energy use for transport ✓ Emissions from transport ✓ More space required for WIP movement, increasing lighting, heating and cooling demand and energy consumption ✓ More packaging required to protect components during movement ✓ Damage and spills during transport ✓ Transport of hazardous material requires special shipping and packaging to prevent risk during accidents
Defects	✓ Raw materials and energy consumed in making the defective products ✓ Defective components require recycling or disposal ✓ More space required for rework and repair, increasing energy use for heating, cooling and lighting
Over Processing	✓ More parts and raw materials consumed per unit of production ✓ Unnecessary processing increases wastes, energy use, and emissions
Waiting	✓ Potential material spoilage or component damage causing waste ✓ Wasted energy from heating, cooling and lighting during production downtime

Source: EPA, 2005, "The Lean and Environment Toolkit, Version 1.0," The U.S. Environmental Protection Agency, Washington, DC.

Table 2 Environmental impacts of wastes

Considering the contributions of lean and green manufacturing to economic, environmental, and social sustainability, it can be strongly supported that they can be considered as concepts of sustainable manufacturing. Therefore, in this thesis, sustainable manufacturing concepts, practices, etc. are used to encompass all these three manufacturing paradigms.

3 Research methodology

In this section, the methodology that is followed in the thesis is explained. The steps of the methodology namely material collection, category selection, descriptive analysis and material evaluation are described.

3.1 Main concepts of literature review

It is stated that "The literature review aims to identify, analyze, assess and interpret a body of knowledge related to a particular topic and is normally required as part of a dissertation or thesis."[37] The main purposes of literature review are to deal with a specific topic and make analysis of the relationships between different studies related with that topic. The aims of literature review can be listed as follows:

- ✓ By summarizing and integrating existing research to show the path of prior research and how a current project is linked to it.
- ✓ By familiarizing the researcher with the latest development in the area and by indentifying gaps in knowledge, as well as weaknesses in previous studies, indicates directions for future research.
- ✓ By pulling together and synthesizing different results helps to establish a theoretical framework.

The methodology of this thesis is derived from an existing process model in the literature.[38] This process model has four steps as follows:

- ✓ Material collection: Limiting and defining the material to be collected
- ✓ Descriptive analysis: Assessing the formal aspects of the material
- ✓ Category selection: Defining categories and structural dimensions to assign the material
- ✓ Material evaluation: Analyzing the material according to the categories and structural dimensions in order to interpret the results.[39]

This process model constitutes the skeleton of the following research methodology which is utilized in this thesis.

[37] Jones, K. (2007). Doing A Literature Review in Health.
[38] Mayring P. (2003). Qualitative Inhaltanalyse – Grundlagen und Techniken. [Qualitative content analysis]. 8th ed. Weinheim, Germany.
[39] Seuring, S., & Müller, M. (2008). From a literature review to a conceptual framework for sustainable supply chain management. *Journal of Cleaner Production , Vol. 16* (5), 1699-1710.

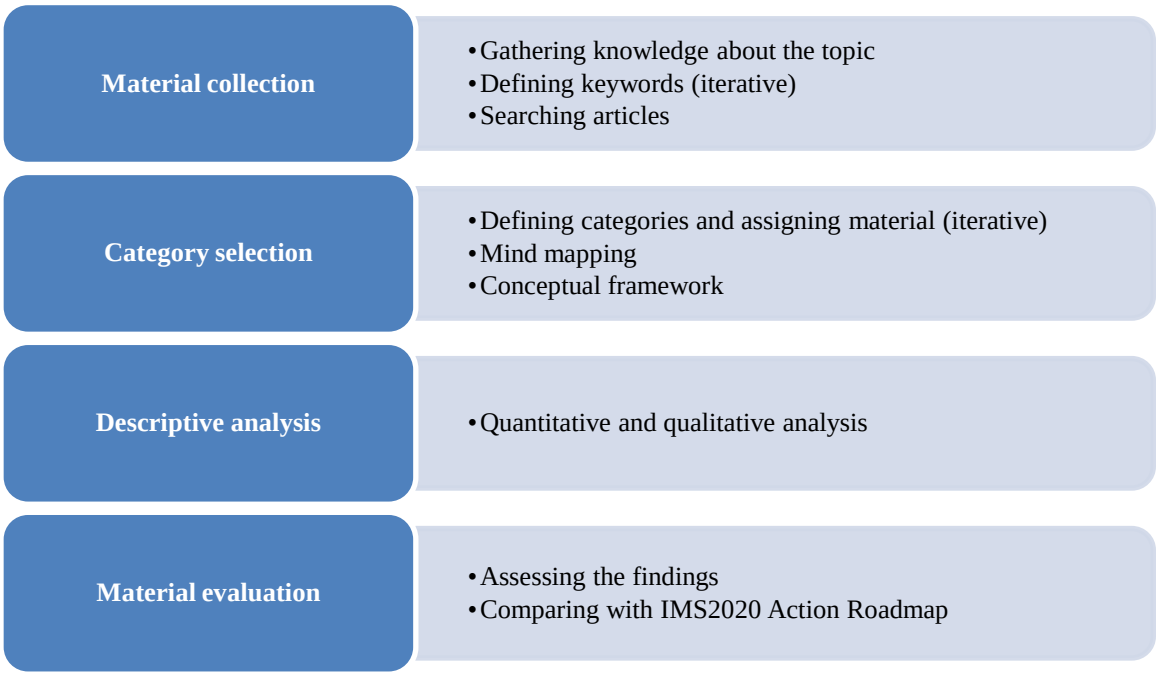


Figure 6 Research methodology of the thesis

All the steps are done by two researchers which enable to decrease the risk of uncovered and unclear topics, biases and inconsistency. Also repeating each step several times increased the reliability of the thesis.

3.2 Research methodology steps

3.2.1 Material collection

In order to collect relevant material three sub steps are followed: Gathering knowledge about the topic, defining keywords iteratively and searching articles.

As a starting point a web based search for the term sustainable manufacturing is done in order to comprehend what sustainable manufacturing is and which keywords define this concept. According to the search results, a file which includes the references for the searched websites, summaries of the documents related to the topic, some interpretations about the sources and the topics need to be questioned is prepared.

After gathering main information, initial keywords related to sustainable manufacturing are listed. In the latter steps of the searching, brainstorming activities and new finding about the topic cause to update the initial keyword several times and the final version is generated with keywords like green manufacturing, eco-efficiency, green machining technologies etc. (Appendix 1).

According to the keyword list, the needed material is collected from major databases websites such as Wiley (www.wiley.com), Emerald (www.emeraldinsight.com), Elsevier (www.sciencedirect.com) and Taylor and Francis (http://www.tandfonline.com). The scope of the thesis and the following limitations are the main factors that shape the article search.

Limitations:

1. This thesis considers only papers in peer-reviewed scientific journals in English.
   How the peer-viewed scientific journals are selected?
   The impact factor is a quantitative tool for ranking and evaluating journals and it is provided by Journal Citation Report (JCR), a publication of Thomson Reuters (when it was known as The Institute for Scientific Information - ISI). Impact factor is a measure to show the frequency with which the "average article" in a journal has been cited in a given period of time. The annual JCR impact factor is a ratio between citations and recent citable items published. Thus, the impact factor of a journal is calculated by dividing the number of current year citations to the source items published in that journal during the previous two years.[40] In order to determine which journals should be in the scope of this thesis, ISI Knowledge impact factor database is benefitted. The journals are chosen from the categories Engineering – Environmental; Engineering – Industrial, Engineering – Manufacturing, Engineering – Mechanical, Engineering – Multidisciplinary and Environmental Science. The aims and the scope of the journals are read to decide the relevance to sustainable manufacturing.
2. Papers in languages other than English and the categories differ from the above listed ones are excluded, i.e Medicine, Art, Accounting etc.
3. Only the papers focusing on discrete manufacturing are encompassed in the thesis. Papers related with process industry are not included.
4. Only the research articles are covered in the study. Seminar and conference reports, workshop results or books are not included to the research materials.
5. Papers whose core topics are eco-design or product design are excluded (except the ones embedded in the end of life options articles), because the aim of this paper to observe the processes not products.
6. Papers related with green supply chain management are excluded, because this thesis focuses on only a part of supply chain related with the manufacturing processes, not the whole supply chain.
7. Papers published between January 1999 and July 2011 are taken into consideration.

Considering the limitations and the scope of the thesis journals that are listed in Engineering – Manufacturing and Engineering - Environmental categories are searched article by article. If

[40] ISI Knowledge Impact Factor. (1994).Thomson Reuters.
http://thomsonreuters.com/products_services/science/free/essays/impact_factor/ (22.05.2011)

journals are listed in other categories such as Engineering – Mechanical or Engineering – Multidisciplinary firstly a keyword search is conducted. In the case that there are no related articles after the keyword search in the journal, that journal is skipped. Otherwise, all the issues of the journals are explored one by one. During the research period 29 journals out of 61 are skipped since they do not contain related articles. The related articles are collected in an article database in the format of Table 3. Here just the main columns are exhibited.

Name of the Journal	Rating/ Impact factor	Publication year	Name of the authors	Name of the articles related with SM	Abstracts of the articles	Notes	Classification	Type of the article
Journal of Cleaner Production	1.867	2011						

Table 3 A short view of article database

At the end of the material collection activity, 680 articles are collected in the database. By reading articles, the irrelevant ones are eliminated and the final database includes 389 articles that meet the requirements of the scope and the limitations of the thesis.

3.2.2 Category selection

After collecting 389 articles, the key concepts of each article are written down as keywords in order to be benefitted in latter phases i.e. preparing the class names and mind map. In order to cover these key concepts some major class titles are determined. All the articles are assigned to the related class considering their core concepts. By utilizing the class titles and the class relationships, a mind map is formed which contains enough classes to encompass the entire research articles, a detailed explanation and the mind map can be seen in the following section (Figure 8). This mind map helped to shape the conceptual framework of the thesis (Figure 9).

3.2.3 Descriptive analysis

It is stated that there are two main approaches for qualitative content analysis which are inductive category development and deductive category application.[41] In deductive approach the analytic categories are selected before reading the materials. In this thesis, distributing articles among the years and dividing the articles according to the research methodologies such as case study, research paper are determined deductively. However, in inductive approach, categories are developed from the material i.e. pillars of sustainability.

Distributing articles among years and dividing articles according to the research methodologies are inspired from existing literature reviews. In the article database file

[41] Mayring, P. (2000). Qualitative Content Analysis. Forum: Qualitative Social Research [On-line Journal], Vol. 1(2). Available at: http://qualitative-research.net/ (20.08.2011)

information of these two categories are stored. After reading the articles it is observed that defining a category which considers the pillars of sustainability could be beneficial because most of the articles focused at least one of these dimensions. This category is named as ESET because of Environmental, Social, Economic and Technological aspects.

In order to analyze the data Microsoft Office Excel and its filtering option are utilized. Whole analysis of the gathered data is explained in the State of the art analysis section detailed. The qualitative analyses are processed based on the collected articles and expressed verbally in the form of summarizing and explaining, whereas quantitative analyses are represented with graphs and charts.

3.2.4 Material evaluation

Material evaluation includes the interpretation and the assessing of the findings. In this section it is aimed to show if there is a pattern in the development of sustainable manufacturing concepts or what is the current situation and what are the gaps in the research area. After deciding the current situation of and the gaps in sustainable manufacturing, the results are compared with the findings of IMS2020 Action Roadmap, which is an EU project, to show whether the developments of sustainable manufacturing in the 1999-2011 time interval are able to underpin the actions that are needed to be taken between 2011 and 2013 and the vision that is desired to be achieved in the year 2020.

4 Towards the conceptual framework

All the gathered articles are classified according to their core concepts and they tried to be fitted into a framework to conceptualize the findings. Considering general manufacturing systems a basic framework is generated. According to the basic framework classes are mapped to see the linkages and the relationships between each other. After constructing the mind map, it is observed that the basic framework is not sufficient to explain the different layers of the classes. Therefore, by inspiring from basic framework and mind map a new conceptual framework is derived.

4.1 Database construction

The objective of this thesis is to make a study of the state of the art analysis of sustainable manufacturing in order to show the current situation and developments of sustainable manufacturing. Data is the most important used material in SOTA analysis and the vital steps of database construction are as follows:

1. Data gathering: Collecting the related material from different sources.
2. Data purification: Eliminating unrelated data from relevant ones.
3. Data analyzing: Analyzing data to make it useable and meaningful for the evaluation.

4.1.1 Data gathering

Firstly a web based search was done for the term sustainable manufacturing. There are many conferences, university and organization web pages related with the core topics *sustainable manufacturing* and *sustainability*. Since they are popular topics for environmentalists, social scientists and the engineers, there are many news, articles, theses, reports, books and personal blogs related with these terms. After having a general idea about sustainable manufacturing as a result of web based search, all possible keywords that might be related with the topic are written down. Then, brainstorming exercise and discussions are benefitted to generate a common keyword list. This list guided the thesis during the research period, and in each step it was updated several times according to the new findings.

By using the keywords and the knowledge gained from the general search, the scientific data gathering stage is started. In order to be scientific this thesis considers only papers in peer-reviewed scientific journals in English. As it is mentioned in the limitations part, journals were selected by considering their impact factors, scopes and aims. Totally 61 journals were reviewed. All the issues of journals in the manufacturing and environment categories from 1999 to 2011 were reviewed article by article. Journals before 1999 were not taken into considerations because the concept is known approximately for 20 years and a sample for 12

years might be enough to see the current situation and the developments during this time interval. In other categories such as mechanical engineering or engineering - multidisciplinary, a keyword search was conducted and if there were some related articles in the journal, those journal are also reviewed article by article. In 29 journals there was not any related keyword search result and these journals were excluded from the scope of the thesis. All the related articles are recorded in the article database.

4.1.2 Data purification

680 articles are collected in the database. All the abstracts and notes about the articles are read several times together and they are categorized in 3 groups: yes, no and maybe. Since the collection part was done by two researchers separately and the purification part was done together from two different points of views, the reliability of the thesis was increased. By reading the materials together, the probability of biases and the risk of being subjective are decreased. It also helped to see and show other aspects of the materials which might be unnoticed during the first review.

According to the scope and limitations of the thesis, most of the articles were eliminated in the second review. For example, if the articles are related with product design or eco-design, they were not covered in the scope of the thesis and sent to the no class, because in this thesis just the manufacturing processes are considered not the products. Also if there is an article related with process industry instead of discrete manufacturing, it was directly recorded as a no article. Articles related with green supply chain, in detail transportation, customer relationships, distributors and logistics were also excluded.

Articles in the no category were reviewed two times, and if they were still no, their statuses changed to X which means definitely no. If there was a possibility that it might be related with the topic, it was moved to the maybe class. In order to decide for definitely yes articles researchers read all abstracts 3-4 times. After redoing the same assessment for maybe articles too finally 389 articles remained in definitely yes category.

4.1.3 Data analysis

These 389 articles were assessed 2-3 times more and researchers tried to write down the key concepts of each article. By using these key concepts researchers tried to determine some class titles to cover all these articles. Each article was fitted in at least one category and a mind map was generated.

The publication year of each article was stored in the database file. By using this data an analysis for distribution of the articles among the years was done. The details of these analyses can be found in the State of the art analysis section. In the database file article types

like case study, research article or survey are recorded too. The last dimension is related with the main aspects of the articles such as environmental, economic, social or technological and it is named as ESET. Results of each analysis are examined in the analysis section of SOTA analysis section.

4.2 Basic framework

Before starting with the state of the art analysis of the thesis, a basic framework was generated as a point of departure and keywords were brainstormed and defined taking into account that framework. In the framework, since the topic of interest of this thesis is sustainable manufacturing, manufacturing related processes were put in the center of the model and the factors that are entering the system were labeled as input in general, whereas the factors leaving or results of the system were labeled as output of the system. Management related to manufacturing was accepted as an external factor considering its effect on input, manufacturing related processes and output.

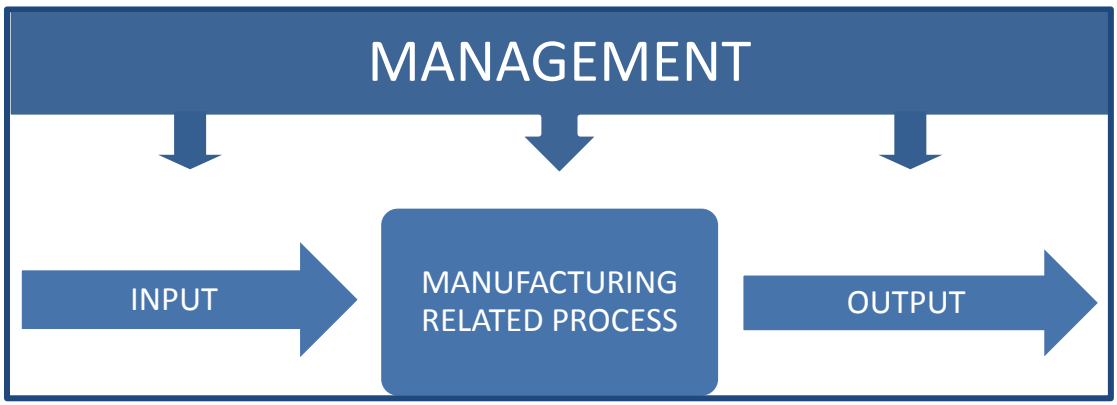


Figure 7 Basic framework

The core part of the framework, so called *manufacturing related processes*, included manufacturing paradigms which might be covered under sustainable manufacturing, such as lean, green and sustainable manufacturing. Additionally, manufacturing phases; planning of the process and production, quality and inventory control, life cycle assessment and performance evaluation issues were listed under this topic. *Input* considered all the things that are entering the system. Raw materials, energy, and technology were the resources of the system; in addition equipments and workers were accepted as inputs since they might be evaluated as the factors that are entering the system. *Output* covered all the factors that are leaving the system and focused on the outputs / results of the manufacturing process. It involved end of life options, waste, emissions etc. Pollution prevention, emissions and waste management were listed under this topic, since they are more focused on the output of the system and try to handle the problems related to these issues. Performance of the system (Eco-efficiency, productivity etc.) was considered as *output*, since it was based on the results of the manufacturing process. *Management*, as a concept above all the parts of the framework,

was drawn as a module that is in interaction with *manufacturing related processes*, *input* and *output*. It covered environmental management, industrial symbiosis, and regulations etc. in short the external factors that are affecting manufacturing process.

Benefiting from the framework, the clear borders of the research topic were defined. Considering the wide range of the research, green and sustainable supply chain issues were excluded from the research scope to make the thesis more focused on the manufacturing phase rather than the whole product's life cycle. The scope of this research is limited to discrete manufacturing industry. Since the core interest of the research is based on the manufacturing process, not the product, product related issues were not taken into consideration, e.g. eco-design.

Considering the sub-topics of each module and the scope of the thesis, keywords were brainstormed and defined. A couple of keywords that are used in this thesis are; environmental, ecological, green, clean, sustainable, sustainability, etc. For the full list see Appendix 1.

4.3 Mind mapping

Mind mapping is "a process of surveying, assessing and linking the information, knowledge, competencies and proficiencies held by individuals and groups within an organization".[42] In order to facilitate the grouping of the classes in a logical manner, mind mapping was utilized in this thesis.

In order to establish a database and to make it ready for the SOTA analysis, table of contents of each journal were reviewed title by title to choose the articles that have at least one keyword that have been defined before and show relevance to sustainable manufacturing concept. 61 journals were reviewed - 32 journals gave the articles that are related with sustainable manufacturing concepts (see Appendix 2) - , and 680 articles that might have connection with the research topic were collected. Each article was read and the relevance of each article with the research was questioned, and if they were found relevant, main concepts of the articles were taken as a note in order to be benefited in forming the final classes. Temporary classes were formed in the first review phase to be redefined or used as a step in this iterative process. After reviewing the list of the articles a couple of times, the final form of the classes was defined and it was ensured that each article was assigned to at least one class. Since the topics are not mutually exclusive, some articles can be assigned more than one class.

[42] Keyes J. (2006). Knowledge Management, Business Intelligence, and Content Management: The IT Practitioner's Guide. Taylor & Francis Group, LLC.

The list of the classes was written down and a framework that might encompass them perfectly was tried to be constructed. Benefiting from the basic framework, the classes were assigned to the existing modules, if they might fit into their scope, otherwise the scope of the existing modules was reviewed and their scope and borders were updated and widened to cover all the classes. While *input* and *output* parent classes were kept the same, the name of the *manufacturing related processes* parent class was changed as *operations* in order to clarify the concept of the class. *Management* parent class scope was found to be very narrow, therefore to cover external factors, industrial symbiosis and network, which affect the companies exogenously rather than the internal management strategies of the company, the class was revised as *management & exogenous factors*.

To do the mind mapping, these four parent classes were drawn as the branches of the tree, and the classes that belong to each parent class were considered as the leaves on these branches. The mind mapping was processed taken into account the interrelations between classes, super classes and parent classes. The knowledge map was finalized when all classes were assigned to at least one class and their relations, if there is, with the other classes were drawn explicitly.

Input module, as a parent class, involves the raw materials that enter the system to be processed, the resources such as energy, technology, equipments that play an active role in the manufacturing process and also work force whose involvement is almost a must in the process in order to support the process by supervising and controlling it or taking an active role itself. Raw material articles generally address the issues on usage of virgin or recycled / reused materials, and their consumption levels. As a very important topic for the last decades, energy articles in general focus on reduction on their consumption and alternative energy sources. Equipments articles cover machining and tooling related issues and their effects on sustainability and technology articles point out clean / environmental technologies and information systems. Lastly, employee articles generally discover the relation between employment and employee involvement with manufacturing paradigms that remain in the borders of this research. Although it is not encountered any articles related with resources such as land and water, and also physical plant, and investments, general web based research showed that these topics might be covered under this parent class. However, in the current mind map they are not taken into consideration since they do not have a ground in the articles database.

Operations parent class is the one with the widest scope since it is the one which shows direct relevance with the research topic. It covers manufacturing paradigms and techniques, planning phase and control issues in the manufacturing process, and the evaluation. Manufacturing paradigms might be gathered in 3 groups considering their evolution in the last 20 years. Lean manufacturing, whose main focus is elimination and prevention of wastes, can be accepted as a primitive form of sustainable manufacturing, since it helps to improve

environmental performance through elimination of hazardous wastes and to better the usage of resources. Green manufacturing, which covers cleaner production, environmentally conscious manufacturing, environmentally benign manufacturing and green manufacturing, is assumed as a general concept that mainly focuses on environmental issues without disregarding economic concerns. And lastly, as the most comprehensive manufacturing paradigm, sustainable manufacturing aims at sustaining development through manufacturing activities that encompass the three pillars of sustainability, environmental, economic and social aspects. Planning group consists of process planning and design, production planning and scheduling, and methodology and modeling phases. Process planning and design articles consider changes in the manufacturing process for end of life options utilization or environmental concerns and sustainability. Production planning and scheduling articles generally cover material and resource planning issues and production planning and scheduling for conserving resources, utilizing end of life options and embedding disassembly in the production plans. Methodology and modeling articles includes articles that are integrating environmental concerns into optimization of the systems. Control group consists of two subgroups as inventory and quality control. Inventory control articles focus on production-inventory strategies of the firms under environmental constraints, whereas quality control articles cover Total Quality Environmental Management (TQEM). Although it has a wide range focusing on the whole product life cycle, life cycle assessment articles might be covered under this parent class with a focus on manufacturing process.

Output parent class covers the issues focusing on preventing or managing the outcomes of the system such as waste and pollution in order to excel in environmental and/or economic areas and achieve sustainability and the results of the manufacturing process which show the performance of the system. This parent class consists of end of life options, waste management, pollution prevention, emissions, and environmental performance. Firstly, end of life options' articles focus on disassembly of the products in order to be used in remanufacturing, reuse operations, etc., recycling activities to convert waste into new materials. Remanufacturing, reuse and recycling are the main topics that are discussed amongst researchers. Waste management, pollution prevention and emissions classes cover the articles related to their practices and policies. Considering the similarities between the concepts and the target they aim at, all of the articles related to end of life options, waste management, pollution prevention and emissions might be covered under waste management, since to some extent they all might be accepted as managing the wastes of the system in different ways.

Management & exogenous factors parent class covers the issues that have an effect on the manufacturing process, its inputs and outputs. *Management* controls the manufacturing process at the enterprise level, whereas *exogenous factors* are those which have the authority to control the manufacturing systems from outside of the company. Environmental

Management Systems are the ones which take environmental concerns into consideration. They have a close relation with regulations since they are affected by governmental interventions like ISO 14001, take back laws, etc. Business performance issues are better to be covered at *management & exogenous factors* parent class, since they generally depend on the management policies of the companies, and they are at the enterprise level. Competitiveness and eco-efficiency related issues are popular topics of this class. Regulations, industrial ecology, network and external factors have a strong effect on companies. Regulations, as ISO 14001, take back laws and tradable permits; enforce the companies to behave more sensitively to environmental or sustainability issues by applying penalties and sanctions to them. External factors articles try to figure out the barriers, challenges, drivers, initiatives, motivation factors or promotions' effects on implementing sustainable manufacturing activities in the company. They might depend on the culture of the company or the country. Industrial ecology and network articles generally aim at revealing the linkage between manufacturers and suppliers. Network articles focus on the effects of the manufacturer on the supplier's environmental performance and sensitivity. Lastly, industrial ecology, as a well developed network where firms collaborate by exchanging their waste and energy (which might be utilized as a feedstock in other processes while it is a waste in one process) in order to achieve environmental and economic efficiency, finds place for itself under this parent class.

The mind map might be seen in Figure 8. All of the classes of this map will be explained in detail in the State of the art analysis section and the latest progresses in the literature will be discovered. The mind map of the current research might be developed broadening the scope of the research topic. In addition to sustainable manufacturing activities, manufacturing of sustainable products might be included in the topic to make the research scope more comprehensive. And to bring a new and wider perspective to the research topic, sustainable supply chains might be taken into consideration to see the big picture. Reviewing 61 journals with impact factors can surely be accepted as a rich sample, however there still exists a plethora of journals which might have something pertinent to sustainable manufacturing concept. Moreover, including conference and seminar papers, and earth summit and sustainability centre reports will help see the exact and up-to-date progress in sustainable manufacturing in world.

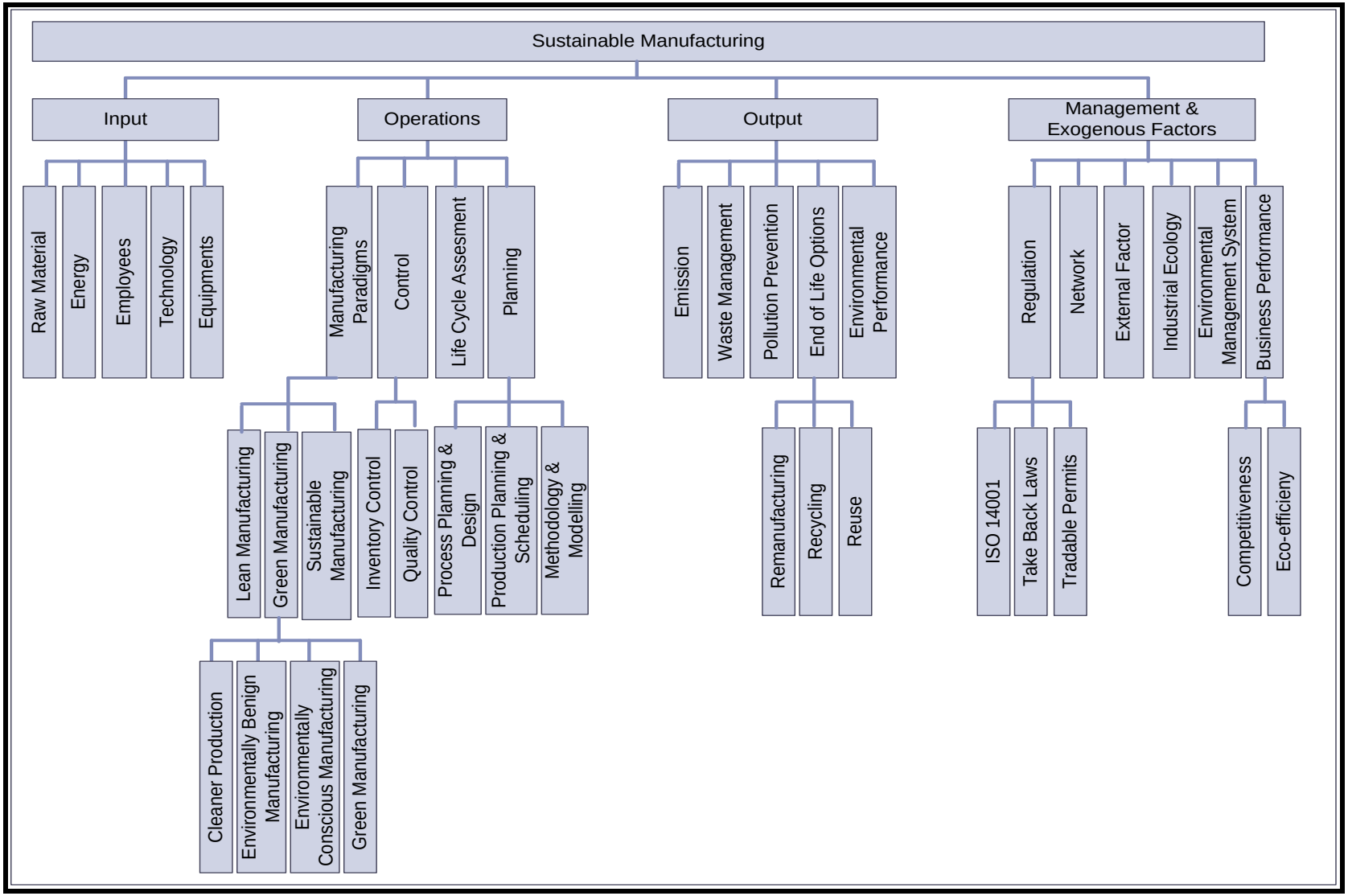


Figure 8 Sustainable manufacturing mind map

4.4 Conceptual framework

Basic framework was too generalized therefore it was not enough to fulfill the scope of the thesis. First of all the basic framework could not cover all the classes and show the relationships between each class entirely. Besides, in the basic framework regulations, industrial ecology and environmental management systems were in the same module. However, it is not possible to express all these different concepts within one module, especially in one layer. The most suitable framework in order to embrace all the classes and relationships should be with different layers. With layers it is easy to distinguish the different roles and impacts of each class. For instance, environmental management systems are not directly related with manufacturing however, they are not totally independent from the manufacturing like regulations. To satisfy this need, 3 different layers were generated namely eco-system, management and operations (Figure 9). The subclasses were assigned to the related layer. However, there were some subclasses like external factors and performances, which could not be classified strictly in one layer. Both of these subclasses had some aspects related with sub- and super-layers. For example, while environmental performance is related with manufacturing operations, eco-efficiency and competitiveness are directly related with management operations. Therefore, they were placed between two different layers, as an intermediate level as it is seen in the framework (Figure 9).

The three layers will be explained in the following paragraphs. The e*co-system* layer includes the exogenous factors that the company does not have a powerful effect on them. In this layer the relationships that the companies have with an external body like government, suppliers or competitors is examined. Regulations, industrial ecology and networks are the classes under the eco-system parent class. Regulations class includes articles that are generally related with governmental sanctions and rules. ISO14000 standards and their effects on the companies, mandatory or voluntary implementations of environmental regulations were examined within regulations class. Industrial symbiosis is defined as sharing of services, utility, and by-product resources among diverse industrial actors in order to add value, reduce costs and improve the environment.[43]The main motto of industrial symbiosis might be "output of a company can be input of another company". All the articles in the industrial ecology class explain the relationship between input and output companies and their environmental effects. Network is the last class in the eco-system layer. Here the relationship between company and its suppliers is examined. Since competitiveness increases in the global world day by day, companies try to improve the relationship within the network and also try to keep control of the network management. Sustainability is one of the most popular topics nowadays, so companies value this issue. Even suppliers can force the company to be more environmental and sustainable or

[43] Agarwal, A., Strachan, P. (2008). Is Industrial Symbiosis only a Concept for Developed Countries? The Journal for Waste & Resource Management Professionals, The Chartered Institution of Wastes Management; 42.

vice versa. In addition to industry, relationships and networks are appreciated by academia too and there are substantial amount of articles which can be examined under network class.

Management layer covers the administrative operations, which contain endogenous factors that are directly affected by the company. Environmental management systems (EMS) are the only main class in management layer. EMS class contains articles about company management strategies considering environmental factors and effects. These management strategies are generally voluntarily, not forced by an external body, which means they are endogenous factors.

External factors subclass is located between third and second layers. It includes the articles with the main concepts like barriers, adoptions, incentives and promotions to/for sustainable manufacturing. Causes for them might be from enterprise or national level. For instance, there are some articles recounting the behavior of the companies against sustainable manufacturing topics due to anxiety of bad reputation or competitiveness, they are enterprise level external factors.[44] Besides, there are articles related with governmental actions to promote or adopt companies to the sustainable manufacturing applications or barriers – drivers for these applications.[45] Since it is not significant to separate them into two different classes, an intermediate level is established and all the articles are covered under one title. The same case is also valid for performances class. Performances can be the result of manufacturing or management activities. When the products are manufactured with environmental or sustainability concerns, results should be related with environmental performance of manufacturing. However, competitiveness or business performance metrics occur as a result of managerial decisions. Thus, performance subclass is also determined as an intermediate level.

Last but not least, operations layer which is the basic level includes the manufacturing related activities. If just a simple manufacturing system is imagined, the main operations can be listed as:

1. Input materials enter to the system.
2. After that the production and the processes of these input materials should be planned.
3. According to these plans they have to be manufactured.
4. Control is one of the vital processes in the manufacturing system. Each manufactured item should be controlled.
5. The results of the control should be evaluated in order to improve or change the system.

[44] Fryxell, G. E; Szeto, A. (2002). The Influence of Motivations for Seeking ISO 14001 Certification: an Empirical Study of ISO 14001 Certified Facilities in Hong Kong. Journal of Environmental Management, Volume 65 (3), pp: 223-238.
[45] Rahimifard, S. et al. (2009). Barriers, Drivers and Challenges for Sustainable Product Recovery and Recycling . International Journal of Sustainable Engineering, Volume 2 (2), pp: 80-90.

6. Finally, finished goods should leave the system to be used material. After usage recovery methods are applicable for them.

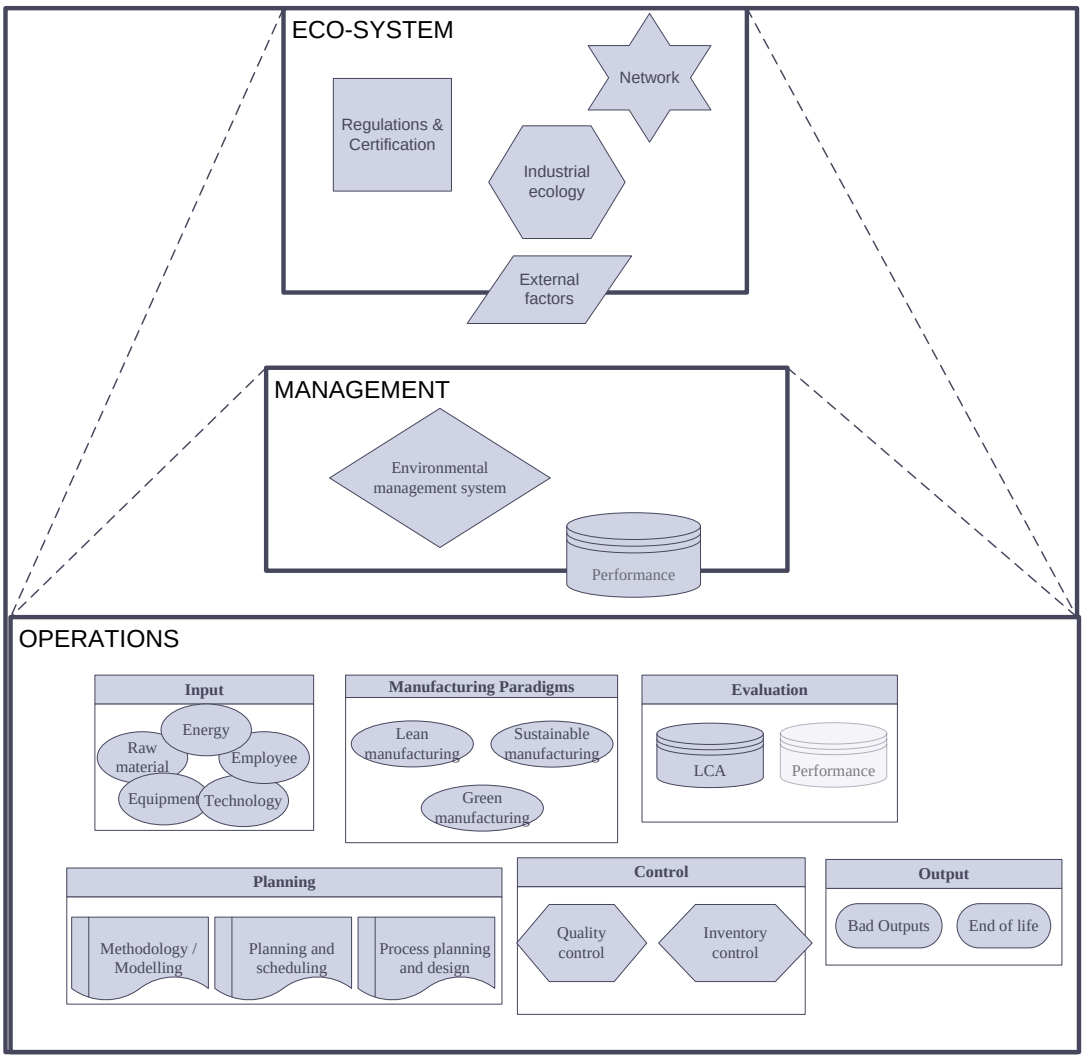


Figure 9 Conceptual framework of sustainable manufacturing

Considering these main steps general manufacturing units are arranged sequentially and aim to exhibit sustainable manufacturing processes in each main step. Input class includes the articles related with the items that enter to the system as resource or supporting material such as raw material, equipment, employee, energy or technology. Planning processes are production planning and scheduling, process planning and design, and methodology / modeling. All the manufacturing paradigms namely lean, green and sustainable manufacturing are covered under manufacturing title. Quality Control and Inventory Control constitute the essential part of control class. Life Cycle Assessment (LCA) is the most important evaluation tool which is mentioned in this thesis and the evaluation results are gathered under evaluation sub-class. Finally, output class contains articles pertinent to the end

of life options and the effects of and the precautions to waste management, pollution prevention and emissions.

The features of each parent class, class and their subclasses will be explained in the analysis part in detail.

5 State of the art analysis

For the state of the art analysis of sustainable manufacturing, the articles that are published between January 1999 and July 2011 in the selected journals according to their impact factors are collected. In order to determine the point that sustainable manufacturing has reached the collected materials are analyzed. The analysis is accomplished by utilizing the article database. Then, the distribution of articles according to 3 dimensions namely yearly based, article type based and ESET based are demonstrated. After the analysis, all the classes in all layers are evaluated to show the development of sustainable manufacturing during the predetermined time interval. The references are not cited in the text directly, instead of it the tables of the articles under each class are shown in Appendix 3.

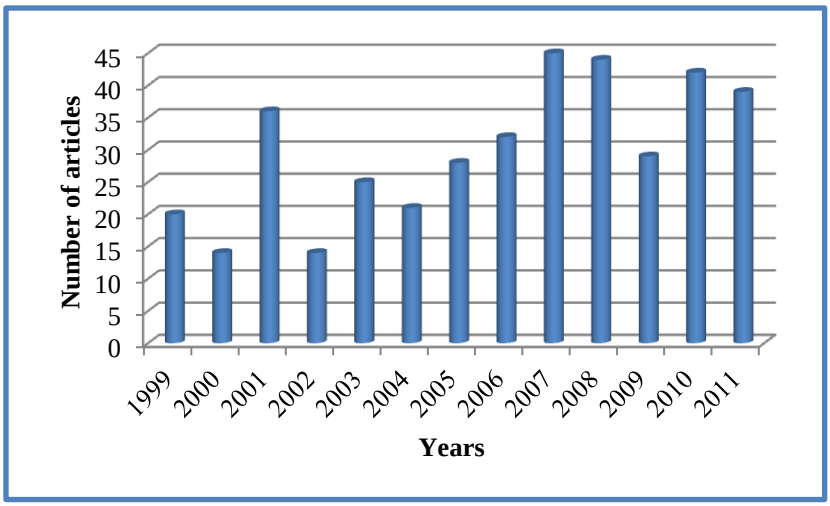
5.1 General analysis of the articles

The scope of the thesis is defined as *sustainable manufacturing* concepts that focus on manufacturing processes following the sequence from input through planning, manufacturing, control and evaluation to output in discrete manufacturing industries also considering endogenous and exogenous factors like environmental management systems and regulations that have a direct effect on the implementation of sustainable manufacturing practices. It excludes process industries, products and services, supply chain management, eco-design concepts and supporting activities not directly related with manufacturing like green marketing, green purchasing, green packaging and green reporting.

The collected articles by considering the scope and the limitations of the thesis are analyzed regarding to three dimensions namely yearly based, article type based and ESET based.

1. *Yearly based analysis*

According to the limitations and the scope of the thesis, the articles published between January 1999 and July 2011 in the peer-reviewed journals are examined. There exist 389 articles related to the *sustainable manufacturing* concepts. The distribution of these articles among years is visualized by using Excel graphs and the following figures exhibit the results (Figure 10). The fitted trendline proves that there is an increasing trend in the number of published articles among years. This may indicate that the importance and the attractiveness of the *sustainable manufacturing* concepts have arisen year by year.



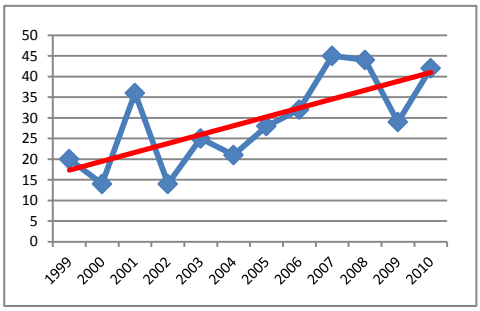


Figure 10 The distribution of the articles among years

2. *Article type based*

The collected 389 articles are classified according to their types, *research article*, *empirical study*, *case study*, *methodology and literature review*. This dimension serves to comprehend the contribution of different type of academic studies to the development of sustainable manufacturing. Research articles and literature reviews give general information about the core topics and generally consist of descriptive parts. Although empirical studies, case studies and methodologies include descriptive parts, they assist to exemplify the practical applications and their results on sustainable manufacturing. The following pie chart represents the distribution of article types (Figure 11). If an article demonstrates the specifications of more than one class, it is classified under a combined class. For instance, if an article proposes a methodology and conducts a survey at the same time it is classified under *methodology*, *empirical study* class. As it is seen from the chart, research articles constitute the major part of the published articles with 212 papers. Empirical study, methodology and case study classes follow it with 57, 53 and 36 articles respectively. By taking combined classes into consideration empirical study, methodology and case study classes contain 67, 74 and 56 articles respectively. Literature review is the less attractive research type with 7 articles.

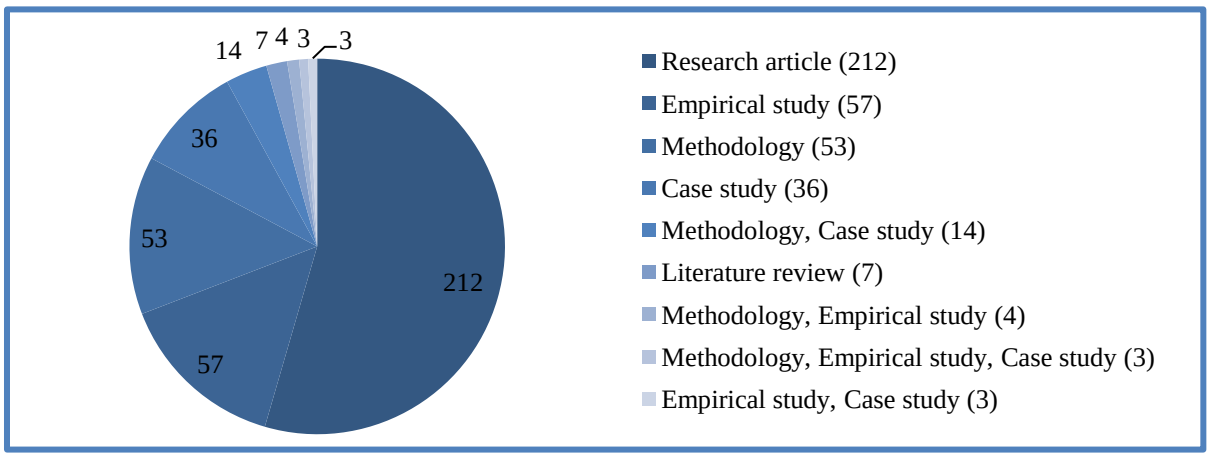


Figure 11 The distribution of the article types

3. *ESET based analysis*

Sustainability has three pillars namely environmental, social, and economic. However, in the last years the increasing importance of technologic developments has forced to include technology as the fourth pillar. To reach sustainable development, all of these pillars should be taken into account. In order to see if the articles meet sustainable manufacturing and development, articles are evaluated considering all the pillars: environmental, social, economic and technological (ESET). Articles from environmental, economic and social aspects evaluate the developments by taking environmental, economic and social objectives into account respectively and try to provide sustainability in these aspects. Technology articles include applications of sustainable technologies which use less energy, resources and reduce hazardous substances and pollutants and encourage usage of recycled and reused materials. For instance, machining technologies and software technologies are covered under this pillar. All the articles in the database are not applicable to categorize in one of these aspects, because instead of evaluating any pillar they focus on the description of general concepts or adoption, application, and promotion for or barriers to sustainable manufacturing concepts. Thus, they are collected under the class called *others.*

The following figure shows the distribution of all the articles according to their pillars - ESET type (Figure 12). 148 papers examine their core topics only from environmental point of view. And totally 253 papers give some results related with environmental sustainability. Articles that cover more pillars at the same time are assumed as supporting sustainable manufacturing more than others. From the results shown in the pie chart, it is obvious that social sustainability and technology aspects have not attracted enough attention for the researchers. The reasons might be expressed that they do not have high economic impacts on manufacturing activities or there is not any big pressure or punishment for their adoption to the manufacturing systems.

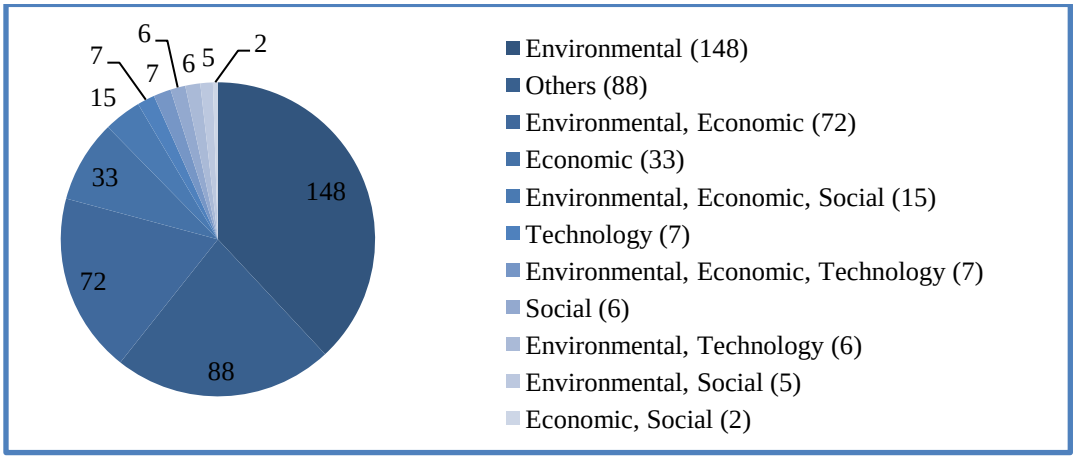


Figure 12 The distribution of the articles according to the ESET type

5.2 Eco-system

Eco-system layer constitutes the top layer of the framework. This layer is named as *Eco-system*, since it covers the external factors that the company does not have the power to control and change but has a role in the whole system. The company is the center point of this layer, and the effects of the external factors on the company is tried to figure out. The company is exposed to the directing effects of *Regulations & Certifications*, *External Factors*, *Industrial Ecology*, and *Network*. Governmental and international interventions such as ISO 14001 and take back laws form the *Regulations & Certifications* class where the company is constrained by the standards of them by being imposed sanctions or penalties. These administrative rules have a very compelling impact on the management strategy of the company. *External Factors* class is formed to cover the articles in which barriers, drivers, motivating factors or promoting factors' effects on implementing sustainable manufacturing activities in the company are worked out. This class is laid between *Eco-system* and *Management* layers as an intermediate layer, since while it has a strong connection with the exterior agents, such as government initiatives and promotions, it also depends on the factors related to the company's culture and management strategy. *Network* class is developed to discover the relationship between the supplier and the manufacturer and the influence of the manufacturer on the supplier's environmental performance and sensitivity. Lastly, *Industrial Ecology* class represents the articles related to this concept. Similar to *Network* as being based on a network between firms, *Industrial Ecology* focuses on developed networks aiming at increased resource utilization, environmental and economic efficiency where firms collaborate by exchanging materials, energy, water, and/or by-products so that a firm can utilize materials, energy, water, and/or by-products of the other firm as a feedstock in its processes. These classes will be explained in detail in the following parts.

The distribution of the articles in *Eco-system* parent class is as follows:

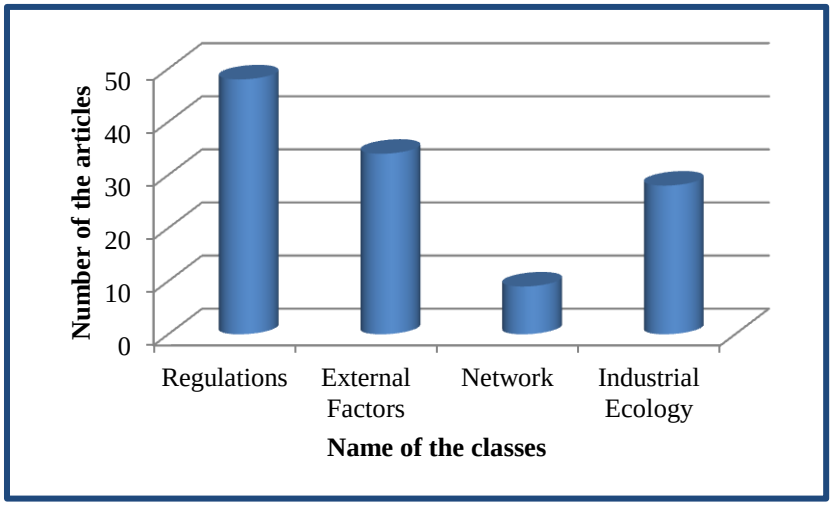


Figure 13 The distribution of the articles in Ecosystem class

Regulations & Certification constitutes the highest portion of this parent class with 48 papers, whereas number of articles published about *External Factors*, *Industrial Ecology* and *Network* are 34, 9 and 28 respectively.

5.2.1 External factors

There exist several factors that affect the implementation of sustainable manufacturing activities in companies. Drivers and motivating factors, and barriers to implementing sustainable manufacturing activities and promoting these activities might be considered as *External Factors* to manufacturing processes since instead of playing an active role in sustainable processes, they support/hinder the sustainability of the systems. They might be the factors affecting the manufacturing activities of the companies from outside of the company externally, as well as from the company inside.

In this research, 34 articles that might be covered under this class exist, and Journal of Cleaner Production contributes to these numbers with the highest portion (24 articles). 20 of the articles focus on factors affecting cleaner production, therefore it is not surprising that most of the articles come from Journal of Cleaner Production. The distribution of the articles among years might be seen in Figure 14. It might be concluded that as sustainable manufacturing and related concepts become familiar with the companies, the need to investigate the barriers to or drivers for sustainable manufacturing activities tends to decrease over the years, and loses its importance.

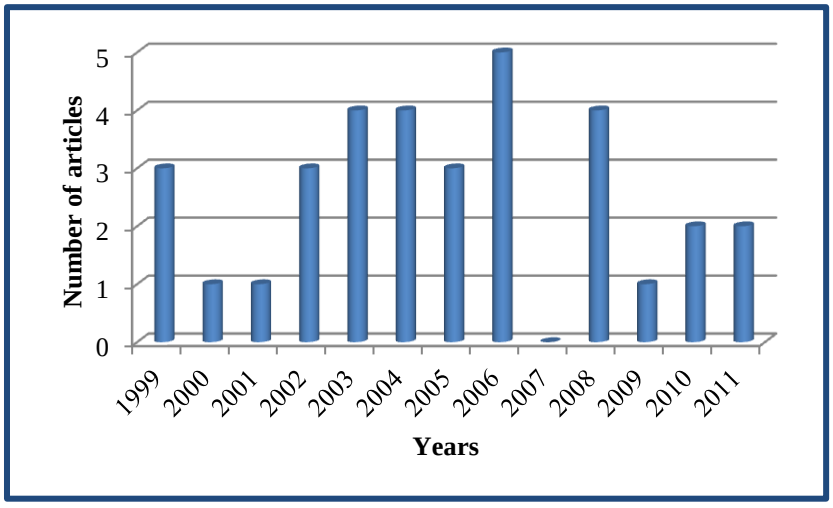


Figure 14 The distribution of the articles in External Factors class

On the transition to sustainable manufacturing, companies have encountered many obstacles in the adoption of cleaner production activities. These obstacles have hindered/retarded the change in the companies and postponed it for years. ISO standards and cleaner production adoption have not attracted the interest in the companies as they have deserved. Many factors

that might be accepted as barriers to implementation of sustainable manufacturing activities have been discovered.

Barriers to adoption of sustainable manufacturing activities are generally grouped under 4 classes as: (a) policy and market barriers, (b) financial and economic barriers, (c) technical and information barriers, (d) managerial and organizational barriers. It is found that lack of economic incentive policies and legal and financial support are the policy and market barriers. Weak/poor environmental enforcements also hinder the implementation of sustainable manufacturing activities. High initial capital costs required to adopt the techniques or upgrade the technology and the absence of mechanisms that might support the companies in implementing the sustainable systems financially constitute the financial and economic barriers. The lack of information about sustainable manufacturing concepts, such as waste minimization and pollution prevention, and the technologies required cause the informational barriers whereas the lack of technical competences and infrastructure cause the technical barriers. The lack of awareness and unwillingness to change in the management and employee level and the lack of commitment constitute the managerial and organizational barriers.

Although there are many barriers to implementing sustainable manufacturing activities, there also exit many motivating factors and drivers for implementing them, since they ensure many benefits for the companies. These benefits might be considered also as motivating factors because these stimulate interest in the companies to transit to sustainable manufacturing by abandoning traditional mentality.

Drivers and motivating factors for sustainable manufacturing might be listed as follows: (a) economic drivers, (b) market drivers, (c) regulatory drivers. Applying sustainable manufacturing in the companies provide the companies many economic benefits by decreasing the amount of resource used in the manufacturing processes, reducing energy and water usage, and minimizing wastes and increasing productivity. In addition, they help the companies cope with the global market by improved competitiveness and meet the product specifications in foreign markets. This increases the chance to export their goods to the other countries and therefore increase their sales and profits. Additionally, the will of the companies to enhance their reputation in the market might be listed as a market driver. Lastly, environmental regulations and policies play an important role as drivers, since they force the companies to obey the standards by imposing penalties and sanctions on them. Not only current environmental regulations but anticipated future environmental regulations influence the decision of the companies.

To promote sustainable manufacturing concepts in the companies and help the companies overcome the barriers to adopt them, Cleaner Production Centers are established and several training programs are offered in many countries. These aim at auditing and supporting the companies in the adoption and implementation phases of sustainable manufacturing activities.

The awareness of the industry representatives, governmental and financial institutions are increased by the activities of these centers and training programs. These activities focus on the diffusion of information, education, training and communication. These centers, as independent industry consulting firms, train and give advices to their clients to help them choose the best solution for their companies. As they inform the companies about sustainable manufacturing concepts and support them, more motivated and successful projects take place in the companies.

5.2.2 Regulations & Certifications

Regulations & Certifications class is formed to cover the articles that focus on environmental regulations and ISO standards. These rules, mandatory or voluntary, have an effect on the implementation of sustainable manufacturing concepts in the companies. Environmental regulations, covering tradable permits, take back laws, waste management policies and end of life vehicle legislations etc., force the companies to comply with the environmental restrictions in order to decrease the negative impact of the companies on the environment. On the other hand, ISO Standards are composed of voluntary international standards that companies might integrate into environmental management systems to better their systems.

In this research, 48 articles that might be covered under this class exist, and Journal of Cleaner Production contributes to these numbers with the highest portion (21 articles). 30 of the articles focus on ISO 14001 Standard, although there exist plenty of ISO Standards that might be grouped under this class. It is interesting that ISO articles attract more attention than environmental regulations in research. Articles that focus on environmental regulations are found to be related with the effects of environmental regulations on competitiveness, productivity, production–inventory strategies, end of life vehicles processes, and industrial symbiosis. 4 of the relevant articles focus on the production-inventory strategies under environmental constraints, but the other topics do not attract more attention; there is 1 article about each topic. The distribution of the articles among years might be seen in Figure 15. With the results obtained from this research, it might be deducted that with the increasing awareness of the necessities for the implementation of sustainable manufacturing concepts, the interest in the environmental regulations and ISO Standards shows tendency to increase in the last years.

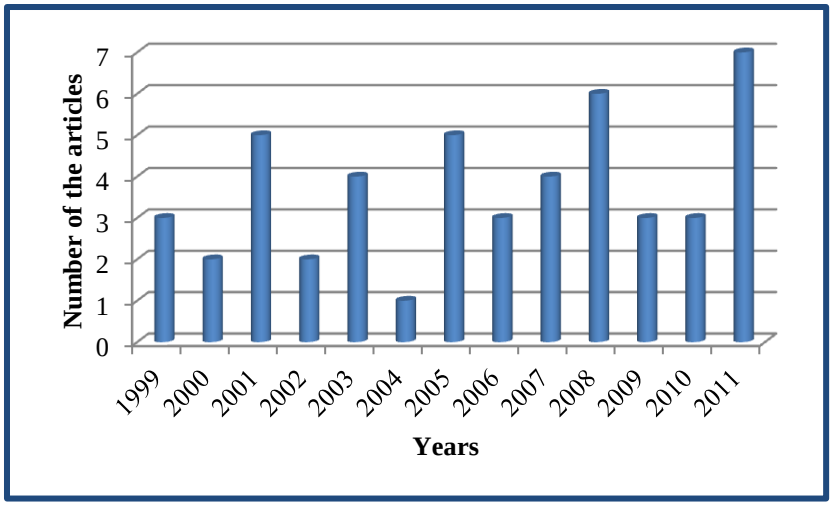


Figure 15 The distribution of the articles in Regulations & Certifications class

There exists a lot of research conducted to figure out if environmental regulations activate social and economic gains; however their direct costs for companies, unforeseen effects on economic development, productivity and international competitiveness are still under discussion.

Environmental regulations have an effect on the production-inventory strategies of the firms depending on the pollution charge per unit. If it is larger than a threshold, the environmental policy of the government will be effective. Models are developed to define the optimal solutions which embed environmental policies into the system. The regulations also contribute to industrial symbiosis development by defining clear goals and supporting the businesses' activities. In addition, regulations which are relevant to end of life vehicles have a positive effect mostly on 'end-of-pipe' solutions, such as innovations in recycling. Although the regulations are not integrated in design phase yet, recyclates are started to use in automotive companies due to conform to the related legislations more.

The effects of regulations on business performances, such as competitiveness and productivity, are questioned to discover if the regulations have really positive effects on the companies. No evidence is found that environmental regulations related to waste water, packaging waste and clean air exert any improvement on the competitiveness of the firms, and on the other hand also it is not proved that environmental regulations affect the competitiveness negatively. Departing from Porter's argument46 that supports that more stringent environmental regulation positively affects the companies' performances by encouraging innovations, it is found that strengthening environmental regulations at first decreases productivity, but after a couple of years, when the innovation has been completed, it causes an increase in productivity. This proof refutes the deduction of the systematic studies

[46] Porter, M. E.; van der Linde, C. (1995). Toward a new conception of the environment-competitiveness relationship. Journal of Economic Perspective, Vol. 9(4), pp.97-118.

that supports the inexistence of the relation between environmental regulations and productivity since they only focus on the immediate effect of implementing environmental regulations.

The compliance of the companies with environmental regulations depends on many factors. Market based factors, such as pressures to produce more differentiated products, to reduce costs, to satisfy quality employees, and to innovate in products and processes, are significant factors that trigger the companies' compliance. On the other hand, the costly adoption of sustainable manufacturing practices and technologies deters the companies from conforming to the regulations. The reduction of costs with the help of tax breaks and cost sharing motivates the companies not to violate environmental regulations. Training of the employees to remove their knowledge deficiency, and the moral responsibility of the managers for environmental issues lead to over compliance with environmental regulations.

ISO Standards form the *Certifications* part of the class. Different than the regulations, ISO standards do not compel the companies to conform to the rules since they are voluntary activities. ISO Standards' primary concern is environmental management systems. These standards help the companies manage their environmental activities by supporting them with a framework. ISO, although it is generally used as a synonym of ISO 14001, are composed of a series of standards. In addition to environmental management systems related ones (ISO 14001, 14002, 14004); there exist standards also for environmental auditing (ISO 14010, 14011, 14012) environmental labeling (ISO 14020, 14021, 14022, 14023, 14024, 14025), evaluation of environmental performance (ISO 14031) and life cycle assessment (ISO 14040, 14041, 14042, 14043).[47] The ISO Standard which is the only mentioned one in the articles that are covered in this thesis is ISO 14001 which aims at integrating environmental values into the operations of the companies.

ISO 14001 certification, as a voluntary and process based program, is generally adopted by the companies which have more proactive operations. It transforms the strategy of the companies from externally driven strategies directed by regulations to internally driven strategies. It sets environmental objectives and targets for the companies. It is a long term oriented program since it needs some changes in the design of the processes. The benefits due to implementation of ISO 14001 might be listed as follows: ISO 14001

- ✓ Improves environmental performance of the companies. Waste generation rates are decreased and recycling is improved.
- ✓ Activates higher implementation of environmental practices and improves the systemization of environmental activities.

[47] International Institute for Sustainable Development. (1996). Global Green Standards: ISO 14000 and Sustainable Development.

- ✓ Results in cost savings due to better waste management and recycling activities.
- ✓ Increases reputation of the companies. It is a marketing tool to show the conformance to environmental constraints to the customers. It is beneficial in foreign markets and helpful to meet customer requirements. Since the expectations of the companies are too high in some cases, some might claim that ISO 14001 does not result in expected image benefits.
- ✓ Provides legal compliance.
- ✓ Improves clerical work; documentation, control etc.
- ✓ Betters employee discretion with the help of standardization of the systems. High involvement of employees in making decisions how to meet the environmental objectives of the firms also contributes to the improvement of environmental performance.
- ✓ Encourages higher commitment to the environment and increases environmental awareness.

Although implementation of ISO 14001 has many benefits, high cost of certification might be a deterring factor for the companies. Since the effects of ISO 14001 on business and financial performances are not proved yet, it cannot be concluded that improved environmental performances due to implementation of ISO 14001 go hand in hand with improved business and financial performances. Likewise, the impact of ISO 14001 on pollution prevention is not attested yet (Some articles claim that they are positively related, whereas some articles indicate that there is no significant relation between them.).

5.2.3 Industrial ecology

The need to follow the rules of sustainable development in the industry has given rise to the emergence of the *Industrial Ecology* which imitates the natural ecosystem. It covers the key concepts, industrial symbiosis and eco-industrial parks which try to implement the principles of industrial ecology. Although industrial symbiosis is a broader concept, they both aim at using materials and energy efficiently by sharing them among the industrial actors that take part in, reducing costs, and improving the environment. The firms, which are in a close territory, form a network to exchange material, energy and knowledge.

Industrial Ecology covers the articles that are related with industrial ecology, industrial symbiosis, and eco-industrial parks. The growing importance in Sustainable Manufacturing activities has also caused an increase in this concept. The distribution of the articles among years might be seen in Figure 16. It can be deducted from this table that there is an increasing trend in the research for *Industrial Ecology*. The exceptional increase in 2004 is due to the special issue on “Applications of Industrial Ecology” in Journal of Cleaner Production.

Although there is an increase in the number of the articles related to this topic, the development in Industrial Ecology concepts are not at the desired level in practice.

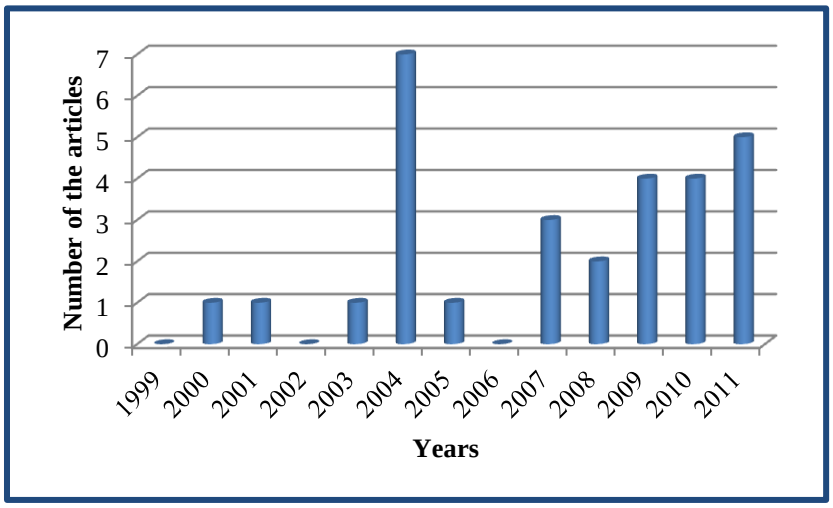


Figure 16 The distribution of the articles in Industrial Ecology class

The common goals of the applications of *Industrial Ecology* are to conserve resources, increase resource usage efficiency, protect the environment, provide economic viability, and bear social responsibility. In many countries, these applications are supported / forced by the governmental institutions to achieve these goals. Fiscal incentives and environmental regulations intend to stimulate the interest and the progress in the applications. Additionally, they also set clear objectives for the companies. They result in efficient use of resources, more eco-efficient production, and better utilization of waste in terms of material and energy. Although the success of these agents in improving the environmental and economic performances of the companies, indirect encouragements can lead to better performances since the companies' own willingness play a more important role in achieving the goals.

Many pilot projects have been conducted especially in developing countries like Brazil and China. Many of them are at the early stages; however they are promising for the sustainable development. Most of them are focused on utility sharing like collaborative wastewater treatment and heat and power generation, which are of low risk, and economically and environmentally beneficial. These factors have a positive influence on the companies' involvement. However, also by benefiting from utility sharing, material, energy, and water wastes should be exchanged in order to provide sustainable development.

It has been proved that the synergistic relations at the inter-sectoral level lead to better environmental improvements than individual units. In addition to the environmental benefits that are gained through utility sharing and symbiosis, economic development is also provided. Forming the networks, and sharing the knowledge and information can foster the emergence of innovative ideas to solve the current and future environmental problems. Although industrial symbiosis and eco-industrial parks seem beneficial for the companies, there exist

some problems in reality. The outputs of one company cannot always substitute for the feedstock of another company. Additionally, in some cases the location of the companies does not enable the participation of a company in an eco-industrial park.

5.2.4 Network

In this thesis, *Network* class is formed to focus on the articles that try to find out the effects of the relationships amongst the actors of the supply chain networks on improving sustainability. These actors are, in general, the companies, their suppliers and customers, and governmental organizations. Taking the suppliers or the customers into consideration will help broaden the scope from company level to supply chain level.

In this research, 9 articles are covered under this class. Journal of Cleaner Production and International Journal of Production Research make the majority of the contribution with 3 articles each. The distribution of the articles is almost constant.

Companies try to improve their sustainability by including their suppliers in implementation of sustainable manufacturing activities. Social networks have a significant positive impact on implementation success of environmental technologies. The suppliers play an important role in improving environmental performance of manufacturing activities when strong partnerships with suppliers are built by supporting them with proper incentive systems.[48] They also affect the dissemination of sustainability-related concepts, such as cleaner technologies, within the companies. Considering the effect of suppliers on the sustainability, companies have started to include environmental performance assessment of the suppliers in the supplier selection processes, and they might intervene in the environmental management practices of the suppliers in order to improve the sustainability of their products and services at the expense of lower transaction costs.

5.3 Management

In this thesis *Management* is assumed as the organ which has the ability to decide for the company and its future. It is an endogenous factor for adoption and barriers to environmental management systems (EMS). *Management* parent class includes *EMS* and *Performances* classes. There are 114 articles which are mentioned at least one of the subclasses of *Management* class. There are some articles related with more than one subclass, because of that the sum of article numbers in all subclasses are bigger than the parent class's total articles (see Figure 17).

[48] Geffen, C. A.; Rothenberg, S. (2000). Suppliers and environmental innovation: The automotive paint process. International Journal of Operations and Production Management, Vol. 20(2), pp.166 – 186.

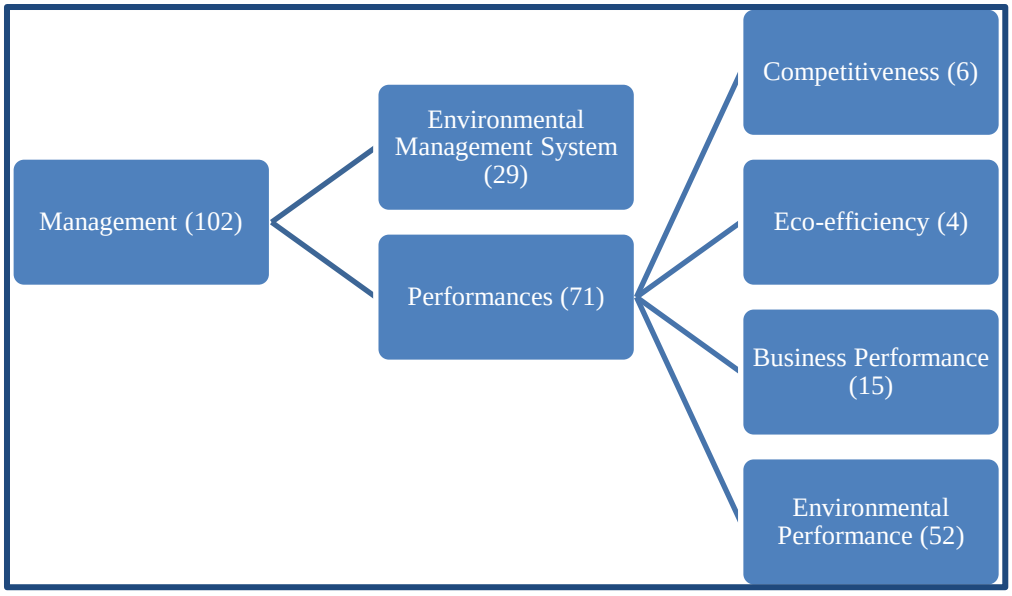


Figure 17 The distribution of the articles in Management class

5.3.1 Environmental management system (EMS)

Environmental management system (EMS) is defined as "part of the overall management system that includes organizational structure, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving, reviewing and maintaining environmental policy" by the International Organization for Standardization (ISO).[49]

All the manufacturing and service firms has an impact on environment and EMS helps these firms to effectively manage or minimize their harmful effects on the environment caused by their activities because improving environmental performance of firms is one way of limiting environmental damages. Firms should integrate environmental values into their operations and they should review the consequences of these activities. By monitoring, constantly reviewing and reporting the results of the system companies may have continuous improvements and effective environmental solutions.

From the first time that it is used in 1996, EMS is always a popular topic for companies; hence it is covered in this thesis too.

In *Environmental Management System* class, 29 articles have been written between years 1999 and 2011 in the journals belong to this thesis's scope. In 1999 and 2009 there is not any related articles to the topic. 2000 (7 articles) and 2008 (6 articles) are the peak years in terms of published article numbers (see Figure 18). From another point of view, majority of the articles comes from 3 journals. International Journal of Cleaner Production, International

[49] ISO (International Organization for Standardization), 1996, ISO 14001: Environmental Management System-Specification with Guidance for Use, No. ISO 1996(E). Geneva, Switzerland: ISO.

Journal of Operations and Production Management, and Production and Operations Management journals contributed to the research with 5, 4 and 4 articles respectively.

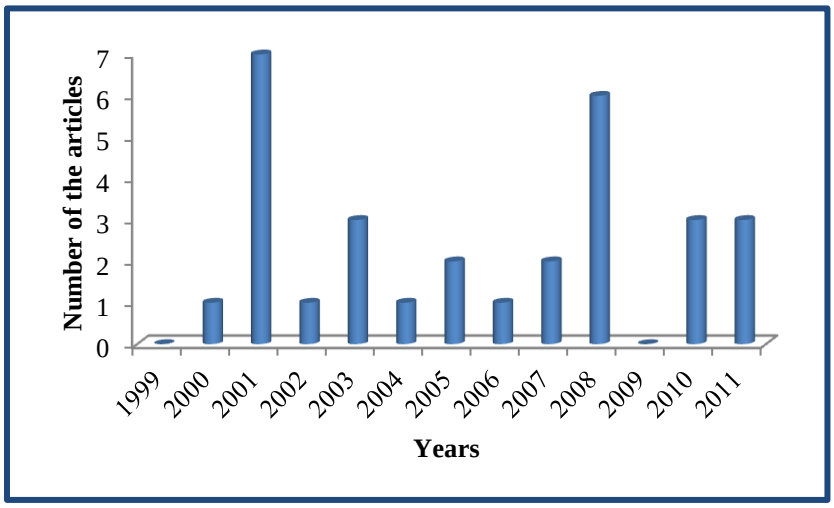


Figure 18 The distribution of the articles in Environmental Management Systems class

As qualitative analysis, articles generally claim that Environmental Management Systems adoption provides many benefits to the companies. It is possible to list EMS's features and its benefits as follows:

1. EMS requires complete documentation and reporting of the whole operations, processes and business activities. This prerequisite of EMS forces companies to make regular revising and updates, which helps companies to see the current developments and take action to follow these developments. Companies benefit from EMS by always updating their knowledge about environmental aspects, legal issues and moves of their competitors which gives opportunity for continuous improvement. Besides, this provides firms to make innovation, to find cost effective solutions and to increase their competitiveness. On the other hand, this advantage has a price: documentation requires a lot of time for collecting and analyzing the data.
2. Many researcher claims that EMS is a strategic tool to have an improved corporate image and to increase market share and. Day by day customers are more conscious about the environment and the future of the world, thus they seek more environmental friendly products. If companies produce or dump less waste and give importance greening their operations, the organization is perceived environmental friendly by customers. In order to be perceived as environmental friendly most of the companies adopt EMS, because it increases their reputation as environmental company. Also, the improved reputation of the organizations could increase sales, market share and profits of the company as well. A step forward of this, since EMS strengthening the company's position in the market; EMS assists organization to gain a competitive advantage.

3. EMS helps companies to decrease cost and increase savings because EMS aims to reduce waste and support pollution prevention. In order to reduce waste companies use new technologies and develop their processes. These improvements provide an advanced system with less operational processes which are beneficial for environment and this advanced system can decrease the manufacturing costs.
4. All these improvements and decrease in operational processes with less waste and high quality could increase the efficiency and the effectiveness of the system. This might increase the competitiveness of the company and force it to continue its improvements continuously.
5. Besides the improvements in operations, EMS results in reduction in organizational risks such as health, safety and environmental. Hence, these positive changes directly motivate employees and trigger them to continue improving system and increasing effectiveness and efficiency.
6. Since there are many national and international laws and regulations that force companies to adopt EMS, in ensures leniency in international trade barriers and easy agreements with suppliers and customers.
7. When EMS helps to decrease in insurance costs it also increase shareholders wealth by reducing environmental risks because less risk makes companies more attractive to invest for stockholders.
8. EMS does not help only the company that implements it, it also assists to enhance the environmental awareness through the supply chain; because companies that apply EMS have tendency to more environmental demands and force their suppliers to be more environmental friendly and sustainable.
9. EMS had a positive impact on the production quality. The main reason is trying to reduce waste, improve the operation processes by reducing non value-added activities and use last technology for these aims. Besides, by forcing suppliers companies demand environmental friendly products and the quality of the items increase. Also, in addition many articles demonstrate that the firms, which use Environmental Management System standards like ISO 14000, have tendency to use quality standards like ISO 9000. Therefore, it is possible to say there is a positive interaction between Environmental Management Systems and Quality Management Systems.

These are the common benefits of EMS that are mentioned in the articles used in this thesis. For sure all the articles agree that EMS increases the environmental performance and decreases environmental damages. Although the application of the system is expensive; it provides cost reduction and other benefits like high sales and market share; hence it amortizes itself in the long run. Besides, additional costs like auditing, maintenance and training are the most common barriers for adopting EMS. Generally small companies prefer just the

implication, not the additional services, till they can have enough experience for EMS implication.

5.3.2 Performances

When companies adopt sustainable manufacturing implementations, in order to see the results and accomplishments of the application; they want to evaluate how effective and efficient their processes are and how they are effective in applying these concepts. Evaluating the performance is the most appropriate technique, because this measurement helps firms to make the criticism of these adoptions. In the literature, there are many articles written about environmental and business performances, performance indicators and subtopics of performance like eco-efficiency and competitiveness. The distribution of all these articles in performance and subclasses in the scope of our thesis is as follows:

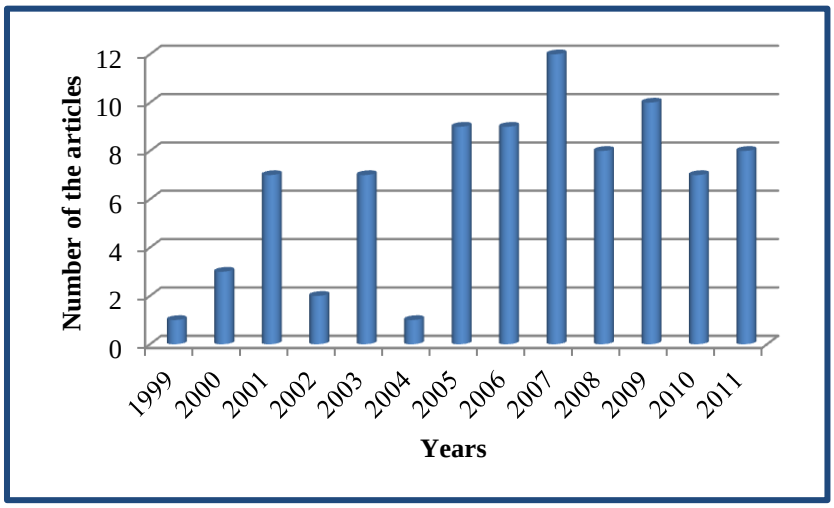


Figure 19 The distribution of the articles in Performances class

Although all the years after 2005 have significant number of publications, 2007 is the peak year with 11 articles relevant to the topic. Between 1999 and 2004 there is at least one article in each year, however after 2005 it is obvious to observe the increase in publication numbers. It might be concluded that in the beginning of the 2000s the main objective is to discover the barriers, incentives, promoting factors to adoption of sustainable manufacturing concepts but later the implementation phase starts and the performances of these implications are evaluated. It might explain the increase after 2005. Also the deduction which is done in external factors is parallel to this explanation; they both support each other from this perspective.

Since the importance of sustainability and environment increases day by day, companies tend to integrate environmental concerns to their strategies and operations. Just integration is not enough; hence companies focus on evaluation because evaluation is vital for continuous

environmental improvement. Because companies may take action in order to improve their current situations according to these performance measurements.

Some performance dimensions may be listed as cost, environmental impact, competitiveness, eco-efficiency, quality, and savings in this section. Amount of waste and pollution can also be accepted as performance indicators. Companies' efficiency and effectiveness could be rated by using these dimensions, metrics and environmental indicators.

It is claimed that sustainable manufacturing activities decrease the harmful effects of operations on environment. Sustainable manufacturing concepts assist to increase economic benefits and competitiveness while decreasing environmental impacts such as resource consumptions, waste emissions.

For instance lean manufacturing has a positive effect on the performance of the companies. These performances can be categorized under three titles like JIT, waste minimization and flow management. JIT includes 6 instruments such as reduction of inventory, preventative maintenance, cycle time reduction, use of new process technology, use of quick changeover techniques and reduction of set-up time. Waste minimization covers these factors: eliminating waste, use of error proofing techniques, use of pull-based production system and removal of bottlenecks. Flow management items are reducing production lot size; focus on single suppliers and continuous/one piece flow. Lean manufacturing affects these items one way or another and they increases the companies' operational performances. Waste minimization category generally impacts environmental performance of the companies, while JIT and flow management categories generally focus on business performances.

Another research has proved the positive effect of lean manufacturing on plant performance. The Research claims that there is a notably correlation between the degree of lean implementation and the levels of quality ($r=0.749$, $p < 0.001$), productivity ($r=0.429$, $p=0.046$) and delivery time ($r=0.577$, $p=0.005$) improvements.

Other examples are generally related with the environmental effects of cleaner production and other sustainable manufacturing paradigms.

It is claimed that there is an overall positive impact of sustainable manufacturing activities on firms' business performance. It is stated that cleaner production is an effective way of obtaining improved material usage, reduced energy consumption and lower emission levels. However, if the cleaner production activity needs high investment like using energy efficient and clean technology, its non-financial performance contribution will be higher than its financial contribution. It means before gaining economic benefit, the advertisement of usage of a clean technology can increase non-financial benefits, like corporate reputation.

To be more quantitative, since 1993, 71 Lithuanian companies implement cleaner production innovations and in return for 15 million EUR investments, they gain more than 9 million EUR. Additionally, after this adoption companies save 18% of electricity, 22% of water consumption, 30% in wastewater volume, 23% in fuel consumption and 52% in expenditure for environmental taxes. Also cleaner production and process optimization allow companies to save energy.

In many articles cleaner production and pollution prevention terms are used together, because cleaner production implications positively influence companies' performances to decrease pollution. And it is strictly suggested that taking precautions like adopting environmental objectives in the first phase of product design, together with quality specifications will have a significant effect on cost, speed and flexibility of operations instead trying to control them after everything finishes. So the level of pollution prevention in a company may give some information about company's performances like cost, speed or environmental friendliness.

In order to evaluate performances and set targets for continuous improvements; companies should have some concrete values on their hands, like indicators and a method to evaluate and interpret these indicators. Environmental performance indicators might be used for monitoring compliance, motivating continuous improvement to support decision making and providing data for reporting. Environmental performance indicators (EPI) should be determined carefully before starting to measure and also the managers should be aware that these indicators are so important for the company and they should support and communicate the environmental strategy throughout the organization. Besides, EPIs support and ensure conformity of environmental processes helping organizations to obtain and maintain the ISO 14001 certification; formalize complex environmental processes and procedures; decentralize and support environmental information systems.

Just having these indicators and their results in enterprise level will not be enough because environmental performances are controlled not only by companies but also by customers and governments. Governments try to force companies with regulations and customers exert pressure to make them more environmental friendly. Thus, organizations monitor their results at national and enterprise levels. Also, they report their environmental performances on their websites. When the companies report their performances on their websites, customers are able to reach this information and this may increase the reputation and competitiveness of the company.

Many articles underpin that there is a positive relationship between environmentally sustainable manufacturing practices and competitiveness. It is claimed that an enterprise's ability to undertake its operations in a way that does not damage environment is a vital part of its competitiveness. It is demonstrated that environmentally sustainable manufacturing activities with extended training modules, can contribute to a more competitive and

environmentally friendly industry, which is required for economic growth. It is claimed that a firm's resources and competitive advantage has a mediator variable role for a positive relationship between environmental protection and financial performance. Also, different type of sustainable manufacturing activities such as pollution prevention and product stewardship are positively related with competitive outcomes like manufacturing cost and product quality.

Not only manufacturing activities affect competitiveness. Management activities are also vital for competitiveness. Environmental management systems support the contribution of supplier management and continuous improvement. By reinforcing this contribution, it has mediated the effects on manufacturing competitiveness in terms of cost, delivery and quality. Besides, green productivity and eco-efficiency support competitiveness too. Both of them will be explained in the following paragraphs.

In this thesis eco-efficiency is defined as follows:

> "Eco-efficiency based on the concept of creating more goods and services while using fewer resources and creating less waste and pollution. Eco-efficiency is a management philosophy that encourages business to search for environmental improvements which yield parallel economic benefits. It focuses on business opportunities and allows companies to become more environmentally responsible and more profitable. It is a key business contribution to sustainable societies. It fosters innovation and therefore growth and competitiveness." [50]

From the definition it is obvious that eco-efficiency is an evaluation for sustainable manufacturing activities.

World Business Council for Sustainable Development has defined some characteristics for supporting companies to become more eco-efficient. These characteristics may be listed as: reducing material and energy intensity, reducing the dispersion of toxic substances, enhancing recyclability, maximizing the usage of renewable resources, extending product durability and increasing service intensity.

There are many articles examining eco-efficiency activities in different countries and sectors, in different size of companies. This may indicate that eco-efficiency is a global performance measurement that gives information to the companies about their economic and environmental performances. However, the application of eco-efficiency in SMEs is less than big companies.

[50] Changing Course. (1992). World Business Council for Sustainable Development (18.08.2011); WBSCD Eco-efficiency. (2005). World Business Council for Sustainable Development (18.08.2011).

Since supporting green productivity and eco-efficiency makes companies more competitive, more innovative and more environmentally responsible as well as contribute much toward the sustainability of the society, Green productivity is the last topic of the performances section.

Green productivity is a strategy for simultaneously enhancing productivity and economic performance to achieve overall socio-economic development. It involves the combined application of appropriate productivity and EMS tools, techniques and technology that reduce the environmental impact of an organization's activities, products and services whilst enhancing profitability and competitive advantage. Green productivity index is defined as the ratio of economic productivity of a product system to its life cycle environmental impact. It indicates that green productivity is a performance measurement from economic and environmental perspectives. It may help companies to improve themselves not only from economic aspect but also environmental aspect. Since green productivity considers both of these aspects it helps companies to decide which activity is better for their operations according to their green productivity indices. If GP index is bigger than 1 it means the system is better than the current one, therefore company can decide to change the system with a better one.

All these performance measures and efficiency of a system will be improved with the support of an environmental technology. It is claimed that the implementation of new technologies has positive effects on environmental efficiency. The optimization of the technological processes with more environmental techniques could be more economically and environmentally.

An investigation shows that a method for environmental assessment of cleaner production technologies allows the evaluation of environmental damages caused by technological processes and manufactured products. By using environmental technologies, organizations could make quantitative analysis related to material and energy flows used in the activities as well to flows of environmental unfriendly products and wastes. These clean technologies consider recycling and recovery of wastes, use of energy recovered in the operations, and environmental loading caused by packaging. Results of this assessment will be beneficial to improve the current system, and to be more environmental friendly and economically efficient.

5.4 Operations

Operations class forms the inner layer of the conceptual framework. It consists of *Input*, *Planning*, *Manufacturing*, *Control*, *Evaluation* and *Output* classes consequently. *Input* class is composed of five subclasses which take into consideration the resources that enter to the manufacturing system. *Planning* class consists of process planning, production planning and

design, and modeling/methodology. In *Manufacturing* class, manufacturing paradigms namely lean, green and sustainable manufacturing, which are under the scope of the thesis are analyzed. *Control* class includes quality and inventory control. In *Evaluation* class, life cycle assessment and environmental performances are taken into account. Lastly, in *Output* class, bad outputs of the manufacturing systems, wastes, emissions and pollution, and end of life management strategies are taken into account.

5.4.1 Input

This class is composed of five resources that are necessary to implement a manufacturing activity. It consists of *Employee*, *Equipments*, *Energy*, *Raw material* and *Technology* which are explained in the following part.

5.4.1.1 Employee

Although sustainability has three pillars which are environmental, economic and social; social issues have been disregarded for a long time. In the social part of sustainability the effects of sustainable manufacturing activities on employment is examined, however in this thesis the effects are reciprocal. Not only the impact of sustainable manufacturing on employment but also the effects of employees on sustainable manufacturing applications are considered (see Figure 20).

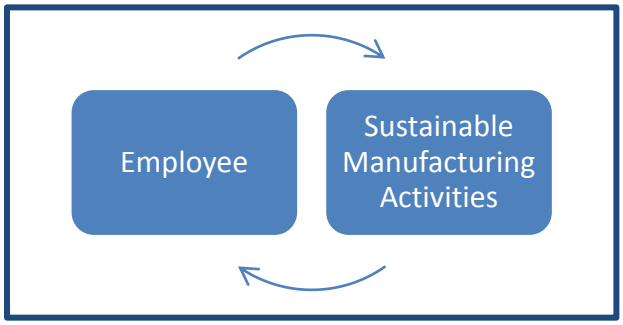


Figure 20 The interaction between employee and sustainable manufacturing activities

It is stated that using clean technologies and environmental innovations can have positive influence on employment and environmental improvements. In addition, these applications provide a significant improvement in job quality coherent to social sustainability. It is claimed that designing environmental policies with minimum negative effects on the employees is vital. The policies that consider reducing unemployment and encourage employment are named as integrated policies, which means environmental and employment policies should be examined together for social and environmental sustainability. Also, there are many political commitments based on sustainability, assume employment as the centre of social dimension of sustainable management.

The interactions between employees and sustainable manufacturing applications can be listed as follows:

1. First effect is physically. Using environmental sustainable manufacturing techniques may help to improve the workplace conditions. So the improved workplace conditions may increase the effectiveness and moral of employees.
2. The studies that are made about lean manufacturing (LM) and its relationship with job stress indicate that there is no direct relationship between LM and job stress. It is claimed that LM is not inherently stressful, but stress level is notably related with managers' decisions about LM systems, design and operations. A statistical study proves that the stress level is not related with quality, productivity or delivery. Also it states that to gain any benefit of a lean system there is no need for any stressful operation.
3. In order to have a better environmental management system, the effects of human resources factors such as top management support, environmental training, employee empowerment, teamwork and reward systems should be considered. Contribution of top management to the EMS may increase the accomplishment of the system, because the top management has the power to encourage the employee empowerment to influence changes, provide training, direct organization culture according to the changes. If human resources factors are not addressed, the success of environmental management systems cannot be complete.
4. Involving employees to the manufacturing systems will increase the efficiency of the system, since the workers know the system better than others. Therefore, environmental standards support the contribution of employees to the sustainable manufacturing systems. For instance, EMAS standards force the contribution of employees in the processes which is a positive qualitative effect on employment.
5. It is demonstrated that environmental management systems have positive effects on employee heath and security. Since sustainable manufacturing techniques and technologies also support human health and security, they improve the quality and security of the workplace, therefore they also have positive impacts on employee health and security.
6. By using sustainable manufacturing methods some changes in the organization of the work can be possible. These adjustments like increase in labor market flexibility and changes in processes can have positive or negative impacts on the quality of employment according to the implementation of measures of activities.
7. Sustainable manufacturing applications and employees cannot be thought separately. If the adoption and implementation of sustainable manufacturing practices are done with the contribution of employees, it will have positive effects on the employment quality. This is because the integration of employees will provide more attention to the needs of employees and will increase the success of the implementation.
8. Sustainable manufacturing techniques and environmental technologies require more skilled workers instead of unskilled ones. Because of that the importance of training

increases and the job specifications need to be adapted to the new sustainable system. Also, by supporting the eco-consulting and R&D departments of eco-industries highly skilled employment can be encouraged.

9. Employee involvement (EI) provides to the organizations competitive advantage and it is claimed that EI programs have a notable importance in environmental performance improvement efforts. Environmentally responsible firms can develop their capabilities easily with employee involvement programs.

The distribution of articles that support all the deductions above is shown in Figure 21. As it is seen from the figure there is no high attention to the topic in terms of published article number. Before 2007 generally there is at least one article. However, after this time the importance of writing about employee topic is decreased in the scope journals. The reason might be that this topic is in the saturation point. Most of the companies have understood the importance of the employees and also academia thinks that they produced enough articles in order to attract the companies' interest about their employees. However, when the technology develops there should be a continuous improvement and adoption for employees. On the other hand, it might also indicate their indifferences in the social aspect of sustainability.

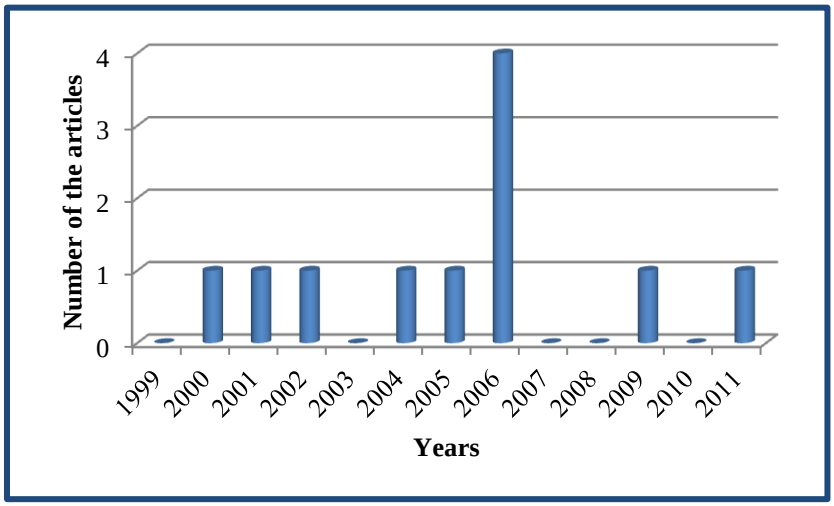


Figure 21 The distribution of the articles in Employee class

5.4.1.2 Equipment

Environmental consciousness increases day by day and manufacturing cannot deny this aspect. One of the most important resources in manufacturing is equipments namely machines and tools, which have a hazardous impact on environment in form of waste, emissions and toxic materials. Therefore, sustainable machining is significantly important for sustainable development objectives.

Conventional machining is not sustainable, thus new alternative machining techniques are evaluated. Cryogenic machining and high pressure jet assisted machining are two alternatives

better than traditional machining in terms of overall cost and sustainability aspects. They are better in energy consumption, waste management, operational safety, employee health, and cost. Besides, they provide shorter cycles, enhanced productivity due to higher outputs and lower investments because of the reduction in the required number of machine-tools.

Since auxiliary supplies such as cutting fluids, coolants, lubricating oil and grease are used in many manufacturing activities like drilling, cutting, reaming etc. they are inseparable from equipments. These cooling and lubrication fluids (CLFs) are used in machining to decrease the temperature and friction to make the machines and tools more effective. However, they are notably harmful, expensive and dangerous which need precautions. It is reported that 7,5 – 17 percent of total manufacturing cost is caused by coolants and coolant management, 16 – 20 percent of product cost is represented by lubrication, whereas cutting tools composes only 4 percent of total manufacturing. In addition to their bad economic performance, oil-based CLFs are highly toxic and less environmental sustainable, because they are obtained from non-sustainable crude oil extracts. Instead oil-based CLFs, vegetable based CLFs that are less toxic and biodegradable materials can be used to offer improved working conditions to employees and better environmental effects. Another solution might be the transfer to cryogenic CLFs which provide decrease in solid waste, water usage, global warming potential, acidification and energy consumption. Cryogenic CLFs' effect on energy is vital, because the ratio between the initial purchase cost of a machine tool and the cost of energy used over a ten-year period is more than one over hundred (1/100).

It is proved that minimum quantity lubrication (MQL) has positive effects on manufacturing processes. MQL applications resulted in a cleaner environment and cost-effective machining technology. It provides a significant cost reduction because it aims to decrease the cost of managing cutting fluids. Although MQL applications produce mist, with mist collection and filtering equipments it can be managed.

Last important topic to mention in this thesis is equipment replacement, which is an important problem for companies. The new technology should satisfy the companies from both economic and environmental aspects so that companies can accept the replacement of existing machining technology with a new one.

For quantitative analysis part, similar situation with energy articles distribution is observable for equipment articles; it can be seen in Figure 22. After 2006, researchers have published more articles pertinent to the topic. Since the MQL applications and replacement of conventional machining with cryogenic machining have increased, the importance of the topic also has arisen.

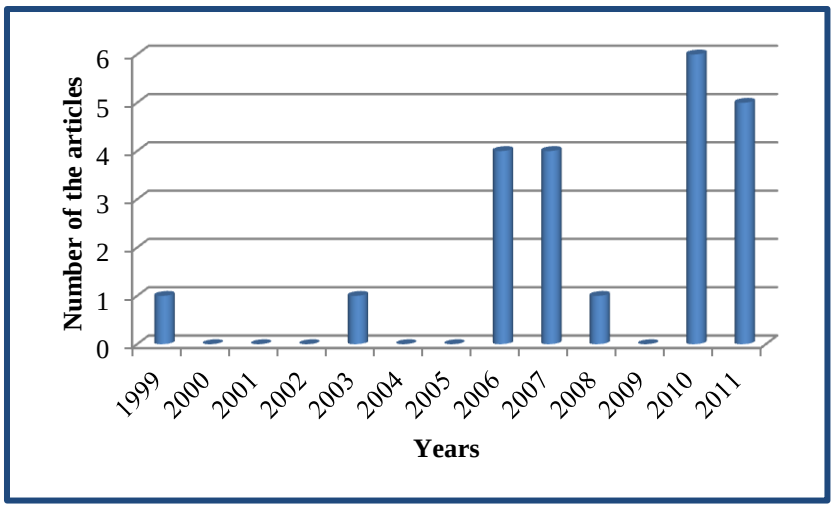


Figure 22 The distribution of the articles in Equipment class

To conclude, sustainable machining technologies provide a comprehensive sustainability to manufacturing in all aspects: economic, environmental and social.

5.4.1.3 Energy

Many reasons impose companies to use renewable energies and to be energy efficient, so to be more sustainable. These reasons might be listed as follows:

- ✓ The rising price of energy
- ✓ The scarcity of oil and gas
- ✓ Environmental legislations to force decreasing energy consumption
- ✓ Global warming and the decrease of green house gases
- ✓ Security of supply
- ✓ Increasing customer awareness about environment

All these effects have influenced also the distribution of articles in the research area. As the energy prices and the scarcity of natural resources increase, researchers have focused on energy topics more and more. The pursuit for renewable energy and the methods to decrease energy usage have positive effect on the published article numbers (see Figure 23).

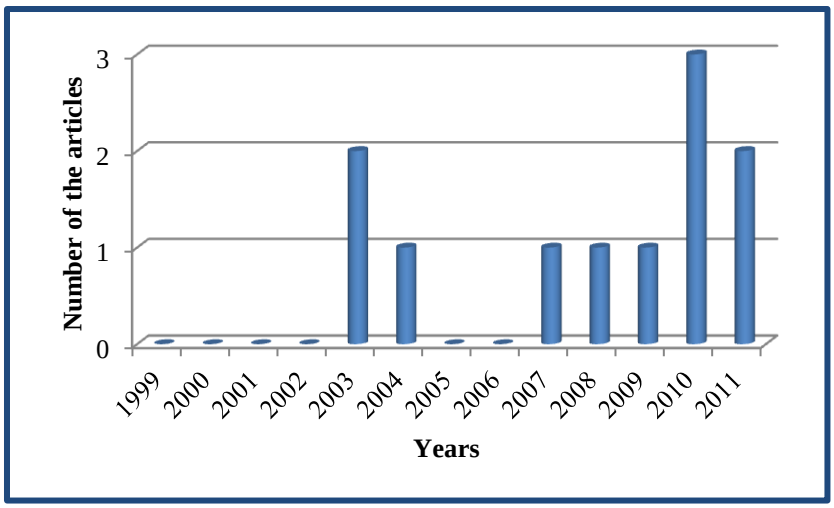


Figure 23 The distribution of the articles in Energy class

To be more energy efficient companies have different type of methods. For instance, for savings in fossil natural resources some companies prefer the use of renewable energy of biomass that can be used for heat, electricity and transportation fuel production. Since the savings of fossil fuel is proportional to the reduction of green house gas emission, using this alternative energy source is environmental friendly and serves to sustainability.

Another example is from textile industry. In order to reduce green house gas emissions the waste from the cotton ginning can be used as an alternative energy source. It substitutes 52% of heavy fuel oil that is used for energy in textile operations. Besides, cotton fiber can also be an alternative energy source because it includes more that 40% carbon.

To be more effective in energy usage, an effective energy management is one of the vital conditions. Therefore, in addition to technical support a comprehensive management system may help to reduce energy consumption and cost. Energy management system standards can increase the success of effective energy management in production. By combining efficient energy usage with less material usage and waste flows, zero carbon manufacturing systems may be achieved. This may benefit companies not only environmental but also economic.

Governments and companies try to find the most effective measures to raise energy efficiency in manufacturing processes. To measure the efficiency of the energy use; companies may define quantitative KPIs and by using these KPIs they can evaluate the relationship between energy efficiency and other manufacturing performances. Labeling is another method to show the energy efficiency level of products and also processes. ENERGY STAR is one of these labels can be applied to many different categories from appliances to lighting. ENERGY STAR is also focusing on sustainable corporate energy management.

5.4.1.4 Raw material

From sustainability perspective, raw material usage is significantly important, since it generates the most important part of the environmental hazards. In the transformation from

raw materials to finish goods, a lot of energy and labor is consumed. Also at the end it produces waste like scraps and pollution. Therefore, material selection is one of the most important activities at the beginning of the production. In material selection phase not only the functional performances of a material are considered, but also the economic and environmental impacts. The best material should satisfy technical, economic and environmental specifications.

Since the scarcity of the resources increases day by day and the expectations of customers for green products increase, companies more focus on raw material selection and usage. Firstly, most of the companies prefer to use recycled materials in their production processes instead of virgin materials. By supporting recycling other EOL options, the usage of virgin materials will be reduced. Hence, the natural resources and raw materials will be able to satisfy the needs of next generations as it is stated in Brundtland Report.

If the collected articles are examined, it can be observed that raw material topic is generally embedded in *end of life*, *waste management*, *manufacturing*, and *performance* class articles. In order to understand the topic better, the linkages between these topics should be analyzed. For instances, raw material usage with environmental considerations can impress the customers and increase the company image, which can increase the competitiveness ability of the firm. Besides, recycled materials will help to waste minimization whereas end of life options provide to slow down the natural resource usage.

5.4.1.5 Technology

On the way moving to green, technology and innovation support this greening procedure as vital drivers. The importance in development and environmental protection on modern technologies is increasing day by day in order to use current resources efficient and effectively so reducing the hazardous effects on environment.

Environmental technologies (ET) can be defined as:

> "Environmental technologies (ET) contain four different categories: measuring, cleansing, cleaner, and clean technologies, differing in their ecological effectiveness. ET reduce pollution at least in one environmental medium, only accepting the transformation of emissions into another form of into another medium as a short term measure in order to cope with harmful pollutants. Thus, ET implements the continuous improvement of process, products and services by the conservation of raw materials and energy by the reduction of toxic substances, waste and emissions within the production cycle."[51]

[51] Environmental technologies for misleading interpretations to an operational categorization and definition

Sometimes *environmental technologies* might be used in form of environmentally sound technologies. A research indicates that the environmental technologies market is valued around EUR 500 billion in the world-wide in 2007.

Companies support environmental technologies to minimize their costs through technology applications. Besides, environmental technologies consider not only effective and efficient production of goods, but also the effects of production on environment.

Besides companies, governments assume that green manufacturing technologies are important in order to reach eco-innovation for a sustainable economic growth. Eco-innovation is defined as "new products and processes which provide customer and business value but significantly decrease environmental impacts". [52] For instance, the UK government states that the development of new green technologies enables new economic growth drivers for 21st century.

The commitment to green growth caused to adoption of Environmental Technologies Action Plan (ETAP) by European Commission. The action plan contains 28 actions in order to better the development and understanding of environmental technologies. European Commission assumes that in order to improve the environment while contributing to competitiveness and growth, especially in economy there is a notably untapped technological potential. The aim is making EU in the following years the leader in developing and applying environmental technologies, which provides an enhanced environmental performance at the operations.

The diffusion of clean technologies depends on endogenous and exogenous factors. Endogenous factor examples are awareness of the existence of innovation, learning economies and increased competition while exogenous factors are like energy prices, regulations and market structure.

Environmental technologies may be used in different forms like measuring, monitoring or reporting. Measuring technologies is so important because it gives change to improve the current system and to continue improvements and innovations. With reporting companies may be more transparent and comprehensible by the stakeholders.

The effects of ETAP (2004) are also seen in the distribution numbers of articles. After understanding the meaning of the action plan and seeing some applications authors tend towards technology articles (see Figure 24). However, although the importance of ICT increases, the importance of this topic in the articles is not observed, at least in the articles those are examined in the scope of this thesis.

[52] James, P.. (1997). The Sustainability Circle: A New Tool for Product Development and Design. Journal of Sustainable Product Design, Vol. 2, pp. 52-57.

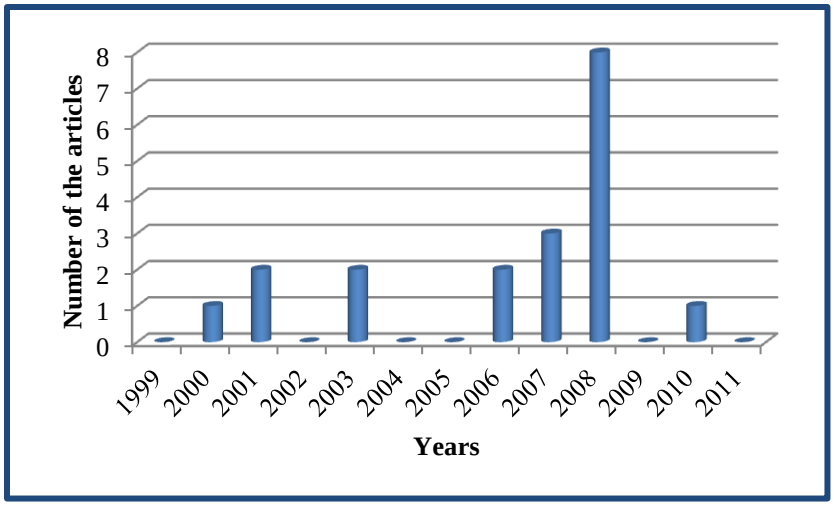


Figure 24 The distribution of the articles in Technology class

5.4.2 Planning

Planning class is composed of the articles that are related with the planning phase of manufacturing processes. It is intended to cover process design and planning, production planning and scheduling, and modeling articles in this class.

It is a concept with growing importance for the industries since remanufacturing, reusing, etc. have been started to be a routine activity for the companies due to imposed regulations and other external factors. However, it might be claimed that this topic has not attracted as much interest as it should. The distribution of the articles in this class among years might be seen in Figure 25. There exist 24 articles directly related with *Planning*. Integrating disassembly activities in the manufacturing processes, implementing material requirements planning (MRP) tools that incorporate environmental concerns and modeling to find out the optimal production-inventory levels under environmental constraints are the most mentioned topics in this class.

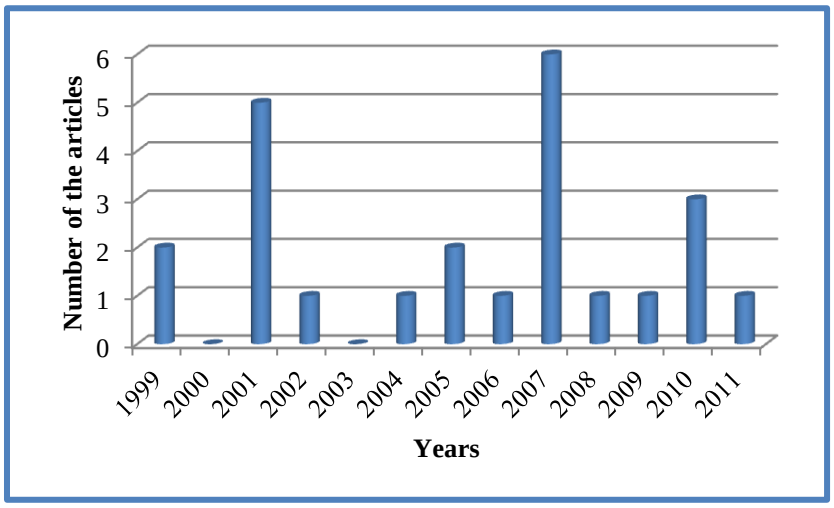


Figure 25 The distribution of the articles in Planning class

Environment focused process design and planning can decrease the product's environmental impact and increase the efficiency of the processes. For example, integrating disassembly into the existing manufacturing processes of the companies by designing and planning processes, and doing scheduling is a very important activity, since disassembly is one of the building blocks for the companies which attempt to benefit from end of life options of the materials.

Material requirements planning (MRP) or enterprise resource planning (ERP) tools that integrate environmental components help managers identify waste streams and eliminate them with implementing proactive measures, and convert them into financial terms. Additionally, the quality of the production schedules can be improved utilizing these tools.

Modeling methods can be used to optimize the processes in order to obtain better time, cost, and environmental results. Optimizing the production schedules or material usage can yield to decreased production time or improved environmental performance due to less waste generation etc. Additionally, models are developed to define the optimal production-inventory levels for the companies under environmental constraints. Although mathematical modeling processes can be very useful in optimizing the processes, the usage of them is limited in the articles under the scope of this thesis. For instance, instead of trying to find out the optimal production-inventory levels of the firms that help them achieve sustainability, the effects of emission trading, etc. on production-inventory level decision models are studied to find the trade-offs between penalties due to regulations and holding costs.

5.4.3 Manufacturing

Manufacturing class covers the manufacturing paradigms that take place in the evolution of sustainable manufacturing concept. Lean manufacturing which might be considered as a primary step in the evolution generally deals with the economic sustainability of the companies since it aims to decrease cost by reducing unnecessary activities in the processes that add no value. In addition, it has been proved that lean manufacturing's focus on waste elimination helps companies improve their environmental performances since its waste show relevance with environmental wastes of the processes. Green manufacturing, as a second step in the evolution, mainly focuses on improving environmental performance of the companies without compromising competitiveness. And lastly, sustainable manufacturing is the most developed form of the manufacturing in the phases of the evolution. It encompasses all three aspects, namely economic, environmental, and social, that are in coherence with the objective of sustainable development.

Lean manufacturing that is covered as a concept of sustainable manufacturing in this thesis, since it has gained acceptance in the literature as a way to improve sustainability of the companies in economic, environmental and social aspects. Although all of the articles that are related with lean manufacturing that stay in the borders of this study are covered when

forming the *Manufacturing* class, only the articles that show a direct linkage with sustainable manufacturing concept will be mentioned in this part rather than the articles that study general lean manufacturing context and practices. The general concept of lean manufacturing might be read in the Basic terminology section.

Implementation of lean manufacturing practices in the companies can lead to many benefits that correspond with the objectives of sustainable manufacturing practices. Initially, since lean manufacturing strives for decreasing any type of waste that creates no value, it increases resource efficiency in the processes which goes hand in hand with the improvements in environmental performance. Likewise the effect of resource efficiency on environmental performance, worker participation in continuous improvements, which is an important factor in lean manufacturing, leads to greater environmental performance.

Waste elimination / minimization helps to reduce production time and cost while improving quality and customer service. Eliminating waste can result in reduced inventories and production costs, shop floor and storage savings, and reduced labor costs without negatively affecting job opportunities. As another benefit, adoption of lean manufacturing positively affects environmental management practices. It becomes easier to adopt environmental management practices in companies once they already internalize lean manufacturing practices. The common focus of environmental management and lean manufacturing practices on waste and inefficiency minimization creates a synergistic ambient and turns into an eco-advantage that results in achieving their business performance objectives. Competitive advantage can be gained benefiting the productivity savings.

Green manufacturing is used a concept which covers cleaner production, environmentally conscious manufacturing, environmentally benign manufacturing and green manufacturing practices under its umbrella in this thesis. Green manufacturing acts proactively to alleviate the negative impacts of manufacturing on the environment. Instead of trying to conform to the stringent environmental regulations by trying to mitigate the adverse effects with the implementation of end of pipe technologies, it aims to solve the problems at source. Green manufacturing practices might be listed as follows:

- ✓ Producing environmental friendly products,
- ✓ Preventing pollution at source,
- ✓ Reducing greenhouse gas emissions,
- ✓ Closed looped manufacturing that incorporates the waste generated in the process back into the system,
- ✓ Reuse and recycling of materials,
- ✓ Reducing material usage,
- ✓ Conserving energy and water,
- ✓ Minimizing waste, both hazardous or otherwise, by optimizing the processes,

- ✓ Redesigning the products to decrease the negative environmental impacts of the product,
- ✓ Increasing recycled material usage in the products
- ✓ Using environmental friendly technologies,
- ✓ Designing the process to optimize it taking the environmental concerns into account,
- ✓ Excelling at environmental innovation focusing on both processes and products.

The motive behind the implementation of green manufacturing practices is affected by compelling regulations, globalization pressures, and increasing competitiveness. The will of the companies to be more socially responsible and meet customers' requirements for more environmental friendly products also stimulate the implementation of green manufacturing practices. However, considering the environmental matters as a cost driver and not being propped up by incentive policies handicap the progress in the transition to green manufacturing. Therefore, governments and Cleaner Production Centers work on promoting these practices by increasing awareness about green manufacturing, preparing training programs, and supporting the companies. Since the employees/workers play a great role in implementing green manufacturing practices, increasing their awareness through training and education help them to be more active in improving the system by taking responsibilities.

When the companies initiate green manufacturing practices, they obtain many positive results. Firstly, adoption of green manufacturing practices has a positive impact on improving the environmental performance of the companies through decreasing material, water, and energy usage, and minimizing pollution, waste, and emissions. Additionally, it has an overall positive impact on business performance. In order to evaluate the effects of the green manufacturing practices on business performance, the cost of implementing them is taken into consideration. If low cost activities are implemented in the companies, then they yield improved financial performance since the investment initially required can payback in a short time period. However, this situation does not hold in case of high cost activities. As an example, implementing clean technologies necessitates a greater financial investment, but the financial improvement cannot be obtained as an immediate economic benefit.

Greater performance improvements can be achieved through the integration of environmental management systems into green manufacturing systems. To give an example, process control systems or environmental audits provide the control over manufacturing activities and ensure continuous improvements. Additionally, TQM activities encourage continuous improvements in the system by supporting environmental management systems. Integrating suppliers into the manufacturing system and assuring the supplier excellence in quality, environmental performance, etc. support the companies on their endeavor to achieve better environmental and business performances.

Sustainable manufacturing concept has emerged in relation with the concept of sustainable development. In addition to giving importance to environmental and economic concerns, sustainable manufacturing has taken social justice and community development, and workers into consideration. Although sustainable manufacturing concept has emerged many years ago, most of the research has been done focusing on environmental and/or economic aspects of sustainable manufacturing which have predominated social aspect of it. In many cases, companies have only shown interest to economic and/or environmental performances. Therefore, in order to measure the effectiveness of the companies in implementing sustainable manufacturing practices comprehensively, additional indicators have been proposed to evaluate the company's success. In addition to the indicators for freshwater consumption, materials used, energy use, and kilograms of waste generated before recycling, etc., rate of customer complaints and/or returns, community spending and charitable contributions as percent of revenues, lost workday injuries and illness case rate, average number of hours of employee training, etc. have been proposed as a tool to measure a wider range of performances of sustainable manufacturing practices. Moreover, since all the topics that are mentioned in this thesis are related with at least one aspect of sustainable manufacturing, all the motivating factors, barriers, regulations, performances, etc. are valid for sustainable manufacturing practices.

When all the three paradigms are analyzed, it is seen that lean manufacturing which is the oldest paradigm and green manufacturing have attracted more attention than sustainable manufacturing (see Figure 26).

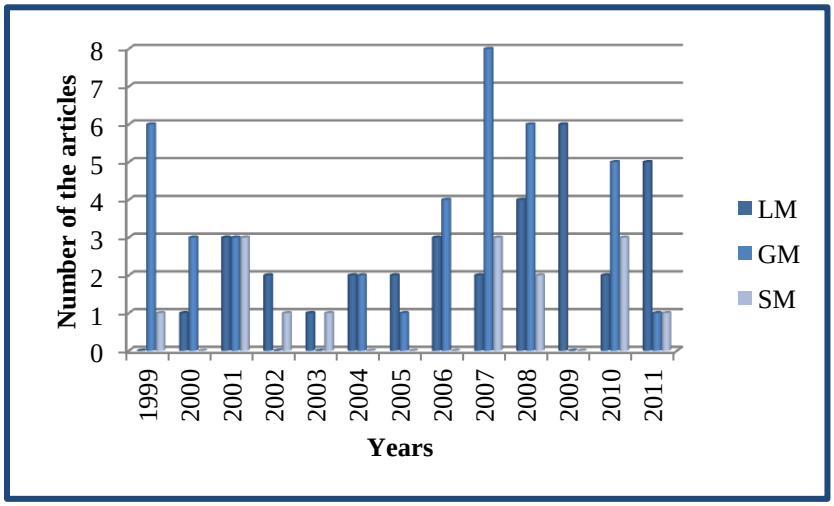


Figure 26 The distribution of the articles in Manufacturing class

5.4.4 Control

Control class if formed to cover the articles related with inventory and quality control. Inventory control articles focus on production-inventory strategies of the firms under

environmental constraints, whereas quality control articles try to figure out the effects of integrating environmental aspect into quality.

5.4.4.1 Inventory control

In order to evaluate the effects of environmental policies, tradable permits, and unit charges due to environmental constraints on the production inventory strategies of the firms, *Inventory control* class is formed. It consists 8 articles and 5 articles of this class are published in International Journal of Production Economics.

The optimal strategies for production-inventory levels of the firms are mathematically modeled integrating emission/pollution charges and standards into the models. As a departure point, Arrow-Karlin model is utilized, and production-inventory models are constructed. As propositions of the models, if the linear emissions charge per unit pollution is smaller than a threshold, the environmental policy does not have an effect on the companies' production-inventory strategies.[53] Likewise, if the linear emissions charge per unit pollution is larger than a threshold, which is calculated based on the model equations, the environmental policy will not be effective. Pollutions standards above the pollution capacity of the firms do not have any influence on the companies. When tradable permits are embedded in the mathematical modeling, it is shown that the firms will sell their pollution rights in order to minimize their total costs. In addition, deterministic models are introduced to define the production-inventory strategies of the firms considering remanufacturing with price and quality and also including defective and usable items. When it is considered that the return rate of the used items depend on the purchasing price and acceptance quality level, it is better to benefit from a mixed strategy combining repair and waste disposal.

When the articles in this class are examined, it is seen that production-inventory level for more sustainable manufacturing practices has not attracted enough attention. The articles are focused on when it is worth to pay the penalties instead of how to reduce the adverse effects of manufacturing on the environment etc.

5.4.4.2 Quality control

As a performance indicator of the firms, quality issues play a very important role for the companies. Since the environmental concerns come to the stage, it has become more important than ever. Therefore Quality control class is formed to discover the reciprocal relation between total quality management and environmental concerns.

Considering the existence of the journals that are completely devoted to quality management issues, surprisingly there does not exist plenty of articles that combine environmental

[53] Arrow, K.J.; Karlin, S. (1958). Production over time with increasing marginal costs. In: Arrow, K.J.; Karlin, S.;Scarf, H. (Eds.), Studies in the Mathematical Theory of Inventory and Production, Stanford Univ. Press, Stanford, pp. 61—69.

concerns with quality issues. In the scope of this thesis, 8 articles are found to be related with this class. Moreover, although environmental issues become a more attractive topic for industry day by day, from the findings of this research it might be deducted that researchers have not paid enough attention to this topic. In the last years, there are no articles related with this topic.

Embracing environmental thinking in the companies' functions and achieving environmental goals also leads to a better quality performance in their processes. The efforts to improve environmental performance and the tools and know how that is utilized in order to achieve it may be effective in reinforcing the quality profile of the companies. The reciprocal relationship between environmental concerns and quality shows itself by affecting each other's performance mutually. Adopting a TQM system in the companies successfully helps to implement environmental management systems in the companies as well. Encompassing them all, total quality environmental management (TQEM) term has emerged to show the correlation between quality and environmental management. Instead of becoming lost in the systems oriented to external regulations, companies should incorporate environmental thinking into existing company functions by adopting TQEM integrated systems. TQEM aims at reducing waste, resource usage, and environmental pollution, controlling and improving the system continuously, and increasing environmental awareness within the employees and the community as well. Focusing on TQEM functions help the companies

- ✓ Meet the stakeholders' demands enhancing the scope from only customers to stakeholders,
- ✓ Comply with environmental regulations in environmental management systems,
- ✓ Survive and improve their positions in the industry.

5.4.5 Evaluation

This part includes life cycle assessment tools to evaluate the performance of the manufacturing processes and the evaluated results of the manufacturing activities.

5.4.5.1 Life cycle assessment

Life cycle assessment (LCA) is a powerful tool to identify and assess the potential environmental impacts throughout the lifecycle of a product, process, or activity. Material and energy usage and releases to the environment are considered from *cradle to grave* – from raw material extraction to use and disposal. By focusing on all the life cycle it prevents to shift of the problem to any other phase of the life cycle or region.

Although LCA is an important concept for last three decades, the first scientific articles were published during 1990s and during this time interval LCA has become a part of sustainable evaluation. After LCA is described and its boundaries and four phases namely, goal and scope

definition, life cycle inventory analysis, life cycle impact assessment, and interpretation are defined in ISO, 2006, the attention to LCA has arisen. It also can be seen in the distribution graph of LCA articles among years (Figure 27).

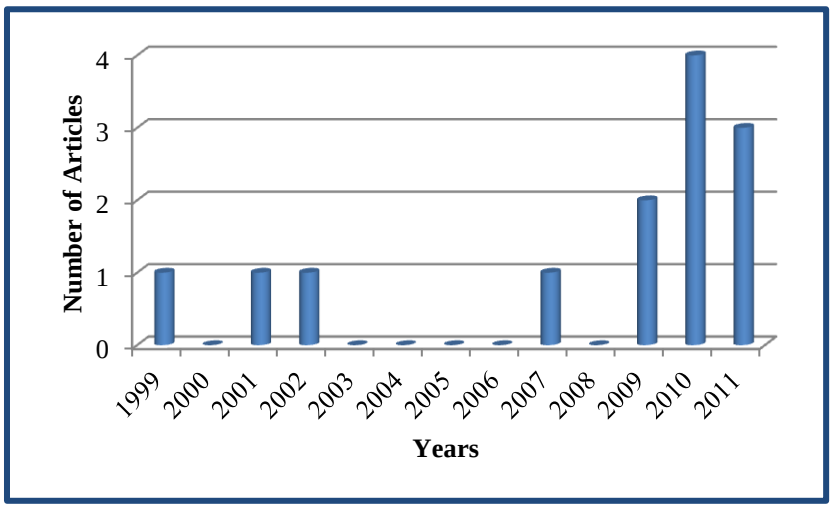


Figure 27 The distribution of the articles in Life cycle assessment class

LCA tool is used to make sustainable decisions and it is claimed that enhancing the ISO LCA framework by integrating economic, social and cultural aspects and assessment methods may move LCA from just environmental towards sustainability evaluation. Sustainable decision making processes can be improved by broadening and deepening the LCA regarding economic and social assessment tools. For instance, life cycle costing (LCC) and social life cycle assessment (SLCA) are tools that consider economic and social objectives respectively. By combining these three assessment methods in one evaluation tool, sustainable evaluation and decision making may be obtained logically while combining all sustainability pillars under one evaluation method.

LCA is a method that can be applied to every industry and product system, therefore all the companies may use this evaluation tool to make their manufacturing processes more sustainable, because outcomes of LCA provides to identify weak and harmful points in the production process and proposes possible solutions for decreasing the risk of environmental impacts. Also the result of LCA can be used by designers to adopt the environmental, economic and social aspects to the products in the early phases of the production, after integrating social and economic aspects.

5.4.5.2 Performances

Since the Performances class is located in the conceptual framework as an intermediate level between *Management* and *Operations* layers, all the performance articles are examined before under *Performances* class in *Management* layer.

5.4.6 Output

Output class is concerned with the concepts that are related with the outputs of the manufacturing systems and their treatments. Wastes, emissions and pollution which are the undesired outputs of manufacturing systems, and their treatments and end of life options which focus on closing the loop of the products by incorporating them into the processes again by evaluating the options, remanufacturing, reuse etc. are covered under this class.

5.4.6.1 Bad outputs

Bad outputs class is formed to cover all the undesired outputs of the manufacturing systems. It covers waste management, emissions and pollution prevention topics. These topics are covered in many classes of the framework, since they are directly connected with *manufacturing paradigms*, *environmental performances* etc. In order to learn more about these concepts, it is better to look at the related classes also. The distribution of the articles that are put under this class is shown in Figure 28.

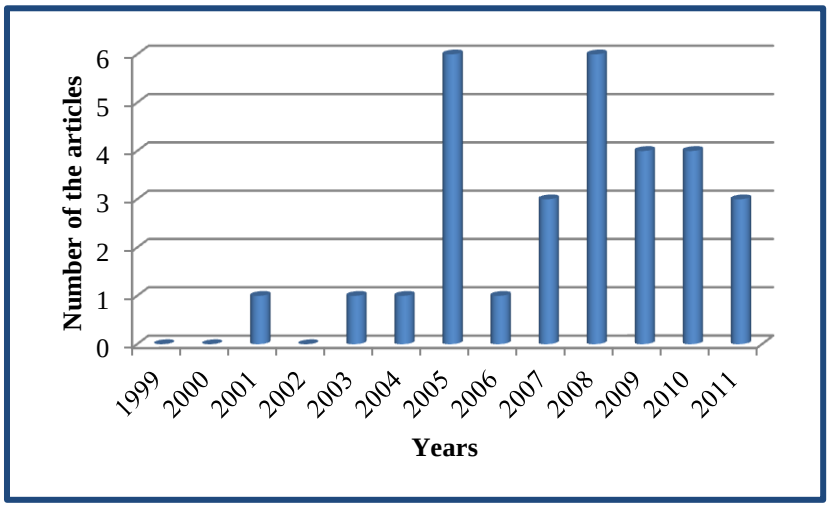


Figure 28 The distribution of the articles in Bad outpus class

Wastes refer to materials or energy that are not transformed into products, but are disposed from the system. They are the *bad outputs* of the processes since instead of adding any value to the product but they impose a burden for the environment. Additionally, they affect the economic situation of the companies due to environmental taxes or inefficient usage of materials and energy.

Waste management articles have a strong connection with the articles under e*nd of life options*, r*aw material*, m*anufacturing paradigms*, etc. The wastes generated in the processes might be reused by re-entering to the system, recycled to be used as a raw material, or minimized through the better utilization of materials and energy.

There exist many waste management applications in the textile industry for minimization or reusing of wastes. Wastewater utilization is a very important concept for this industry due to

excessive production of wastewater in the textile processes. Wastewater is reused or minimized by optimizing scheduling of the activities or reusing wastewater.

With the introduction of WEEE regulations in 2003, the importance of e-waste management has increased. The regulations aimed at decreasing the amount of electronic and electric equipment wastes by extending the producer responsibility for their management.

Reduction in waste results in better utilization of materials and energy, and capital and labor savings. Therefore, in addition to its environmental benefits, it improves the economic sustainability of the companies.

Environmental awareness has grown since 1960s and still preserves its importance. The first response to the adoption of environmental systems and technologies were in form of controlling and treating pollutant emissions of manufacturing activities. However, control is not a certain solution to the problem. Control is a method which tries to gain something from the loss. Developing supplier partnerships, giving more importance to waste elimination and understanding the main personal interests of employees have resulted in a shift from pollution control to pollution prevention. Unlike pollution control, the main feature of pollution prevention approach is "reduction at source". It aims to reduce or eliminate pollutants by using sources such as raw material, energy and water etc. efficiently during the production process.

Pollution prevention takes precautions at the beginning of the manufacturing processes compromising quality specifications and it is claimed that pollution prevention has a notably positive effect on cost, speed and flexibility objectives whereas pollution control has a negative impact.

Pollution prevention's benefits can be listed as effecting cost efficiency factors and internal company performance through increased productivity, resource utilization, improved process efficiency and reduced environmental impact. Also in the long run it may contribute to the competitiveness ability of the company.

Although there are not many articles directly related with *Emissions*, it is an important topic related with many sides of manufacturing. Changing energy resources, benefiting more from biodegradable energy resources or reducing energy consumption in the companies directly affects emissions release, therefore it might be concluded that *Energy* articles have many things in common with the articles under this class.

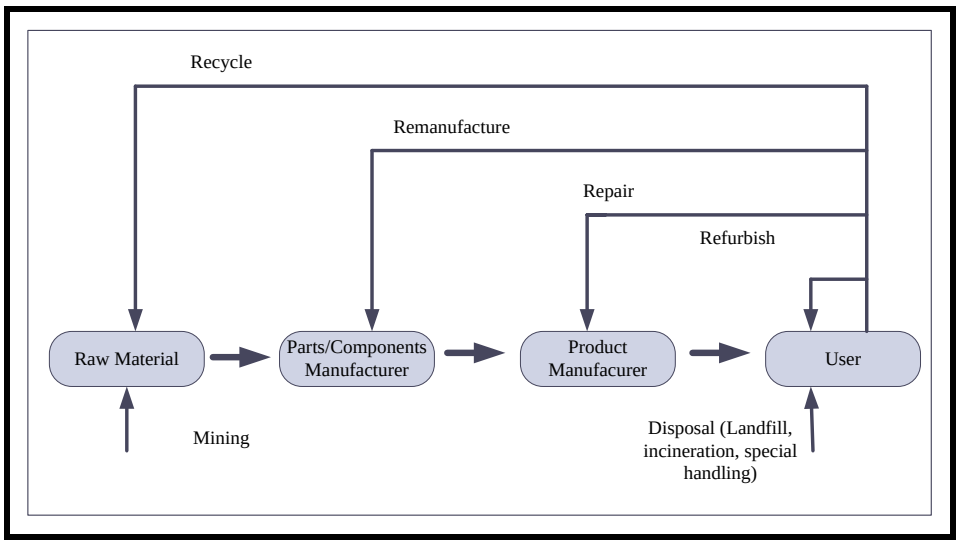
With the introduction of Kyoto Protocol in 1997, policy makers and countries have committed themselves to decreasing greenhouse has (GHG) emissions. Since the manufacturing sector contributes for one third of global CO_2 emissions, many regulations, such as tradable permits, have been introduced in many countries to control the emissions levels of the companies.

Additionally, ISO 14001 intends to reduce emissions due to manufacturing activities as well as other unwelcome results, such as pollution, etc. However, application of ISO 14001 Standards and emissions do not show a strong correlation since it has not been proved if there is a positive effect of ISO 14001 on emissions reduction. First adapters of ISO 14001 might lower their emissions due to being operated under ISO 14001 for a longer time. However, since ISO 14001 is not a regulation, it cannot force a company to improve its environmental performance. Therefore, in many cases it cannot go beyond being a marketing tool for the companies.

5.4.6.2 End of life options

Since sustainable manufacturing is growing into importance, manufacturing organizations have started to realize the necessity of the responsible usage and management of resources during the life cycle of a product with giving special attention to the planning of product retirement. The most common end of life (EOL) options are reuse, remanufacture, recycle, incinerate, landfill and special handling. The definitions of these EOL options are as follows:

1. Reuse: Using the product as is in the same (direct) or another (indirect) implementation.
2. Remanufacture: Retaining the serviceable parts, refurbishing usable parts or replacement of the identical or reworked parts from obsolete products.
3. Recycling: Reprocessing a product into a form that can be utilized in the same or another product.
4. Incineration: Burning materials in order to gain heat and electricity.
5. Landfill: Dumping materials without intrinsic value in landfills.
6. Special handling: Mandatory handling of toxic or hazardous materials.



Source: Shah, P., Gosavi, A., Nagi, R., Pack, C. (2008). A miachine learning approach to optimize the usage of recycled material in a remanufacturing environment

Figure 29 The differences between EOL options

In order to decide which EOL option is most related with the product, there exist some general guidelines. For instance, if the material is a pure metal, recycling might be the best option, whereas if it contains an alloy inside recycling to a low level or sending it to the landfill can be proper. For ceramics if recycling is not a good option, incineration is appropriate to use its energy. But the main decision about the end of life can only be made by human intervention, because these definitions require foreknowledge about the manufacturing processes.

Disassembly and eco-design are the two topics that are generally mentioned in EOL articles. These two topics intertwine because it is needed to retrieve the desired parts and subassemblies by separating a product its subparts for using in EOL options. Disassembly allows the extraction of high recovery value or hazardous materials, from the product. In order to extract the parts, the optimal stage of disassembly should be determined by considering environmental impacts, cost or disassembly time. Taking environment into account differentiates disassembly from shredding, although shredding is less time consuming.

Although product based activities are not taken into consideration in this thesis, eco-design topic is shortly mentioned under EOL class, because eco-design (term used in Europe) or design for environment (term used in the USA) is the vital part of the EOL options. Design for environment proposes a new way for developing products where the environmental aspects are important as other objectives like functionality, durability, cost, aesthetics, and quality. To increase the feasibility of EOL options, eco-design should be applied in the earlier phases of product development processes. By designing products in an effective way for disassembly, the effort, cost, time, energy and environmental effect of disassembly process can be mitigated. Product lifespan management is a strategy under design for environment concept. It targets reducing environmental impacts of products by decreasing resource consumption, pollution and waste. As an important fact, using materials as long as possible is not good for environment or economy. Companies should decide the optimum life span to replace the materials so they can benefit from the old materials while they are still working.

Generally end of life options are related with companies' environmental and economic performances. EOL options provide more utilization of one material by closing the life cycle of it, in other words products, its sub-products or recycled parts reenter to the system and make the life cycle a loop. This usage of products more than one time impacts raw material usage positively and decrease the environmental effect of the system. In addition, using fewer raw materials can cause to decrease the cost of the products and provide economic benefits to the companies. However, if the cost for EOL options is too high, the needed time is too long to prepare the material for reentering to the system, or the quality decreases after EOL

options, adopting EOL options will not be logical since they cannot compete with cheap and high quality products.

Besides general EOL articles, there exist some articles that focus only one sub-topic of EOL such as remanufacturing, reuse or recycle. Some general notes from these special topics are as follows:

1. Remanufacturing requires disassembling of the products into sub-components, repairing the defective components and then reassembling the components to reproduce the products. This option conserves a significant proportion of the used energy and labor that are consumed for the product in the first production, besides conserving its material value.
2. Since reused materials turn into the raw material state, they lose the energy and labor utilized during the first production.
3. Unlike material recycling and disposal, remanufacturing can decrease the environmental impacts by keeping the geometrical form of the product. Hence, it is accepted as more eco-efficient approach in EOL.
4. Companies' recycling performance is notably influenced by certifications. If companies are certified with ISO14001 certifications earlier than other companies, they will have better recycling performances. Also small companies may improve their recycling performance more than the bigger ones, if both of them have ISO14001 certification.
5. Reuse option does not only consider the reusing of materials but also data and knowledge. During each phase of decision, the reuse of the data is required.
6. It is essential to increase the recyclability of electric and electronic products in order to decrease the negative impact on environment. In the last years the attention to this topic increased. For instance, WEEE Directive (2003) is a legislation which forces companies to support the re-usage of electric and electronic equipments.

Lastly a research made in Greek manufacturing firms indicated some drivers and barriers for product recovery activities (PRA). It claims that they are also applicable for other European companies with similar economics.

Drivers:

1. The possibility to decrease the production cost by using recovered components and materials instead of new ones
2. For improving company's environmental image and the increased environmental awareness of customers
3. The force of government by regulations

4. To gain more competitive advantage or to decrease the competitive pressure of other companies in environmental topics

Barriers:

1. PRA may complicate the company's manufacturing and logistics activities
2. The investment to establish the PRA may be highly uncertain
3. The investment may be not economically justifiable
4. It requires a specialized know-how and staff

5.5 Evaluation of the state of the art

Increasing prices of raw materials and energy, depletion of natural resources and increasing environmental awareness of customers have attracted the interest of the companies, governments and universities towards sustainable manufacturing. The applications of the companies, the regulations of the governments and the academic research of universities about sustainable manufacturing concepts have increased in number and broaden in number of covered topics in the last decades. The fifth chapter – the state of the art analysis of this thesis aims to generate a sound database of academic articles that are published between January 1999 and July 2011 in peer-reviewed scientific journals about sustainable manufacturing concepts.

In order to make the analysis of the current situation of sustainable manufacturing and to see the developments during the last decade, firstly all the articles are classified regarding to their core topics and the classes are fitted into a three-layered conceptual framework according to their relationships. Since the topics are not mutually exclusive, there are many articles that are assigned to more than one class. After the construction of conceptual framework, the core points, evolution and the milestones of each class are summarized by reading all the articles that are collected in the database and the trends of the classes are tried to be determined. Besides, 3 analysis dimensions, namely yearly based, article type based and ESET based are formed and articles are analyzed according to these dimensions. The results of the dimension analysis are summarized and visualized in the previous subsection 5.5.1.

The following deductions - observing trends and defining gaps in the research area - are derived from all the summaries and analysis that are done till now. Since the collected articles are not sector or country based, the results and deductions might be different from sector to sector or country to country. Also, the deductions are made only based on the articles in the database. If the research is done by enhancing the time interval and increasing the number of journals that are reviewed, the deductions might be more reliable.

- ✓ Some concepts are more popular than others during the evolution of sustainable manufacturing.

  In Eco-system layer Regulations & Certifications and External Factors, in Management layer Environmental Management System and Performances (as an intermediate layer) and in Operations layer Input, Manufacturing Paradigms, Evaluation and Output classes are the most attractive concepts according to their published article numbers.

  Since the governments tend to force companies to be more environmental friendly with regulations and legislations, Regulations & Certifications class has lots of articles about regulations, the barriers, drivers and initiatives for adoption of these regulations and later their implementations and effects on the companies.

  Although the main reason for the attractiveness of classes in Operations layer is their significantly important effects on the environment and operation costs, the high number of subclasses that are included by almost each class also contributes to the increase in the publication number. Under the Manufacturing Paradigms class, the paradigms that consider environmental impacts rather than economic or social ones are more appealing for companies and as well as for universities.
- ✓ Some sustainable manufacturing concepts are rarely mentioned during the last decade. In Eco-system layer Network and in Operation layer Planning and Control classes are the less attractive concepts related with sustainable manufacturing according to the publication number.

  The scope and the definition of Network class which are used in this thesis might be the reason for the few numbers of articles. In this thesis, Network class is formed to focus on the articles that try to find out the effects of the relationships amongst the actors of the networks on improving the sustainability of manufacturing in the companies. Since the relationships among supply chain or the green supply chain management topics are not included in the scope of the thesis, all the articles are not covered under this class title. If the research is done from supply chain point of view, many articles might be covered under this subject.

  Since the companies concentrate first on the applications related directly with manufacturing or show economic impacts immediately, Planning and Control topics may not be that much interesting for them and maybe this might have affected the number of publications.
- ✓ The interest in the environmental regulations and ISO Standards shows tendency to increase in the second half of the timeline according to the distribution of published articles. This might demonstrate that the interest and the intervention of the governments have increased on sustainable manufacturing topics.
- ✓ External Factors class generally covers the articles related to barriers to, promotions, and adopting factors for sustainable manufacturing concepts. The distribution of the

articles in this class shows a decreasing pattern. It might be concluded that as sustainable manufacturing and related concepts become familiar with the companies, the need to investigate the barriers to or drivers for sustainable manufacturing activities tends to decrease over the years, and loses its importance.

- ✓ It can be deducted from the distribution of Industrial Ecology articles that there is an increasing trend in the research. Although there is an increase in the number of the articles related to this topic, the development in Industrial Ecology concepts are not at the desired level in practice.
- ✓ Environmental management systems *(EMS)* are attractive for the companies due to their positive impact on the environment, economy and social life. However, since their implementation costs, especially costs of additional services are too high, small companies hesitate to apply these management systems. On the other hand, the small companies that implement EMS prefer to wait till they have some experiences about the topic, in order to buy additional services like auditing and training. Since the diffusion of sustainable manufacturing concepts among SMEs is important, SMEs should be encouraged to adopt EMS and their additional services.
- ✓ A significant increase in publication number of Performances class articles is observable. It might be concluded that in the beginning of the 2000s the main objective is to discover the barriers, incentives, promoting factors to adoption of sustainable manufacturing concepts but later implementation phase starts and the performances of these implications are evaluated. It might explain the increasing trend in the publication number after 2005. Also the deduction which is done in External Factors is parallel to this explanation; they both support each other from this perspective.
- ✓ Depletion of resources is one of the major risks that companies should face. To avoid the excessive consumption of natural resources, companies should figure out methods to decrease raw material usage. The decrease in raw material usage should be supported by end of life options. Companies should prefer recycled materials instead of virgin materials. However, the technologies that provide less material usage are not common in companies. Organizations give importance to economic objectives rather than environmental and social ones; therefore they should be forced to adopt technologies that help to decrease material usage.
- ✓ From employee perspective, most of the articles are related with the effects of workers on improving sustainable manufacturing concepts and their implementations. Few articles are related with the effects of sustainable manufacturing on employees, their health and security. As a result of these deductions, the social part of sustainable manufacturing should be examined more deeply. The number of articles regarding employees' health and security may increase in the following years.

- ✓ Increased energy prices and the waste generated due to energy production direct the organizations towards to be more energy efficient. In order to be more energy efficient the first way is to convert traditional energy resources into renewable ones. Biodegradable energy sources are more environmental friendly and there is an increasing trend towards them
- ✓ Equipment articles are generally focused on machining and tooling technologies that provide using less energy and cooling and lubrication fluids. However, by combining machining technology with ICT systems like sensors or RFID devices are missing. There are just a few articles that mention about ICT system integration in machining. These machining systems should be developed by encouraging ICT systems, in order to be more sustainable and to have a high quality in the manufacturing system.
- ✓ In the Planning class there are few articles related to sustainable manufacturing concepts. The main gap in this class is that there are limited numbers of articles in MRP and ERP topics, although they are significantly important in planning phase activities.
- ✓ LCA is a tool to assess the environmental effect of not only products but also processes and activities. Although it is one of the major tools in sustainable manufacturing, it only considers environmental effects. By combining it with life cycle costing (LCC) and social life cycle assessment (SLCA) more sustainable assessments could be done. There is an increasing interest to the field of deepening and broadening LCA concept by integrating other aspects like social and economic.
- ✓ Regarding to 389 articles in the database, there is a limited number of articles about the topics information and communication technology (ICT), research and development (R&D), and innovation. There is no article directly related with one of these topics and their implications on sustainable manufacturing concepts. Only few articles indicate some applications of these concepts, however they are not enough for the globalizing and developing world with ICT applications, more innovative techniques and R&D activities. Since ICT is a popular concept in recent years, this gap seems to decrease in the following years with more focus of researchers.
- ✓ Most of the sustainable manufacturing articles are related with environmental concerns. Although the greenness of processes is as important as the greenness of products, labeling is done mainly on the products. However the greenness of the production processes is also important in terms of sustainability. There is a gap in this field. There is only one process labeling article in the entire database which needs to be researched more.
- ✓ In order to benefit efficiently from a machine or tool, maintenance is a vital operation. By maintaining machines regularly, a standard quality can be achieved and the downtimes can be reduced in order to impede the money loss. Also regular maintenance is a must for employee health and security, because it may minimize the

harmful effect of machines on employees' health and security by taking precautions for machining accidents. Besides the effects on quality and cost also for the social aspect of the sustainability, maintenance research should continue increasingly. Despite the importance of this issue for the machining operations, it is surprising that there is not enough number of articles related with maintenance to achieve sustainability.

- ✓ It is observed that the articles in Inventory Control class generally consider only environmental concerns instead of sustainability. The main reason that forces companies to be more environmental is the economic issues. If they do not keep their inventory level at an optimum level, they should pay more money or government force them to be more environmental otherwise punish the companies with some fee.
- ✓ It is observed that the articles in Inventory Control class do not give enough importance to define the optimal production inventory level for sustainability issues. Instead of focusing on assuring sustainable manufacturing systems, they only work on to find when it is worth to pay penalties due to environmental constraints, such as tradable permits.
- ✓ Although quality is a very important concern for manufacturing systems, integration of environmental concerns into quality management has not been achieved yet based on the findings of the research. TQEM has not attracted the attention that it is expected.
- ✓ Pollution Prevention, Waste Management and Emissions classes might be evaluated together. There is an increasing trend in these output related concepts. Companies concentrate on decreasing harmful effect of their outputs on environment and by doing this they aim to gain economic advantage.
- ✓ End of life (EOL) options are one of the most appealing topics that are covered in this thesis. Thanks to its positive economic and environmental impacts on the organizations, companies prefer using recovered materials in case they do not contradict their quality. This topic is well researched, and seems promising for future improvements for bettering sustainability performance of the firms.
- ✓ Since the small and medium sized enterprises (SMEs) constitute around 70% of the manufacturing industry (in some countries around 90%), their contribution to sustainable manufacturing applications is really necessary. In order to decrease the environmental hazardous substances and increase social and economic sustainability with sustainable technology implications, the integration of SMEs is significantly important and there are notably numbers of published articles related with this topic.
- ✓ Considering the pillars of the sustainability, the companies and the researchers have given the most importance to environmental concerns. Most of the articles are focused on the environmental aspect of sustainability. 148 of the articles are focused directly on environmental concerns, whereas 253 of the articles take environmental concerns

into consideration additional to some of the other aspects. On the other hand, social sustainability has not been given enough importance, there are only 6 articles that are directly related with the social aspects of sustainability. The same situation also holds for technology, there are only 7 articles focused on this topic. The other aspects of sustainability rather than the environmental and economic concerns, social and technological aspects should be taken into consideration to fulfill the requirements of sustainable manufacturing.

- ✓ It is observed that the number of the articles on sustainable manufacturing concepts tends to increase in the course of time. It might be a good indicator that the attention to sustainability issues has been increasing.

6 Discussion

This section of the thesis is devoted to show similarities and differences between the findings of the thesis with the action that are defined in IMS2020 Action Roadmap. In the following steps, the description of IMS2020 project, the aim of the discussion, comparative analysis, and discussion of the results are examined sequentially.

6.1 Introduction to IMS2020

IMS2020 is a project that was initiated in January 2009 and supported by European Union. It is funded by the NMP division of the European Commission within the IMS Framework. The abbreviation IMS stands for *Intelligent Manufacturing Systems*. IMS2020 aims at creating roadmaps towards intelligent manufacturing systems by the year 2020. IMS2020 emphasizes the actions that are needed to be taken in order to attain the milestones by the year 2020. It shows which developments should be provided in the manufacturing industry in order to have a sustainable industry by the year 2020. [54]

In this project, there are five main areas namely

- ✓ Sustainable Manufacturing, Products and Services
- ✓ Energy Efficient Manufacturing
- ✓ Key Technologies
- ✓ Standardization
- ✓ Innovation, Competence Development and Education.

Since two of the main areas match with the topic of the thesis, Sustainable Manufacturing, Products and Services and Energy Efficient Manufacturing, these key areas are examined in order to define the actions that are related with the scope of the thesis.

6.2 Analytical methodology

This roadmap has been used to compare the current situation on the way to sustainable manufacturing in the literature and the actions that are needed to be taken to fulfill the requirements to achieve a more sustainable industry. The similarities and the differences between the current data up to now and the future requirements are demonstrated.

Considering the main focus of the thesis, the actions in IMS2020 project that can be compared with the findings of the thesis are defined. These actions are covered under the key areas, Sustainable Manufacturing, Products and Services and Energy Efficient Manufacturing which

[54] IMS2020, 2009. IMS2020-Action Roadmap on Key Areas 1, 2 and 3. http://data.fir.e/projektseiten/ims2020/files/Action_Roadmap.pdf.

are relevant with the scope. The list of the relevant actions can be found in Table 4. Although there are more actions that are related with sustainable manufacturing, a limited number of actions are chosen which are covered in the scope of the thesis. The relevant actions do not completely match with the existing classes that are defined in the state of the art analysis, however general deductions, which are made while evaluating the articles, are exploited to make the comparisons.

It is aimed to figure out if the findings of the current literature search can underpin the actions defined in Action Roadmap to be taken between 2011 and 2013 and it is attainable to have a sustainable industry in 2020 based on the current findings. It is intended to observe the gaps and lagged areas behind the developments, thus demonstrate where improvements can be made.

In order to assimilate the point that the literature has reached, a wide analysis of the state of the art is accomplished and the results are evaluated in Section 4. On the other hand, to comprehend the developments to be achieved, the roadmap is analyzed and the findings are summarized in the next part. The intersecting points between the results of both analyses are interpreted in order to see the parallelism between them.

However, when doing the comparison, many limitations have been encountered. Therefore, the limitations should be taken into consideration while assessing the results. The limitations are as follows:

- ✓ First of all, IMS2020 is a project which has utilized the knowledge of many universities and companies about providing a sustainable industry. While developing IMS2020 project, the developments in the recent years were born in mind. However, the state of the art analysis is based on the scientific articles that are published between 1999 and 2011.
- ✓ Additionally, the thesis is based on the articles that are published in the journals that have an impact factor, leaving out any conference/seminar paper, workshop report etc. Thus the current topics that are discussed in the seminars, conferences or workshops cannot be reflected in the articles concurrently, since writing an article and publishing it take some time. Therefore, the studies conducted in the articles lag approximately 2 years behind and this might cause a difference between the reality and the literature.
- ✓ Lastly, since the main focus is manufacturing, it might overlook some concepts that are not the primary concern of the thesis. As an example, energy related topics are not deeply investigated in this thesis, since they constitute only one branch of the *Input* class. However, since it is one of the three key area topics, in this case the actions that are needed to be taken according to IMS2020 Action Roadmap encompass broader views than the thesis. The same situation also holds in Information and Communications Technology integration to the companies. If the journals that are

directly related with energy or ICT concepts are searched instead of the ones which have a direct interest in manufacturing topics, more accurate results can be obtained on these topics.

To cope with these limitations, some assumptions are made.

- ✓ While examining the patterns of the sustainable manufacturing concepts, if there is an increasing trend in the field, the continuity of the interest in the topic is expected. For instance, since the awareness of electric and electronic products' recovery is grown in the last years, a sound research in this topic is expected in the following years.
- ✓ During the comparison, in order to compensate the lagged time between the reality and the literature, general information on the current situation is taken into account.

6.3 Comparative analysis

In this part of the thesis, the actions that are chosen from the roadmap are described from two different perspectives, IMS2020 Action Roadmap and the state of the art of sustainable manufacturing. In addition, to what extent the current practices of sustainable manufacturing in the literature can fulfill the actions' requirements is questioned. The following table summarizes these aspects.

Research Topic	IMS 2020	State of the Art – Sustainable Manufacturing
Quality Embedded Manufacturing	Providing wirelessly networked and remotely monitored intelligent control systems for manufacturing systems with high sustainability characteristics by enhancing quality management	Integrating environmental concerns into quality management systems, but no ICT integration
Green Controller for Machining	Utilizing Green Controller for machining to monitor and control that will help reduce energy and natural resources consumption and toxic substances	Developing new machining technologies to reduce the environment impacts of machining, but no monitoring and control
Material Reuse Optimization	Developing technologies and tools to improve materials reuse and recycle and spreading the usage of them also in less advanced sectors	Developing technologies and tools for reuse utilization in all sectors to be able to respond to the stakeholders' requirements
Optimization for Electronic Sustainability	Optimizing the end of life treatments of electronic products to provide sustainability improvements	Increasing attention to the end of life options of electronic products to expand their life cycle
Management of Hazardous Substances in Manufacturing	Managing the usage and generation of hazardous substances to reduce their impacts on the environment, human health and safety with the help of developed production methods, ICT solutions and recuperation technologies	Focusing on decreasing the usage and generation of hazardous substances to reduce their impacts on the environment, human health and safety, but no ICT integration
EOL Management Supporting Technologies	Optimizing remanufacturing processes by focusing on the remanufacturing system control considering the quality change	Developing EOL options by paying attention to the quality specifications of the products to benefit from products as much as possible

Emission Reduction Technologies	Developing emission reduction technologies to allow significant reduction of stack emissions	Using emission reduction technologies to reduce emissions significantly
Maintenance Concept for Sustainability	Improving the application of maintenance by benefitting from new concepts integrating sustainability related aspects	Maintenance concept is not emphasized in the related articles
Real-time Life Cycle Assessment	Developing life cycle tools by using data and information existing in various sources to be used in design processes	Developing life cycle tools in order to decrease environmental impact in the early phases of production
New Workplaces for Aging and Disabled Workers	Renewing the work processes and workplaces to enable the integration of aging and disabled people into the manufacturing system	Improving the quality of workplace and bettering work processes for employee health and safety, but not for aging and disabled people
Sustainable SMEs	Increasing the sustainability of SMEs through the adoption of proper methodologies and business models to meet the competitive, environmental and social challenges	Activities for improving sustainability of SMEs by adopting sustainable manufacturing techniques and technologies
Energy Autonomous Factory	Creating factories that are self-sufficient in meeting their energy needs by generating their own energy according to their demand	Factories generally outsource energy from suppliers however there are few examples of energy autonomous factory by using their wastes
Energy Utilization in Collaborative Framework	Collaborating companies and industries on a cross-sector and cross-industry basis to use energy and waste streams in a symbiotic way	Industrial symbiosis applications in order to utilize waste and energy of collaborating companies
Management and Control of Energy Consumption	Integrating measurement and control systems for deciding about and implementing energy efficiency improvement measures	Measurement and control techniques for energy efficiency, but no sensors or ICT systems

Table 4 The comparison of the intersecting topics of IMS2020-Action Roadmap on Key Areas 1, 2 and 3 and the thesis

Considering the scope and the limitations of the comparison, the differences and the similarities between the actions that are defined in IMS2020 Action Roadmap and the findings of the thesis are evaluated as follows:

- ✓ *Quality Embedded Manufacturing* focuses on embedding smart devices into the equipments in order to remotely monitor them in a wirelessly networked system in a real-time. Through this system the information about the status of the products, processes, and machines will be tracked. It will enable to control the manufacturing operations completely and detect quality defects which contribute to predict exceptional cases and take actions to correct them in advance. A manufacturing system with high sustainability characteristics will result in producing high quality products and less waste, and using less energy.

  In the research: Considering the articles that are in hand, new machining technologies are developed to improve the quality of the products. However, quality management and machines are not integrated by utilizing Information and Communications Technology (ICT) in the reviewed articles. The monitoring of the machining processes is mentioned only in one article mainly. Total Quality Management Systems which are

taking environmental concerns into consideration remain limited to establish a system fully integrated with ICT applications.

Therefore, the current findings of the literature do not underpin the desired level of quality embedded manufacturing. However, if the ICT integration to the companies is encouraged, achieving the desired level will be facilitated.

Year	Name of the authors	Name of the article
2011	K. Bunse, M. Vodicka, P. Schönsleben, M. Brülhart, F. O. Ernst	Integrating energy efficiency performance in production management – gap analysis between industrial needs and scientific literature

Table 5 The list of the articles that are published on monitoring of the machining processes

- ✓ *Green Controller for Machining* intends to monitor and control the machining processes to define the most energy consuming and environmentally impacting phase of their lifecycles that will help to reduce energy and material consumption and toxic substances production.

  In the research: Developing new technologies to reduce the adverse environmental impacts of machining is an appealing concept for the researchers. There are many examples about machining techniques, usage of lubricants to reduce their environmental impacts, etc. However, none of them are focused on controlling the machining processes to see the the energy consuming and environmentally impacting phases.

  The examples of these technological developments are not observed in the reviewed articles. Reviewing the journals related with machining technologies can be more beneficial to see the current situation of this concept.

- ✓ *Material Reuse Optimization* addresses the development of the technologies and tools to improve materials reuse and recycle and spreading the usage of them in less advanced sectors. Self disassembly technologies, de-manufacture, methods, IT tools and best practices to be used by large companies and also SMEs should be included in the research scope.

  In the research: Recycling and reuse options for end of life treatment are very important issues that have attracted the interest of the researchers so far. However, the articles that are reviewed do not mention any examples of the applications of recycling and reuse in SMEs. On the other hand, if the articles are evaluated disregarding their core points, without considering if they are related with end of life options or regulations etc., there is a common view that SMEs should be integrated into the development of sustainable manufacturing systems to achieve sustainability since they constitute a big portion of the manufacturing industry. In order to provide SMEs integration to the sustainable industry, studies have been conducted on them.

There are many studies conducted on material reuse optimization in the literature which supports this action. Since SMEs hesitate to adopt sustainable manufacturing concepts due to cost concerns, they need to be encouraged to apply these concepts.

- ✓ *Optimization for Electronic Sustainability* aims at optimizing end of life treatments of electronic products to decrease their significant effect on the environment. Recycling techniques improvements, producer take back systems, RFTags for advanced identification technologies, and closing the loop of the products are greatly important to handle the problems.

  In the research: Handling e-wastes play an important role. This topic has become important in the last 4 years, starting from 2007 in the literature. This might be due to the fact that WEEE Directive was introduced in 2003 in some countries, and in the course of time, it started to spread over other countries. The list of the articles that are published on this topic is as follows:

Year	Name of the authors	Name of the article
2007	S. Webster, S. Mitra	Competitive strategy in remanufacturing and the impact of take-back laws
2008	M. S. Abu Bakar, S. Rahimifard	Ecological and economical assessment of end-of-life waste recycling in the electrical and electronic recovery sector
2009	W.-H. Tsai, S.-J. Hung	Treatment and recycling system optimization with activity-based costing in WEEE reverse logistics management: an environmental supply chain perspective
2009	J. Johansson, C. Luttropp	Material hygiene: improving recycling of WEEE demonstrated on dishwashers
2010	P. Georgiadis, M. Besiou	Environmental and economical sustainability of WEEE closed-loop supply chains with recycling: a system dynamics analysis
2010	C. Luttropp, J. Johansson	Improved recycling with life cycle information tagged to the product
2011	C.-J. Chung, H.-M. Wee	Short life-cycle deteriorating product remanufacturing in a green supply chain inventory control system

Table 6 The list of the articles that are published on electronic products treatment

The related articles try to figure out the effects of the legislation on electric and electronic product recovery and how to improve end of life options, especially recycling. In one article, RFID tagging to the products in order to look for relevant recycling information in databases and also enable to add waste handling information and track substances that are assumed to be non toxic at the production to see if they are really are.

This topic attracts attention due to its newness to the researchers. The increasing attention to the issues related with electric and electronic products sustainability seems promising for the future research. The findings of the literature are parallel with the requirements of the action.

- ✓ *Management of Hazardous Substances in Manufacturing* focuses on managing the usage and generation of hazardous substances to reduce their impacts on the

environment, human health and safety with the help of developed production methods, ICT solutions and recuperation technologies.

In the research: By utilizing environmentally friendly machining technologies to reduce the adverse environmental impacts of lubricants, cooling fluids, etc., implementing end of life treatments to the products to decrease the amount of waste, developing technologies to manage wastes, prevent pollutions and reduce toxic emissions serve to manage hazardous substances usage and generation in the manufacturing processes.

Managing hazardous substances in manufacturing develops in the expected path, however ICT integration to the solutions is not adopted yet according to the topics that are discussed in the related articles.

- ✓ *EOL Management Supporting Technologies* intend to optimize remanufacturing processes by focusing on the remanufacturing system control in order to have a system with higher efficiency which provides cost effective re-use of remanufactured components without compromising quality specifications. The real-world information in the real time can be gathered by the manufacturing control system. The information can be used for reacting on the system change or skipping the redundant operations for specific part quality too.

  In the research: Since the quality of a product is significantly important for the producers, the companies that provide recovered materials to producers pay attention to the quality specifications of the components. In the researched articles, the decision for the most appropriate EOL option is given according to the quality objective, because if the quality of a product decreases after recycling, producers do not accept these items. For instance incineration of the products in order to be benefitted from their heat energy or secondary recycling which produces less qualified components are the most preferred methods because of quality changes.

  Although the EOL management supporting technologies are benefitted in the current situation, the decision is not made with the help of ICT technologies, sensors or RFID tags or the articles that are covered in this thesis do not mention any of these technologies.

- ✓ *Emission Reduction Technologies* focuses on emission reduction technologies that allow significant reduction of stack emissions and to increase energy efficiency. Developing emission reduction technologies coordinately across sectors may provide benefits from applying similar reduction technologies in different industries. Since there is no need to develop different technologies to decrease emissions, if the organizations work in a symbiotic way, it may speed up Research and Development activities.

In the research: Although there are not many articles that directly focus on emission reduction only, this concept is mentioned in almost every article that is concerned with environmental sustainability.

In the current state of the art analysis there exist many articles that deal with emission reduction technologies for abating emissions significantly, however there is no research related with developing any emission reduction technology adaptable to different industries in a symbiotic way.

- ✓ *Maintenance Concept for Sustainability* is a vital concept for improving sustainability in manufacturing since it leads to longer machine life cycles and better equipment performance in terms of resource and energy consumption. Innovative and predictive maintenance concepts should be developed in a holistic manner that integrates minimization of the total cost of the machines and the amount of CO_2 produced.

  In the research: There are only two articles in the database of this research related with maintenance concept for sustainability. Considering the importance of maintenance for sustainability, the number of the articles in the existing database is far from meeting the expectations. The list of the related articles might be seen in Table 7.

Year	Name of the authors	Name of the article
2007	S. Dellagi, N. Rezg, X. Xie	Preventive maintenance of manufacturing systems under environmental constraints
2007	J. P. Liyanage	Operations and maintenance performance in production and manufacturing assets: The sustainability perspective

Table 7 The list of the articles that are published on maintenance

- ✓ *Real Time Life Cycle Assessment* focuses on the usage of life cycle data information of previous products by life cycle assessment tools in order to provide precise evaluation of life cycle impacts of a new product. As a result of this, life cycle assessment method allows designers to use this data in order to design products regarding to environmental and sustainability impacts and life cycle cost of products in addition to technical specifications.

  In the research: Life cycle assessment tools provides data and information to the organizations in order to take precautions in the early phases of production in order to decrease environmental impacts of products and as well as processes.

  The result of the state of the art analysis of this thesis is also parallel to the findings and expectations of IMS2020 Action Roadmap.

- ✓ *New Workplaces for Aging and Disabled Workers* is an important concept in aging societies for providing these people better lives. Renewing the workplaces to enable the integration of aging and disabled people into the manufacturing systems will improve the system's sustainability in terms of social aspect.

In the research: The thesis does not include any article related to this topic. The importance of social sustainability in the literature is undervalued, considering this the realization of this action will be utopian.

- ✓ *Sustainable SMEs* is one of the crucial topics in the IMS2020 Action Roadmap. Since SMEs represent around 90% of all private sector firms, their contribution to sustainable development is highly important. With applying technologies to and training of SMEs, their competitiveness, environmental and social challenges can be increased.

  In the research: To achieve sustainability in SMEs is considered very important in the literature. Since SMEs have a huge impact on the environment, their integration of sustainable manufacturing techniques and compliance with environmental regulations are vital.

  In the current literature there is a significant number of articles related with SMEs and encouraging them in sustainable manufacturing concepts. It supports that this concept will grow in the following years.

- ✓ *Energy Autonomous Factory* is a self-sufficient factory in meeting its energy need by generating its own energy according to its demand. In order to reduce energy consumption, renewable energy sources and in situ production of energy should be encouraged.

  In the research: Energy articles are generally focused on reducing energy consumption and using biodegradable energy resources. Mainly because of economic objectives and also environmental reasons companies prefer renewable energy resources, however most of the companies outsource their energy from an outside company instead of in situ production. Although there is not any in situ energy production example in the current literature, there are some sectors which use their wastes in order to produce energy. For instance, in textile industry cotton gin is an alternative resource to produce environmental friendly energy.

  All these information indicates that the current literature do not support energy autonomous factory for the near future. However, the sectors that use their wastes to produce energy can be a precursor for this concept.

- ✓ *Energy Utilization in Collaborative Frameworks* focuses on collaborative relationships between companies/industries. The aim of these relationships is to utilize the wastes of the companies, which can be in energy or byproduct form, more efficiently in a symbiotic way. The waste streams of the companies are pretreated before being usable by another company. To make this system environmentally and economically applicable, advancements in technology should be made to increase the utilization of alternative fuels and raw materials derived from waste at cross-industry level.

In the research: This topic is widely discussed in the literature especially in the last four years. The increasing trend in the number of the articles that are published on collaborative relationship between companies or industries, which are covered under Industrial Ecology in the thesis, seems promising for the future developments in this area. However, the core points of the articles generally focus on the limiting or success factors in establishing these collaborative relationships, their effects on the companies performances etc.

If advancements in technologies for improved relationships are expected to occur in the maturity phase of this concept, then we can claim that the related articles in hand are in between the initialization and development phase.

- ✓ *Management and Control of Energy Consumption* focuses on integrating measurement and control systems for deciding about and implementing energy efficiency improvement measures. The information is gathered by sensors and in-process measurements and is used to facilitate the control and improvement of the energy efficiency.

  In the research: There are articles related with measurement and control techniques for energy efficiency. Companies give importance to measuring energy efficiency of their production systems in order to better their system and have continuous improvement. However, there is no evidence about ICT usage or existence of sensors or smart devices for measurement and control.

  The results of the literature review are not supportive for the expected level of management and control of energy consumption due to lack of ICT integration. Providing ICT integration can increase the quality of management and control of energy consumption of current situation.

6.4 Discussion of the results

Based on the comparison between the findings from the current literature search and the actions that need to be taken according to IMS2020 Action Roadmap, some concluding remarks can be underlined in order to give an insight about where the sustainable manufacturing concepts are currently and whether it is attainable to have a sustainable industry in 2020.

Considering all the actions, almost all of the actions have found a place in the literature. There have been studies conducted on material reuse optimization, management of hazardous substances in manufacturing, emission reduction technologies etc. The common missing point in these actions is ICT integration to the manufacturing systems. This can cause inaccurate, ineffective and inefficient systems due to the lack of smart devices usage in monitoring, measuring and controlling.

Although Action Roadmap has given a lot importance to ICT integration in almost every action, the current situation in the literature is not at the same level as it is expected. However, one should keep in mind that the findings from the literature on this topic cannot exactly indicate where the companies stand and what are discussed on this topic in the conferences, seminars etc. Since ICT is a popular concept these days, its usage in manufacturing systems to achieve sustainability will be spread over the companies to improve the current applications of sustainable manufacturing practices and will take a considerable place in the literature on sustainable manufacturing. When it is achieved, the actions on *Quality Embedded Manufacturing, Green Controller for Machining, Optimization for Electronic Sustainability* etc. will be completed.

The lack of ICT integration might be due to high investment costs, the requirements for technical knowledge, skilled workers and training. Because of that companies hesitate to adopt ICT in the manufacturing systems. The integration should be encouraged because ICT leads manufacturing systems to more intelligent ones.

Secondly, implementation of sustainable manufacturing practices in small and medium sized enterprises (SMEs) can contribute to the future of sustainable industry. Many articles are focused on the dissemination of the practices in SMEs, and their integration with them. Since SMEs constitute approximately %90 of the manufacturing companies, their adoption of sustainable manufacturing practices matter a lot for the sustainability of the industry. This endeavor in the literature to integrate the SMEs seems promising for a more sustainable industry.

Not integrating sustainable manufacturing systems into SMEs is a significant loss considering their portion in the industry. The increased integration activities in the industry can lead the current system to a comprehensive sustainable manufacturing system.

The energy related topics are not fully covered regarding the researched articles. The examples of energy autonomous factory have not been observed yet. Waste utilization for energy generation has been mentioned, but in situ applications do not exist. Looking from the industrial ecology perspective, it seems probable to have energy utilization in collaborative Frameworks, but not in the very close future. Collaborative relationships between companies remain limited considering the researched articles. Since these collaborative relationships are not disseminated yet in terms of material, energy etc. sharing, it might take some time to achieve this action.

It is more beneficial for the industry to provide sustainability in the symbiotic relationships rather than the individual endeavors, because the collaborative activities give better results than individual ones. This will lead to achieve more sustainability gains with less effort.

Maintenance of a machine is a very vital issue, since machining plays a very important role in achieving sustainability. But surprisingly, there exist only two articles about maintenance for sustainability which might be an indicator of being not well investigated in the literature on sustainable manufacturing concepts. In order to get more accurate information about this topic, the scope of the journals should be shifted from manufacturing based to machining based. In that case, it might be possible to find more detailed information about maintenance. However, from the evidence in hand, maintenance for sustainability is far from contributing to achieve a sustainable industry.

In the analysis of the related articles that are under the scope of the thesis, it is seen that the social aspect of sustainability is overlooked in many cases. New workplaces for aging and disabled workers which is a very particular issue regarding the social aspect of sustainability has not attracted any attention. In order to achieve a sustainable industry in 2020 many steps should be taken on this topic.

In short, in order to reach the vision of IMS2020 project, the current manufacturing systems need to be shifted to more intelligent, comprehensive, symbiotic and socially responsible manufacturing systems. However, on the way to achieving a sustainable industry in 2020, the current research stays behind what is expected. Improvements in many aspects, such as ICT integration, are needed to catch up with the actions defined in IMS2020 Action Roadmap, but the existing conditions lay the groundwork for the improvements on sustainability.

7 Conclusion

Manufacturing has forced the environment to bear the burden of degradation, for the sake of the economic progress that it has provided for the industries and the countries. Environmental degradation, depletion of natural resources, increased global warming, and climate change have started to affect the future of the world. These prominent troubles have increased the environmental awareness of the society towards a more sustainable future. In addition to environmental awareness, increased raw material and energy prices, stringent environmental regulations to control or even stop the degradation have initiated a movement away from traditional manufacturing methods. As a result, *sustainable manufacturing* concept has grown into importance in recent years to handle these troubles and satisfy the needs of today's and future's generation taking into account environmental, economic and social progression.

In the thesis, it is aimed to evaluate the evolution of sustainable manufacturing concepts from 1999 to 2011 to summarize the milestones of the defined classes, clarify their effects on sustainable manufacturing, and to observe their developments and evaluate the trends in the defined classes - if there are -. Additionally, it is intended to compare the findings of the state of the art analysis with the actions that are needed to be taken according to IMS2020 Action Roadmap to see if the current studies meet the expectations to achieve a sustainable industry in 2020.

To reply these questions a well grounded state of the art analysis of sustainable manufacturing is accomplished. In order to make a reliable assessment, generating a sound background with the comprehension of previous developments is essential. 389 articles from 32 peer-reviewed journals are collected in the database which includes the information of the article identification, the article types (research article, case study, empirical study, etc.) and the core pillars of articles (environmental, social, economic or technological). This database is utilized to generate the classification, the mind map and the three layered conceptual framework.

By reading all the articles, using the sound database and the conceptual framework, general analyses of each class are conducted. Firstly, all the articles are assessed according to three dimensions namely yearly, article type and ESET (environmental, social, economic and technological) based. It is concluded that there is an increasing trend in the number of publications about sustainable manufacturing concepts year by year. Research articles constitute the main part of the research with 212 articles and empirical study, methodology and case study contribute with 67, 74 and 56 articles respectively. Literature review is the less attractive research type with 7 articles. From ESET analysis point of view, 253 articles cover environmental sustainability and 129 articles deal with economic sustainability. The results of the analysis indicate that, social sustainability and technology aspects are less interested. The

reasons might be expressed that they do not have high economic impacts on manufacturing activities or there is not any big pressure or punishment for their adoption to the manufacturing systems. The articles that mention about the barriers to, adoptions, initiatives and promotions for sustainable manufacturing concepts instead of any specific sustainability pillar are collected under the class *others.*

In particular, some classes such as *regulations, external factors, environmental management systems, performances, input, manufacturing paradigms, evaluation* and *output* are more attractive than others during the evolution of sustainable manufacturing according to their published article numbers. On the other hand *network, planning* and *control* classes are less attractive topics and rarely mentioned in the collected articles.

Secondly, all the articles are summarized to understand what and where the each sustainable manufacturing concept is. Here, the descriptions, milestones and the trends of each class are expressed and general deductions about the completed research are written down. Beside the analysis based on the published article numbers, the trends in the sustainable manufacturing concepts are tried to be determined considering the content. Some major deductions are as follows:

Since the proportion of SMEs in general manufacturing companies and their contribution to the degradation of the environment are notably high, the interest on the integration of SMEs to the sustainable manufacturing is increased. The increased awareness of society forced government to take precautions and make environmental regulations.

Companies target to optimize their energy and raw material usage due to the increased energy and raw material prices and environmental awareness. Therefore, they try to utilize from new energy resources which are renewable and less hazardous for the environment and integrate end of life options to their systems in order to decrease the virgin material usage.

Industrial ecology is an alternative way which serves to decrease the harmful effects of wastes in addition to general end of life options and that supports the increase in the gaining sustainability in a symbiotic way. While the usage of machining and energy technologies is increasing, the importance of ICT integration to these topics is discarded. Although the importance of ICT grows day by day, ICT integration to the industries is not in the desired level.

The findings of the state of the art analysis of the current research are compared with the actions that are defined in IMS2020 Action Roadmap. IMS2020 Action Roadmap has defined the actions that are needed to be taken between 2011 and 2013 to enable to have a sustainable industry by the year 2020. As a result of the comparison, it is found that the most important gap between the current research and the actions is the lack of ICT integration to the

manufacturing technologies. Additionally, issues considering energy utilization have not attracted attention in the literature as much as it is needed. However, the developments in the last decade in increasing the efficiency of material utilization, integrating SMEs into development of sustainability in the industry etc. have laid the groundwork for improvements on sustainability. In short, on the way to achieving a sustainable industry in 2020, the current research stays behind what is expected, but the developments in the practices seem promising for a sustainable future.

The results of the current study can be improved by enhancing the borders of the study. The scope can be widened by adding the excluded topics such as eco-design, sustainable supply chains etc. Additionally, the number of the reviewed journals can be increased to examine the developments from a wider point of view. The journals that are not directly related with manufacturing, such as energy, can be included to search in detail for every branch of sustainable manufacturing concepts.

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9 Appendices

Appendix 1 List of the keywords

List of the keywords
Sustainable
Sustainability
Sustainable manufacturing
Social sustainability
Lean (manufacturing)
Green (manufacturing)
Clean (manufacturing)
Eco-efficiency
Environmental
Ecological
LCA
Process design
End of life options
Recovery
Remanufacturing
Recycling
Emissions
Pollution prevention
Toxic material
Waste management
Green machining
Hazardous substances
ISO14000
Environmental conscious
Energy efficient
Raw material
Environmental technology
Environmental management
Industrial symbiosis

Appendix 2 List of the journals

List of the journals
Benchmarking: An International Journal
Business Strategy and the Environment
Computers & Industrial Engineering
European Journal of Industrial Engineering
IEEE Transactions on Engineering Management
Integrated Manufacturing Systems (till 2004 Journal of Manufacturing Technology Management)
International Journal of Advanced Manufacturing Technology
International Journal of Business Performance Management
International Journal of Computer Integrated Manufacturing
International Journal of Life Cycle Assessment
International Journal of Machine Tools and Manufacture
International Journal of Operations and Production Management
International Journal of Production Economics
International Journal of Production Research
International Journal of Productivity and Performance Management
International Journal of Quality & Reliability Management
International Journal of Sustainable Engineering
International Journal of Technology Management
Journal of Business Logistics
Journal of Cleaner Production
Journal of Environmental Management
Journal of Manufacturing Systems
Journal of Operations Management
Journal of Productivity Analysis
Machining Science and Technology
Manufacturing and Service Operations Management
Materials and Manufacturing Processes
Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture
Production and Operations Management
Production Planning and Control
Supply Chain Management: An International Journal
Total Quality Management and Business Excellence

Appendix 3 List of the articles in the layers

Eco-system

Regulations

Int J of Production Economics	1999	Production strategies under environmental constraints in an Arrow–Karlin model
J of Cleaner Production	1999	Regulatory and self-regulatory measures as routes to promote cleaner production
Int J of Quality & Reliability Management	1999	An evaluation of success factors using the AHP to implement ISO 14001-based EMS
J of Cleaner Production	2000	The ISO 14001 certification of a machine-process
Int J of Operations and Production Management	2000	The relationship between ISO 14001 and continuous source reduction programs
Int J of Production Economics	2001	Production strategies under environmental constraints: Continuous-time model with concave costs
Business Strategy and the Environment	2001	Combating environmental repercussions through 'TQEM' and 'ISO 14000'
Integrated Manufacturing Systems	2001	An analytical hierarchy process assessment of the ISO 14001 environmental management system
Production and Operations Management	2001	STAKEHOLDERS AND COMPETITIVE ADVANTAGE: THE CASE OF ISO 14001
J of Cleaner Production	2001	Developing a methodology for analysis of benefits and shortcomings of ISO 14001 registration: lessons from experience of a large machinery manufacturer
J of Environmental Management	2002	A study of compliance with environmental regulations of ISO 14001 certified companies in Korea
Int J of Production Research	2002	Certifying environmental management systems by the ISO 14001 standards
J of Cleaner Production	2003	Critical factors for implementing ISO 14001 standard in United States industrial companies
J of Cleaner Production	2003	Policies influencing cleaner production: the role of prices and regulation
Int J of Production Research	2003	Influence of the perception of the external environmental pressures on obtaining the ISO 14001 standard in Spanish industrial companies
Int J of Quality & Reliability Management	2003	Implementing ISO 14000 in Sweden: motives, benefits and comparisons with ISO 9000
J of Cleaner Production	2004	Recycling performance of firms before and after adoption of the ISO 14001 standard

Int J of Production Economics	2005	The effects of emission trading on production and inventories in the Arrow–Karlin model
J of Cleaner Production	2005	The impact of environmental regulation on competitiveness in the German manufacturing industry—a comparison with other countries of the European Union
J of Cleaner Production	2005	Implementing ISO 14001: is it beneficial for firms in newly industrialized Malaysia?
J of Cleaner Production	2005	Decision traps in ISO 14001 implementation process: case study results from Illinois certified companies
J of Cleaner Production	2005	Towards implementation of ISO 14001 environmental management systems in selected industries in China
IEEE Transactions on Engineering Management	2006	Standardization and Discretion: Does the Environmental Standard ISO 14001 Lead to Performance Benefits?
Business Strategy and the Environment	2006	ISO 14001 – experiences, effects and future challenges: a national study in Austria
Integrated Manufacturing Systems	2006	How organisational culture impacts on the implementation of ISO 14001:1996 – a UK multiple-case view
Int J of Production Economics	2007	Tradable permits and production-inventory strategies of the firm
J of Cleaner Production	2007	Is European end-of-life vehicle legislation living up to expectations? Assessing the impact of the ELV Directive on 'green' innovation and vehicle recovery
Proceedings of the Institution of Mechanical Engineers, Part B: J of Engineering Manufacture	2007	Computer-aided recycling process planning for end-of-life electrical and electronic equipment
J of Operations Management	2007	Competitive strategy in remanufacturing and the impact of take-back laws
Int J of Production Economics	2008	Operations management practices linked to the adoption of ISO 14001: An empirical analysis of Spanish manufacturers
J of Cleaner Production	2008	Underlying mechanisms in the maintenance of ISO 14001 EM system
J of Productivity Analysis	2008	Environmental regulation and productivity: testing the porter hypothesis
Benchmarking: An Int J	2008	A study on the ISO 14000 certification and organizational performance of Indian manufacturing firms
J of Cleaner Production	2008	Evaluation of critical success factors of implementation of ISO 14001 using analytic hierarchy process (AHP): a case study from Malaysia
J of Cleaner Production	2008	ISO 14001 certification in Brazil: motivations and benefits
Business Strategy and the	2009	Explaining the impact of ISO 14001 on emission performance: a dynamic capabilities perspective

Environment		on process and learning
J of Environmental Management	2009	Environmental compliance: The good, the bad, and the super green
J of Environmental Management	2009	Global warming and environmental production efficiency ranking of the Kyoto Protocol nations
J of Cleaner Production	2010	Waste management policies for industrial symbiosis development: case studies in European countries
Int J of Life Cycle Assessment	2010	Life cycle assessment of nine recovery methods for end-of-life tyres
J of Cleaner Production	2010	Alternative models for environmental management in SMEs: the case of Ekoscan vs. ISO 14001
Int J of Production Economics	2011	Customer, regulatory, and competitive pressure as drivers of environmental innovation
J of Cleaner Production	2011	The effect of ISO 14001 certification on toxic emissions: an analysis of industrial facilities in the north of Spain
J of Cleaner Production	2011	ISO 14001 and solid waste generation rates in US manufacturing organizations: an analysis of relationship
J of Cleaner Production	2011	Does ISO 14001 work in Brazil?
J of Cleaner Production	2011	Diffusion of ISO 14001 EM systems in China: rethinking on stakeholders' roles
J of Cleaner Production	2011	ISO 14001 certification and financial performance: selection-effect versus treatment-effect
Int J of Operations and Production Management	2011	Do drivers matter for the benefits of ISO 14001?

External Factors

J of Cleaner Production	1999	Cleaner industrial production practice in Ethiopia: problems and prospects
J of Cleaner Production	1999	Applications of a corporate synergy system to promote cleaner production in small and medium enterprises
J of Cleaner Production	1999	Cleaner production in SMEs through a partnership with (local) authorities: successes from the Netherlands
Supply Chain Management: An Int J	2000	Supporting small businesses in their transition to lean production
Int J of Technology Management	2001	Factors influencing the implementation of environmental management system at Amica-Wronki SA
J of Cleaner Production	2002	Assessment of the potential of cleaner production implementation in Polish enterprises

J of Cleaner Production	2002	Awareness and adoption of cleaner production in small to medium-sized businesses in the Geelong region, Victoria, Australia
J of Environmental Management	2002	The influence of motivations for seeking ISO 14001 certification: an empirical study of ISO 14001 certified facilities in Hong Kong
Int J of Production Research	2003	Influence of the perception of the external environmental pressures on obtaining the ISO 14001 standard in Spanish industrial companies
Int J of Quality & Reliability Management	2003	Implementing ISO 14000 in Sweden: motives, benefits and comparisons with ISO 9000
J of Cleaner Production	2003	Promoting financing of cleaner production investments—UNEP experience
J of Cleaner Production	2003	Promotion of cleaner production investments: international experience
J of Cleaner Production	2003	Recent experiences and challenges in promoting cleaner production investments in developing countries
J of Cleaner Production	2004	Organisational factors determining the implementation of cleaner production measures in the corporate sector
J of Cleaner Production	2004	Outline of a national strategy for cleaner production: The case of Egypt
J of Cleaner Production	2004	A programmatic review of UNIDO/UNEP national cleaner production centres
J of Cleaner Production	2004	Institutional capacity building for pollution prevention centres in Central and Eastern Europe with special reference to Lithuania
J of Cleaner Production	2005	Policy and operational constraints for the implementation of cleaner production in Zambia
J of Cleaner Production	2005	Cleaner production in Iran: necessities and priorities
J of Cleaner Production	2005	Sustainable Production Programme in Setúbal Region (PROSSET)—final results
J of Cleaner Production	2006	Beyond barriers: examining root causes behind commonly cited Cleaner Production barriers in Vietnam
J of Cleaner Production	2006	Encouraging industry to assess and implement cleaner production measures
J of Cleaner Production	2006	National program for cleaner production (CP) in Iran: a framework and draft
J of Cleaner Production	2006	Limitations of cleaner production programmes as organisational change agents I. Achieving commitment and on-going improvement
J of Cleaner Production	2006	Limitations of cleaner production programmes as organisational change agents. II. Leadership, support, communication, involvement and programme design
J of Cleaner Production	2008	Barriers to the implementation of cleaner production in Chinese SMEs: government, industry and expert stakeholders' perspectives

J of Cleaner Production	2008	The evolution of the ENERGY STAR® energy performance indicator for benchmarking industrial plant manufacturing energy use
J of Cleaner Production	2008	Drivers for and barriers to environmentally sound technology adoption by manufacturing plants in nine developing countries
J of Cleaner Production	2008	ISO 14001 certification in Brazil: motivations and benefits
Int J of Sustainable Engineering	2009	Barriers, drivers and challenges for sustainable product recovery and recycling
J of Environmental Management	2010	Evolution and diversification of National Cleaner Production Centres (NCPCs)
Int J of Advanced Manufacturing Technology	2010	Handling WEEE waste flows: on the effectiveness of producer responsibility in a globalizing world
Int J of Operations and Production Management	2011	Do drivers matter for the benefits of ISO 14001?
J of Business Logistics	2011	Transaction Cost and Institutional Drivers of Supplier Adoption of Environmental Practices

Network

J of Cleaner Production	1999	How social networks influence the dissemination of cleaner technologies to SMEs
Int J of Operations and Production Management	2000	Suppliers and environmental innovation: The automotive paint process
IEEE Transactions on Engineering Management	2001	Social networks and the implementation of environmental technology
Supply Chain Management: An Int J	2005	Use the supply relationship to develop lean and green suppliers
Int J of Production Research	2006	Employing dynamic fuzzy membership functions to assess environmental performance in the supplier selection process
Int J of Production Research	2007	Towards sustainable production networks
J of Cleaner Production	2008	Improving sustainability through effective reuse of product returns: minimizing waste in a batch blending process environment
Int J of Production Research	2009	Supply chain networks with corporate social responsibility through integrated environmental decision-making
J of Cleaner Production	2011	Diffusion of ISO 14001 EM systems in China: rethinking on stakeholders' roles

Industrial Ecology

Business Strategy and the Environment	2000	Industrial ecology and regionalization of economic governance: an opportunity to 'localize' sustainability?
Business Strategy and the Environment	2001	Changing economies of scale – synergies between implementation of an ecological tax reform and development of industrial ecosystems
Business Strategy and the Environment	2003	Planning eco-industrial parks: an analysis of Dutch planning methods
Business Strategy and the Environment	2004	Eco-industrial development and economic development: industrial ecology or place promotion?
J of Cleaner Production	2004	Experiences from early stages of a national industrial symbiosis programme in the UK: determinants and coordination challenges
J of Cleaner Production	2004	Eco-industrial park initiatives in the USA and the Netherlands: first lessons
J of Cleaner Production	2004	Applying ecosystem concepts to the planning of industrial areas: a case study of Singapore's Jurong Island
J of Cleaner Production	2004	The industrial region as a promising unit for eco-industrial development—reflections, practical experience and establishment of innovative instruments to support industrial ecology
J of Cleaner Production	2004	Industrial ecology in the strategic sustainable development model: strategic applications of industrial ecology
J of Cleaner Production	2005	Industrial symbiosis networks and the contribution to environmental innovation: The case of the Landskrona industrial symbiosis programme
Business Strategy and the Environment	2007	Developing integration in a local industrial ecosystem – an explorative approach
J of Cleaner Production	2007	Reflections on implementing industrial ecology through eco-industrial park development
J of Environmental Management	2007	Industrial sustainability in China: Practice and prospects for eco-industrial development
J of Cleaner Production	2008	Physical principles and simulations on the structural evolution of eco-industrial systems
J of Environmental Management	2008	Strategies for sustainable development of industrial park in Ulsan, South Korea—From spontaneous evolution to systematic expansion of industrial symbiosis
J of Cleaner Production	2009	Game theory approach to the analysis of inter-plant water integration in an eco-industrial park
J of Cleaner Production	2009	The conceptual model of an eco-industrial park based upon ecological relationships
J of Cleaner Production	2009	Eco-industrial park development in Rio de Janeiro, Brazil: a tool for sustainable development

J of Cleaner Production	2009	Industrial ecosystems as technological niches
J of Cleaner Production	2010	A case study of industrial symbiosis development using a middle-out approach
J of Cleaner Production	2010	Waste management policies for industrial symbiosis development: case studies in European countries
J of Cleaner Production	2010	Developing country experience with eco-industrial parks: a case study of the Tianjin Economic-Technological Development Area in China
J of Cleaner Production	2010	Eco-industrial parks: national pilot practices in China
Business Strategy and the Environment	2011	The role of Embeddedness in Industrial Symbiosis Networks: Phases in the Evolution of Industrial Symbiosis Networks
Business Strategy and the Environment	2011	Assessing collective firm behavior: comparing industrial symbiosis with possible alternatives for individual companies in Oahu, HI
J of Cleaner Production	2011	The dynamics of industrial symbiosis: a proposal for a conceptual framework based upon a comprehensive literature review
J of Cleaner Production	2011	Industrial symbiosis and the policy instruments of sustainable consumption and production
J of Cleaner Production	2011	Critical success and limiting factors for eco-industrial parks: global trends and Egyptian context

Management

Environmental Management Systems

Production Planning and Control	2000	Manufacturing management strategies for environmental protection: Toward the environmental upgrading of management and manufacturing systems to cope with environmental laws
Production and Operations Management	2001	PLANT-LEVEL ENVIRONMENTAL MANAGEMENT ORIENTATION: THE INFLUENCE OF MANAGEMENT VIEWS AND PLANT CHARACTERISTICS
Production and Operations Management	2001	COMPARING THE ENVIRONMENTAL AND QUALITY INITIATIVES OF BALDRIGE AWARD WINNERS
Int J of Operations and Production Management	2001	Sustainability, greenhouse gas emissions and international operations management
Int J of Operations and Production Management	2001	Achieving sustainability through attention to human resource factors in environmental management

Business Strategy and the Environment	2001	Environmental commitment and manufacturing excellence: a comparative study within Canadian industry
Int J of Technology Management	2001	Factors influencing the implementation of environmental management system at Amica-Wronki SA
Production and Operations Management	2001	STAKEHOLDERS AND COMPETITIVE ADVANTAGE: THE CASE OF ISO 14001
Production Planning and Control	2002	Implications of environmental management for operations management
Int J of Operations and Production Management	2003	A new approach to the valuation of production investments with environmental effects
J of Cleaner Production	2003	The use of Environmental Management Accounting (EMA) for identifying environmental costs
Benchmarking: An Int J	2003	Environmental management systems for internal corporate environmental benchmarking
Business Strategy and the Environment	2004	Environmental management and strategic positioning of Spanish manufacturing industries
Production and Operations Management	2005	Sustainable Operations Management
J of Cleaner Production	2005	Towards implementation of ISO 14001 environmental management systems in selected industries in China
Business Strategy and the Environment	2006	Environmental considerations within manufacturing strategy: an international study
J of Cleaner Production	2007	Improving cleaner production through the application of EM tools in China
J of Cleaner Production	2007	The diffusion of environmental management in Greece through rationalist approaches: driver or product of globalisation?
Int J of Production Economics	2008	Environmental management and manufacturing performance: The role of collaboration in the supply chain
Int J of Operations and Production Management	2008	Environmental management system certification and its influence on corporate practices: Evidence from the automotive industry
Int J of Production Research	2008	The effect of manufacturing pro-activity on environmental management: an exploratory analysis
Integrated Manufacturing Systems	2008	Integrated production machines and systems – beyond lean manufacturing
IEEE Transactions on Engineering Management	2008	Assessing the Core Resources in the Environmental Management System From the Resource Perspective and the Contingency Perspective
J of Cleaner Production	2008	Environmental impact evaluation using a cooperative model for implementing EMS (ISO 14001) in

		small and medium-sized enterprises
J of Cleaner Production	2010	Alternative models for environmental management in SMEs: the case of Ekoscan vs. ISO 14001
Int J of Production Economics	2010	Mediated effect of environmental management on manufacturing competitiveness: An empirical study
J of Environmental Management	2010	Environmental management intentions: An empirical investigation of Argentina's polluting firms
Int J of Production Economics	2011	Impact of lean manufacturing and environmental management on business performance: An empirical study of manufacturing firms
Int J of Life Cycle Assessment	2011	Environmental life cycle assessment (LCA) as a tool for identification and assessment of environmental aspects in environmental management systems (EMS) Part 2: case studies
Int J of Life Cycle Assessment	2011	Environmental life cycle assessment as a tool for identification and assessment of environmental aspects in environmental management systems (EMS) part 1: methodology

Performances

Int J of Business Performance Management	1999	'Green" performance measurement
Int J of Operations and Production Management	2000	Lean production and sustainable competitive advantage
J of Cleaner Production	2000	Development of environmental performance indicators for textile process and product
J of Cleaner Production	2000	Cleaner Production and Environmental Impact Assessment: a UK perspective
J of Cleaner Production	2001	Eco-efficiency gains from remanufacturing: A case study of photocopier remanufacturing at Fuji Xerox Australia
Production and Operations Management	2001	LEAN, GREEN, AND THE QUEST FOR SUPERIOR ENVIRONMENTAL PERFORMANCE
Production and Operations Management	2001	LEAN AND GREEN? AN EMPIRICAL EXAMINATION OF THE RELATIONSHIP BETWEEN LEAN PRODUCTION AND ENVIRONMENTAL PERFORMANCE
Int J of Operations and Production Management	2001	Environmental performance as an operations objective
Int J of Business Performance Management	2001	Environmental performance measurement in business: current practice and future trends
J of Cleaner Production	2001	Indicators of sustainable production: framework and methodology

J of Cleaner Production	2001	Indicators of sustainable production
Int J of Production Research	2002	Environmental impact assessment in an uncertain environment
Integrated Manufacturing Systems	2002	A model for evaluating the degree of leanness of manufacturing firms
J of Cleaner Production	2003	A method for evaluating the overall technical and economic performance of environmental innovations in production cycles
J of Cleaner Production	2003	A method for evaluating the overall technical and economic performance of environmental innovations in production cycles
J of Cleaner Production	2003	Managing the environmental performance of production facilities in the electronics industry: more than application of the concept of cleaner production
J of Cleaner Production	2003	A multiple-criteria environmental impact assessment for the plastic injection molding process: a methodology
Production and Operations Management	2003	ENVIRONMENTAL PERFORMANCE AS A DRIVER OF SUPERIOR QUALITY
Int J of Production Research	2003	Environmental effects of physical life span of a reusable unit following functional and physical failures in a remanufacturing system
Int J of Production Research	2003	Hierarchical environmental impact evaluation of a process in printed circuit board manufacturing
J of Cleaner Production	2004	Measurement of green productivity and its improvement
J of Cleaner Production	2005	The impact of environmental regulation on competitiveness in the German manufacturing industry—a comparison with other countries of the European Union
J of Cleaner Production	2005	Cleaner production and profitability: analysis of 134 industrial pollution prevention (P2) project reports
J of Cleaner Production	2005	Assessing the sustainability performances of industries
J of Cleaner Production	2005	An environmental performance resource impact indicator for life cycle management in the manufacturing industry
J of Cleaner Production	2005	Cleaner production and sustainability
J of Cleaner Production	2005	Assessing the sustainability performances of industries
J of Cleaner Production	2005	Environmental management accounting applications and eco-efficiency: Case studies from Japan
J of Cleaner Production	2005	Environmental aspects when manufacturing products mainly out of metals and/or polymers
Benchmarking: An Int J	2005	Lessons from benchmarking environmental performance at automobile assembly plants
IEEE Transactions on	2006	Standardization and Discretion: Does the Environmental Standard ISO 14001 Lead to Performance

Engineering Management		Benefits?
J of Productivity Analysis	2006	The cost implications of waste reduction: factor demand, competitiveness and policy implications
J of Cleaner Production	2006	Eco-efficiency and SMEs in Nova Scotia, Canada
J of Cleaner Production	2006	Regional eco-efficiency indicators e a participatory approach
J of Cleaner Production	2006	The evaluation of Cleaner Production performance in Lithuanian industries
Business Strategy and the Environment	2006	Corporate environmental performance evaluation: a measurement model and a new concept
Int J of Productivity and Performance Management	2006	Green productivity indexing: A practical step towards integrating environmental protection into corporate performance
Int J of Productivity and Performance Management	2006	Application of constrained management and lean manufacturing in developing best practices for productivity improvement in an auto-assembly plant
Int J of Production Research	2006	A new approach to environmental-performance evaluation
J of Operations Management	2007	Competitive strategy in remanufacturing and the impact of take-back laws
IEEE Transactions on Engineering Management	2007	Green Manufacturing: An Evaluation of Environmentally Sustainable Manufacturing Practices and Their Impact on Competitive Outcomes
J of Cleaner Production	2007	Eco-efficiency and ecodesign in electrical and electronic products
J of Cleaner Production	2007	EU COST Action 628: life cycle assessment (LCA) of textile products, eco-efficiency and definition of best available technology (BAT) of textile processing
J of Cleaner Production	2007	Cleaner production and eco-efficiency initiatives in Western Australia 1996–2004
J of Cleaner Production	2007	Material flows and environmental impacts of manufacturing systems via aggregated input–output models
J of Cleaner Production	2007	An environmental assessment method for cleaner production technologies
J of Cleaner Production	2007	Sustainability Victoria: influencing resource use, towards zero waste and sustainable production and consumption
J of Cleaner Production	2007	Assessment of cleaner production uptake: method development and trial with small businesses in Western Australia
J of Cleaner Production	2007	Using structural equation modeling to test environmental performance in small and medium-sized manufacturers: can SEM help SMEs?
Integrated Manufacturing Systems	2007	Operations and maintenance performance in production and manufacturing assets: The sustainability perspective
Int J of Life Cycle Assessment	2007	Eco-efficiency

		Combining life cycle assessment and life cycle costs via normalization
Int J of Sustainable Engineering	2008	Ecological and economical assessment of end-of-life waste recycling in the electrical and electronic recovery sector
Benchmarking: An Int J	2008	A study on the ISO 14000 certification and organizational performance of Indian manufacturing firms
J of Operations Management	2008	Defining and developing measures of lean production
Int J of Production Economics	2008	Environmental management and manufacturing performance: The role of collaboration in the supply chain
J of Cleaner Production	2008	Environmental evaluation of localising production as a strategy for sustainable development: a case study of two consumer goods in Jamaica
J of Productivity Analysis	2008	Environmental regulation and productivity: testing the porter hypothesis
J of Environmental Management	2008	Environmental performance indicators: An empirical study of Canadian manufacturing firms
Int J of Productivity and Performance Management	2008	Green productivity: moving the agenda
J of Environmental Management	2009	The whole relationship between environmental variables and firm performance: Competitive advantage and firm resources as mediator variables
Int J of Operations and Production Management	2009	Lean manufacturing, non-financial performance measures, and financial performance
Int J of Production Research	2009	Treatment and recycling system optimisation with activity-based costing in WEEE reverse logistics management: an environmental supply chain perspective
Computers & Industrial Engineering	2009	Evaluating firm's sustainable production indicators in uncertainty
J of Environmental Management	2009	The whole relationship between environmental variables and firm performance: Competitive advantage and firm resources as mediator variables
J of Operations Management	2009	Reconceptualizing the effects of lean on production costs with evidence from the F-22 program
Production and Operations Management	2009	How Plant Managers' Experiences and Attitudes Toward Sustainability Relate to Operational Performance
Int J of Operations and Production Management	2009	Lean manufacturing, non-financial performance measures, and financial performance
Int J of Operations and Production Management	2009	Lean and agile manufacturing: external and internal drivers and performance outcomes
Business Strategy and the	2009	Explaining the impact of ISO 14001 on emission performance: a dynamic capabilities perspective

Environment		on process and learning
Int J of Production Economics	2010	Mediated effect of environmental management on manufacturing competitiveness: An empirical study
J of Cleaner Production	2010	Impact of cleaner production on business performance
J of Cleaner Production	2010	Eco-efficiency in the SMEs of Venezuela. Current status and future perspectives
J of Cleaner Production	2010	Environmental assessment of laser assisted manufacturing: case studies on laser shock peening and laser assisted turning
J of Cleaner Production	2010	Improvement of agility and sustainability: A case study in an Indian rotary switches manufacturing organisation
Integrated Manufacturing Systems	2010	Impact of lean strategy on operational performance: a study of Thai manufacturing companies
J of Cleaner Production	2010	Eco-efficiency trends of the Flemish industry: decoupling of environmental impact from economic growth
Production Planning and Control	2011	Eco-efficiency for sustainable manufacturing: an extended environmental costing method
Int J of Production Economics	2011	Impact of lean manufacturing and environmental management on business performance: An empirical study of manufacturing firms
Int J of Production Economics	2011	Impact of lean manufacturing and environmental management on business performance: An empirical study of manufacturing firms
J of Cleaner Production	2011	ISO 14001 certification and financial performance: selection-effect versus treatment-effect
J of Cleaner Production	2011	Environmental assessment of green hardboard production coupled with a laccase activated system
Computers & Industrial Engineering	2011	The Operations-Time Chart: A graphical tool to evaluate the performance of production systems – From batch-and-queue to lean manufacturing
Materials and Manufacturing Processes	2011	Economic and Environmental Criteria and Trade-Offs for Recovery Processes
Int J of Advanced Manufacturing Technology	2011	Development of an environmental performance assessment method for manufacturing process plans

Operations

Input

Raw Material

J of Cleaner Production	2003	Reduction in resource consumption by process modifications in cotton wet processes
J of Cleaner Production	2004	Partitioning of resources in production: an empirical analysis
J of Cleaner Production	2007	Sustainability Victoria: influencing resource use, towards zero waste and sustainable production and consumption
Int J of Production Research	2007	The use of recycled materials in manufacturing: implications for supply chain management and operations strategy
J of Cleaner Production	2008	Environmental evaluation of localising production as a strategy for sustainable development: a case study of two consumer goods in Jamaica
J of Cleaner Production	2008	Life cycle engineering methodology applied to material selection, a fender case study
Proceedings of the Institution of Mechanical Engineers, Part B: J of Engineering Manufacture	2009	Zero carbon manufacturing facility — towards integrating material, energy, and waste process flows

Energy

J of Cleaner Production	2003	Reduction in resource consumption by process modifications in cotton wet processes
Production and Operations Management	2003	HAZARDOUS WASTE DISPOSAL: A WASTE-FUEL BLENDING APPROACH
J of Cleaner Production	2004	Partitioning of resources in production: an empirical analysis
Int J of Production Research	2007	Operational methods for minimization of energy consumption of manufacturing equipment
J of Cleaner Production	2008	The evolution of the ENERGY STAR® energy performance indicator for benchmarking industrial plant manufacturing energy use
Proceedings of the Institution of Mechanical Engineers, Part B: J	2009	Zero carbon manufacturing facility — towards integrating material, energy, and waste process flows

of Engineering Manufacture		
J of Cleaner Production	2010	Development of alternative energy sources for GHG emissions reduction in the textile industry by energy recovery from cotton ginning waste
Proceedings of the Institution of Mechanical Engineers, Part B: J of Engineering Manufacture	2010	Methodology for adapting metal cutting to a green economy
J of Cleaner Production	2010	Cleaner production alternatives: Biomass utilisation options
J of Cleaner Production	2011	Integrating energy efficiency performance in production management – gap analysis between industrial needs and scientific literature
J of Cleaner Production	2011	Evaluating the use phase energy requirements of a machine tool system

Equipments

Proceedings of the Institution of Mechanical Engineers, Part B: J of Engineering Manufacture	1999	Environmentally clean metal cutting processes—machining on the way to dry cutting
Int J of Production Research	2003	Classification scheme for lean manufacturing tools
Machining Science and Technology	2006	EXAMINING THE ROLE OF CUTTING FLUIDS IN MACHINING AND EFFORTS TO ADDRESS ASSOCIATED ENVIRONMENTAL/HEALTH CONCERNS
Machining Science and Technology	2006	ENVIRONMENTALLY CONSCIOUS MACHINING AND GRINDING WITH CRYOGENIC COOLING
Materials and Manufacturing Processes	2006	Environmentally Friendly Precision Machining
Machining Science and Technology	2006	LUBRICATION MECHANISMS OF LN2 IN ECOLOGICAL CRYOGENIC MACHINING
J of Cleaner Production	2007	Environmental aspects of laser-based and conventional tool and die manufacturing
J of Cleaner Production	2007	Micro-flood (MF) technology for sustainable manufacturing operations that are coolant less and occupationally friendly
Int J of Production Research	2007	Operational methods for minimization of energy consumption of manufacturing equipment
Int J of Production Research	2007	Preventive maintenance of manufacturing systems under environmental constraints

Int J of Machine Tools and Manufacture	2008	A comprehensive tool-wear/tool-life performance model in the evaluation of NDM (near dry machining) for sustainable manufacturing
J of Cleaner Production	2010	Transitioning to sustainable production – part II: evaluation of sustainable machining technologies
J of Cleaner Production	2010	Macro-level environmental comparison of near-dry machining and flood machining
J of Cleaner Production	2010	Sustainable machining: selection of optimum turning conditions based on minimum energy considerations
J of Cleaner Production	2010	Transitioning to sustainable production – Part I: application on machining technologies
Integrated Manufacturing Systems	2010	A technology enabler for green machining: minimum quantity lubrication (MQL)
Proceedings of the Institution of Mechanical Engineers, Part B: J of Engineering Manufacture	2010	Methodology for adapting metal cutting to a green economy
J of Cleaner Production	2011	Evaluating the use phase energy requirements of a machine tool system
J of Cleaner Production	2011	Green renewal: incorporating environmental factors in equipment replacement decisions under technological change
European J of Industrial Engineering	2011	A framework for assessing the cost effectiveness of lean tools
Int J of Advanced Manufacturing Technology	2011	A multi-criteria decision method for sustainability assessment of the use phase of machine tool systems
J of Cleaner Production	2011	Eco-friendly dyeing of wool using natural dye from weld as co-partner with synthetic dye

Employee

Int J of Operations and Production Management	2000	Linking operational and environmental improvement through employee involvement
Int J of Operations and Production Management	2001	Achieving sustainability through attention to human resource factors in environmental management
J of Cleaner Production	2002	The quantitative and qualitative impacts of clean technologies on employment
Int J of Operations and Production Management	2004	Innovation and hybridization: Managing the introduction of lean production into Volvo do Brazil

J of Cleaner Production	2005	Cleaner production and sustainability
J of Operations Management	2006	Could lean production job design be intrinsically motivating? Contextual, configurational, and levels-of-analysis issues
Int J of Operations and Production Management	2006	The effects of lean production on worker job stress
IEEE Transactions on Engineering Management	2006	Standardization and Discretion: Does the Environmental Standard ISO 14001 Lead to Performance Benefits?
Int J of Operations and Production Management	2006	The effects of lean production on worker job stress
Production and Operations Management	2009	How Plant Managers' Experiences and Attitudes Toward Sustainability Relate to Operational Performance
J of Cleaner Production	2011	Primary prevention for worker health and safety: cleaner production and toxics use reduction in Massachusetts

Technology

Int J of Operations and Production Management	2000	Exploring the linkage between investment in manufacturing and environmental technologies
Integrated Manufacturing Systems	2001	Environmental information systems based on enterprise resource planning
Proceedings of the Institution of Mechanical Engineers, Part B: J of Engineering Manufacture	2001	Computer-based product structure analysis for technical goods regarding optimal end-of-life strategies
J of Cleaner Production	2003	Sustainable production and consumption systems—cooperation for change: assessing and simulating the willingness of the firm to adopt/develop cleaner technologies. The case of the In-Bond industry in northern Mexico
Proceedings of the Institution of Mechanical Engineers, Part B: J of Engineering Manufacture	2003	Development of a method for calculating the environmentally optimum lifespan of electrical household products
Business Strategy and the Environment	2006	Environmental technical and administrative innovations in the Canadian manufacturing industry

Proceedings of the Institution of Mechanical Engineers, Part B: J of Engineering Manufacture	2006	A web-based information system to support end-of-life product recovery
J of Cleaner Production	2007	EU COST Action 628: life cycle assessment (LCA) of textile products, eco-efficiency and definition of best available technology (BAT) of textile processing
J of Cleaner Production	2007	Environmental technologies – from misleading interpretations to an operational categorisation & definition
J of Cleaner Production	2007	An environmental assessment method for cleaner production technologies
J of Cleaner Production	2008	General wisdom concerning the factors affecting the adoption of cleaner technologies: a survey 1990–2007
J of Cleaner Production	2008	The diffusion of clean technologies: a review with suggestions for future diffusion analysis
J of Cleaner Production	2008	Drivers for and barriers to environmentally sound technology adoption by manufacturing plants in nine developing countries
J of Cleaner Production	2008	Polluting emissions standards and clean technology trajectories under competitive selection and supply chain pressure
J of Cleaner Production	2008	European environmental technologies action plan (ETAP)
Int J of Technology Management	2008	The environmental sustainability of information systems: considering the impact of operational strategies and practices
Proceedings of the Institution of Mechanical Engineers, Part B: J of Engineering Manufacture	2008	Evaluation of environmentally conscious manufacturing programs using multiple attribute decision-making methods
J of Cleaner Production	2008	Multi-state initiative to enhance pollution prevention technology diffusion using the ADOP2T model
Integrated Manufacturing Systems	2010	Green technology and eco-innovation: Seven case-studies from a Russian manufacturing context

Planning

J of Manufacturing Systems	2002	Disassembly modeling, planning, and application
Int J of Production Research	2007	Integrated environmental process planning for the design and manufacture of automotive

		components
Proceedings of the Institution of Mechanical Engineers, Part B: J of Engineering Manufacture	2007	Computer-aided recycling process planning for end-of-life electrical and electronic equipment
Int J of Advanced Manufacturing Technology	2007	Research on the diagnosis and improvement method of a process route in an enterprise production process in terms of sustainable development III
Int J of Production Research	2001	Green MRP: identifying the material and environmental impacts of production schedules
Integrated Manufacturing Systems	2001	Environmental information systems based on enterprise resource planning
Proceedings of the Institution of Mechanical Engineers, Part B: J of Engineering Manufacture	2001	Disassembly planning and scheduling: Review and further research
Production and Operations Management	2001	MATERIAL PLANNING FOR A REMANUFACTURING FACILITY
Int J of Advanced Manufacturing Technology	2007	Research on the diagnosis and improvement method of a process route in an enterprise production process in terms of sustainable development III
Proceedings of the Institution of Mechanical Engineers, Part B: J of Engineering Manufacture	2008	The effect of ordering policies for a manufacturing cell changing to lean production
J of Cleaner Production	2010	Conserving water by optimizing production schedules in the dyeing industry
Int J of Production Economics	1999	Concepts and methods for a production integrated environmental protection
Int J of Production Economics	1999	Production strategies under environmental constraints in an Arrow–Karlin model
Int J of Production Economics	2001	Production strategies under environmental constraints: Continuous-time model with concave costs
J of Cleaner Production	2004	Environmental optimisation of a hydro-moulding process
J of Cleaner Production	2005	Modelling manufacturing evolution: thoughts on sustainable industrial development
Int J of Production Economics	2005	The effects of emission trading on production and inventories in the Arrow–Karlin model
J of Cleaner Production	2006	Multi-objective modeling and optimization for cleaner production processes
J of Cleaner Production	2007	Using structural equation modeling to test environmental performance in small and medium-sized manufacturers: can SEM help SMEs?
Int J of Production Economics	2007	Tradable permits and production-inventory strategies of the firm
Computers & Industrial	2009	A production–inventory model with remanufacturing for defective and usable items in fuzzy-

Engineering		environment
Computers & Industrial Engineering	2010	A production/remanufacturing inventory model with price and quality dependant return rate
Int J of Computer Integrated Manufacturing	2010	Green-product-design value and information-technology investment on replenishment model with remanufacturing
Int J of Production Economics	2011	Short life-cycle deteriorating product remanufacturing in a green supply chain inventory control system

Lean Manufacturing

Int J of Operations and Production Management	2000	Lean production and sustainable competitive advantage
Production and Operations Management	2001	LEAN, GREEN, AND THE QUEST FOR SUPERIOR ENVIRONMENTAL PERFORMANCE
Production and Operations Management	2001	LEAN AND GREEN? AN EMPIRICAL EXAMINATION OF THE RELATIONSHIP BETWEEN LEAN PRODUCTION AND ENVIRONMENTAL PERFORMANCE
Int J of Operations and Production Management	2001	Lean indicators and manufacturing strategies
Int J of Operations and Production Management	2002	Is “lean” a universal production system?: Batch production in the automotive industry
Integrated Manufacturing Systems	2002	A model for evaluating the degree of leanness of manufacturing firms
J of Operations Management	2003	Lean manufacturing: context, practice bundles, and performance
Int J of Operations and Production Management	2004	Innovation and hybridization: Managing the introduction of lean production into Volvo do Brazil
Manufacturing and Service Operations Management	2004	To Pull or Not to Pull: What Is the Question?
Int J of Production Research	2005	Kaizen costing for lean manufacturing: a case study
J of Manufacturing Systems	2005	A review of lean assessment in organizations: An exploratory study of lean practices by electronics manufacturers

J of Operations Management	2006	Could lean production job design be intrinsically motivating? Contextual, configurational, and levels-of-analysis issues
Int J of Productivity and Performance Management	2006	Application of constrained management and lean manufacturing in developing best practices for productivity improvement in an auto-assembly plant
Manufacturing and Service Operations Management	2006	Extending the Horizons: Environmental Excellence as Key to Improving Operations
Int J of Production Research	2007	Lean tool selection in a die casting unit: a fuzzy-based decision support heuristic
J of Operations Management	2007	The genealogy of lean production
Integrated Manufacturing Systems	2008	Integrated production machines and systems – beyond lean manufacturing
J of Operations Management	2008	Defining and developing measures of lean production
Int J of Production Research	2008	Optimal batch quantity models for a lean production system with in-cycle rework and scrap
Int J of Technology Management	2008	Analysis of efficiency of lean production implemented in multi-national optic enterprises
Int J of Operations and Production Management	2009	Lean manufacturing, non-financial performance measures, and financial performance
Int J of Operations and Production Management	2009	Lean and agile manufacturing: external and internal drivers and performance outcomes
Int J of Operations and Production Management	2009	Lean manufacturing, non-financial performance measures, and financial performance
Integrated Manufacturing Systems	2009	Selection of lean manufacturing systems using the analytic network process – a case study
Benchmarking: An Int J	2009	Application of benchmarking for assessing the lean manufacturing implementation
J of Operations Management	2009	Reconceptualizing the effects of lean on production costs with evidence from the F-22 program
Int J of Production Research	2010	A comparative study of lean and agile manufacturing with a related survey of current practices in the UK
Supply Chain Management: An Int J	2010	Lean competence: integration of theories in operations management practice
Int J of Production Economics	2011	Impact of lean manufacturing and environmental management on business performance: An empirical study of manufacturing firms
Production Planning and Control	2011	Adapting lean manufacturing principles to the textile industry
Int J of Production Research	2011	A framework for assessing the use of lean production practices in manufacturing cells

Integrated Manufacturing Systems	2011	The impact of lean operations on the Chinese manufacturing performance
Integrated Manufacturing Systems	2011	Design of lean manufacturing systems using value stream mapping with simulation: A case study

Green Manufacturing

J of Cleaner Production	1999	Issues for better implementation of cleaner production in Asian small and medium industries
Computers & Industrial Engineering	1999	Caught between ecology and economy: end-of-life aspects of environmentally conscious manufacturing
Computers & Industrial Engineering	1999	A methodological framework for evaluating environmentally conscious manufacturing programs
Computers & Industrial Engineering	1999	Issues in environmentally conscious manufacturing and product recovery: a survey
J of Cleaner Production	1999	Regulatory and self-regulatory measures as routes to promote cleaner production
J of Cleaner Production	1999	Cleaner production in New Zealand
IEEE Transactions on Engineering Management	2000	Investigating the linkage between total quality management and environmentally responsible manufacturing
J of Cleaner Production	2000	Cleaner Production and Environmental Impact Assessment: a UK perspective
J of Cleaner Production	2000	Cleaner production options for lead-acid battery manufacturing industry
Int J of Operations and Production Management	2001	Manufacturing's role in corporate environmental sustainability - Concerns for the new millennium
Int J of Sustainable Engineering	2001	From cleaner production and value management to sustainable value
J of Cleaner Production	2001	Lessons from cleaner production experiences in Indian hosiery clusters
Int J of Operations and Production Management	2004	Greening production: a South-East Asian experience
J of Cleaner Production	2004	From cleaner production to sustainable industrial production modes
J of Cleaner Production	2005	Environmentally benign manufacturing: Observations from Japan, Europe and the United States
Business Strategy and the Environment	2006	End-of-pipe or cleaner production? An empirical comparison of environmental innovation decisions across OECD countries

Int J of Quality & Reliability Management	2006	Determinants of environmentally responsible operations: a review
J of Cleaner Production	2006	Multi-objective modeling and optimization for cleaner production processes
J of Cleaner Production	2006	Environmentally benign manufacturing – A workshop report
IEEE Transactions on Engineering Management	2007	Green Manufacturing: An Evaluation of Environmentally Sustainable Manufacturing Practices and Their Impact on Competitive Outcomes
J of Cleaner Production	2007	To make zero emissions technologies and strategies become a reality, the lessons learned of cleaner production dissemination have to be known
J of Cleaner Production	2007	The need for Clean Production and Product Re-design
J of Cleaner Production	2007	Cleaner production in New Zealand: taking stock
J of Cleaner Production	2007	Cleaner production and eco-efficiency initiatives in Western Australia 1996–2004
J of Cleaner Production	2007	Assessment of cleaner production uptake: method development and trial with small businesses in Western Australia
J of Cleaner Production	2007	Benchmarking to trigger cleaner production in small businesses: drycleaning case study
J of Cleaner Production	2007	Improving cleaner production through the application of Environmental Management tools in China
J of Cleaner Production	2008	Development of a sustainability policy model for promoting cleaner production: a knowledge integration approach
J of Cleaner Production	2008	Cleaner production practices in a medium size gold-plated jewelry company in Brazil: when little changes make the difference
J of Cleaner Production	2008	Barriers to the implementation of cleaner production in Chinese SMEs: government, industry and expert stakeholders' perspectives
J of Cleaner Production	2008	Cleaner production: an economical option for ISO certification in developing countries
J of Cleaner Production	2008	An empirical evaluation of cleaner production practices in Turkey
J of Cleaner Production	2008	Applying 3DCE to environmentally responsible manufacturing practices
Benchmarking: An Int J	2010	Green operations initiatives in the automotive industry: An environmental reports analysis and benchmarking study
J of Cleaner Production	2010	Regional initiatives on promoting cleaner production in China: a case of Liaoning
J of Cleaner Production	2010	Impact of cleaner production on business performance
J of Cleaner Production	2010	The theory of inventive problem solving (TRIZ) as option generation tool within cleaner production projects

J of Environmental Management	2010	Environmentally conscious manufacturing and product recovery (ECMPRO): A review of the state of the art
J of Cleaner Production	2011	A system model for green manufacturing

Sustainable Manufacturing

Int J of Production Economics	1999	Sustainable production – a new paradigm for a new millennium
Proceedings of the Institution of Mechanical Engineers, Part B: J of Engineering Manufacture	2001	Life cycle management and assessment: Approaches and visions towards sustainable manufacturing
J of Cleaner Production	2001	Indicators of sustainable production: framework and methodology
J of Cleaner Production	2001	Indicators of sustainable production
Int J of Production Research	2002	Global manufacturing and the sustainable economy
J of Cleaner Production	2003	Sustainable production and consumption systems—cooperation for change: assessing and simulating the willingness of the firm to adopt/develop cleaner technologies. The case of the In-Bond industry in northern Mexico
Int J of Production Research	2007	Towards sustainable production networks
J of Cleaner Production	2007	Sustainability Victoria: influencing resource use, towards zero waste and sustainable production and consumption
J of Cleaner Production	2007	Micro-flood (MF) technology for sustainable manufacturing operations that are coolant less and occupationally friendly
Int J of Sustainable Engineering	2008	A comparison of four sustainable manufacturing strategies
Int J of Machine Tools and Manufacture	2008	A comprehensive tool-wear/tool-life performance model in the evaluation of NDM (near dry machining) for sustainable manufacturing
Int J of Production Research	2010	Sustainable manufacturing: a case study of the forklift painting process
J of Cleaner Production	2010	Transitioning to sustainable production – part II: evaluation of sustainable machining technologies
J of Cleaner Production	2010	Transitioning to sustainable production – Part I: application on machining technologies
Production Planning and Control	2011	The emergence of sustainable manufacturing practices

Control

Inventory Control

Int J of Production Economics	1999	Production strategies under environmental constraints in an Arrow–Karlin model
Int J of Production Economics	2001	Production strategies under environmental constraints: Continuous-time model with concave costs
Int J of Production Economics	2005	The effects of emission trading on production and inventories in the Arrow–Karlin model
Int J of Production Economics	2007	Tradable permits and production-inventory strategies of the firm
Computers & Industrial Engineering	2009	A production–inventory model with remanufacturing for defective and usable items in fuzzy-environment
Computers & Industrial Engineering	2010	A production/remanufacturing inventory model with price and quality dependant return rate
Int J of Computer Integrated Manufacturing	2010	Green-product-design value and information-technology investment on replenishment model with remanufacturing
Int J of Production Economics	2011	Short life-cycle deteriorating product remanufacturing in a green supply chain inventory control system

Quality Control

Total Quality Management and Business Excellence	1999	Quality issues in lean production implementation: A case study of a French automotive supplier
IEEE Transactions on Engineering Management	2000	Investigating the linkage between total quality management and environmentally responsible manufacturing
Production and Operations Management	2001	COMPARING THE ENVIRONMENTAL AND QUALITY INITIATIVES OF BALDRIGE AWARD WINNERS
Business Strategy and the Environment	2001	Combating environmental repercussions through ‘TQEM’ and ‘ISO 14000’
Int J of Quality & Reliability Management	2001	Environmental managers and departments as driving forces of TQEM in Spanish industrial companies

Production and Operations Management	2003	ENVIRONMENTAL PERFORMANCE AS A DRIVER OF SUPERIOR QUALITY
Manufacturing and Service Operations Management	2006	Extending the Horizons: Environmental Excellence as Key to Improving Operations
Business Strategy and the Environment	2007	Measuring TQEM returns from the application of quality frameworks

Evaluation

Life Cycle Assessment

J of Cleaner Production	1999	A methodology for the life cycle and sustainability analysis of manufacturing processes
Proceedings of the Institution of Mechanical Engineers, Part B: J of Engineering Manufacture	2001	Life cycle management and assessment: Approaches and visions towards sustainable manufacturing
Proceedings of the Institution of Mechanical Engineers, Part B: J of Engineering Manufacture	2001	Economic and ecological aspects in product life cycle evaluation
Int J of Life Cycle Assessment	2007	LCA of global supply chains — from production through to end of life management LCA for the food chain in the region (Session 1) LCA for the waste chain in the region (Session 2)
J of Environmental Management	2009	Recent developments in Life Cycle Assessment
Int J of Life Cycle Assessment	2009	Application of life cycle assessment to the production of man-made crystal glass
J of Cleaner Production	2010	Options for broadening and deepening the LCA approaches
Int J of Production Research	2010	Sustainable manufacturing: a case study of the forklift painting process
Int J of Life Cycle Assessment	2010	Life cycle assessment of nine recovery methods for end-of-life tyres
Int J of Life Cycle Assessment	2010	Note on the critical review of the study “Life Cycle Assessment for the different used tyres recycling methods” prepared for Aliapur by Ecobilan
J of Cleaner Production	2011	Environmental analysis of the production of natural cork stoppers in southern Europe (Catalonia – Spain)
Int J of Life Cycle Assessment	2011	Environmental life cycle assessment (LCA) as a tool for identification and assessment of environmental aspects in environmental management systems (EMS)

		Part 2: case studies
Int J of Life Cycle Assessment	2011	Environmental life cycle assessment as a tool for identification and assessment of environmental aspects in environmental management systems (EMS) part 1: methodology

Output

Bad outputs

Production and Operations Management	2003	HAZARDOUS WASTE DISPOSAL: A WASTE-FUEL BLENDING APPROACH
J of Cleaner Production	2004	Partitioning of resources in production: an empirical analysis
J of Cleaner Production	2005	An effective technique for wastewater minimisation in batch processes
J of Cleaner Production	2005	Synthesis of maximum water recovery network for batch process systems
Int J of Operations and Production Management	2005	A model for the assessment of waste in job shop environments
J of Productivity Analysis	2006	The cost implications of waste reduction: factor demand, competitiveness and policy implications
Int J of Production Research	2007	A decision-making model for waste management in the footwear industry
Int J of Sustainable Engineering	2008	New chemical process waste treatment technologies for a sustainable printed circuit board manufacturing process
J of Cleaner Production	2008	Implementing sustainable laundering procedures for textiles in a commercial laundry and thus decreasing wastewater burden
J of Cleaner Production	2009	Wood waste management practices and strategies to increase sustainability standards in the Australian wooden furniture manufacturing sector
J of Environmental Management	2009	Producer responsibility for e-waste management: Key issues for consideration – Learning from the Swiss experience
Proceedings of the Institution of Mechanical Engineers, Part B: J of Engineering Manufacture	2009	Zero carbon manufacturing facility — towards integrating material, energy, and waste process flows
J of Cleaner Production	2010	Conserving water by optimizing production schedules in the dyeing industry

J of Cleaner Production	2010	Waste management policies for industrial symbiosis development: case studies in European countries
Int J of Advanced Manufacturing Technology	2010	Handling WEEE waste flows: on the effectiveness of producer responsibility in a globalizing world
J of Cleaner Production	2011	ISO 14001 and solid waste generation rates in US manufacturing organizations: an analysis of relationship
J of Cleaner Production	2011	Reusing wastewater of madder natural dye for wool dyeing
J of Cleaner Production	2008	The value of adding design-for-the-environment to pollution prevention assistance options
J of Cleaner Production	2005	Cleaner production and profitability: analysis of 134 industrial pollution prevention (P2) project reports
J of Cleaner Production	2008	Pollution prevention of cotton-cone reactive dyeing
J of Cleaner Production	2008	Multi-state initiative to enhance pollution prevention technology diffusion using the ADOP2T model
Int J of Operations and Production Management	2001	Sustainability, greenhouse gas emissions and international operations management
J of Cleaner Production	2005	Cleaner production as climate investment—integrated assessment in Taiyuan City, China
Int J of Production Economics	2005	The effects of emission trading on production and inventories in the Arrow–Karlin model
J of Cleaner Production	2007	To make zero emissions technologies and strategies become a reality, the lessons learned of cleaner production dissemination have to be known
J of Cleaner Production	2007	Practical experiences with the implementation of the concept of zero emissions in the surface treatment industry in Austria
J of Cleaner Production	2008	Polluting emissions standards and clean technology trajectories under competitive selection and supply chain pressure
Business Strategy and the Environment	2009	Explaining the impact of ISO 14001 on emission performance: a dynamic capabilities perspective on process and learning
J of Cleaner Production	2010	Development of alternative energy sources for GHG emissions reduction in the textile industry by energy recovery from cotton ginning waste
J of Cleaner Production	2011	The effect of ISO 14001 certification on toxic emissions: an analysis of industrial facilities in the north of Spain

End of Life Options

J of Operations Management	2007	Remaining life estimation of used components in consumer products: Life cycle data analysis by Weibull and artificial neural networks
Computers & Industrial Engineering	1999	Caught between ecology and economy: end-of-life aspects of environmentally conscious manufacturing
Computers & Industrial Engineering	1999	Issues in environmentally conscious manufacturing and product recovery: a survey
J of Manufacturing Systems	1999	Design charts for remanufacturing assessment
J of Manufacturing Systems	2000	A decision-making model for materials management of end-of-life electronic products
J of Cleaner Production	2001	Eco-efficiency gains from remanufacturing: A case study of photocopier remanufacturing at Fuji Xerox Australia
Int J of Production Research	2001	Configuration analysis to support product redesign for end-of-life disassembly
Integrated Manufacturing Systems	2001	Development of integrated design for disassembly and recycling in concurrent engineering
Proceedings of the Institution of Mechanical Engineers, Part B: J of Engineering Manufacture	2001	Computer-based product structure analysis for technical goods regarding optimal end-of-life strategies
Proceedings of the Institution of Mechanical Engineers, Part B: J of Engineering Manufacture	2001	Disassembly planning and scheduling: Review and further research
Int J of Advanced Manufacturing Technology	2001	A Multi-Objective Methodology for Evaluating Product End-of-Life Options and Disassembly
Production and Operations Management	2001	MANAGING PRODUCT RETURNS FOR REMANUFACTURING
IEEE Transactions on Engineering Management	2002	Incorporating component reuse, remanufacture, and recycle into product portfolio design
J of Manufacturing Systems	2002	Disassembly modeling, planning, and application
Int J of Production Research	2003	Quotes for environmentally weighted recyclability (QWERTY): concept of describing product recyclability in terms of environmental value
Int J of Production Research	2003	Environmental effects of physical life span of a reusable unit following functional and

		physical failures in a remanufacturing system
Proceedings of the Institution of Mechanical Engineers, Part B: J of Engineering Manufacture	2003	Development of a method for calculating the environmentally optimum lifespan of electrical household products
J of Cleaner Production	2003	Product recovery with some byte: an overview of management challenges and environmental consequences in reverse manufacturing for the computer industry
Production and Operations Management	2003	HAZARDOUS WASTE DISPOSAL: A WASTE-FUEL BLENDING APPROACH
J of Cleaner Production	2004	Recycling performance of firms before and after adoption of the ISO 14001 standard
J of Cleaner Production	2004	Third-party demanufacturing as a solution for extended producer responsibility
Int J of Production Research	2004	Car disassembly and ergonomics in Sweden: current situation and future perspectives in light of new environmental legislation
Int J of Production Research	2005	A bill of materials-based approach for end-of-life decision making in design for the environment
Int J of Production Research	2005	Integrated approach for disassembly processes generation and recycling evaluation of an end-of-life product
Proceedings of the Institution of Mechanical Engineers, Part B: J of Engineering Manufacture	2006	A web-based information system to support end-of-life product recovery
Proceedings of the Institution of Mechanical Engineers, Part B: J of Engineering Manufacture	2006	Innovative manufacturing technologies for the disassembly of consumer goods
Int J of Production Research	2007	A model of the operations concerned in remanufacture
Int J of Production Research	2007	Evaluation of product performance in product family design re-use
Int J of Production Research	2007	Development of robust design-for-remanufacturing guidelines to further the aims of sustainable development
Int J of Production Research	2007	Value flow characterization during product lifecycle to assist in recovery decisions
Int J of Production Research	2007	A multi-objective evolutionary algorithm for EOL product recovery optimization: turbocharger case study
Proceedings of the Institution of Mechanical Engineers, Part B: J of Engineering Manufacture	2007	Computer-aided recycling process planning for end-of-life electrical and electronic equipment

Computers & Industrial Engineering	2008	Optimal manufacturing–remanufacturing policies in a lean production environment
Int J of Sustainable Engineering	2008	Ecological and economical assessment of end-of-life waste recycling in the electrical and electronic recovery sector
J of Cleaner Production	2009	Wood waste management practices and strategies to increase sustainability standards in the Australian wooden furniture manufacturing sector
Int J of Sustainable Engineering	2009	Barriers, drivers and challenges for sustainable product recovery and recycling
Int J of Sustainable Engineering	2009	Addressing decision making for remanufacturing operations and design-for-remanufacture
Int J of Production Research	2009	Eco-architecture analysis for end-of-life decision making
Int J of Production Research	2009	Treatment and recycling system optimisation with activity-based costing in WEEE reverse logistics management: an environmental supply chain perspective
J of Cleaner Production	2009	Product life-cycle implications for remanufacturing strategies
J of Cleaner Production	2009	Material hygiene: improving recycling of WEEE demonstrated on dishwashers
Int J of Sustainable Engineering	2009	Review and future of active disassembly
J of Cleaner Production	2010	A hierarchical end-of-life decision model for determining the economic levels of remanufacturing and disassembly under environmental regulations
J of Cleaner Production	2010	Improved recycling with life cycle information tagged to the product
J of Cleaner Production	2010	Ecodesign methods focused on remanufacturing
Int J of Advanced Manufacturing Technology	2010	Environmental and economical sustainability of WEEE closed-loop supply chains with recycling: a system dynamics analysis
Int J of Production Research	2010	A machine learning approach to optimise the usage of recycled material in a remanufacturing environment
Int J of Computer Integrated Manufacturing	2010	Green-product-design value and information-technology investment on replenishment model with remanufacturing
J of Environmental Management	2010	Environmentally conscious manufacturing and product recovery (ECMPRO): A review of the state of the art
Int J of Production Economics	2011	Short life-cycle deteriorating product remanufacturing in a green supply chain inventory control system
J of Cleaner Production	2011	Implementing extended producer responsibility: vehicle remanufacturing in China
Int J of Operations and Production Management	2011	Drivers and obstacles of product recovery activities in the Greek industry

Appendix 4 List of the articles according to the dimensions

Name of the Journal	Publication year	Name of the authors	Name of the articles	ESET	Type of the article
J of Operations Management	2009	Tyson R. Browning, Ralph D. Heath	Reconceptualizing the effects of lean on production costs with evidence from the F-22 program	Economic	Research article
J of Operations Management	2007	Scott Webster, Supriya Mitra (November, 2007)	Competitive strategy in remanufacturing and the impact of take-back laws	Economic	Research article
J of Operations Management	2007	Matthias Holweg	The genealogy of lean production	Others	Research article
J of Operations Management	2007	M.I. Mazhar, S. Kara, H. Kaebernick (November, 2007)	Remaining life estimation of used components in consumer products: Life cycle data analysis by Weibull and artificial neural networks	Environmental	Research article
J of Operations Management	2007	Rachna Shah, Peter T. Ward (June, 2007)	Defining and developing measures of lean production	Others	Empirical study
J of Operations Management	2006	Suzanne de Treville, John Antonakis	Could lean production job design be intrinsically motivating? Contextual, configurational, and levels-of-analysis issues	Social	Research article
J of Operations Management	2003	Rachna Shah, Peter T. Ward	Lean manufacturing: context, practice bundles, and performance	Others	Empirical study
Int J of Production Economics	2011	Baris Yalabik, Richard J. Fairchild (June, 2011)	Customer, regulatory, and competitive pressure as drivers of environmental innovation	Environmental, Economic	Methodology

Int J of Production Economics	2011	Ma Ga (Mark) Yang, Paul Hong, Sachin B. Mod (February, 2011)	Impact of lean manufacturing and environmental management on business performance: An empirical study of manufacturing firms	Environmental	Empirical study
Int J of Production Economics	2010	Chen-Lung Yang, Shu-Ping Lin, Ya-hui Chan, Chwen Sheu (January, 2010)	Mediated effect of environmental management on manufacturing competitiveness: An empirical study	Environmental, Economic	Empirical study
Int J of Production Economics	2011	Chun-Jen Chung, Hui-Ming Wee (January, 2011)	Short life-cycle deteriorating product remanufacturing in a green supply chain inventory control system	Environmental	Research article
Int J of Production Economics	2008	Javier González-Benito, Óscar González-Benito (May, 2008)	Operations management practices linked to the adoption of ISO 14001: An empirical analysis of Spanish manufacturers	Environmental	Empirical study
Int J of Production Economics	2008	Stephan Vachon, Robert D. Klassen (February, 2008)	Environmental management and manufacturing performance: The role of collaboration in the supply chain	Environmental	Research article
Int J of Production Economics	2007	Imre Dobos (July, 2007)	Tradable permits and production-inventory strategies of the firm	Environmental, Economic	Research article
Int J of Production Economics	2005	Imre Dobos (January, 2005)	The effects of emission trading on production and inventories in the Arrow–Karlin model	Environmental, Economic	Research article
Int J of Production Economics	2001	Imre Dobos (May, 2001)	Production strategies under environmental constraints: Continuous-time model with concave costs	Environmental, Economic	Research article
Int J of Production Economics	1999	Christopher O'Brien (April, 1999)	Sustainable production – a new paradigm for a new millennium	Environmental, Economic	Research article
Int J of Production Economics	1999	H.-J Bullinger, J.von Steinaecker, A Weller (April, 1999)	Concepts and methods for a production integrated environmental protection	Environmental, Economic	Methodology
Int J of Production Economics	1999	Imre Dobos (March, 1999)	Production strategies under environmental constraints in an Arrow–	Environmental	Research article

				Karlin model		
Production and Operations Management		2009	Mark Pagell and David Gobeli (May/June, 2009)	How Plant Managers' Experiences and Attitudes Toward Sustainability Relate to Operational Performance	Environmental, Economic, Social	Research article
Production and Operations Management		2005	Paul R. Kleindorfer, Kalyan Singhal and Luk N. Van Wassenhove (December, 2005)	Sustainable Operations Management	Environmental, Economic, Social	Research article
Production and Operations Management		2003	A. DALE FLOWERS, KEVIN LINDERMAN (September, 2003)	HAZARDOUS WASTE DISPOSAL: A WASTE-FUEL BLENDING APPROACH (pages 307–319)	Environmental	Case study
Production and Operations Management		2003	ROBERT SROUFE (September, 2003)	ENVIRONMENTAL PERFORMANCE AS A DRIVER OF SUPERIOR QUALITY	Environmental	Research article
Production and Operations Management		2001	SANDRA ROTHENBERG, FRITS K. PIL and JAMES MAXWELL (September, 2001)	LEAN, GREEN, AND THE QUEST FOR SUPERIOR ENVIRONMENTAL PERFORMANCE	Environmental	Research article
Production and Operations Management		2001	ANDREW A. KING and MICHAEL J. LENOX (September, 2001)	LEAN AND GREEN? AN EMPIRICAL EXAMINATION OF THE RELATIONSHIP BETWEEN LEAN PRODUCTION AND ENVIRONMENTAL PERFORMANCE	Environmental	Empirical study
Production and Operations Management		2001	ROBERT D. KLASSEN (September, 2001)	PLANT-LEVEL ENVIRONMENTAL MANAGEMENT ORIENTATION: THE INFLUENCE OF MANAGEMENT VIEWS AND PLANT CHARACTERISTICS	Environmental	Empirical study
Production and Operations Management		2001	LINDA C. ANGELL (September, 2001)	COMPARING THE ENVIRONMENTAL AND QUALITY INITIATIVES OF BALDRIGE AWARD WINNERS	Environmental	Research article

Production and Operations Management	2001	MAGALI DELMAS (September, 2001)	STAKEHOLDERS AND COMPETITIVE ADVANTAGE: THE CASE OF ISO 14001	Environmental	Empirical study
Production and Operations Management	2001	GERALDO FERRER and D. CLAY WHYBARK (June, 2001)	MATERIAL PLANNING FOR A REMANUFACTURING FACILITY	Others	Research article
Production and Operations Management	2001	V. DANIEL R. GUIDE Jr., LUK N. VAN WASSENHOVE (June, 2001)	MANAGING PRODUCT RETURNS FOR REMANUFACTURING	Environmental, Economic	Research article
IEEE Transactions on Engineering Management	2008	Wu, S.J.; Melnyk, S.A.; Calantone, R.J.; Fordham Univ., New York (april 2008)	Assessing the Core Resources in the Environmental Management System From the Resource Perspective and the Contingency Perspective	Environmental	Empirical study
IEEE Transactions on Engineering Management	2007	Rusinko, C.A.; Philadelphia Univ., Philadelphia (23 july 2007)	Green Manufacturing: An Evaluation of Environmentally Sustainable Manufacturing Practices and Their Impact on Competitive Outcomes	Environmental, Economic	Research article
IEEE Transactions on Engineering Management	2006	Link, S.; Naveh, E.; Fac. of Ind. Eng. & Manage., Technion-Israel Inst. of Technol., Haifa (23 Oct 2006)	Standardization and Discretion: Does the Environmental Standard ISO 14001 Lead to Performance Benefits?	Environmental, Social	Research article
IEEE Transactions on Engineering Management	2002	Mangun, D.; Thurston, D.L.; Decision Syst. Lab., Univ. of Illinois, Urbana, IL, USA	Incorporating component reuse, remanufacture, and recycle into product portfolio design	Economic	Methodology
IEEE Transactions on Engineering Management	2000	Curkovic, S.; Melnyk, S.A.; Handfield, R.B.; Calantone, R.; Dept. of Manage., Western Michigan Univ., Kalamazoo, MI, USA	Investigating the linkage between total quality management and environmentally responsible manufacturing	Others	Research article

IEEE Transactions on Engineering Management	2001	Johnston, D.A.; Linton, J.D.; Schulich Sch. of Bus., York Univ., Toronto, Ont.	Social networks and the implementation of environmental technology	Social	Empirical study
J of Cleaner Production	2011	G.Y. Qi, S.X. Zeng, C.M. Tam, H.T. Yin, J.F. Wu, Z.H. Dai (July, 2011)	Diffusion of ISO 14001 environmental management systems in China: rethinking on stakeholders' roles	Environmental	Empirical study
J of Cleaner Production	2011	D. Sakr, L. Baas, S. El-Haggar, D. Huisingh	Critical success and limiting factors for eco-industrial parks: global trends and Egyptian context	Environmental	Research article
J of Cleaner Production	2011	Suvi Lehtoranta, Ari Nissinen, Tuomas Mattila, Matti Melanen	Industrial symbiosis and the policy instruments of sustainable consumption and production	Environmental, Economic	Research article
J of Cleaner Production	2011	Frank Boons, Wouter Spekkink, Yannis Mouzakitis (June-July, 2011)	The dynamics of industrial symbiosis: a proposal for a conceptual framework based upon a comprehensive literature review	Environmental	Literature review
J of Cleaner Production	2011	Ahmed M. Deif	A system model for green manufacturing	Environmental, Economic	Case study
J of Cleaner Production	2011	Mohammad Mirjalili, Khosro Nazarpoor, Loghman Karimi (June-July, 2011)	Eco-friendly dyeing of wool using natural dye from weld as co-partner with synthetic dye	Environmental	Research article
J of Cleaner Production	2011	Alberto Gomez, Monica A. Rodriguez (June-July, 2011)	The effect of ISO 14001 certification on toxic emissions: an analysis of industrial facilities in the north of Spain	Environmental, Economic	Research article
J of Cleaner Production	2011	Matthew Franchetti (June-July, 2011)	ISO 14001 and solid waste generation rates in US manufacturing organizations: an analysis of relationship	Environmental, Economic	Empirical study
J of Cleaner Production	2011	Katharina Bunse, Matthias Vodicka, Paul Schönsleben, Marc Brülhart, Frank O. Ernst (April-May, 2011)	Integrating energy efficiency performance in production management – gap analysis between industrial needs and scientific literature	Others	Research article

J of Cleaner Production	2011	Wang Xiang, Chen Ming (April-May, 2011)	Implementing extended producer responsibility: vehicle remanufacturing in China	Environmental	Research article
J of Cleaner Production	2011	Oliver Ioan Avram, Paul Xirouchakis (April-May, 2011)	Evaluating the use phase energy requirements of a machine tool system	Environmental	Methodology
J of Cleaner Production	2011	Ali Shams-Nateri (April-May, 2011)	Reusing wastewater of madder natural dye for wool dyeing	Economic	Research article
J of Cleaner Production	2011	Karla R. Armenti, Rafael Moure-Eraso, Craig Slatin, Ken Geiser	Primary prevention for worker health and safety: cleaner production and toxics use reduction in Massachusetts	Environmental, Social	Research article
J of Cleaner Production	2011	Sara González-García, Gumersindo Feijoo, Carol Heathcote, Andreas Kandelbauer, M. Teresa Moreira (March, 2011)	Environmental assessment of green hardboard production coupled with a laccase activated system	Environmental	Research article
J of Cleaner Production	2011	Thomas W. Sloan (January-February, 2011)	Green renewal: incorporating environmental factors in equipment replacement decisions under technological change	Environmental, Economic	Research article
J of Cleaner Production	2011	Jesús Rives, Ivan Fernandez-Rodriguez, Joan Rieradevall, Xavier Gabarrell (January-February, 2011)	Environmental analysis of the production of natural cork stoppers in southern Europe (Catalonia – Spain)	Environmental	Research article
J of Cleaner Production	2011	Iñaki Heras-Saizarbitoria, José F. Molina-Azorín, Gavin P.M. Dick (January, 2011)	ISO 14001 certification and financial performance: selection-effect versus treatment-effect	Economic	Research article
J of Cleaner Production	2011	Otávio José de Oliveira, José Roberto Serra, Manoel Henrique Salgado (January, 2011)	Does ISO 14001 work in Brazil?	Environmental	Empirical study
J of Cleaner Production	2010	Ferna´ndez, M. B., Go´mez, T., Capuz, S. F.	Eco-efficiency in the SMEs of Venezuela. Current status and future perspectives	Others	Empirical study

J of Cleaner Production	2010	Han Shi, Marian Chertow, Yuyan Song	Developing country experience with eco-industrial parks: a case study of the Tianjin Economic-Technological Development Area in China	Environmental	Case study
J of Cleaner Production	2010	Ling Zhang, Zengwei Yuan, Jun Bi, Bing Zhang, Beibei Liu	Eco-industrial parks: national pilot practices in China	Others	Research article
J of Cleaner Production	2010	Weili Jiang, Zengwei Yuan, Jun Bi, Li Sun (November, 2010)	Conserving water by optimizing production schedules in the dyeing industry	Environmental	Methodology, Case study
J of Cleaner Production	2010	Yong Geng, Wang Xinbei, Zhu Qinghua, Zhao Hengxin	Regional initiatives on promoting cleaner production in China: a case of Liaoning	Others	Case study
J of Cleaner Production	2010	J. Van Caneghem, C. Block, H. Van Hooste, C. Vandecasteele (September, 2010)	Eco-efficiency trends of the Flemish industry: decoupling of environmental impact from economic growth	Environmental, Economic	Research article
J of Cleaner Production	2010	Hyun Bok Lee, Nam Wook Cho, Yoo Suk Hong (September, 2010)	A hierarchical end-of-life decision model for determining the economic levels of remanufacturing and disassembly under environmental regulations	Environmental, Economic	Methodology
J of Cleaner Production	2010	Fu Zhao, William Z. Bernstein, Gautam Naik, Gary J. Cheng (September, 2010)	Environmental assessment of laser assisted manufacturing: case studies on laser shock peening and laser assisted turning	Environmental, Economic	Case study
J of Cleaner Production	2010	Franci Pusavec, Davorin Kramar, Peter Krajnik, Janez Kopac (August, 2010)	Transitioning to sustainable production – part II: evaluation of sustainable machining technologies	Environmental, Economic, Social	Case study
J of Cleaner Production	2010	S.X. Zeng, X.H. Meng, H.T. Yin, C.M. Tam, L. Sun (July, 2010)	Impact of cleaner production on business performance	Economic	Research article
J of Cleaner Production	2010	Inês Costa, Paulo Ferrão (June, 2010)	A case study of industrial symbiosis development using a middle-out approach	Environmental, Economic	Case study

J of Cleaner Production	2010	S. Vinodh (July, 2010)	Improvement of agility and sustainability: A case study in an Indian rotary switches manufacturing organisation	Environmental	Case study
J of Cleaner Production	2010	Domnita Fratila (July, 2010)	Macro-level environmental comparison of near-dry machining and flood machining	Environmental	Case study
J of Cleaner Production	2010	M.F. Rajemi, P.T. Mativenga, A. Aramcharoen (July, 2010)	Sustainable machining: selection of optimum turning conditions based on minimum energy considerations	Environmental, Economic	Research article
J of Cleaner Production	2010	Iñaki Heras, German Arana (May, 2010)	Alternative models for environmental management in SMEs: the case of Ekoscan vs. ISO 14001	Others	Empirical study
J of Cleaner Production	2010	Peter Mizsey, Laszlo Racz (May, 2010)	Cleaner production alternatives: Biomass utilisation options	Others	Research article
J of Cleaner Production	2010	A. Zabaniotou, K. Andreou (May, 2010)	Development of alternative energy sources for GHG emissions reduction in the textile industry by energy recovery from cotton ginning waste	Environmental, Economic	Methodology
J of Cleaner Production	2010	Inês Costa, Guillaume Massard, Abhishek Agarwal (May, 2010)	Waste management policies for industrial symbiosis development: case studies in European countries	Environmental, Economic	Research article
J of Cleaner Production	2010	Conrad Luttropp, Jan Johansson (March, 2010)	Improved recycling with life cycle information tagged to the product	Environmental	Research article
J of Cleaner Production	2010	Harish Kumar Jeswani, Adisa Azapagic, Philipp Schepelmann, Michael Ritthoff (January, 2010)	Options for broadening and deepening the LCA approaches	Environmental, Economic, Social	Research article
J of Cleaner Production	2010	Johannes Fresner, Jürgen Jantschgi, Stefan Birkel, Josef Bärnthaler, Christina Krenn (January, 2010)	The theory of inventive problem solving (TRIZ) as option generation tool within cleaner production projects	Environmental	Methodology

J of Cleaner Production	2010	Franci Pusavec, Peter Krajnik, Janez Kopac (January, 2010)	Transitioning to sustainable production – Part I: application on machining technologies	Environmental, Economic, Social	Research article
J of Cleaner Production	2010	Daniela C.A. Pigosso, Evelyn T. Zanette, Américo Guelere Filho, Aldo R. Ometto, Henrique Rozenfeld (January, 2010)	Ecodesign methods focused on remanufacturing	Environmental	Research article
J of Cleaner Production	2009	Irene Mei Leng Chew, Raymond R. Tan, Dominic Chwan Yee Foo, Anthony Shun Fung Chiu	Game theory approach to the analysis of inter-plant water integration in an eco-industrial park	Environmental	Methodology
J of Cleaner Production	2009	G. Daian, B. Ozarska (November, 2009)	Wood waste management practices and strategies to increase sustainability standards in the Australian wooden furniture manufacturing sector	Environmental	Research article
J of Cleaner Production	2009	Johan Östlin, Erik Sundin, Mats Björkman (July, 2009)	Product life-cycle implications for remanufacturing strategies	Others	Research article
J of Cleaner Production	2009	Ewa Liwarska-Bizukojc, Marcin Bizukojc, Andrzej Marcinkowski, Andrzej Doniec (May, 2009)	The conceptual model of an eco-industrial park based upon ecological relationships	Environmental	Methodology, Case study
J of Cleaner Production	2009	Lilian Bechara Elabras Veiga, Alessandra Magrini	Eco-industrial park development in Rio de Janeiro, Brazil: a tool for sustainable development	Others	Research article
J of Cleaner Production	2009	Emmanuel D. Adamides, Yannis Mouzakitis	Industrial ecosystems as technological niches	Technology	Research article
J of Cleaner Production	2009	Jan Johansson, Conrad Luttropp (January, 2009)	Material hygiene: improving recycling of WEEE demonstrated on dishwashers	Environmental	Research article
J of Cleaner Production	2008	Michaela A. Balzarova, Pavel Castka (December, 2008)	Underlying mechanisms in the maintenance of ISO 14001 environmental management system	Others	Case study
J of Cleaner Production	2008	Cui Hua Huo, Li He Chai	Physical principles and simulations on the structural evolution of eco-	Others	Research article

			industrial systems		
J of Cleaner Production	2008	Dongwon Shin, Mark Curtis, Donald Huisingh and, Gerard I. Zwetsloot (November, 2008)	Development of a sustainability policy model for promoting cleaner production: a knowledge integration approach	Others	Empirical study
J of Cleaner Production	2008	Inês Ribeiro, Paulo Peças, Arlindo Silva, Elsa Henriques (November, 2008)	Life cycle engineering methodology applied to material selection, a fender case study	Environmental, Economic, Technology	Methodology, Case study
J of Cleaner Production	2008	Lisa M. Ellram, Wendy Tate, Craig R. Carter (October, 2008)	Applying 3DCE to environmentally responsible manufacturing practices	Environmental	Research article
J of Cleaner Production	2008	S.N. Russell, J.M. Allwood (September, 2008)	Environmental evaluation of localising production as a strategy for sustainable development: a case study of two consumer goods in Jamaica	Environmental	Case study
J of Cleaner Production	2008	Murali Sambasivan, Ng Yun Fei (September, 2008)	Evaluation of critical success factors of implementation of ISO 14001 using analytic hierarchy process (AHP): a case study from Malaysia	Economic, Social	Empirical study, Case study
J of Cleaner Production	2008	Sabina Fijan, Rebeka Fijan, Sonja Šostar-Turk (August, 2008)	Implementing sustainable laundering procedures for textiles in a commercial laundry and thus decreasing wastewater burden	Environmental	Research article
J of Cleaner Production	2008	N.A. Ibrahim, Nabil M. Abdel Moneim, E.S. Abdel Halim, M.M. Hosni (August, 2008)	Pollution prevention of cotton-cone reactive dyeing	Environmental, Economic	Research article
J of Cleaner Production	2008	B.F. Giannetti, S.H. Bonilla, I.R. Silva, C.M.V.B. Almeida (July, 2008)	Cleaner production practices in a medium size gold-plated jewelry company in Brazil: when little changes make the difference	Environmental, Economic	Research article

J of Cleaner Production	2008	H. Shi, S.Z. Peng, Y. Liu, P. Zhong (May, 2008)	Barriers to the implementation of cleaner production in Chinese SMEs: government, industry and expert stakeholders' perspectives	Others	Methodology, Empirical study
J of Cleaner Production	2008	Kyle M. Bartholomew, Timothy C. Lindsey, John O. Sparks, Deb McKinley (April, 2008)	Multi-state initiative to enhance pollution prevention technology diffusion using the ADOP2T model	Technology	Research article
J of Cleaner Production	2008	Thomas J. Bierma, Frank L. Waterstraat (April, 2008)	Marketing P2–CP to business – past, present, and possible future	Others	Research article
J of Cleaner Production	2008	Gale Boyd, Elizabeth Dutrow, Walt Tunnessen (April, 2008)	The evolution of the ENERGY STAR® energy performance indicator for benchmarking industrial plant manufacturing energy use	Environmental	Research article
J of Cleaner Production	2008	Fran Kurk, Patrick Eagan (April, 2008)	The value of adding design-for-the-environment to pollution prevention assistance options	Environmental	Research article
J of Cleaner Production	2008	Zahiruddin Khan (January, 2008)	Cleaner production: an economical option for ISO certification in developing countries	Environmental	Case study
J of Cleaner Production	2008	Iuri Gavronski, Geraldo Ferrer, Ely Laureano Paiva (January, 2008)	ISO 14001 certification in Brazil: motivations and benefits	Environmental, Economic, Social	Empirical study
J of Cleaner Production	2008	Carlos Montalvo (January, 2008)	General wisdom concerning the factors affecting the adoption of cleaner technologies: a survey 1990–2007	Technology	Empirical study
J of Cleaner Production	2008	René Kemp, Massimiliano Volpi (January, 2008)	The diffusion of clean technologies: a review with suggestions for future diffusion analysis	Technology	Research article
J of Cleaner Production	2008	Hilmi Yüksel (January, 2008)	An empirical evaluation of cleaner production practices in Turkey	Environmental	Empirical study

J of Cleaner Production	2008	Ralph Luken, Frank Van Rompaey (January, 2008)	Drivers for and barriers to environmentally sound technology adoption by manufacturing plants in nine developing countries	Technology	Empirical study
J of Cleaner Production	2008	Maïder Saint Jean (January, 2008)	Polluting emissions standards and clean technology trajectories under competitive selection and supply chain pressure	Environmental, Technology	Research article
J of Cleaner Production	2008	Ignacio Calleja, Luis Delgado (January, 2008)	European environmental technologies action plan (ETAP)	Environmental, Technology	Research article
J of Cleaner Production	2007	Aoe, T	Eco-efficiency and ecodesign in electrical and electronic products.	Environmental	Research article
J of Cleaner Production	2007	M.G. Kassolis (December, 2007)	The diffusion of environmental management in Greece through rationalist approaches: driver or product of globalisation?	Environmental, Economic	Research article
J of Cleaner Production	2007	David Gibbs, Pauline Deutz (November 2007)	Reflections on implementing industrial ecology through eco-industrial park development	Environmental	Empirical study
J of Cleaner Production	2007	Leo Baas (September, 2007)	To make zero emissions technologies and strategies become a reality, the lessons learned of cleaner production dissemination have to be known	Environmental	Research article
J of Cleaner Production	2007	Eija Nieminen, Michael Linke, Marion Tobler, Bob Vander Beke (September, 2007)	EU COST Action 628: life cycle assessment (LCA) of textile products, eco-efficiency and definition of best available technology (BAT) of textile processing	Environmental, Economic, Technology	Research article
J of Cleaner Production	2007	Ruediger Kuehr (September, 2007)	Environmental technologies – from misleading interpretations to an operational categorisation & definition	Environmental, Technology	Research article

J of Cleaner Production	2007	H. Xue, V. Kumar, J.W. Sutherland (September, 2007)	Material flows and environmental impacts of manufacturing systems via aggregated input–output models	Environmental	Methodology, Case study
J of Cleaner Production	2007	Muna Lakhani (September, 2007)	The need for Clean Production and Product Re-design	Environmental	Research article
J of Cleaner Production	2007	Tadeusz Fijał (2007)	An environmental assessment method for cleaner production technologies	Environmental, Technology	Methodology
J of Cleaner Production	2007	W.R. Morrow, H. Qi, I. Kim, J. Mazumder, S.J. Skerlos (2007)	Environmental aspects of laser-based and conventional tool and die manufacturing	Environmental, Economic, Technology	Case study
J of Cleaner Production	2007	P.W. Marksberry (2007)	Micro-flood (MF) technology for sustainable manufacturing operations that are coolant less and occupationally friendly	Technology	Research article
J of Cleaner Production	2007	Greg Brown, Lesley Stone (2007)	Cleaner production in New Zealand: taking stock	Others	Research article
J of Cleaner Production	2007	Rene van Berkel (2007)	Cleaner production and eco-efficiency initiatives in Western Australia 1996–2004	Others	Research article
J of Cleaner Production	2007	Simon Clay, Diana Gibson, Jon Ward (2007)	Sustainability Victoria: influencing resource use, towards zero waste and sustainable production and consumption	Environmental	Research article
J of Cleaner Production	2007	Alan Howgrave-Graham, Rene van Berkel (2007)	Assessment of cleaner production uptake: method development and trial with small businesses in Western Australia	Environmental, Economic	Empirical study
J of Cleaner Production	2007	William Altham (2007)	Benchmarking to trigger cleaner production in small businesses: drycleaning case study	Environmental	Case study
J of Cleaner Production	2007	C. Hicks, R. Dietmar (2007)	Improving cleaner production through the application of environmental management tools in China	Environmental, Economic	Research article

J of Cleaner Production	2007	Dennis M. Hussey, Patrick D. Eagan (2007)	Using structural equation modeling to test environmental performance in small and medium-sized manufacturers: can SEM help SMEs?	Environmental	Research article
J of Cleaner Production	2007	Jason Gerrard, Milind Kandlikar (2007)	Is European end-of-life vehicle legislation living up to expectations? Assessing the impact of the ELV Directive on 'green' innovation and vehicle recovery	Environmental	Research article
J of Cleaner Production	2006	Coˆ te´, R., Booth, A., Louis, B.	Eco-efficiency and SMEs in Nova Scotia, Canada	Others	Research article
J of Cleaner Production	2006	Mickwitz, P., Melanen, M., Rosenstro, U., Seppa¨ la, J	Regional eco-efficiency indicators e a participatory approach	Environmental, Economic, Social	Research article
J of Cleaner Production	2006	Irina Kliopova, Jurgis Kazimieras Staniskis (2006)	The evaluation of Cleaner Production performance in Lithuanian industries	Environmental, Economic, Technology	Research article
J of Cleaner Production	2006	Carrie L. Mitchell	Beyond barriers: examining root causes behind commonly cited Cleaner Production barriers in Vietnam	Others	Research article
J of Cleaner Production	2006	Bruce Taylor	Encouraging industry to assess and implement cleaner production measures	Environmental	Case study
J of Cleaner Production	2006	Bert Bras, Jacqueline A. Isaacs, Michael Overcash	Environmentally benign manufacturing – A workshop report	Environmental	Research article
J of Cleaner Production	2006	Xiaoping Jia, Tianzhu Zhang, Fang Wang, Fangyu Han	Multi-objective modeling and optimization for cleaner production processes	Environmental, Economic	Methodology
J of Cleaner Production	2006	S. Ghazinoory, D. Huisingh	National program for cleaner production (CP) in Iran: a framework and draft	Others	Research article
J of Cleaner Production	2006	Lesley J. Stone	Limitations of cleaner production programmes as organisational change agents I. Achieving commitment and on-going improvement	Environmental, Economic, Social	Research article

J of Cleaner Production	2006	Lesley J. Stone	Limitations of cleaner production programmes as organisational change agents. II. Leadership, support, communication, involvement and programme design	Others	Research article
J of Cleaner Production	2005	Burritt, R. L., Saka, C.	Environmental management accounting applications and eco-efficiency: case studies from Japan	Environmental, Economic	Case study
J of Cleaner Production	2005	Thokozani Majozi	An effective technique for wastewater minimisation in batch processes	Environmental	Methodology, Case study
J of Cleaner Production	2005	Dominic Chwan Yee Foo, Zainuddin Abdul Manan, Yin Ling Tan	Synthesis of maximum water recovery network for batch process systems	Environmental	Methodology
J of Cleaner Production	2005	Murat Mirata, Tareq Emtairah	Industrial symbiosis networks and the contribution to environmental innovation: The case of the Landskrona industrial symbiosis programme	Environmental	Research article
J of Cleaner Production	2005	Levy Siaminwe, Kazhila C. Chinsembu, Michelo Syakalima	Policy and operational constraints for the implementation of cleaner production in Zambia	Others	Research article
J of Cleaner Production	2005	James Scott Baldwin, Peter M. Allen, Belinda Winder, Keith Ridgway	Modelling manufacturing evolution: thoughts on sustainable industrial development	Others	Methodology
J of Cleaner Production	2005	S. Ghazinoory	Cleaner production in Iran: necessities and priorities	Others	Research article
J of Cleaner Production	2005	Alessia Ghisellini, Deborah L. Thurston	Decision traps in ISO 14001 implementation process: case study results from Illinois certified companies	Environmental	Case study
J of Cleaner Production	2005	S. X. Zeng, C. M. Tam, Vivian W. Y. Tam, Z. M. Deng	Towards implementation of ISO 14001 environmental management systems in selected industries in China	Environmental	Empirical study

J of Cleaner Production	2005	Ursula Triebswetter, David Hitchens	The impact of environmental regulation on competitiveness in the German manufacturing industry—a comparison with other countries of the European Union	Environmental	Case study
J of Cleaner Production	2005	A. C. Brent, J. K. Visser	An environmental performance resource impact indicator for life cycle management in the manufacturing industry	Environmental	Research article
J of Cleaner Production	2005	Enrico Cagno, Paolo Trucco, Lorenzo Tardini	Cleaner production and profitability: analysis of 134 industrial pollution prevention (P2) project reports	Environmental, Economic	Research article
J of Cleaner Production	2005	Gudolf Kjaerheim	Cleaner production and sustainability	Environmental, Economic, Social	Research article
J of Cleaner Production	2005	Ana Paula Duarte, Fernando Ventura, Cristina Rocha, Justina Catarino, Rui Frazão, Rui Fernandes, Anabela Maia, Paula Trindade, Ana Lança, Constança Peneda	Sustainable Production Programme in Setúbal Region (PROSSET)—final results	Environmental, Economic, Social	Research article
J of Cleaner Production	2005	Carin Labuschagne, Alan C. Brent, Ron P.G. van Erck	Assessing the sustainability performances of industries	Environmental, Economic, Social	Research article
J of Cleaner Production	2005	Lee Peng Tan	Implementing ISO 14001: is it beneficial for firms in newly industrialized Malaysia?	Environmental	Empirical study
J of Cleaner Production	2005	Timothy Gutowski, Cynthia Murphy, David Allen, Diana Bauer, Bert Bras, Thomas Piwonka, Paul Sheng, John Sutherland, Deborah Thurston, Egon Wolff	Environmentally benign manufacturing: Observations from Japan, Europe and the United States	Environmental	Research article
J of Cleaner Production	2005	Mats Zackrisson	Environmental aspects when manufacturing products mainly out of	Environmental	Research article

			metals and/or polymers		
J of Cleaner Production	2005	Heidi E. Staff Mestl, Kristin Aunan, Jinghua Fang, Hans Martin Seip, John Magne Skjelvik, Haakon Vennemo	Cleaner production as climate investment—integrated assessment in Taiyuan City, China	Environmental, Economic	Research article
J of Cleaner Production	2004	Perry Pei-Ju Yang, Ong Boon Lay	Applying ecosystem concepts to the planning of industrial areas: a case study of Singapore's Jurong Island	Environmental	Case study
J of Cleaner Production	2004	Jouni Korhonen	Industrial ecology in the strategic sustainable development model: strategic applications of industrial ecology	Environmental, Economic	Research article
J of Cleaner Production	2004	Thomas Sterr, Thomas Ott	The industrial region as a promising unit for eco-industrial development—reflections, practical experience and establishment of innovative instruments to support industrial ecology	Technology	Research article
J of Cleaner Production	2004	R.R. Heeres, W.J.V. Vermeulen, F.B. de Walle	Eco-industrial park initiatives in the USA and the Netherlands: first lessons	Others	Research article
J of Cleaner Production	2004	Murat Mirata	Experiences from early stages of a national industrial symbiosis programme in the UK: determinants and coordination challenges	Others	Research article
J of Cleaner Production	2004	Paul H. Templet	Partitioning of resources in production: an empirical analysis	Environmental, Economic	Empirical study
J of Cleaner Production	2004	Tak Hur, Ik Kim, Ryoichi Yamamoto	Measurement of green productivity and its improvement	Environmental, Economic	Research article
J of Cleaner Production	2004	Khalid A. Babakri, Robert A. Bennett, Subba Rao, Matthew Franchetti	Recycling performance of firms before and after adoption of the ISO 14001 standard	Others	Empirical study

J of Cleaner Production	2004	G. Zilahy	Organisational factors determining the implementation of cleaner production measures in the corporate sector	Others	Empirical study
J of Cleaner Production	2004	M. M. Hamed, Y. El Mahgary	Outline of a national strategy for cleaner production: The case of Egypt	Others	Research article
J of Cleaner Production	2004	Ralph A. Luken, Jaroslav Navratil	A programmatic review of UNIDO/UNEP national cleaner production centres	Environmental, Economic	Research article
J of Cleaner Production	2004	Jurgis K. Staniskis, Valdas Arbaciauskas	Institutional capacity building for pollution prevention centres in Central and Eastern Europe with special reference to Lithuania	Others	Research article
J of Cleaner Production	2004	Jürg M. Grutter, Hans-Peter Egler	From cleaner production to sustainable industrial production modes	Environmental, Economic, Technology	Research article
J of Cleaner Production	2004	J. Del Alamo, J. C. Fernández, M. Hernández, Y. Núñez, R. Irusta, J. L. Del Valle	Environmental optimisation of a hydro-moulding process	Environmental	Research article
J of Cleaner Production	2004	A. J. Spicer, M. R. Johnson	Third-party demanufacturing as a solution for extended producer responsibility	Others	Research article
J of Cleaner Production	2003	Khalid A. Babakri, Robert A. Bennett, Matthew Franchetti	Critical factors for implementing ISO 14001 standard in United States industrial companies	Others	Empirical study
J of Cleaner Production	2003	A. Huhtala	Promoting financing of cleaner production investments—UNEP experience	Economic	Research article
J of Cleaner Production	2003	J. K. Staniskis, Z. Stasiskiene	Promotion of cleaner production investments: international experience	Environmental, Economic	Research article
J of Cleaner Production	2003	E. Ciccozzi, R. Checkenya, A. V. Rodriguez	Recent experiences and challenges in promoting cleaner production investments in developing countries	Others	Research article

J of Cleaner Production	2003	Christine Jasch	The use of Environmental Management Accounting (EMA) for identifying environmental costs	Environmental, Economic	Methodology
J of Cleaner Production	2003	G. Barbiroli, A. Raggi	A method for evaluating the overall technical and economic performance of environmental innovations in production cycles	Environmental, Economic	Methodology
J of Cleaner Production	2003	Carlos Montalvo Corral	Sustainable production and consumption systems—cooperation for change: assessing and simulating the willingness of the firm to adopt/develop cleaner technologies. The case of the In-Bond industry in northern Mexico	Environmental, Economic, Technology	Empirical study, Case study
J of Cleaner Production	2003	Charles David White, Eric Masanet, Christine Meisner Rosen, Sara L. Beckman	Product recovery with some byte: an overview of management challenges and environmental consequences in reverse manufacturing for the computer industry	Environmental	Research article
J of Cleaner Production	2003	N. Kiran-Ciliz	Reduction in resource consumption by process modifications in cotton wet processes	Environmental	Research article
J of Cleaner Production	2003	L. Reijnders	Policies influencing cleaner production: the role of prices and regulation	Economic	Research article
J of Cleaner Production	2003	M. H. Nagel	Managing the environmental performance of production facilities in the electronics industry: more than application of the concept of cleaner production	Environmental	Research article
J of Cleaner Production	2003	Kit-Fai Pun, Ip-Kee Hui, Winston G. Lewis, Henry C. W. Lau	A multiple-criteria environmental impact assessment for the plastic injection molding process: a methodology	Environmental	Methodology, Empirical study

J of Cleaner Production	2002	Andrzej Doniec, Janusz Reichel, Marta Buliska	Assessment of the potential of cleaner production implementation in Polish enterprises	Others	Empirical study
J of Cleaner Production	2002	M. Getzner	The quantitative and qualitative impacts of clean technologies on employment	Social	Research article
J of Cleaner Production	2002	S. K. T. Andrews, J. Stearne, J. D. Orbell	Awareness and adoption of cleaner production in small to medium-sized businesses in the Geelong region, Victoria, Australia	Others	Empirical study
J of Cleaner Production	2001	Vesela Veleva, Michael Ellenbecker	Indicators of sustainable production: framework and methodology	Environmental, Economic, Social	Research article
J of Cleaner Production	2001	V. Veleva, M. Hart, T. Greiner, C. Crumbley	Indicators of sustainable production	Environmental, Economic, Social	Research article
J of Cleaner Production	2001	Venkatesan Narayanaswamy, J. Ashley Scott	Lessons from cleaner production experiences in Indian hosiery clusters	Environmental	Research article
J of Cleaner Production	2001	Alberto Petroni	Developing a methodology for analysis of benefits and shortcomings of ISO 14001 registration: lessons from experience of a large machinery manufacturer	Economic	Methodology
J of Cleaner Production	2001	Wendy Kerr, Chris Ryan	Eco-efficiency gains from remanufacturing: A case study of photocopier remanufacturing at Fuji Xerox Australia	Environmental, Economic	Case study
J of Cleaner Production	2000	Xin Ren	Development of environmental performance indicators for textile process and product	Environmental	Research article
J of Cleaner Production	2000	N. N. B. Salvador, J. Glasson, J. M. Piper	Cleaner Production and Environmental Impact Assessment: a UK perspective	Environmental	Methodology
J of Cleaner Production	2000	Huzefa Dahodwalla, Sunil Herat	Cleaner production options for lead-acid battery manufacturing industry	Environmental	Research article

J of Cleaner Production	2000	Fabio Orecchini	The ISO 14001 certification of a machine-process	Environmental	Case study
J of Cleaner Production	1999	Negussie Retta	Cleaner industrial production practice in Ethiopia: problems and prospects	Others	Research article
J of Cleaner Production	1999	A. B. Culaba, M. R. I. Purvis	A methodology for the life cycle and sustainability analysis of manufacturing processes	Environmental	Research article
J of Cleaner Production	1999	Shen-yann Chiu, Jerry H. Huang, Chih-Sen Lin, Yi-hua Tang, Wen-huei Chen, Shen-Chia Su	Applications of a corporate synergy system to promote cleaner production in small and medium enterprises	Others	Research article
J of Cleaner Production	1999	Marieke Gombault, Stephan Versteege	Cleaner production in SMEs through a partnership with (local) authorities: successes from the Netherlands	Environmental	Case study
J of Cleaner Production	1999	A. P. Duarte, M. C. Peneda, C. Rocha, C. Saraiva, J. Catarino, R. Frazão, M. Marçal, P. Trindade, F. Ventura, C. Clérigo, R. Fernandes, A. Lança, R. Lopes, A. Maia, R. de Wijn	Sustainable Production Programme in Setúbal Region (PROSSET)—preliminary results	Others	Research article
J of Cleaner Production	1999	Hugo Verheul	How social networks influence the dissemination of cleaner technologies to SMEs	Others	Research article
J of Cleaner Production	1999	C. Visvanathan, S. Kumar	Issues for better implementation of cleaner production in Asian small and medium industries	Others	Research article
J of Cleaner Production	1999	Ruth Hillary, Nils Thorsen	Regulatory and self-regulatory measures as routes to promote cleaner production	Others	Research article
J of Cleaner Production	1999	Carol Boyle	Cleaner production in New Zealand	Others	Research article

Int J of Operations and Production Management	2011	Paraskevi Kapetanopoulou, George Tagaras, (Greece)	Drivers and obstacles of product recovery activities in the Greek industry	Others	Empirical study
Int J of Operations and Production Management	2011	Iñaki Heras-Saizarbitoria, German Arana Landín, José Francisco Molina-Azorín, (Spain)	Do drivers matter for the benefits of ISO 14001?	Others	Empirical study
Int J of Operations and Production Management	2009	Rosemary R. Fullerton, William F. Wempe	Lean manufacturing, non-financial performance measures, and financial performance	Economic	Research article
Int J of Operations and Production Management	2009	Mattias Hallgren, Jan Olhager	Lean and agile manufacturing: external and internal drivers and performance outcomes	Economic	Methodology, Empirical study
Int J of Operations and Production Management	2008	P. González, J. Sarkis, B. Adenso-Díaz, (Spain - USA)	Environmental management system certification and its influence on corporate practices: Evidence from the automotive industry	Others	Empirical study
Int J of Operations and Production Management	2006	Robert Conti, Jannis Angelis, Cary Cooper, Brian Faragher, Colin Gill	The effects of lean production on worker job stress	Social	Empirical study
Int J of Operations and Production Management	2005	Ibrahim A. Rawabdeh	A model for the assessment of waste in job shop environments	Economic	Methodology, Empirical study, Case study
Int J of Operations and Production Management	2004	Terry Wallace	Innovation and hybridization: Managing the introduction of lean production into Volvo do Brazil	Social	Research article
Int J of Operations and Production Management	2004	Purba Rao	Greening production: a South-East Asian experience	Environmental	Empirical study

Int J of Operations and Production Management	2003	Santiago García González, Ana Gessa Perera, Francisco Aguado Correa	A new approach to the valuation of production investments with environmental effects	Environmental, Economic	Case study
Int J of Operations and Production Management	2002	Richard Cooney	Is “lean” a universal production system?: Batch production in the automotive industry	Others	Research article
Int J of Operations and Production Management	2001	Angel Martínez Sánchez, Manuela Pérez Pérez	Lean indicators and manufacturing strategies	Others	Empirical study
Int J of Operations and Production Management	2001	Malcolm R. Hill	Sustainability, greenhouse gas emissions and international operations management	Others	Research article
Int J of Operations and Production Management	2001	Bonnie F. Daily, Su-chun Huang	Achieving sustainability through attention to human resource factors in environmental management	Social	Research article
Int J of Operations and Production Management	2001	Jerónimo de Burgos Jiménez, José J. Céspedes Lorente	Environmental performance as an operations objective	Environmental	Research article
Int J of Operations and Production Management	2001	Joseph Sarkis	Manufacturing’s role in corporate environmental sustainability - Concerns for the new millennium	Environmental	Research article
Int J of Operations and Production Management	2000	Michael A. Lewis	Lean production and sustainable competitive advantage	Economic	Case study
Int J of Operations and Production Management	2000	Robert D. Klassen	Exploring the linkage between investment in manufacturing and environmental technologies	Environmental, Technology	Research article

Int J of Operations and Production Management	2000	Mark D. Hanna, W. Rocky Newman, Pamela Johnson	Linking operational and environmental improvement through employee involvement	Environmental, Social	Research article
Int J of Operations and Production Management	2000	Charlette A. Geffen, Sandra Rothenberg	Suppliers and environmental innovation: The automotive paint process	Environmental	Research article
Int J of Operations and Production Management	2000	Shinichi Kitazawa, Joseph Sarkis	The relationship between ISO 14001 and continuous source reduction programs	Others	Case study
Production Planning and Control	2011	M. Despeisse; F. Mbaye; P. D. Ball; A. Levers (2011)	The emergence of sustainable manufacturing practices	Others	Literature review
Production Planning and Control	2011	George L. Hodge, Kelly Goforth Ross, Jeff A. Joines & Kristin Thoney	Adapting lean manufacturing principles to the textile industry	Economic	Methodology, Empirical study, Case study
Production Planning and Control	2011	Enrico Cagno, Guido J.L. Micheli & Paolo Trucco	Eco-efficiency for sustainable manufacturing: an extended environmental costing method	Environmental, Economic	Case study
Production Planning and Control	2002	R. Anthony Inman (2002)	Implications of environmental management for operations management	Environmental	Research article
Production Planning and Control	2000	Shizue Kubokawa; Ichiro Saito (2000)	Manufacturing management strategies for environmental protection: Toward the environmental upgrading of management and manufacturing systems to cope with environmental laws	Environmental	Research article
Int J of Sustainable Engineering	2001	Justina Catarino; José João Henriques; Anabela Maia; Jorge Alexandre; Fátima Rodrigues; David Camocho (2011)	From cleaner production and value management to sustainable value	Others	Methodology
Int J of Sustainable Engineering	2009	John Carrell; Hong-Chao Zhang; Derrick Tate; Hua Li (2009)	Review and future of active disassembly	Environmental, Economic	Research article

Int J of Sustainable Engineering	2009	S. Rahimifard; G. Coates; T. Staikos; C. Edwards; M. Abu-Bakar (2009)	Barriers, drivers and challenges for sustainable product recovery and recycling	Others	Research article
Int J of Sustainable Engineering	2009	Winifred L. Ijomah (2009)	Addressing decision making for remanufacturing operations and design-for-remanufacture	Environmental, Economic	Research article
Int J of Sustainable Engineering	2008	Narinder Bains; Martin Goosey; Rod Kellner (2008)	New chemical process waste treatment technologies for a sustainable printed circuit board manufacturing process	Environmental, Economic	Research article
Int J of Sustainable Engineering	2008	Salwa H. Abdul Rashid; Stephen Evans; Philip Longhurst (2008)	A comparison of four sustainable manufacturing strategies	Environmental, Economic	Literature review
Int J of Sustainable Engineering	2008	M. S. Abu Bakar; S. Rahimifard (2008)	Ecological and economical assessment of end-of-life waste recycling in the electrical and electronic recovery sector	Environmental, Economic	Research article
Business Strategy and the Environment	2011	Marian Chertow, Yuko Miyata	Assessing collective firm behavior: comparing industrial symbiosis with possible alternatives for individual companies in Oahu, HI	Environmental, Economic	Research article
Business Strategy and the Environment	2011	Teresa Doménech, Michael Davies	The role of Embeddedness in Industrial Symbiosis Networks: Phases in the Evolution of Industrial Symbiosis Networks	Others	Methodology
Business Strategy and the Environment	2009	Michael V. Russo	Explaining the impact of ISO 14001 on emission performance: a dynamic capabilities perspective on process and learning	Environmental	Research article
Business Strategy and the Environment	2007	Anna Wolf, Mats Eklund, Mats Söderström	Developing integration in a local industrial ecosystem – an explorative approach	Economic, Social	Methodology

Business Strategy and the Environment	2007	Sime Curkovic, Robert Sroufe and Robert Landeros	Measuring TQEM returns from the application of quality frameworks	Economic	Methodology
Business Strategy and the Environment	2006	Manuel Frondel, Jens Horbach and Klaus Rennings	End-of-pipe or cleaner production? An empirical comparison of environmental innovation decisions across OECD countries	Environmental	Empirical study
Business Strategy and the Environment	2006	Déirdre Crowe and Louis Brennan	Environmental considerations within manufacturing strategy: an international study	Environmental	Empirical study
Business Strategy and the Environment	2006	Irene Henriques, Perry Sadorsky	Environmental technical and administrative innovations in the Canadian manufacturing industry	Others	Research article
Business Strategy and the Environment	2006	Elisabeth Schylander and André Martinuzzi	ISO 14001 – experiences, effects and future challenges: a national study in Austria	Environmental	Research article
Business Strategy and the Environment	2006	Shuangyu Xie, Kohji Hayase	Corporate environmental performance evaluation: a measurement model and a new concept	Environmental	Methodology, Empirical study
Business Strategy and the Environment	2004	Pauline Deutz, David Gibbs	Eco-industrial development and economic development: industrial ecology or place promotion?	Economic	Empirical study
Business Strategy and the Environment	2004	Roberto Fernández Gago and Mariano Nieto Antolín	Environmental management and strategic positioning of Spanish manufacturing industries	Environmental	Empirical study
Business Strategy and the Environment	2003	Marcus G. van Leeuwen, Dr Walter J. V. Vermeulen, Pieter Glasbergen	Planning eco-industrial parks: an analysis of Dutch planning methods	Environmental	Research article

Business Strategy and the Environment	2001	Christoph Bey	Changing economies of scale – synergies between implementation of an ecological tax reform and development of industrial ecosystems	Economic	Research article
Business Strategy and the Environment	2001	Marie-Josée Roy, Olivier Boiral and Denis Lagacé	Environmental commitment and manufacturing excellence: a comparative study within Canadian industry	Environmental	Empirical study
Business Strategy and the Environment	2000	Saeed Parto	Industrial ecology and regionalization of economic governance: an opportunity to 'localize' sustainability?	Environmental, Economic, Social	Research article
Business Strategy and the Environment	2001	R. V. Jayathirtha	Combating environmental repercussions through 'TQEM' and 'ISO 14000'	Environmental	Research article
Manufacturing and Service Operations Management	2006	Charles J. Corbett and Robert D. Klassen	Extending the Horizons: Environmental Excellence as Key to Improving Operations	Environmental	Research article
Manufacturing and Service Operations Management	2004	Wallace J. Hopp, Mark L. Spearman	To Pull or Not to Pull: What Is the Question?	Others	Research article
Supply Chain Management: An Int J	2010	Glenn Parry, John Mills, Celine Turner	Lean competence: integration of theories in operations management practice	Others	Methodology
Supply Chain Management: An Int J	2005	Dayna F. Simpson, Damien J. Power (2005)	Use the supply relationship to develop lean and green suppliers	Environmental, Economic	Literature review
Supply Chain Management: An Int J	2000	M.L. Emiliani	Supporting small businesses in their transition to lean production	Others	Research article

Int J of Production Research	2011	Saurin, Tarcisio Abreu; Marodin, Giuliano Almeida; Ribeiro, Jose Luis Duarte	A framework for assessing the use of lean production practices in manufacturing cells	Others	Methodology, Empirical study, Case study
Int J of Production Research	2010	Kim, Junbeum; Park, Kwangho; Hwang, Yongwoo; Park, Ildo	Sustainable manufacturing: a case study of the forklift painting process	Environmental	Case study
Int J of Production Research	2010	Shah, Purvin; Gosavi, Abhijit; Nagi, Rakesh	A machine learning approach to optimise the usage of recycled material in a remanufacturing environment	Environmental, Economic	Research article
Int J of Production Research	2010	Y. Y. Yusuf & E. O. Adeleye	A comparative study of lean and agile manufacturing with a related survey of current practices in the UK	Economic	Empirical study
Int J of Production Research	2009	Kwak, Min Jung; Hong, Yoo Suk; Cho, Nam Wook	Eco-architecture analysis for end-of-life decision making	Others	Research article
Int J of Production Research	2009	Tsai, W. -H.; Hung, Shih-Jieh	Treatment and recycling system optimisation with activity-based costing in WEEE reverse logistics management: an environmental supply chain perspective	Environmental	Methodology
Int J of Production Research	2009	Cruz, J. M.; Matsypura, D	Supply chain networks with corporate social responsibility through integrated environmental decision-making	Environmental, Economic	Research article
Int J of Production Research	2008	Gonzalez-Benito, J.	The effect of manufacturing pro-activity on environmental management: an exploratory analysis	Environmental	Research article
Int J of Production Research	2008	Pablo Biswas & Bhaba R. Sarker	Optimal batch quantity models for a lean production system with in-cycle rework and scrap	Economic	Methodology
Int J of Production Research	2007	Ijomah, W. L.; Childe, S. J	A model of the operations concerned in remanufacture	Environmental, Economic	Methodology
Int J of Production Research	2007	Xu, Q. L.; Ong, S. K.; Nee, A. Y. C.	Evaluation of product performance in product family design re-use	Others	Methodology, Case study

Int J of Production Research	2007	Singh, S.; Goodyer, J.; Popplewell, K.	Integrated environmental process planning for the design and manufacture of automotive components	Environmental	Research article
Int J of Production Research	2007	Geldermann, J.; Treitz, M.; Rentz, O.	Towards sustainable production networks	Environmental, Economic	Research article
Int J of Production Research	2007	Mouzon, Gilles; Yildirim, Mehmet B.; Twomey, Janet	Operational methods for minimization of energy consumption of manufacturing equipment	Environmental	Methodology
Int J of Production Research	2007	Staikos, T.; Rahimifard, S.	A decision-making model for waste management in the footwear industry	Environmental	Methodology, Case study
Int J of Production Research	2007	Field, Joy M.; Sroufe, Robert P.	The use of recycled materials in manufacturing: implications for supply chain management and operations strategy	Economic	Case study
Int J of Production Research	2007	Ijomah, W. L.; McMahon, C. A.; Hammond, G. P.; Newman, S. T.	Development of robust design-for-remanufacturing guidelines to further the aims of sustainable development	Environmental	Research article
Int J of Production Research	2007	Kumar, V.; Shirodkar, P. S.; Camelio, J. A.; Sutherland, J.	Value flow characterization during product lifecycle to assist in recovery decisions	Economic	Methodology
Int J of Production Research	2007	Jun, H.-B.; Cusin, M.; Kiritsis, D.; Xirouchakis, P.	A multi-objective evolutionary algorithm for EOL product recovery optimization: turbocharger case study	Environmental, Economic	Methodology, Case study
Int J of Production Research	2007	Dellagi, S.; Rezg, N.; Xie, X.	Preventive maintenance of manufacturing systems under environmental constraints	Environmental	Methodology
Int J of Production Research	2007	R. K. Singh, S. Kumar, A. K. Choudhury & M. K. Tiwari	Lean tool selection in a die casting unit: a fuzzy-based decision support heuristic	Economic	Methodology, Case study
Int J of Production Research	2006	Nakashima, K.; Nose, T.; Kuriyama, S.	A new approach to environmental-performance evaluation	Environmental	Methodology

Int J of Production Research	2006	Humphreys, P.; McCloskey, A.; McIvor, R.; Maguire, L.; Glackin, C	Employing dynamic fuzzy membership functions to assess environmental performance in the supplier selection process	Environmental	Research article
Int J of Production Research	2005	González, B.; Adenso-Díaz, B	A bill of materials-based approach for end-of-life decision making in design for the environment	Economic	Methodology
Int J of Production Research	2005	Modarress, B.; Ansari, A.; Lockwood, D. L.	Kaizen costing for lean manufacturing: a case study	Economic	Methodology
Int J of Production Research	2005	S. Gerner; A. Kobeissi; B. David; Z. Binder; B. Descotes-Genon	Integrated approach for disassembly processes generation and recycling evaluation of an end-of-life product	Environmental, Economic	Methodology
Int J of Production Research	2004	Karolina Kazmierczak; Jørgen Winkel; Rolf H. Westgaard	Car disassembly and ergonomics in Sweden: current situation and future perspectives in light of new environmental legislation	Others	Research article
Int J of Production Research	2003	J. Huisman; C. B. Boks; A. L. N. Stevels	Quotes for environmentally weighted recyclability (QWERTY): concept of describing product recyclability in terms of environmental value	Environmental	Research article
Int J of Production Research	2003	Susumu Okumura; Toshimitsu Morikuni; Norio Okino	Environmental effects of physical life span of a reusable unit following functional and physical failures in a remanufacturing system	Environmental	Research article
Int J of Production Research	2003	Pavnaskar S.J.; Gershenson J.K.; Jambekar A.B	Classification scheme for lean manufacturing tools	Others	Research article
Int J of Production Research	2003	Hui I.K.; Li C.P.; Lau H.C.W.	Hierarchical environmental impact evaluation of a process in printed circuit board manufacturing	Environmental	Methodology, Case study
Int J of Production Research	2003	Del BrÍo J.Á.; Junquera B.	Influence of the perception of the external environmental pressures on obtaining the ISO 14001 standard in	Others	Research article

			Spanish industrial companies		
Int J of Production Research	2002	O'Brien C.	Global manufacturing and the sustainable economy	Environmental, Economic	Research article
Int J of Production Research	2002	Vastag G.; Melnyk S.A	Certifying environmental management systems by the ISO 14001 standards	Others	Empirical study, Case study
Int J of Production Research	2002	Hui I. K.; He L.; Dang C.	Environmental impact assessment in an uncertain environment	Environmental	Methodology, Case study
Int J of Production Research	2001	Melnyk S. A.; Sroufe R. P.; Montabon F. L.; Hinds T. J.	Green MRP: identifying the material and environmental impacts of production schedules	Environmental, Economic	Methodology
Int J of Production Research	2001	Viswanathan S.; Allada V	Configuration analysis to support product redesign for end-of-life disassembly	Environmental	Research article
Computers & Industrial Engineering	2010	Ahmed M.A. El Saadany, Mohamad Y. Jaber (2010)	A production/remanufacturing inventory model with price and quality dependant return rate	Economic	Methodology
Computers & Industrial Engineering	2011	Lluis Cuatrecasas-Arbos, Jordi Fortuny-Santos, Carla Vintro-Sanchez	The Operations-Time Chart: A graphical tool to evaluate the performance of production systems – From batch-and-queue to lean manufacturing	Others	Methodology, Case study
Computers & Industrial Engineering	2009	Ming-Lang Tseng, Louie Divinagracia, Rochelle Divinagracia (2009)	Evaluating firm's sustainable production indicators in uncertainty	Others	Methodology
Computers & Industrial Engineering	2009	Arindam Roy, Kalipada Maity, Samarjit kar, Manoranjan Maiti (2009)	A production–inventory model with remanufacturing for defective and usable items in fuzzy-environment	Economic	Research article
Computers & Industrial Engineering	2008	Sergio Rubio, Albert Corominas (2008)	Optimal manufacturing–remanufacturing policies in a lean production environment	Others	Methodology

Computers & Industrial Engineering	1999	Carsten Nagel, Peter Meyer (1999)	Caught between ecology and economy: end-of-life aspects of environmentally conscious manufacturing	Environmental, Economic	Methodology, Case study
Computers & Industrial Engineering	1999	Joseph Sarkis (1999)	A methodological framework for evaluating environmentally conscious manufacturing programs	Environmental	Methodology
Computers & Industrial Engineering	1999	Askiner Gungor, Surendra M. Gupta (1999)	Issues in environmentally conscious manufacturing and product recovery: a survey	Environmental	Empirical study
J of Productivity Analysis	2008	Paul Lanoie, Michel Patry and Richard Lajeunesse	Environmental regulation and productivity: testing the porter hypothesis	Others	Empirical study
J of Productivity Analysis	2006	Wendy Chapple, Richard Harris and Catherine J. Morrison Paul	The cost implications of waste reduction: factor demand, competitiveness and policy implications	Economic	Methodology
Total Quality Management and Business Excellence	1999	Klas Soderquist & Jaideep Motwani	Quality issues in lean production implementation: A case study of a French automotive supplier	Others	Case study
Integrated Manufacturing Systems	2011	Shahram Taj, Cristian Morosan	The impact of lean operations on the Chinese manufacturing performance	Economic	Research article
Integrated Manufacturing Systems	2011	Anand Gurumurthy, Rambabu Kodali	Design of lean manufacturing systems using value stream mapping with simulation: A case study	Others	Case study
Integrated Manufacturing Systems	2010	Dean Bartlett, Anna Trifilova	Green technology and eco-innovation: Seven case-studies from a Russian manufacturing context	Environmental, Technology	Case study

Integrated Manufacturing Systems	2010	Shams Rahman, Tritos Laosirihongthong, Amrik S. Sohal	Impact of lean strategy on operational performance: a study of Thai manufacturing companies	Environmental, Economic	Empirical study
Integrated Manufacturing Systems	2010	Nourredine Boubekri, Vasim Shaikh, Phillip R. Foster	A technology enabler for green machining: minimum quantity lubrication (MQL)	Environmental, Economic, Technology	Research article
Integrated Manufacturing Systems	2009	G. Anand, Rambabu Kodali	Selection of lean manufacturing systems using the analytic network process – a case study	Others	Case study
Integrated Manufacturing Systems	2008	Author(s): D.T. Pham, P.T.N. Pham, A. Thomas	Integrated production machines and systems – beyond lean manufacturing	Economic	Methodology
Integrated Manufacturing Systems	2007	Jayantha P. Liyanage	Operations and maintenance performance in production and manufacturing assets: The sustainability perspective	Environmental, Economic, Social	Research article
Integrated Manufacturing Systems	2006	Michaela A. Balzarova, Pavel Castka, Christopher J. Bamber, John M. Sharp	How organisational culture impacts on the implementation of ISO 14001:1996 – a UK multiple-case view	Others	Case study
Integrated Manufacturing Systems	2002	Horacio Soriano-Meier, Paul L. Forrester	A model for evaluating the degree of leanness of manufacturing firms	Others	Empirical study
Integrated Manufacturing Systems	2001	K.F. Pun, I.K. Hui	An analytical hierarchy process assessment of the ISO 14001 environmental management system	Environmental	Empirical study
Integrated Manufacturing Systems	2001	Ke-Zhang Chen	Development of integrated design for disassembly and recycling in concurrent engineering	Environmental	Methodology

Integrated Manufacturing Systems	2001	A.J.D. Lambert, M.H. Jansen, M.A.M. Splinter	Environmental information systems based on enterprise resource planning	Environmental	Research article
Int J of Computer Integrated Manufacturing	2010	Chun-Jen Chung; Hui-Ming Wee (2010)	Green-product-design value and information-technology investment on replenishment model with remanufacturing	Economic	Methodology
Int J of Quality & Reliability Management	2006	Kit Fai Pun (2006)	Determinants of environmentally responsible operations: a review	Environmental	Research article
Int J of Quality & Reliability Management	2003	Bozena Poksinska, Jens Jörn Dahlgaard, Jörgen A.E. Eklund (2003)	Implementing ISO 14000 in Sweden: motives, benefits and comparisons with ISO 9000	Others	Empirical study
Int J of Quality & Reliability Management	2001	Jesús Ángel del Brío, Esteban Fernández, Beatriz Junquera, Camilo José Vázquez (2001)	Environmental managers and departments as driving forces of TQEM in Spanish industrial companies	Environmental	Research article
Int J of Quality & Reliability Management	1999	Kwai-Sang Chin, Simon Chiu, V.M. Rao Tummala (1999)	An evaluation of success factors using the AHP to implement ISO 14001-based EMS	Others	Research article
Benchmarking: An Int J	2010	Breno Nunes, David Bennett (2010)	Green operations initiatives in the automotive industry: An environmental reports analysis and benchmarking study	Environmental	Research article
Benchmarking: An Int J	2009	Anand Gurumurthy, Rambabu Kodali (2009)	Application of benchmarking for assessing the lean manufacturing implementation	Others	Case study
Benchmarking: An Int J	2008	P. Padma, L.S. Ganesh, Chandrasekharan Rajendran (2008)	A study on the ISO 14000 certification and organizational performance of Indian manufacturing firms	Environmental	Empirical study

Benchmarking: An Int J	2005	Sandra Rothenberg, Brian Schenck, James Maxwell (2005)	Lessons from benchmarking environmental performance at automobile assembly plants	Environmental	Research article
Benchmarking: An Int J	2003	Deanna H. Matthews (2003)	Environmental management systems for internal corporate environmental benchmarking	Environmental	Research article
Int J of Technology Management	2008	Ben-Jeng Wang	Analysis of efficiency of lean production implemented in multi-national optic enterprises	Economic	Research article
Int J of Technology Management	2008	Nardia Haigh, Andrew Griffiths	The environmental sustainability of information systems: considering the impact of operational strategies and practices	Environmental	Research article
Int J of Technology Management	2002	Vittorio Biondi, Fabio Iraldo, Sandra Meredith	Achieving sustainability through environmental innovation: the role of SMEs	Environmental	Research article
Int J of Technology Management	2001	Alina Matuszak-Flejszman, Tom Bramorski	Factors influencing the implementation of environmental management system at Amica-Wronki SA	Others	Research article
J of Business Logistics	2011	Wendy L. Tate, Kevin J. Dooley, Lisa M. Ellram	Transaction Cost and Institutional Drivers of Supplier Adoption of Environmental Practices	Environmental, Economic	Research article
J of Environmental Management	2010	Mehmet Ali Ilgin, Surendra M. Gupta (2010)	Environmentally conscious manufacturing and product recovery (ECMPRO): A review of the state of the art	Environmental	Literature review
J of Environmental Management	2010	Rene Van Berkel (2010)	Evolution and diversification of National Cleaner Production Centres (NCPCs)	Others	Research article
J of Environmental Management	2010	Diego Alfonso Vazquez Brust, Catherine Liston-Heyes (2010)	Environmental management intentions: An empirical investigation of Argentina's polluting firms	Environmental	Empirical study

J of Environmental Management	2009	María D. López-Gamero, José F. Molina-Azorín, Enrique Claver-Cortés (2009)	The whole relationship between environmental variables and firm performance: Competitive advantage and firm resources as mediator variables	Environmental, Economic	Research article
J of Environmental Management	2009	JunJie Wu (2009)	Environmental compliance: The good, the bad, and the super green	Environmental	Research article
J of Environmental Management	2009	Göran Finnveden, Michael Z. Hauschild, Tomas Ekvall, Jeroen Guinée, Reinout Heijungs, Stefanie Hellweg, Annette Koehler, David Pennington, Sangwon Suh (2009)	Recent developments in Life Cycle Assessment	Environmental	Research article
J of Environmental Management	2009	Deepali Sinha Khetriwal, Philipp Kraeuchi, Rolf Widmer (2009)	Producer responsibility for e-waste management: Key issues for consideration – Learning from the Swiss experience	Others	Research article
J of Environmental Management	2009	Ehsan H. Feroz, Raymond L. Raab, Gerald T. Ulleberg, Kamal Alsharif (2009)	Global warming and environmental production efficiency ranking of the Kyoto Protocol nations	Environmental	Research article
J of Environmental Management	2008	Jean-François Henri, Marc Journeault (2008)	Environmental performance indicators: An empirical study of Canadian manufacturing firms	Environmental	Research article
J of Environmental Management	2008	Hung-Suck Park, Eldon R. Rene, Soo-Mi Choi, Anthony S.F. Chiu (2008)	Strategies for sustainable development of industrial park in Ulsan, South Korea—From spontaneous evolution to systematic expansion of industrial symbiosis	Environmental, Economic	Empirical study
J of Environmental Management	2007	Yiping Fang, Raymond P. Côté, Rong Qin (2007)	Industrial sustainability in China: Practice and prospects for eco-industrial development	Others	Research article
J of Environmental Management	2002	Dong-Myung Kwon, Min-Seok Seo, Yong-Chil Seo (2002)	A study of compliance with environmental regulations of ISO 14001 certified companies in Korea	Environmental	Empirical study

J of Environmental Management	2002	Gerald E. Fryxell, Agnes Szeto (2002)	The influence of motivations for seeking ISO 14001 certification: an empirical study of ISO 14001 certified facilities in Hong Kong	Others	Research article
Proceedings of the Institution of Mechanical Engineers, Part B: J of Engineering Manufacture	2010	B C Rao	Methodology for adapting metal cutting to a green economy	Environmental	Methodology
Proceedings of the Institution of Mechanical Engineers, Part B: J of Engineering Manufacture	2009	P D Ball, S Evans, A Levers, and D Ellison	Zero carbon manufacturing facility — towards integrating material, energy, and waste process flows	Environmental, Economic	Methodology
Proceedings of the Institution of Mechanical Engineers, Part B: J of Engineering Manufacture	2008	S Bhat	The effect of ordering policies for a manufacturing cell changing to lean production	Others	Methodology
Proceedings of the Institution of Mechanical Engineers, Part B: J of Engineering Manufacture	2008	R V Rao	Evaluation of environmentally conscious manufacturing programs using multiple attribute decision-making methods	Environmental	Methodology

Proceedings of the Institution of Mechanical Engineers, Part B: J of Engineering Manufacture	2007	M S Abu Bakar, S Rahimifard	Computer-aided recycling process planning for end-of-life electrical and electronic equipment	Environmental, Economic	Research article
Proceedings of the Institution of Mechanical Engineers, Part B: J of Engineering Manufacture	2006	E Uhlmann, F Elbing, and J Dittberner	Innovative manufacturing technologies for the disassembly of consumer goods	Environmental	Research article
Proceedings of the Institution of Mechanical Engineers, Part B: J of Engineering Manufacture	2006	A Rahimifard, S T Newman, and S Rahimifard	A web-based information system to support end-of-life product recovery	Environmental	Methodology
Proceedings of the Institution of Mechanical Engineers, Part B: J of Engineering Manufacture	2003	A M Chalkley, E Billett, D Harrison, and G Simpson	Development of a method for calculating the environmentally optimum lifespan of electrical household products	Environmental	Research article

Proceedings of the Institution of Mechanical Engineers, Part B: J of Engineering Manufacture	2001	E Westkämper, L Alting, and G Arndt	Life cycle management and assessment: Approaches and visions towards sustainable manufacturing	Environmental, Economic	Research article
Proceedings of the Institution of Mechanical Engineers, Part B: J of Engineering Manufacture	2001	E Westkämper, J Niemann, and A Dauensteiner	Economic and ecological aspects in product life cycle evaluation	Environmental, Economic	Research article
Proceedings of the Institution of Mechanical Engineers, Part B: J of Engineering Manufacture	2001	K Feldmann, S Trautner, H Lohrmann, and K Melzer	Computer-based product structure analysis for technical goods regarding optimal end-of-life strategies	Environmental	Research article
Proceedings of the Institution of Mechanical Engineers, Part B: J of Engineering Manufacture	2001	D-H Lee, J-G Kang, and P Xirouchakis	Disassembly planning and scheduling: Review and further research	Environmental, Economic	Literature review

Proceedings of the Institution of Mechanical Engineers, Part B: J of Engineering Manufacture	1999	H Popke, Th Emmer, and J Steffenhagen	Environmentally clean metal cutting processes—machining on the way to dry cutting	Environmental	Empirical study
Int J of Productivity and Performance Management	2008	Tom Tuttle, John Heap	Green productivity: moving the agenda	Environmental	Research article
Int J of Productivity and Performance Management	2006	Shahram Taj, Lismar Berro	Application of constrained management and lean manufacturing in developing best practices for productivity improvement in an auto-assembly plant	Economic	Research article
Int J of Productivity and Performance Management	2006	N. Mohan Das Gandhi, V. Selladurai, P. Santhi	Green productivity indexing: A practical step towards integrating environmental protection into corporate performance	Environmental, Economic	Research article
Int J of Business Performance Management	2001	M. Bennett, P. James	Environmental performance measurement in business: current practice and future trends	Environmental	Research article
Int J of Business Performance Management	1999	Bjorn Andersen, Tom Fagerhaug	'Green'' performance measurement	Environmental	Research article
European J of Industrial Engineering	2011	Imad Alsyouf, Raid Al-Aomar, Heba Al-Hamed, Xiaojin Qiu	A framework for assessing the cost effectiveness of lean tools	Economic	Case study
J of Manufacturing Systems	2005	Toni L. Doolen, Marla E. Hacker	A review of lean assessment in organizations: An exploratory study of lean practices by electronics manufacturers	Others	Empirical study

J of Manufacturing Systems	2002	Ying Tang, MengChu Zhou, Eyal Zussman, Reggie Caudill	Disassembly modeling, planning, and application	Environmental	Literature review
J of Manufacturing Systems	2000	Yue Yu, Kai Jin, Hong C. Zhang, Frederick F. Ling, David Barnes	A decision-making model for materials management of end-of-life electronic products	Environmental	Methodology
J of Manufacturing Systems	1999	David G. Mabee, Michael Bommer, William D. Keat	Design charts for remanufacturing assessment	Others	Case study
Materials and Manufacturing Processes	2011	Shivom Sharma, Y. C. Chua & G. P. Rangaiah	Economic and Environmental Criteria and Trade-Offs for Recovery Processes	Environmental, Economic	Methodology
Materials and Manufacturing Processes	2006	J. Kundrák, A. G. Mamalis, K. Gyáni & A. Markopoulos	Environmentally Friendly Precision Machining	Environmental	Research article
Machining Science and Technology	2006	D. P. Adler, W. W.-S. Hii, D. J. Michalek & J. W. Sutherland	EXAMINING THE ROLE OF CUTTING FLUIDS IN MACHINING AND EFFORTS TO ADDRESS ASSOCIATED ENVIRONMENTAL/HEALTH CONCERNS	Environmental, Social	Research article
Machining Science and Technology	2006	S. Paul & A. B. Chattopadhyay	ENVIRONMENTALLY CONSCIOUS MACHINING AND GRINDING WITH CRYOGENIC COOLING	Environmental, Economic	Research article
Machining Science and Technology	2006	Shane Y. Hong	LUBRICATION MECHANISMS OF LN2 IN ECOLOGICAL CRYOGENIC MACHINING	Environmental	Methodology
Int J of Life Cycle Assessment	2011	Anna Lewandowska, Alina Matuszak-Flejszman, Katarzyna Joachimiak and Andreas Ciroth	Environmental life cycle assessment (LCA) as a tool for identification and assessment of environmental aspects in environmental management systems (EMS) Part 2: case studies	Environmental	Empirical study

Int J of Life Cycle Assessment	2011	Anna Lewandowska	Environmental life cycle assessment as a tool for identification and assessment of environmental aspects in environmental management systems (EMS) part 1: methodology	Environmental	Empirical study
Int J of Life Cycle Assessment	2010	Catherine Clauzade, Philippe Osset, Charlotte Hugrel, Aude Chappert and Maxime Durande, et al.	Life cycle assessment of nine recovery methods for end-of-life tyres	Environmental, Economic	Research article
Int J of Life Cycle Assessment	2010	Henri Lecouls and Walter Klöpffer	Note on the critical review of the study "Life Cycle Assessment for the different used tyres recycling methods" prepared for Aliapur by Ecobilan	Environmental	Empirical study
Int J of Life Cycle Assessment	2009	Riccardo M. Pulselli, Roberto Ridolfi, Benedetto Rugani and Enzo Tiezzi	Application of life cycle assessment to the production of man-made crystal glass	Environmental	Research article
Int J of Life Cycle Assessment	2007	Andreas Kicherer, Stefan Schaltegger, Heinrich Tschochohei and Beatriz Ferreira Pozo	Eco-efficiency Combining life cycle assessment and life cycle costs via normalization	Environmental, Economic	Research article
Int J of Life Cycle Assessment	2007	Atsushi Inaba, Masayuki Sagisaka, Toshisuke Ozawa and Tomoko Kobayashi	LCA of global supply chains — from production through to end of life management LCA for the food chain in the region (Session 1) LCA for the waste chain in the region (Session 2)	Environmental	Research article
Int J of Advanced Manufacturing Technology	2011	Oliver Avram, Ian Stroud and Paul Xirouchakis	A multi-criteria decision method for sustainability assessment of the use phase of machine tool systems	Environmental, Economic	Methodology
Int J of Advanced Manufacturing Technology	2011	Zhigang Jiang, Hua Zhang and John W. Sutherland	Development of an environmental performance assessment method for manufacturing process plans	Environmental	Methodology

Int J of Advanced Manufacturing Technology	2010	Patroklos Georgiadis and Maria Besiou	Environmental and economical sustainability of WEEE closed-loop supply chains with recycling: a system dynamics analysis	Environmental, Economic	Methodology
Int J of Advanced Manufacturing Technology	2010	Bastiaan C. J. Zoeteman, Harold R. Krikke and Jan Venselaar	Handling WEEE waste flows: on the effectiveness of producer responsibility in a globalizing world	Others	Research article
Int J of Advanced Manufacturing Technology	2007	X. C. Tan, F. Liu, D. C. Liu, Li Zheng, H. Y. Wang and Y. H. Zhang	Research on the diagnosis and improvement method of a process route in an enterprise production process in terms of sustainable development III	Environmental	Methodology, Case study
Int J of Advanced Manufacturing Technology	2001	S.G. Lee, S.W. Lye and M.K. Khoo	A Multi-Objective Methodology for Evaluating Product End-of-Life Options and Disassembly	Environmental	Methodology
Int J of Machine Tools and Manufacture	2008	P.W. Marksberry, I.S. Jawahir	A comprehensive tool-wear/tool-life performance model in the evaluation of NDM (near dry machining) for sustainable manufacturing	Environmental, Social	Methodology