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LITERATURE SURVEY OF GSCM WITH INTERRELATED CONCEPTS

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Abstract: *This paper is a review of papers with keywords Green Supply Chain Management, Lifecycle Assessment, Product Lifecycle Management, Product Life Cycle Management and Life Cycle Management. Number of articles and doctoral theses written with above mentioned concepts, methods and models were analyzed, leading to a summarized presentation of papers with their interrelated appearance. This paper is an extended article of paper published on 5th International Conference: Management of Technology - Step to Sustainable Production (MOTSP 2013).*

Keywords: *Green Supply Chain Management, Life Cycle Assessment, Product Life Cycle Management, greening*

INTRODUCTION

Nowadays, the increase in greenhouse gas (GHG) emissions in the atmosphere is currently one of the most serious environmental treats. Due to GHG emissions we will be witnesses of climate change which will cause damaging impacts in the next few decades [1]. These will primarily affect the natural and human systems [2]. At the same time these emissions are also a limiting factor for the economic growth of some countries, especially those in the transition process [3]. One of the reasons for that is the Kyoto protocol, adopted in December 1997 at The Third Conference of Parties (COP-3) in Kyoto, at which the industrial world agreed to reduce the emissions of greenhouse gases approximately 6 to 8 % below 1990 levels by 2008–2012 [4]. In the meantime, also due to the climate change and the increase in environmental awareness all over the world, the concept of Green Supply Chain Management appeared. It is often defined as integrating environmental thinking into supply chain management [5].Within that concept many greening elements aimed at the reduction of materials, energy, waste, pollution and emissions, or promoting the usage of recyclable materials and renewable energy sources, are introduced in various segments of supply chains. The proof lies in number of examples from industry, as well as in significant interest of academic community that could be seen through research papers, doctoral thesis and research projects.

There are three main reasons why companies implement the greening process into their corporation [6, 7]:

- *Legislation - they have to comply with the environmental regulations,*
- *Marketing - addressing the environmental concerns of their customers,*
- *Ecological awareness - mitigate the environmental impact of their production activities.*

Today there are many concepts, methods and models which are dealing with ecology, cleaner production, greener supply chains etc. However, mentioned examples and literature is not always fully clear and identical in terms of terminology used, while those various concepts, methods and models are appearing as a topic with practically same ultimate goal - greener processes of supply chain/production.

This paper is an overview paper of Green Supply Chain Management (GSCM) with Life Cycle Assessment (LCA), Product Lifecycle Management (PLM), Product Life Cycle Management (PLCM) and Life Cycle Management (LCM) terms. The research was based on literature survey within two

databases that contain number of relevant scientific journals, databases of doctoral thesis, and additionally standards and directives related to sustainable development. Research methodology is explained with more details in chapter 2 and findings in chapter 3, preceding with the brief explanations of mentioned concepts, methods and models. This is the first part of the research with aims to identify interrelations among those concepts, methods and models similarities and differences appearing in approaches of various authors, leading to an overall better understanding of broad concept of GSCM.

Life Cycle Assessment, Product Lifecycle Management, Product Life Cycle Management, Life Cycle Management

The development of LCA methodology has its roots back in the late 1960's and early 1970's when the first studies applying a life cycle perspective on a process system took place in the USA, focusing on environmental impacts from different types of beverage containers [8].

When we compare LCA and PLM/PLCM/LCM we can found some differences. In ISO 14040 LCA is defined as the "compilation and evaluation of the inputs, outputs and potential environmental impacts of a product system throughout its life cycle". Thus, LCA is a tool for the analysis of the environmental burden of products at all stages in their life cycle - from the extraction of resources, through the production of materials, product parts and the product itself, and the use of the product to the management after it is discarded, either by reuse, recycling or final disposal (in effect, therefore, "from the cradle to the grave") [9].

In industry, PLM is the process of managing the entire lifecycle of a product from its conception, through design and manufacture, to service and disposal, and should be distinguished from PLCM. PLM describes the engineering aspect of a product, from managing descriptions and properties of a product through its development and useful life; whereas, PLCM refers to the commercial management of life of a product in the business market with respect to costs and sales measures [10]. While LCM is an integrated model to assist in businesses managing the total life cycle of products and services towards more sustainable consumption and production patterns [11]. Figure 1 presents LCA method while Figure 2 presents PLM model.

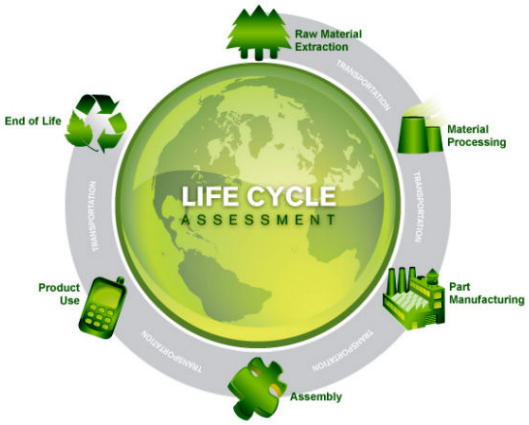

Figure 1 – LCA method

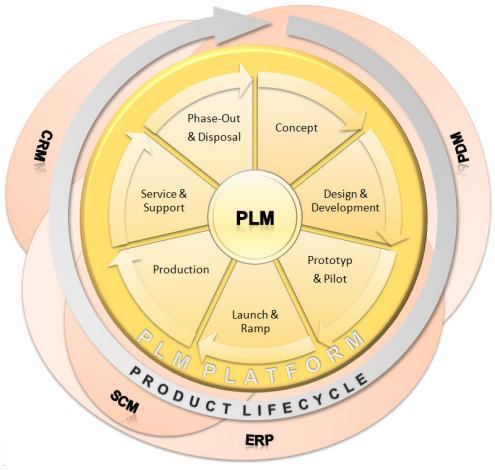

Figure 2 – PLM model

From the definition and picture we can see that the major difference between LCA and PLM is that LCA analyzes raw material and its extraction, material processing and product life cycle, while PLM deals only with product life cycle. Also LCA/PLCM/LCM are very similar; all take the whole life cycle thinking into consideration, only LCA is a tool for analyzing environmental burden of products while PLCM and LCM are models which can use LCA as a tool in their life cycle thinking.

Green Supply Chain Management

From the definition of Supply Chain management given by the Council of Supply Chain Management Professionals (CSCMP) [12], "Supply chain management encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities." Importantly, it

also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third party service providers and customers. In essence, supply chain management integrates supply and demand management within and across companies. Making it green, it could be simply illustrated as in Figure3.

GSCM is a field of implementation of green thinking in all the segments of companies' activities and with focusing on the definition of SCM and the three basic groups of activities - procurement, operations and logistics, green supply chain management could be illustrated as in Figure 4 [7].

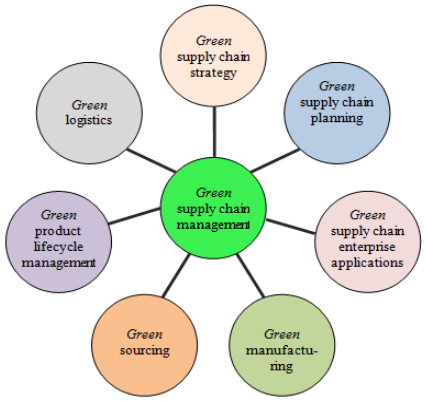

Figure 3 – Elements of Green supply chain management

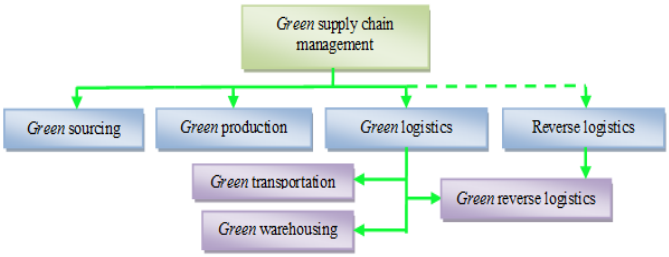

Figure 4 – Basic groups of GSCM activities related to SCM definition

RESEARCH METHODOLOGY

The research was done through these two databases:

- *Science Direct,*
- *Scopus.*

These databases contain some relevant journals in field of energy, industrial engineering, production and ecology such as:

- *Journal of Power Sources,*
- *Journal of Cleaner Production,*
- *Journal of Manufacturing Processes,*
- *Journal of Ecology,*
- *Journal of Environmental Economics and Management,*
- *Journal of Computer Assisted Learning,*
- *Journal of Applied Ecology,*
- *Journal of Industrial Ecology,*
- *Journal of Operations Management,*
- *Journal of Advanced Research,*
- *Computers & Operations Research,*
- *European Journal of Operational Research,*
- *International Journal of Life Cycle Assessment,*
- *International Journal of Logistics Systems and Management,*
- *Logistics Research,*
- *European Journal of Purchasing & Supply Management,*
- *Journal of Purchasing & Supply Management.*

Research of papers was done in three steps. In the first step, these databases were searched using the following terms:

- *GSCM or Sustainable Supply Chain Management (SSCM) or Environmental Supply Chain Management (ESCM),*
- *LCA,*
- *Life Cycle Engineering (LCE),*
- *PLM or PLCM or LCM,*
- *Green Logistics (GL) or Sustainable Logistics (SL) or Environmental Logistics (EL) or Clean Logistics (CL),*
- *Green Production (GP) or Sustainable Production (SP) or Environmental Production (EP) or Clean Production (CP),*
- *Greening,*
- *Industrial Ecology (IE).*

In the second step of the research, the data bases were searched in order to find papers that are mentioning the following terms:

- *(GSCM or SSCM or ESCM) and (LCA),*
- *(GSCM or SSCM or ESCM) and (PLM or PLCM or LCM),*
- *(LCA) and (PLM or PLCM or LCM),*
- *(GSCM or SSCM or ESCM) and (LCA) and (PLM or PLCM or LCM).*

In the third step, papers mentioning (GSCM or SSCM or ESCM) and (LCA) and (PLM or PLCM or LCM) are analyzed.

In addition to the above mentioned concepts, methods and models some standards and directive are also connected with sustainable development.

So, with the concept of sustainable developments are often associated the following standards and directives:

- *ISO 9001 Quality management systems - Requirements,*
- *ISO 14001 Environmental management systems - Requirements with guidance for use,*
- *ISO 14040 Environmental management - Life cycle assessment - Principles and framework,*
- *ISO 14051 Environmental management - Material flow cost accounting - General framework,*
- *ISO 14062 Environmental management - Integrating environmental aspects into product design and development,*
- *ISO 14064 Greenhouse gases - part 1, 2, 3,*
- *ISO 26000 Guidance on social responsibility,*
- *ISO 50001 Energy management systems - Requirements with guidance for use,*
- *OHSAS 18001 Occupational health and safety management systems,*
- *WEEE Waste Electrical and Electronic Equipment Directive,*
- *RoHs Directive on the restriction of the use of certain Hazardous substances in electrical and electronic equipment,*
- *IPP Integrated Product Policy,*
- *EuP Energy using Products directive,*
- *ELV End of Life Vehicles directive,*
- *EPA Environmental Protection Act,*
- *PPW Packaging & Packaging Waste directive,*
- *EMAS Eco-Management & Audit Scheme directive,*
- *VOC Volatile Organic Compounds directive,*
- *ED Eco-design directive.*

RESEARCH RESULTS

The results of the first step are presented in Figure 5, while Figure 6 presents the results of the second step of the research.

From the results of first two steps of the research it is evident that number of published papers is raising yearly. More and more papers are related to sustainability, and their numbers is proving actual trends and complexities in this area. In order to investigate deeply the current state regarding this issue, third step of research was done. 83 papers using (GSCM or SSCM or ESCM) and (LCA) and (PLM or PLCM or LCM) were identified and analyzed. Figure 7 presents a classification of those papers according to the origin of authors, while Figure 8 presents the classification of papers according to the type of the paper.

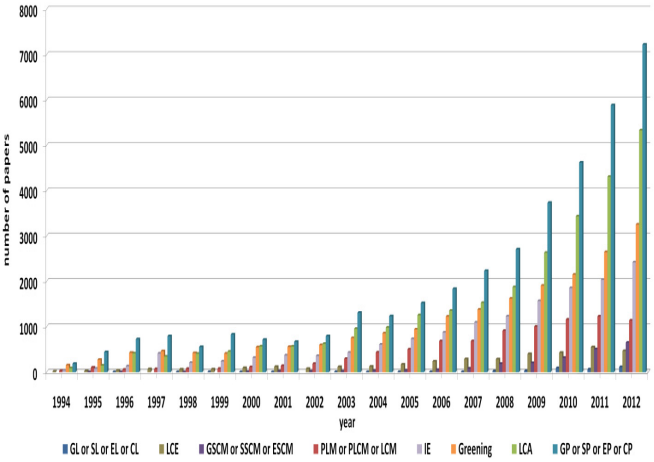

Figure 5 – Numbers of published papers by year after the first step of the research

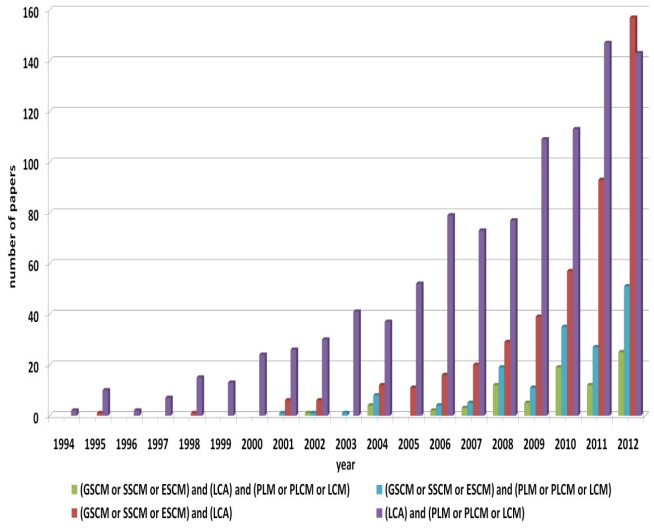

Figure 6 – Numbers of published papers by year after the second step of the research

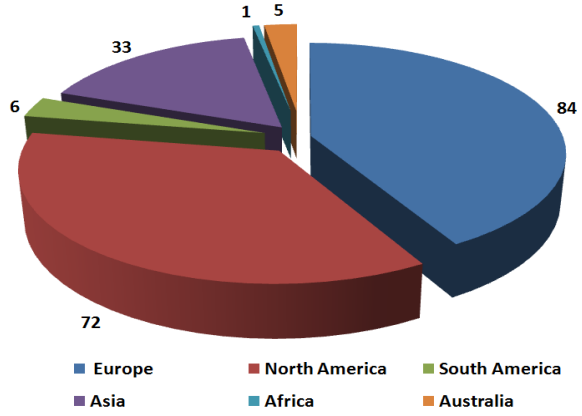

Figure 7 – Classification of papers according to the origin of authors [number of papers]

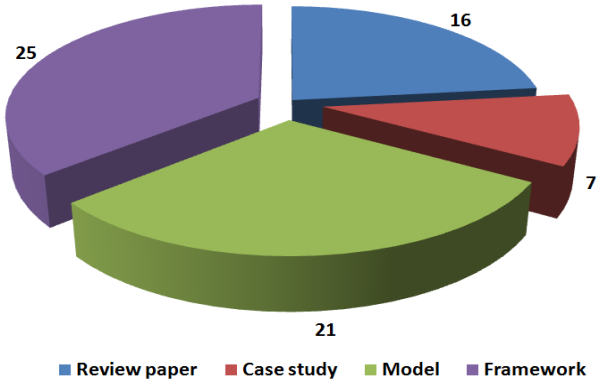

Figure 8 – Classification of papers according to the type of paper [number of papers]

From Figure 7 it is evident that most papers come from Europe and North America, which allows assumption that these two continents are working the most in the field of sustainability. Although 83 papers were found in databases, some of them appear in both databases, so 69 papers (references from [13] to [81]) were actually analyzed. 7 of them are case study papers, presenting an example of the implementation of a concept, method or model of sustainability in practice. There are 16 review papers of written literature. The rest are scientific papers, divided into two categories. In first category there are 21 papers aimed to define some kind of mathematical model. In the second category there are 25 papers aimed to propose a conceptual model, framework or guidelines. That category has the most papers. To illustrate the topics and approaches, bellow is given brief overviews of some of them. Complete list of analyzed papers is given in Table 1.

Chen and others [17] gave a reviewed literature related with green strategies within green supply chains such as (green design, green procurement, green production and green marketing).They also defines a model for the selection of appropriate strategies using analytical network process.

Despeisse and others [20] analyzed the written papers related to sustainable production (they search database according on the terms: green manufacturing, clean production, sustainable production, eco-conscious production, industrial ecology, etc.). Based on a review of written literature and analysis of gaps in the literature and practice, they define ecosystem production model based on industrial ecology. The model is based on the flow of the materials, energy and waste in order to for better understanding and defining the interactions between operations within manufacturing, suppliers and the building in the environment.

Table 1 – Overview of analyzed papers

LCA, PLM, PLCM, LCM, LCE	*Bejarski & others [16], Cellura & others [22], Heiskanen [30], Lainez & others [46], Lai & others [57], Balkau & Sonnemann [71] and Serung [74]*
ISO 14001, OHSAS, European environmental directives	*Prajogo & others [45], Asif & others [54], Yung &others [58] and Khanna [59,64]*
GSCM, ESCM, SSCM	*Ageron & others [13] Chean & others [17], Gopalakrishnan & others [26], Guillen-Gosalbez & Grossman [27], Hassini & others [29], Hutchins & Sutherland [31], Kumar & Putnam [34], Kuo & others [35], Lainez & Puigjaner [36], Liu & others [37], Munoz & others [42], Lainez & others [46], Seuring [47-50, 74], Zhu & Cote [51], Zhu & others [52], Sarkis [53], Nakano [55], Jaegler & Burat [62], Hollos & others [63], Mollenkopf & others [65], Hong & others [66], Olson & others [69], Jaegler & Burlat [70], Vermeulen [73], Mele & others [75], Metta & others [76] Liu & others [79] and Vermeulen & Ras [81]*
Model for supplier selection	*Bai & Sarkis [14] and Bala & others [15]*
Eco-design of the products	*Chen & others [18], Ellram [23], Ferrera [24], Kengpol & Boonkanit [33], Pigosso & others [44], Ramani & others [67], Olson & others [69] and Metta & others [76]*
IE	*Despeisse & others [20] and Serung [74]*
GP, EP, SP, CP	*Despeisse & others [20], Duflou & others [21], Ellram [23], Gunasekaran & others [28], Ilgin & Gupta [32], Luh & others [38], Maxwell & others [41], Park & others [43], Nakano [55], Dou & Sarkis [56], Haapala & others [60], Arena & others [61], Wang & Cote [68], Geldermann & others [72], Dunk [77], Liu & others [79] and Bi [80]*
Review paper	*Chiu & others [19]*
Energy saving	*Duflou & others [21]*
Waste management	*Geng & others [51]*
GL, EL, SL, CL	*Venus [95] and Lai & others [57]*
Sustainable marketing	*Mariadoss & others [40], Vermeulen [73], Dunk [77] and Sarkis & others [78]*

Hassini & others [29] gave a framework for the introduction of sustainable supply chain management based on literature studies of written papers about sustainable supply chain since 2000 to 2010 year. In paper they also gave an example of implementation of SSCM in the Canadian company that produce and distribute electricity. The emphasis is given to the importance of defining and measuring the performance of SSCM's. Authors point out that each company must develop its own indicators that can be matched and their importance is to measure the achievement of sustainable initiatives and allowing the new initiatives to be created.

Seuring [50] 2012 analyzes written papers in the past 15 years dealing with GSCM and SSCM. He analyzes papers that propose a mathematical model of GSCM, or SSCM. The same author [74] analyzed the similarities and differences between the integrated supply chain management, industrial symbiosis, LCM and supply chain management.

Sarkis [53] shows the relationship between GSCM and other green strategies, such as network management of supply chains, the sustainability of supply and demand, or corporate social responsibility network, ESCM, green purchasing and green procurement, environmental purchase, sustainable supply chain and EL and GL. This paper provides a framework that helps to understand the difference between the methodologies. Author also defines five flows of resources related to green supply chains and 9 boundaries and limitations of green supply chain. Thus, the flows within the green supply chain are: flows of materials, services, finance, information and waste, while the boundaries of green supply chain are: information, legal, cultural, organizational, technological, political, economic, temporary and proximal (physical and geographical location).

Holos & others [63] analyzed papers related to the sustainable supply chains. They propose a triple bottom line approach which involved economic, environmental and social component. They conducted a survey in Western Europe related to sustainable supply chains and analyzed it. The survey concludes that sustained cooperation of suppliers, in relation to the strategic-oriented procurement has a positive impact on green and social procurement. While social practices and sustainable cooperation between suppliers do not have a significant impact on the performance of the enterprise, green practices have a positive impact on reducing the cost and performance of the company.

Liu & others [95] analyzed more than 100 papers dealing with sustainable concepts, methods and models. An analyzed paper deals with the study of LCA, multi-criteria decision-making, sustainable design, with SP and sustainable supply chains. In conclusion, the authors said that there are three trends related to sustainability: sustainability has moved to the entire LCA from the evaluation of a single phase, sustainability has moved from single criteria decision-making to the multiple criteria decision-making and sustainability has become an integrated systematic methodology compared to the previous stand-alone approach.

Bi [80] analyzed the production models and sustainability within them. In paper he analyzes three things, the production needs, differences between models and limitations and bottle necks of the model. The author proposes 6R model of sustainable production as a model that provides the largest component f sustainability. Model 6R is consists of: remanufacture, redesign, recover, reuse, recycle and reduce.

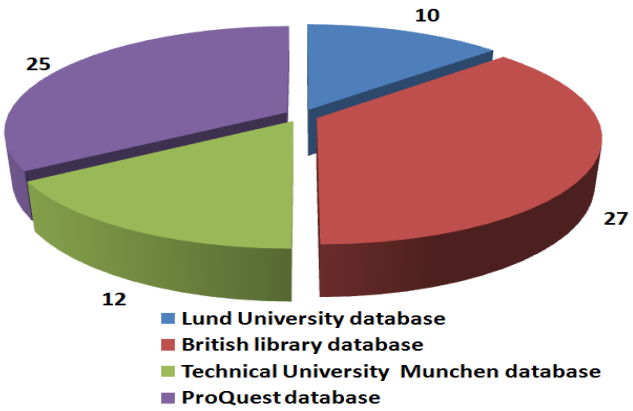

Figure 9 – Number of doctoral thesis appearing in 4 available databases

In order to obtain detailed insight into the current state and trends, doctoral theses are also researched regarding the topic of sustainability. Research was carried out according to the concepts, methods and models presented in Figure 5 (as in first step for

the paper), using four available databases. Results are presented in Figure 9, while overview of analyzed doctoral theses is presented in Table 2.

Table 2 – Overview of doctorial theses

LCA, PLM, PLCM, LCM, LCE	den Boer [83], Winkler [84], Fuchs [85], Herrmann [89], Weckert [90], Frad [91], Bitzer [92], Bungert [93], Lindhqvist [95], Tojo [96], Nawrocka [97], van Rossem [99], Johansson [100], Li [107], Nunes [114], Mead [118], Plant [121], Kamal [129] and Whatling [130], Choi J. [131], Hutchins [134], Hazen [135], Reap [136], Kim [137], Camacho [138], Ilgin [139], Vaccaro [140], Zhou [141], Chaabane [142], Cunion [143], Francois [144], Al-Fandi [147]
ISO 14001, OHSAS, European environmental directives	Nawrocka [97], Kronsell [98], van Rossem [99], Johansson [100], Rodhe [101], Parekh [112], Stewart [120], Plant [121] and Collins-Webb [127], Choi J. [131], Khiewnavawongsa [132], Kim [137], Zhou [141], Cunion [143], Cooper [150], Noh [151], Mil-Homens [153], Robinson [155]
GSCM, ESCM, SSCM	Abukhader [94], Nawrocka [97], Kogg [102], Schwartz [104], Hall [105], Huang [109], Nunes [114], Mason [117], Saibani [119], Hoejmose [122], Nassar [123], Holt [124] and Kim [126], Khiewnavawongsa [132], Wolfe [133], Hutchins [134], Hazen [135], Kim [137], Camacho [138], Ilgin [139], Vaccaro [140], Zhou [141], Chaabane [142], Cunion [143], Altuger-Genc [145], Al-Fandi [147], Huang [148], Choi D. [149], Cooper [150], Ozcan [152]
Eco-design of the products	Tojo [96], Dewberry [110], Plant [121], Hussain [125] and Elias [128], Choi J. [131]
GP, EP, SP, CP	Hanssen [89], Lindhqvist [95], Tojo [96], Nawrocka [97], van Rossem [99], Rodhe [101], Abukhader [103], Nunes [114] and Hussain [125], Kim [137], Ilgin [139], Vaccaro [140], Al-Fandi [147], Huang [148]
Energy saving	Jones [115] and Stamford [116]
Waste management	Zisuh Asong [82], Winkler [84], Zhang[112] and Stewart [120], Sankaranarayanan [146]
GL, EL, SL, CL	Bogatu [87], Garg [88], Davies [111], Nunes [114] and Collins-Webb [127], Sankaranarayanan [146], Al-Fandi [147], Huscroft [154]
Sustainable marketing	Abukhader [103], Jahdi [106], Wang [110] and Mason [117], Cunion [143]

From the researched papers it was seen that graduate students at the University of Lund (Lindhqvist [95], Tojo [96] Nawrocki [97], van Rossem [99]) uses the term Extended Producer Responsibility (EPR) while talking about the responsibility of manufacturers to the entire product lifecycle. On the other hand, British and Americans uses term GSCM when talking about the same topic (Schwartz [104], Hall [105], Huang [109], Nunes [114], Mason [117], Saiban [119], Hoejmose [122] Nassar [123], Holt [124] and Kim [126], Khiewnavawongsa [132], Wolfe [133], Hutchins [134], Hazen [135], Kim [137], Camacho [138], Ilgin [139], Vaccaro [140], Zhou [141], Chaabane [142], Cunion [143], Altuger-Genc [145], Al-Fandi [147], Huang [148], Choi D. [149], Cooper [150], Ozcan [152]). Germans, (den Boer [83], Winkler [84], Fuchs [85], Herrmann [89], Weckert [90], Frad [91], Bitzer [92], Bungert [93] uses terms PLM and LCA when talking about manufacturer's responsibility to the entire product lifecycle.

CONCLUSON

As mentioned before, this paper is a review paper regarding an interrelation between GSCM, LCA and PLM/PLCM/LCM appearing as topics in scientific literature. The vast number of papers could be found dealing with one or more mentioned concepts, methods and models. The purpose of this paper was to narrow the set, identifying and analyzing papers with interrelations between mentioned concepts, methods and models. There is no paper that really connects and analyzes all of the mentioned concepts, methods and models. Most papers are only dealing with just one or two concepts, methods or models, without detailed analysis of others (just mentioning them in paper). Therefore, further research regarding interrelations of all mentioned concept, methods and models is needed. Additionally, it is necessary to link this concepts, methods and models with standards and EU directives for better understanding of trends in sustainable development. The idea is encompass all concepts, methods, models, standards and directives into one general, but applicative framework for implementations of GSCM concept into companies.

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