

Developing of Sustainable Supply Chain Management Indicators in Construction

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Abstract. Most of the existing supply chain management methods and systems are being transferred to construction regardless of the specifics of companies in the construction sector. Numerous complex factors such as ecological, social and economic are required for the continuous evaluation in the modern management of construction sector. The provided studies and the research to examine sustainable supply chain management in construction sector from a holistic perspective, concentrating on mostly long-term sustainable decision-making by the construction company rather than being centered only on the supply chain management for construction projects. This paper identifies a list of sustainability indicators for examining the supply chains of construction companies. Those indicators were categorized and assigned to one or a couple groups by reviewing their use in the previous literature agreeing to the reasoning to way better reflect the SSCM principle of their use in construction companies. The use of indicators can help develop strategies for the construction sector for sustainable policy makers and construction company managers.

1 Introduction

The application of the sustainable supply chain management (SSCM) in construction companies reduces environmental impact, reduces the risk of failure and increases the competitiveness of construction companies. Innovations in the construction sector are accepted slowly. Researchers studying the supply chain and its management state that the performance of supply chains (local and holistic) can be better if the conjunctural relations and processes between companies are actively managed [1, 2, 3]. The management aspect and its importance is often overlooked; it also determines the added value of a construction project.

The construction supply chain includes contractors, manufacturers, building material suppliers, builders and developers, as well as people, carriers, and other intermediaries providing warehousing services, as well as the customer (client). All entities of the construction supply chain (SC) are interconnected by links of finance, information and materials, but not all of them are mandatory in every part of the chain [4]. The actions of the entity and the need of customers determine the structure of the construction supply chain. The supply chain is being treated as a chain of events and cannot be observed for a single

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step or stage; the SC must be treated as a network [5]. A builder can obtain materials from multiple suppliers at once and transfer his product to multiple resellers and intermediaries.

SSCM emphasizes a wider range of actions for SC managers and companies as this requires the development and implementation of policies to improve the environmental, economic and social governance of partners. In general, the SSCM covers four areas: (1) information, product, financial management; (2) management of economic and social factors; (3) technology and new project management; and (4) stakeholder governance.

This paper aims to identify a list of sustainability indicators for examining the supply chains of construction companies.

2 Literature review

The main task of construction supply chain management is to coordinate and integrate material, financial and information flows between customers, suppliers, builders, contractors, material manufacturers, retail and wholesale companies, to control and automate construction and logistics processes. The use of one or more integrated computer systems and the standardization of processes allows construction companies to save time, avoid mistakes, reduce staff numbers and increase the efficiency of the construction process. Ensuring a smooth process of design, construction, planning the logistics, ordering materials and production reduces the sum of workers and specialists needed, shortens construction time and optimizes costs [6].

Most supply chains (not only in the construction field) are commercial which means that they are successful when the desired profitability of the supply chain is achieved [7]. For a construction supply chain to be successful at all stages, supply chain management needs to be assessed. Understanding that all flows in the construction supply chain are cost driven, it can be concluded that effective management of construction flows and coordination of the movement of those flows is an essential condition for success [8].

Supply chain management in the construction sector can address intertwined organizational challenges and offer effective management strategies for potential barriers at any stage of construction [9]. Reviewing the construction supply chain management structure, three main parts can be identified that are indispensable for successful supply chain operations: management elements, business processes and supply chain structure (Fig. 1) [10].

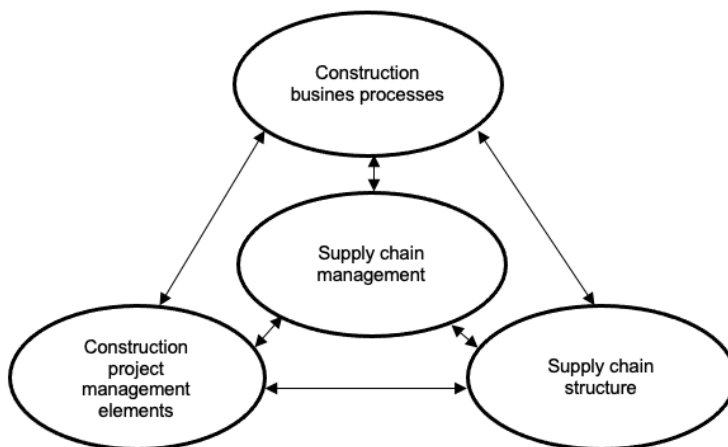


Fig. 1. Simple structure of supply chain management [10].

According to Konovalenko and Ludwig [10], the definition of SCM covers all the main activities of the construction process that create added value for construction companies starting with the exterior and interior design of a building, project planning to the construction and finishing the construction project in time. The main goal in the supply chain of builders and designers is to increase the operation rates, speed up the implementation of construction projects and reduce inventories.

Information systems help to track and transfer customer needs at different levels of the chain in order to minimize the cost of building materials and inventory in the supply chain [11]. All branches of the general construction industry scheme are interconnected and operate as a kind of ecosystem.

Most studies emphasize the need to move towards a sustainable approach in project management, especially in the construction sector. Shen et al. describes the reasons why sustainability should be included in the construction management plan, including competitive activities [12].

Further research of a construction supply chain requires a better understanding of potential threats. According to Boone et al. [13] the diversity of external and internal environmental factors leads to an increase risk in supply chain. Globalization, changes in global policies and other macro-environmental trends increase the risk of challenges (endless pressure to improve efficiency and reduce operating costs as much as possible) or emerging problems. The main objective of risk management is to monitor, control, and assess the supply chain risks that could ensure the maximum profitability growth and continuity in the future in the supply chain [13, 14]. As it is shown in the picture below (Fig. 2), lack of on-time supply of materials and machinery at the right place and time is the most important cause of construction supply chain threats and failures. In order to reduce the consequences of risk and protect the value of the business and the brand the construction organization must decide what it can do in this competitive and complex business environment.

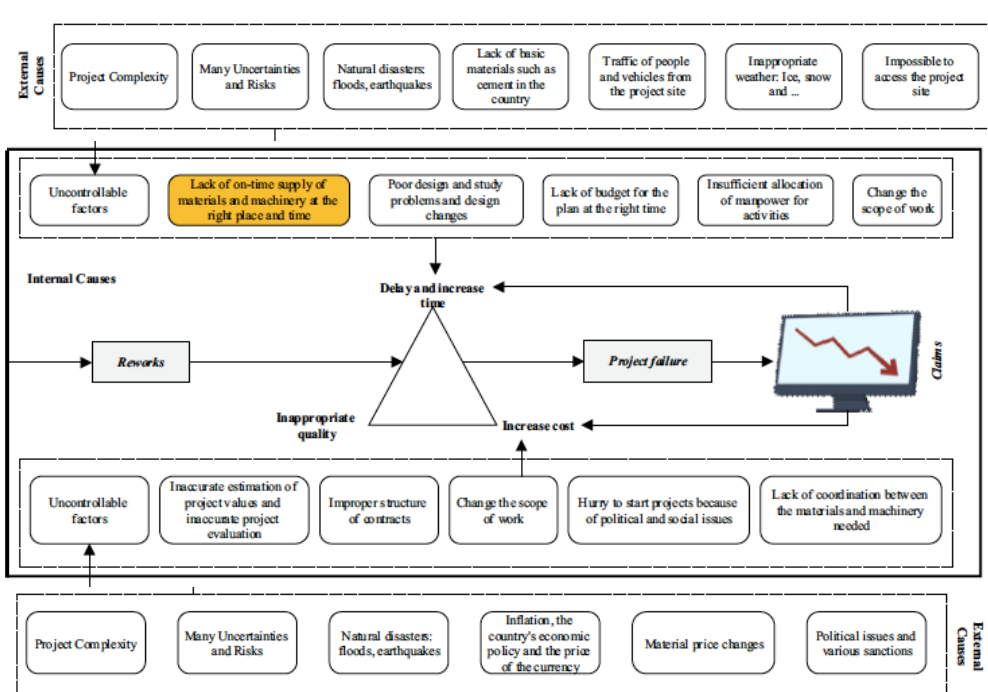


Fig. 2. Construction supply chain threat plan (compiled by the authors according to [14]).

In order to collaborate and manage the supply chain in high-risk situations, the construction company's users and suppliers often come together [15]. Supply chain stability and efficient operation, taking advantage of the company's new opportunities, is reflected in the assured ability to manage the entire logistics process and its participants: costs, products, suppliers, warehousing [16].

It is necessary to identify potential risks followed by risk and consequence assessment in an attempt to flawlessly implement the supply chain risk management problem in the construction sector between which there is sequence and close interdependence. Finally, the right strategy needs to be chosen [17]. Risk monitoring is one of the last steps in the most important and essential stages of the risk management process in the supply chain. It must ensure the continued operation of the construction company without foreseeable hazards or disruptions.

3 Sustainability indicators in construction using SSCM

To address the sustainability issues in the construction sector, it is necessary to understand the relevant indicators. Specific indicators that determine the success of the project are usually used in the construction projects [18].

SSCM integrates sustainability goals and requirements defined by the management of the construction company, external stakeholders, suppliers and customers. In order for the supply chain to be sustainable, some goals like environmental, social, ethical and economic must be achieved by all members of the construction supply chain [19]. A useful perspective could be product life-cycle analysis, which allows the identification of the environmental impact of an item all through its life cycle, starting the stage of designing the product ending the utilization of the product or building [19, 20]. The choice of suppliers of construction materials may be based on various criteria such as environmental, which construction companies must set in conformity with their strategic objectives, policies and regulatory standards [21]. For environmental performances monitoring reasons construction companies could select their suppliers based on environmental criteria or set some policies to be met by their suppliers in order to have business together [20].

Most research related to SSCM relates to the three main pillars of sustainability, which in the Brundtland Report are defined as environmental, economic and social pillars, mostly known as the Triple Bottom Line. These pillars were examined by the SSCM by Carter and Rogers [22] and provided the most frequently cited definitions of the SSCM. However, there are still few tools to evaluate sustainability of a construction company based on the Triple Bottom Line.

Relevant indicators need to be understood in order to address the sustainability of construction. As the basic 3Rs system of Recycle, Reduce and Remanufacture are the main requirement for GSM (Global Supply Chain Management) analysis, Moldan and Dahl contend that not all markers are similarly accurate and quantified [23]. According to Stanitsas et al. [18], before examining the supply chains of construction companies, first it is necessary to divide sustainability indicators into several groups (Fig. 3).

The following groups (economic, social and environmental) make it easier to disaggregate the indicators that are relevant in the sustainable supply chain stages of the construction sector. Triple Bottom Line aspects can be better understood when the SSCM scenario is predictable (pessimistic, realistic, and optimistic). In this article the scenario will not be assessed. Some indicators apply not only to one but to several groups at once.

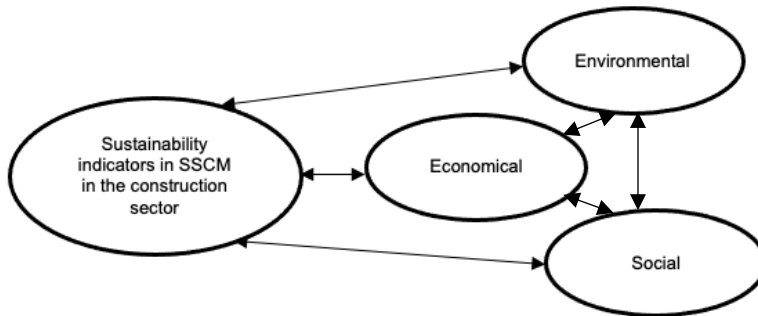


Fig. 3. Groups of Sustainability Indicators in SSCM (compiled by the authors).

Based on the examination of the literature [18, 24-36], it is apparent that there are plenty of indicators with the potential to affect sustainable supply chains in construction. The identified sustainability indicators for examining the supply chains of construction companies are listed in Tables 1, 2 and 3.

Table 1. Economic sustainability indicators in construction companies (compiled by the authors).

Index	Indicator	Which groups are suitable for (economic - ECO, social - SOC, environmental - ENV)
ECO 1	Financial, economic execution of a construction project	ECO
ECO 2	Economic and political stability of the sector	ECO, SOC
ECO 3	Stakeholder participation in the construction project	ECO, SOC
ECO 4	Innovation management, development of new products and tools	ECO, SOC
ECO 5	Targeted marketing and benefits of a construction company	ECO
ECO 6	Effective control of construction projects	ECO
ECO 7	The strategy of best practice, effective strategic planning	ECO, SOC, ENV
ECO 8	Efficient allocation of construction resources	ECO
ECO 9	Management of customer relations, accessibility of necessary contacts	ECO, SOC
ECO 10	Scope management facing the relentless change	ECO
ECO 11	Appropriate ethics of the construction business and organizational culture	ECO, SOC
ECO 12	Premises management technologies and general improvements in tools and techniques	ECO
ECO 13	Construction project cost management and resource planning	ECO, SOC, ENV
ECO 14	Cooperation between members of the supply chain	ECO, SOC
ECO 15	Emphasis on the project results	ECO, SOC
ECO 16	Development of a project management plan for construction management activities	ECO, SOC, ENV
ECO 17	Ability to pay and affordability	ECO
ECO 18	Targeted incentives for owner and workers	ECO
ECO 18	Economic and environmental accounting for a construction project	ECO, ENV

ECO 20	Effective risk management plan	ECO
ECO 21	Implementation of change management strategy	ECO, SOC, ENV
ECO 22	Effective data processing for decision making tools	ECO, SOC
ECO 23	Bureaucratic rationalization	ECO, SOC
ECO 24	Internationalization of a construction company	ECO

Table 2. Environmental sustainability indicators in construction companies (compiled by the authors).

Index	Indicator	Which groups are suitable for (economic - ECO, social - SOC, environmental - ENV)
ENV 1	Environmental education and training for the workers	ENV, SOC
ENV 2	Sustainable project implementation by managing construction project stakeholders	ENV, SOC
ENV 3	Reducing environmental impact considering the life-cycle of construction services, tools and items	ENV, ECO
ENV 4	Use of sustainable building materials	ENV
ENV 5	Environmental management plan	ENV, SOC
ENV 6	Project biodiversity	ENV
ENV 7	Suitable and adaptable details and specifications of environmental design	ENV, ECO
ENV 8	Adaptation to catastrophe risk management and the climate change	ENV, SOC, ECO
ENV 9	Importance of environmental management systems and policies	ENV
ENV 10	Environmental impact assessment project report	ENV, SOC
ENV 11	Construction impact of water quality	ENV, SOC
ENV 12	Environmental responsibility of a construction company	ENV, SOC
ENV 13	The use latest environmental construction technologies and methods	ENV, ECO, SOC
ENV 14	Sustainable use of natural resources	ENV, ECO
ENV 15	Consistent and predictable construction load	ENV
ENV 16	Ecological efficiency of materials and tools used; energy efficiency	ENV, ECO, SOC
ENV 17	Renewable energy sources suitable for use, reduction of fossil fuel	ENV, ECO

Table 3. Social sustainability indicators in the constructional companies (compiled by the authors).

Index	Indicator	Which groups are suitable for (economic - ECO, social - SOC, environmental - ENV)
SOC 1	Social responsibility of a construction company	SOC
SOC 2	Financing of social actions, concepts of social justice	SOC, ECO
SOC 3	Sustainability and organizational culture of construction companies	SOC, ENV, ECO
SOC 4	Socially responsible, ethical work practice	SOC
SOC 5	Sustainable employment, employee satisfaction	SOC, ECO

SOC 6	Community relations and involvement in community issues	SOC, ECO
SOC 7	Respect for human rights and safety	SOC
SOC 8	Employee commitment in the workplace	SOC
SOC 9	Public acceptance of the construction project	SOC
SOC 10	Stakeholder involvement and management	SOC
SOC 11	Independence of political factors from the construction project	SOC
SOC 12	Social impact reports	SOC
SOC 13	Transparent and competitive procurement processes	SOC
SOC 14	Friendly relationship between contractor and supplier	SOC, ECO
SOC 15	The scope of the construction project and the constraints of the project are well defined	SOC, ECO, ENV
SOC 16	A holistic approach to the benefits of a construction project	SOC, ECO, ENV
SOC 17	Emphasis is placed on high quality work ethic	SOC, ECO
SOC 18	Promoting fair competition	SOC, ECO
SOC 19	Implementation of quality management system	SOC
SOC 20	Culture of accountability	SOC
SOC 21	Detailed documentation of construction project contract	SOC
SOC 22	Adaptation to the construction project environment	SOC
SOC 23	Management of the intangible assets	SOC
SOC 24	Tracking of the construction project management stages and processes	SOC

4 Discussion

These indicators listed and analyzed above (economic, environmental and social) for a total of 65 indicators, were compiled and refined according to a list of scientific literature suitable for analyzing sustainable supply chain management in the construction sector. Those indicators were categorized and assigned to one or a couple groups by reviewing their use in the previous literature agreeing to the reasoning to way better reflect the SSCM principle of their use in construction companies (Tables 1, 2 and 3). Column 3 of each table reveals the main relationship between the SSCM of each indicator and the other categories (in environmental, social or economic terms), which is the main criterion for initial classification. Interestingly, most social indicators have a direct link to many management issues, thus reflecting the aspect of sustainable supply chain management [37]. It ought to be noted that the arrange in which the indicators are shown does not reflect their importance.

In analyzing the tables shown above, applicability factors, technical factors and engineering tools are included to the economic side of sustainability. When multi-component productiveness has increased over length of time, a construction project could be considered economically attainable [38]. Quality factors such as value deterioration of the ecological surroundings and damage criterion related to the quality of environmental services are introduced in the environmental feature of the sustainability indicators in the research. Environmental management factors are supply chain practices through which a construction corporation handles the environmental impact of its enterprise actions by supporting a coordinated sustainable planning approach [39]. In the social dimension of management, team factors show how to usefully communicate with the local community and the

stakeholders about a proposal of a new construction project. Communication and collaboration on the success of a sustainability project highlights the operation and shapes up stakeholder acceptance [38]. These indicators include SSCM values, participation of all the users in the SC, help from the team members, association, attainability of technical materials, natural resources, administrative support, external environment, precise project assignments and development goals. In the construction sector, it is crucially important to select technological systems for an effective multi-criteria task completion.

The main aim of sustainability in construction engineering development is to contribute assistance to local communities that have a positive influence on every single aspect of sustainability in SSCM [40, 41]. To disclose the sustainability potential of the end result, research is needed before the first construction phase of the project.

5 Conclusions

The methodology presented in this article provides tools solving SSCM problems in construction sector. This approach could be used for the life-cycle based optimization model of construction companies, software implementations, etc.

The sustainability indicators were divided into three groups such as social (governance), economic and environmental. They were better understood when the SSCM scenario is predictable (pessimistic, realistic, and optimistic). The breakdown of indicators according to the SCM sustainability scenario and their in-depth study provides a basis for project managers and researchers to further analyse and study the indicators of projects in the construction engineering. As a result of this study, managers of the construction projects can more easily plan up to date, advanced sustainable approaches in order to achieve sustainability success in innovative projects, taking into account the identified 65 sustainability indicators: social, environmental and economic. In a real-life scenario, the use of indicators can help develop strategies for the construction sector for sustainable policy makers and construction company managers.

For future research, e.g. factor analysis method could be used to investigate the underlying relationship among the identified sustainability indicators to find out the clusters that can better represent all the indicators and a multiple criteria analysis of alternatives in order to examine the supply chains of construction companies.

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