

Conceptual framework of green supply chain management strategy selection in the Indonesian construction industry

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Abstract. The construction industry is one of the industries that have high environmental risks. The construction supply chain process is the main concern due to environmental damage. The lack of green practices implementation in the Indonesian construction industry causes energy consumption and gas emissions to continue to raise every year which will negatively impact the environment. Green supply chain management (GSCM) is a concept that integrates the environmental aspect of traditional supply chain processes and can provide benefits not only on environmental performance but also on economic and organizational performance. This study aims to identify relevant GSCM practices to implement in the Indonesian construction industry and develop a conceptual framework based on ANP for green supply chain management strategy selection. This study uses the Delphi method and ANP which involves professionals and practitioners in construction. The findings show there are seven green design practices, seven green purchasing practices, nine green construction practices, four internal environmental management practices, and two green operation and maintenance practices that are relevant in the Indonesian construction industry, and also a conceptual framework for strategy selection of green supply chain management in construction.

Keywords: Green supply chain management, Strategy, Selection, Analytic network process, Construction

1 Introduction

Indonesian economy continued to raise, in the third quarter of 2022 it was able to record an increase of 5,72 percent with a total gross domestic product of 5.091,2 trillion rupiahs. Based on Statistics Indonesia, the growth is related to the construction industry which contributed 9,45 percent of the Indonesian gross domestic product [1].

The construction industry requires materials from another industry to produce a construction product, so the supply chain in the construction industry has a contribution to a country's economic growth [2]. However, construction activities are one of the main concerns as they have a negative impact on the environment and ecology, especially

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regarding the consumption of natural resources, pollution, waste, and energy (Badi & Murtagh, 2019; Mojumder & Singh, 2021; Mutingi, 2013).

The construction and building industry is responsible for 36 percent of global energy consumption and 37 percent of the world's carbon emissions [6]. Energy consumption and carbon emission in the Indonesian construction and manufacturing industry continue to raise and in 2019 there are 329 million BOE of energy consumption and 137.040 Gg CO₂e of carbon emission production [7]. The environmental issue that occurs can cause climate change that is already felt nowadays. Throughout 2022 there were disasters that dominated hydrometeorology disasters such as floods, extreme weather, and landslides with a total of 3.233 cases in Indonesia [8]. That issue also can impact the economic aspect namely an increase in environmental management cost which cause a decrease in profits and organizational aspects such as a decrease in the company's brand image and competitiveness [9,10]. The problem caused by the low implementation of green practices in the construction industry in Indonesia such as lack of commitment from top management, non-comprehensive waste management, excessive energy consumption, and lack of provision for the use of material with high recycled content [9,11–13].

The environmental problems that continue to occur require companies to start paying attention and taking action to prevent this problem by reviewing their business process and supply chain [14]. Innovation is needed to green the company's supply chain activities one of which is green supply chain management (GSCM). GSCM can provide benefits regarding the environment, namely reducing energy consumption, reducing waste, reducing hazardous materials by the use of environmentally friendly materials, reducing energy consumption, and reducing carbon emissions [14,15]. Besides benefits to the environment, implementation of GSCM can give cost reduction through saving energy consumption and reducing waste and also can improve the company's brand image [9,12]. According to Setyaning [11], the implementation of GSCM in the construction industry is still rare which can be proved by limited research on GSCM in the construction industry topic. The study about GSCM implementation in the construction industry is necessary due to it can provide an understanding of steps that have to be done to improve this sector, especially in Indonesia. Due to this matter, this study aims to derive relevant GSCM practices in construction so that these practices can be applied in the Indonesian construction sector and also develop a conceptual framework integrating the analytic network process (ANP) for GSCM strategy selection based on GSCM practices in construction.

2 Literature Review

2.1 Construction supply chain

The construction supply chain is a network of organizations and their relationship that include the flow of information, material, and finances between construction owners, consultants, contractors, and suppliers [16]. Supply chain management of construction can be described as an activity to manage resources and interaction relationship between supplier and customer (upstream and downstream) in terms of construction to produce a construction product [17]. Implementation of supply chain management in the manufacturing industry is not a new thing, previous study in the manufacturing industry shows that implementation of supply chain management can improve overall company's performance like profitability and competitiveness [18,19]. According to Othman & Rahman [20], implementation of this concept in the construction industry is challenging due to the construction supply chain being more complex, diverse, and fragmented. It involves many organizations and expert groups participating in the project in completing their specialization of work.

As seen in Figure 1, Balasubramanian and Shukla [21] illustrate that the construction supply chain has two flows namely information flow and material flow. Information flow occurs from the developer (the project owner) to suppliers related to orders and tasks. Material flow occurs from supplier to the developer from raw material to the formation of a construction product namely building, bridge, road, etc. The supply chain management actors involved in the construction industry include the owner (downstream actor), contractor (main actor), and subcontractor or supplier (upstream actor).

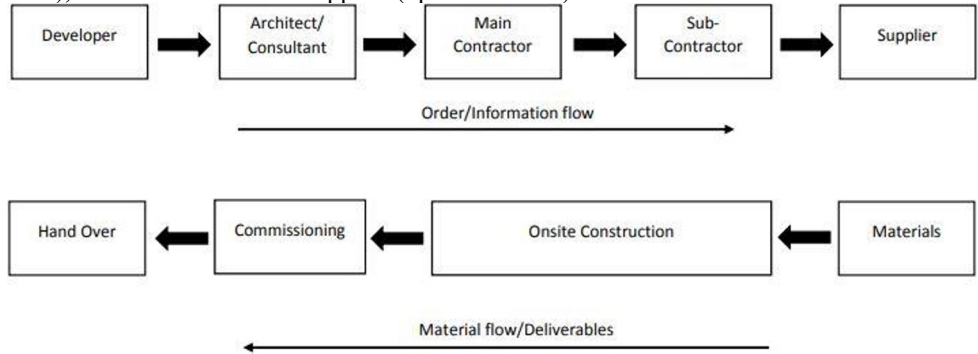


Fig. 1. Construction supply chain model [21]

2.2 Green supply chain management

Green supply chain management (GSCM) is an evolution of supply chain management that integrates environmental factors into the supply chain from the design process to product end-of-life [22]. Meanwhile, according to Putu Artama Wiguna [23], GSCM is an environmentally-based concept that is combined with a conventional supply chain, both upstream and downstream. The implementation of GSCM in construction is meant for greening the project life cycle phase starting from the design phase, until the operation of the building and the end of its life [2].

In the manufacturing industry, the implementation of green supply chain management can minimize the negative environmental damage caused by this sector. Wibowo [2] developed a GSCM framework that was adopted from the manufacturing industry to be applied to the construction industry. Implementation of green practices in each phase is expected to reduce energy consumption and waste [2]. According to Handayani [9], green practices implementation in Indonesian construction is still low. Factors that significantly affect the implementation of GSCM in the Indonesian construction industry are environmental regulation, commitment from top management to green practices implementation, the unavailability of suppliers, and the lack of knowledge and awareness of environmental impact in construction [13].

Implementation of GSCM is necessary because it can improve sustainability performance. This practice reduces the production of carbon emissions, reduces energy consumption, reduces waste, and reduces hazardous material usage [9]. In addition to the environment, GSCM implementation can benefit the economy. Green practices implementation in the construction project can improve economic performance through cost reduction of energy consumption, waste management, and material usage [12]. Also, it has a positive impact on social performance namely the company’s brand image which affects the company’s competitiveness in the long term [14].

2.3 GSCM practices

GSCM practices are practices that are carried out to reduce the negative impact on the environment caused by activities undertaken by the company. In this study, five GSCM practices will be discussed, namely green design, green purchasing, green construction, internal environmental management, and green operation and maintenance.

2.3.1 Green design

Green design refers to the planning of a product or process that makes special consideration of the environmental impact of the product during its entire life cycle [24]. It focuses on preventing environmental damage of a product before it is produced, and used. Green design is an important stage because decisions in this stage would significantly affect the project life cycle especially its impact on the environment [21].

2.3.2 Green Purchasing

Green purchasing is a practice carried out to ensure materials and components purchased meet the environmental requirement including containing recycled components and the absence of hazardous materials [11]. Similarly in the tender stage, environmental considerations are used to select suppliers such as ISO 14001 certification, also knowledge and experience in green construction projects [21].

2.3.3 Green Construction

Green construction refers to the practice in the construction industry carried out to minimize the environmental impact of construction by optimizing the conservation of resources including energy, land, water, and material [2,21]. A study by Balasubramanian and Shukla [9] it is found that green construction can be beneficial to reduce construction costs by saving energy consumption, water consumption saving, and reduce waste which leads to saving in waste management costs.

2.3.4 Internal Environmental Management

Internal environmental management is the company's creation of environmental protection such as the development of environmental policies and environmental targets to ensure the protection of the environment [14]. This practice includes top management commitment, mid-level management support, an environmental audit program, and ISO 14001 certification [12]. Internal environment management is the main factor in green practices because this practice can affect the implementation of other green practices [24].

2.3.5 Green Operation and Maintenance

Operation and maintenance is the final stage of the project life cycle related to the operation of the entire building. Green operation and maintenance in construction include energy conservation and emission reduction so that the building that has been built has minimal environmental damage [25]. One of the green operation and maintenance implementations in construction is green building.

2.4 Analytic network process

The analytic network process (ANP) is a generalization of the analytic hierarchy process (AHP) introduced by Saaty [26], AHP organizes decision problems into a hierarchy structure, while ANP uses a network structure by considering dependencies between elements. ANP is a multi-criterion decision making method that is an effective solution to a complex decision-making problem by simplifying that into a network model structure and assigning subjective importance to each variable and indicator to determine which variable and indicator has the highest priority [26].

3 Research Methodology

This study process starts with problem identification, problem formulation and research objectives, and then is followed by a literature study related to GSCM in the construction industry. Literature studies were conducted to obtain research variables and indicators based on previous studies. The Delphi method and analytic network process (ANP) were used in this study. The Delphi method was used to obtain validation related to variables and indicators, namely GSCM practices including green design, green purchasing, green construction, internal environmental management, and green operation and maintenance which are relevant in the construction industry, especially building projects in Indonesia. Whereas, ANP with super decision software was employed to model the conceptual framework for green supply chain management strategy selection in the construction industry. Two questionnaires were conducted in this study. The first questionnaire was conducted to validate the relevant GSCM practices to be applied in the Indonesian construction industry and the second questionnaire to identify dependencies of the variables and indicators. Respondents in this study were professionals or practitioners involved in the construction supply chain including owners, consultants, contractors, and suppliers.

4 Result and discussion

4.1 Green Design

Green design is the earliest, yet important stage because all decisions made in this stage would affect the subsequent stages of the construction project. Similarly, Balasubramanian and Shukla [21] state that green design significantly affects the project life cycle, especially its impact on the environment. Based on the questionnaire, overall green design practices from the literature study are relevant to implement in the construction industry especially building projects which can be seen in Table 1. In Setyaning's research [11] about GSCM activities in the construction sector, six green design practices that are similar to this study, namely energy-efficient lighting systems, energy-efficient air conditioning systems, recycled materials, prefabricated components, hazardous materials, and wastewater recycling, all of which are relevant in construction.

Table 1. Green Design Questionnaire Result

Green Design Practices	Reference	Respondent					Conclusion
		1	2	3	4	5	
Provision for wastewater recycling	[15,21]	✓	✓	✓	✓	✓	Relevant
Consideration for energy-efficient air conditioning system	[11,21]	✓	✓	✓	✓	✓	Relevant
Consideration for the energy-efficient lighting system	[15,21]	✓	✓	✓	✓	✓	Relevant
Consideration for material with recycled content	[15,21]	✓	-	✓	✓	✓	Relevant
Provision for the use of prefabricated components	[15,21]	✓	✓	✓	✓	✓	Relevant
Environment impact assessment	[21]	✓	✓	✓	✓	✓	Relevant
Consideration to reduce the use of hazardous materials	[21]	✓	✓	✓	✓	✓	Relevant

4.2 Green Purchasing

All seven green purchasing practices obtained from the literature study are relevant and can be applied in the Indonesian construction project. It can be seen in Table 2.

Table 2. Green Purchasing Questionnaire Result

Green Purchasing Practices	Reference	Respondent					Conclusion
		1	2	3	4	5	
Environmentally friendly product	[12,21,27]	✓	✓	✓	✓	✓	Relevant
Purchasing materials with recycled content	[11]	✓	-	✓	✓	✓	Relevant
Purchasing non-hazardous materials	[11]	✓	✓	✓	✓	✓	Relevant
ISO 14001-certified suppliers	[12,21,27]	✓	✓	✓	-	✓	Relevant

Green Purchasing Practices	Reference	Respondent					Conclusion
		1	2	3	4	5	
Providing design specifications to suppliers that include environmental requirements	[14]	✓	✓	✓	✓	✓	Relevant
Cooperation with suppliers for environmental objective	[14,27]	✓	✓	✓	✓	✓	Relevant
Supplier take back their packaging	[15]	✓	✓	✓	✓	✓	Relevant

Green purchasing practices in this study have differences compared to the result by Setyaning [11], in which “Providing design specification that includes the environmental requirement to suppliers during procurement” is considered irrelevant in the construction industry, whereas in this study the practice is considered relevant by respondents and can be applied in construction projects. The study by Balasubramanian and Shukla [9] found that environmental criteria (ISO 14001) as suppliers’ requirement in the tender is the highest level of implementation.

4.3 Green Construction

Nine green construction practices were obtained from the literature study. All of the nine green construction practices in this study are relevant to implement in the construction industry. It can be seen in Table 3 below. Based on results from interviews with respondents “use of prefabricated components in projects” is the practice that has the highest level of implementation in building projects because it can provide benefits in addition to reducing waste but also reduce cost. According to a study from Balasubramanian and Shukla [9], the use of fuel-efficient equipment in projects is the highest level of implementation.

Table 3. Green Construction Questionnaire Result

Green Construction Practices	Reference	Respondent					Conclusion
		1	2	3	4	5	
The use of automation in construction site	[12,15]	✓	✓	✓	-	✓	Relevant
Fuel-efficient equipments are used	[12,15]	✓	✓	✓	✓	✓	Relevant
Comprehensive waste management plan	[12,21]	✓	✓	✓	✓	✓	Relevant
The use of prefabricated components in projects	[21]	✓	✓	✓	✓	✓	Relevant
Recycled materials are used during construction	[21]	✓	-	✓	✓	✓	Relevant

Green Construction Practices	Reference	Respondent					Conclusion
		1	2	3	4	5	
Reducing the use of hazardous materials	[21]	✓	✓	✓	✓	✓	Relevant
Materials are transported in full truckload quantities	[11,21]	✓	✓	-	-	✓	Relevant
Materials are transported in fuel-efficient vehicles	[11,21]	✓	-	✓	✓	✓	Relevant
Reverse logistic (reuse, remanufacturing, recycle)	[2]	✓	✓	✓	✓	✓	Relevant

All the construction activities performed have a large potential generation of waste [28]. A comprehensive waste management plan is necessary to reduce negative environmental impact. Based on the interview with respondents, the handling of construction solid wastes can be done such as by sorting the generated waste; involving third parties to recycle the materials such as plastics, metals, or wood into crafts or stored to be reused in the future projects and the demolition waste can be used for earthwork. According to Karunasena et.al and Perera et.al [29,30] water/liquid waste generated should be stored in drums, containers, or tanks and water/liquid waste that contain hazardous component include chemicals, oils, and greases treated with sedimentation, coagulation, and neutralization technique before disposal.

4.4 Internal Environmental Management

Internal environmental management includes commitment from senior management, cooperation for environmental improvement, environmental compliance, and ISO 14001 certification are relevant practices to be applied in the Indonesian construction industry. It can be seen in Table 4.

Table 4. Internal Environmental Management Questionnaire Result

Internal Environmental Management Practices	Reference	Respondent					Conclusion
		1	2	3	4	5	
Commitment of green practices from senior management in the project	[12,27]	✓	✓	✓	✓	✓	Relevant
Cooperation from all stakeholders for environmental improvement	[12,27]	✓	✓	✓	✓	✓	Relevant
Environmental compliance	[12,27]	✓	✓	✓	✓	✓	Relevant
ISO 14001 certification	[12,27]	✓	✓	✓	✓	✓	Relevant

This practice is the most important in terms of implementing GSCM practices, which without commitment green program in a project cannot be carried out [24]. Internal environmental management, especially commitment from senior managers will be necessary for the development of GSCM in the construction industry [12].

4.5 Green Operation and Maintenance

Green operation and maintenance is a stage to ensure buildings that have been designed and built remain environmentally friendly in their operation. According to respondents, building operations is an important thing that must be considered to achieve sustainability. In terms of green practices in the construction industry, the cost of green management will be greater than the conventional method. However, in the operational stage of the building green management will provide a significant cost saving. Out of two green operation and maintenance practices from the literature study, all of them are relevant to be applied in the construction industry which can be seen in Table 5 below.

Table 5. Green Operation and Maintenance Questionnaire Result

Green Operation and Maintenance Practices	Reference	Respondent					Conclusion
		1	2	3	4	5	
Implementation of green building	[2]	✓	✓	✓	✓	✓	Relevant
Implementation of environmental policy	[2]	✓	✓	✓	✓	✓	Relevant

4.6 Conceptual Framework

To obtain the inter dependencies and outer dependencies of this model, a questionnaire was conducted involving the same five respondents. Criteria in this model are the validated GSCM practices in the construction industry, namely green design, green purchasing, green construction, internal environmental management, and green operation and maintenance. Based on the questionnaire, then the modeling of the framework is done using super decision model. Figure 2 displays the purposed framework of this study.

In this study, there are dependencies between GSCM practices in construction. Green design, green purchasing and green construction have inter dependencies among the practices, and overall green supply chain management practices have relationship with each other. There are differences compared to the study by Adelina & Kusumastuti and Chen et.al [31,32] that are case studies in the manufacturing industry. Green design has relationship to green purchasing and green manufacturing, but there is no relationship between green purchasing and green manufacturing to green design.

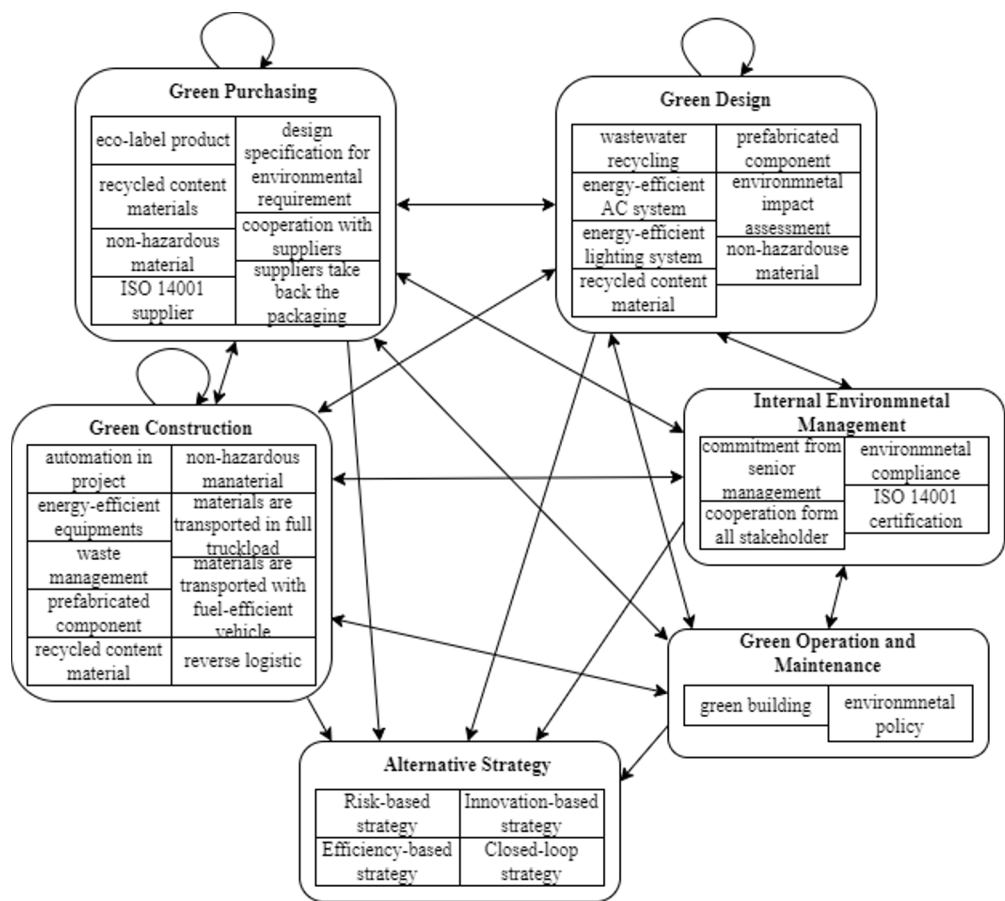


Fig. 2. Conceptual framework of GSCM strategy selection

5 Conclusion

This study aims to identify relevant GSCM practices in construction so that these practices can be applied in the Indonesian construction industry and also develop a conceptual framework integrating the analytic network process (ANP) for GSCM strategy selection based on GSCM practices in construction. This study concludes that there are seven green design practices, seven green purchasing practices, nine green construction practices, four internal environmental practices, and two green operation and maintenance practices that can be implemented in the Indonesian construction industry, especially in building projects. This study also develops a conceptual framework based on the ANP method for GSCM strategy selection in construction using super decision software based on green supply chain management practices in construction that have been validated by respondents.

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