ECO-EFFICIENCY AND ECO-EFFECTIVENESS CONCEPTS
IN SUPPLY CHAIN MANAGEMENT

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Abstract
This paper presents the eco-efficiency and eco-effectiveness concepts in the supply chain management and shows comparison of the latest concepts in supply chain management. That is the first discussion of the newest concept. Implementation of this objective required to define all relevant terms are included in the new concepts in supply chain management. The main aim of this paper is to implicate of eco-efficiency and eco-effectiveness across the supply chain, to provide a comparison of lean, green/sustainable, eco-efficient and eco-effective supply chain and to show importance of these concept in closed-loop supply chain. This paper provides an overview of the current status of eco-efficiency and eco-effectiveness methodology and its applicability for extended supply chain. The objective of eco-efficiency is to deliver better products that have a lower ecological impact and better meet customer needs. Eco-efficiency and eco-effectiveness improvement allows to integrate goals related to environmental concerns and product efficiency and allows to choose the optimal solution for whole supply chain.

Keywords:
eco-efficiency, eco-effectiveness, closed-loop supply chain, Life Cycle Management

1. INTRODUCTION
This paper concerned with the extension of supply chain management with eco-efficiency and eco-effectiveness concepts. That is the first discussion of the concepts in supply chain management. The newest concept is eco-effectiveness. Eco-effectiveness and cradle-to-cradle design present an alternative design and production concept to the strategies of zero emission and eco-efficiency.

Integration of environmental and economical aspects and taking into account all aspects of sustainable development is one of the new trends in supply chain management. The contribution of research [1] on closed-loop supply chains was a methodology that has been defined performance measures for auditing purposes of the forward and reverse components of supply chains and has been assisted in assessing the importance of integration between different tiers of supply chains. New trends of supply chain management include: lean, green and resilience concept [2]. Detailed information about principle, the application of forecasting in capacity planning, creation with partners of one of the cooperation forms such as supply chain, demand chain, lean supply chain, agile supply chain, leagile supply chain, and using the DBR (Drum Buffer Rope), APS (Advanced Planning System) and SCP (Supply Chain Planning) systems were presented in paper [3]. In this paper were developed and broadening new concepts in supply chain management related with environmental aspects and eco-innovation.

2. ENVIRONMENTAL CONCEPTION IN SUPPLY CHAIN MANAGEMENT
Management of the supply chain can be understood as an ability to manage the network of relationships included in the chain of organization. However, it also necessitates the requirement to incorporate various, often contradictory views represented by stakeholders. That causes problems with costs, quality,
responsiveness and reliability – the issues that, according to the traditional way of thinking, influence efficiency and effectiveness. Moreover, it brings environmental problems arising from the concept of balanced development. Changes initiated within the supply chains that take environmental factors into consideration, lead to changes in sources of purchase, locations of warehouses and production plants, technologies and production processes or the way transportation is organized. In such cases, it seems justified to settle the best configuration of the supply chain from the financial, social and ecological cost perspective. Any partial analysis of that issue, often made during the product distribution stage, may lead to a slight improvement of the ecological aspect of the conducted activities, usually affecting only for a single link of the chain, whereas the whole supply chain may suffer destabilization and decreased efficiency.

The supply chain is usually shaped by many entities (enterprises and other types of organizations) which primary goal is to provide their customers with the best possible quality of the final product. The response time to demands of the market plays a substantial role in competitiveness of each link and the whole chain, therefore modern business strategies more and more frequently stress the necessity of cooperation in those complex inter-organizational systems. The supply chain, understood as a sequence of processes that finally lead to supply of the best possible product to the customer, is a complex system and requires a detailed description. While describing it, one may refer both to its structure and the processes executed within it. By taking the structural approach of the supply chain, the following structures can be differentiated [4] a business breakdown structure of the chain which distinguishes links that co-operate in the supply chain, and a flow structure that focuses on physical, informational and financial streams that occur between the sources of materials and the final receiver. Analysis of the processes in the supply chain focuses on the issue of action coordination. That may include choice of suppliers, shaping the level of reserves, development of partnerships and other activities. Coordination of processes comprises all activities which lead to establishment of their conduct and such shared utilization of available resources, which all links of the chain have access to, that effective and successful accomplishment of the goals is assured. Apart from the classic understanding of the notion of supply chain, the available literature [4,5,6] contains other notions that stress various aspects of configuration and functioning of supply chains. One of the growing trends which is more and more often included in management of the supply chain is “sustainable development”. That caused appearance and development of other notions, such as e.g. “green supply chain” and “sustainable supply chain” and others.

The Green Supply Chain extends the supply chain by considering the backward flow and the environment impacts of the Supply Chain activities. The backward flow is known as reverse supply chain. The Green Supply Chain was adapted from Beamon [7] and Cash and Wilkerson [8]. An extensive state-of-the-art review for the green supply chain management is presented by Srivastava [9].

The Sustainable Supply Chain extends the supply chain by considering the backward flow (reverse supply chain) and the environmental, economic and social aspects. According to the sustainable development principles non-renewable resource depletion should be minimize. Exergy as useful tool to measure sustainable supply chain was showed in paper [11].

One of the new trends in supply chain management is Sustainable Supply Network, which is comprised of raw materials as they flow from source to product to disposal/reuse. It encompasses people, environmental and human rights activities, information flow and resource consumption. Every organization is involved in multiple supply networks as a manufacturer and/or consumer [10].

Lean Supply Chain extends the supply chain by considering the streamline of processes which allows eliminating waste and non-value added activities. Companies have a number of areas in their supply chain where waste can be identified as time, costs or inventory. To create a leaner supply chain companies must examine each area of the supply chain [12,13].

Jayanet et al. [14] presented a state of the art literature review concerned with perspectives in reverse supply chain management. In recent years, in the context of sustainable resource management, there is a new concept, that of reverse logistics, for which there are synonymous terms such as: reverse logistics,
Ecologistics, logistics in the field of recycling or waste logistics. The problems of waste management are increasingly falling into the field of logistics – this is reflected in the growth of reverse logistics. Reverse logistics enables the realization of the idea of a circular economy, which is a departure from the linear model of raw material flow, to a model of closed material-energy cycles. Reverse logistics – because of the complexity and increasing importance in logistics processes – has become one of the most important areas of the eco-efficiency rise. New system solutions are observed as essential to increasing the eco-efficiency level of reverse management. Different kinds of recovery in integrated supply-chain was shown by Graczyk et al. [15]. Reverse logistics is defined as the process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal [16]. Reverse logistics includes activities such as: recovery, recycling, reuse, redesigning, remanufacturing, refurbishing and repair. Optimal use of the activities allows to get efficient and effective recovery logistics systems. The structure of closed-loop supply chain was shown in Fig. 1.

3. THE NEWEST CONCEPTS IN SUPPLY CHAIN MANAGEMENT

The concept of sustainable development in management is no longer a secondary factor to decide about competitive advantage. An increase in awareness of consumers makes them expect a logistics product which, at the same time, fulfills ecological expectations. Links of the supply chain usually choose such sources for purchases that offer more ecologically-aware materials or they modify their own actions by implementation of recycling, energy-saving devices and similar solutions. However, those trends are not yet widespread and do not occur in all links of the supply chain. In many cases, eco-friendly activity of the links may lead to conflicts due to divergent goals of the stakeholders and other links. One of the ways to reconcile those demands and soften differences among links of the supply chain is to treat balanced development as an integral part of the system operating within the supply chain, along with supplies, length of the cycle, quality and costs of materials, production and logistics [5,17]. The leader plays an essential role in shaping of the balanced supply chain. The leader maintains good relations with suppliers and in that way limits the risk of failure for planned and currently executed pro-ecological initiatives. Manufacturing, distribution and use of the product are the stages that cause more or less influence on the environment. As a consequence, this leads to occurrence of negative effects that require control. The outcome of processes in the supply chains that do not undergo sufficient monitoring and control may be dangerous pollution which depreciates the quality of living and causes increases of investment expenditure [5]. Links of the supply chain which execute their activities according to the rules of balanced development should take into consideration such environmental criteria as energy and material consumption of conducted processes, amounts of emitted pollutants, etc., also due to legal conditions related to those activities. Those criteria are focused on the issue of eco-efficiency, which should become one of the criteria of assessment of the supply chain [17].

Eco-efficiency is one of the key factors of sustainable development, which integrates environmental considerations with economic analysis to improve products and technologies in full life cycle. The concept of eco-efficiency (EE) was first introduced by Schaltegger and Sturm (1990) [18], the concept only became popular after adoption by the World Business Council for Sustainable Development (WBCSD) in 1992. The methodology of eco-efficiency calculation is known for almost twenty years. According to WBCSD “Eco-efficiency is achieved by the delivery of competitively-priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life-cycle to a level at least in line with the earth’s estimated carrying capacity”. In short, it is concerned with creating more value with less impact [19]. Application of life cycle assessment and life cycle costing for eco-efficiency assessment has been using in Central Mining Institute in Poland for several years [20]. On the basis of previous studies it was found that life cycle approach has significant potential for improving eco-efficiency [21].
Fig. 1. Conception of Closed-loop supply chain
Source: own study
The newest concept is eco-effectiveness. Cradle to Cradle (C2C) is an innovation framework used since the 1990s in order to design products and services which are beneficial in economic, health and environmental terms. A central component of the eco-effectiveness concept, cradle-to-cradle design provides a practical design framework for creating products and industrial systems in a positive relationship with ecological health and abundance, and long-term economic growth. Against this background, the transition to eco-effective industrial systems is a five-step process beginning with an elimination of undesirable substances and ultimately calling for a reinvention of products by reconsidering how they may optimally fulfill the need or needs for which they are actually intended while simultaneously being supportive of ecological and social systems. Eco-effectiveness is a concept for the production and consumption of goods and services that goes beyond the reduction of negative consequences implied in eco-efficiency and zero emission. Eco-effectiveness positively defines the beneficial environmental, social, and economic traits of goods and services, thereby eliminating the fundamental problems (material flow quality limitations, antagonism to economic growth and innovation, and toxicity) that arise in eco-efficiency strategies. Based on the comparative analysis supply chain concepts, the differences and similarities have been presented in Table 1.

Table 1. A comparison between new concepts in supply chain management

<table>
<thead>
<tr>
<th></th>
<th>Lean</th>
<th>Green/sustainable</th>
<th>Eco-efficient</th>
<th>Eco-effective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kind of supply chain</td>
<td>Opened and closed loop supply chain</td>
<td>Opened and closed loop supply chain</td>
<td>Opened and closed-loop supply chain</td>
<td>Only closed-loop supply chain</td>
</tr>
<tr>
<td>General purpose</td>
<td>Maximize profits through cost reduction</td>
<td>Improving ecological efficiency</td>
<td>Improving ecological and economic efficiency</td>
<td>Improving product in life cycle from cradle to cradle (C2C)</td>
</tr>
<tr>
<td>Main idea</td>
<td>Elimination of waste</td>
<td>Pollution prevention</td>
<td>Zero: zero waste emission, zero resource use and zero toxicity</td>
<td>Quality in life cycle</td>
</tr>
<tr>
<td>Focus</td>
<td>Focus on cost reduction and increased flexibility</td>
<td>Focus on sustainable development</td>
<td>Focus on doing things right</td>
<td>Focus on doing right things</td>
</tr>
<tr>
<td>Product design</td>
<td>Maximize performance and minimize cost</td>
<td>Eco-design</td>
<td>Cradle to grave design</td>
<td>Cradle to cradle design</td>
</tr>
<tr>
<td>KPI (Key indicator)</td>
<td>Cost, Service level</td>
<td>CO₂, eco-indicator, etc.</td>
<td>Integrated economic and environmental indicators</td>
<td>Indicators in life cycle from cradle to cradle (C2C)</td>
</tr>
<tr>
<td>Concept</td>
<td>Zero waste</td>
<td>Environmental protection</td>
<td>Eco-efficiency</td>
<td>Eco-effectiveness</td>
</tr>
<tr>
<td>Waste management</td>
<td>Recycling</td>
<td>Recycling</td>
<td>Recycling</td>
<td>Upcycling</td>
</tr>
</tbody>
</table>

Source: own analysis based on [6,22,23,24]

4. SUMMARY
In this paper new trends and perspectives in supply chain management were presented. It was done comparison of Lean, Green, Eco-efficient and Eco-effective concepts in supply chain. This paper concluded that life cycle approach has significant potential for improving eco-efficiency in supply chain and eco-efficiency analysis is incorporated with eco-effectiveness analysis. However, measurement of eco-effectiveness of the whole supply chain is a difficult issue, mainly due to complexity of its structure. Further research will be focused on assessment of eco-efficiency and eco-effectiveness of logistic subsystems conducted with use of partial indices. Such approach allows to assess changes in logistic subsystems along
with the factors that determine them and, subsequently, to join them in order to conduct full assessment of the supply chain, taking into consideration the economic and ecological aspects.

LITERATURE


