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The sustainable infrastructure through the construction supply chain carbon footprint approach

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Abstract

The sustainable development concept is an important issue in construction industry, which becomes important mainly because of its role in infrastructure provision. Infrastructure availability will affect economic growth and increase a country's competitiveness. Indonesia as a developing country still needs to build a lot of physical infrastructure. The concept of sustainable infrastructure development is in line with the Indonesian government's development plans for the period of 2014-2015 called Nawa Cita. Carbon footprint modelling is one of the methods that contributes to the realization of sustainable infrastructure development. This paper describes the approach of sustainable infrastructure development through carbon footprinting in the construction supply chain. In the construction industry, carbon footprinting gives information in total emission of carbon dioxide (CO_2) in every stage of a construction project's supply chain activities. In creating a carbon footprint model, life cycle analysis (LCA) is used as a supporting instrument to estimate the carbon dioxide (CO_2) emissions in each stage of the supply chain activities. It is shown that the implementation of sustainable infrastructure development needs a synergy from all parties involved in the construction supply chain.

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Keywords: Sustainable development concept; carbon footprint

1. Introduction

The sustainable issue is a growing issue almost in all sectors such as industry, economy, infrastructure, etc. The issue continues to grow and becomes an interesting issue that a lot of research has been conducted to generate a real and effective action on defining the sustainable concept [1]. The today's sustainable growing issue also becomes a

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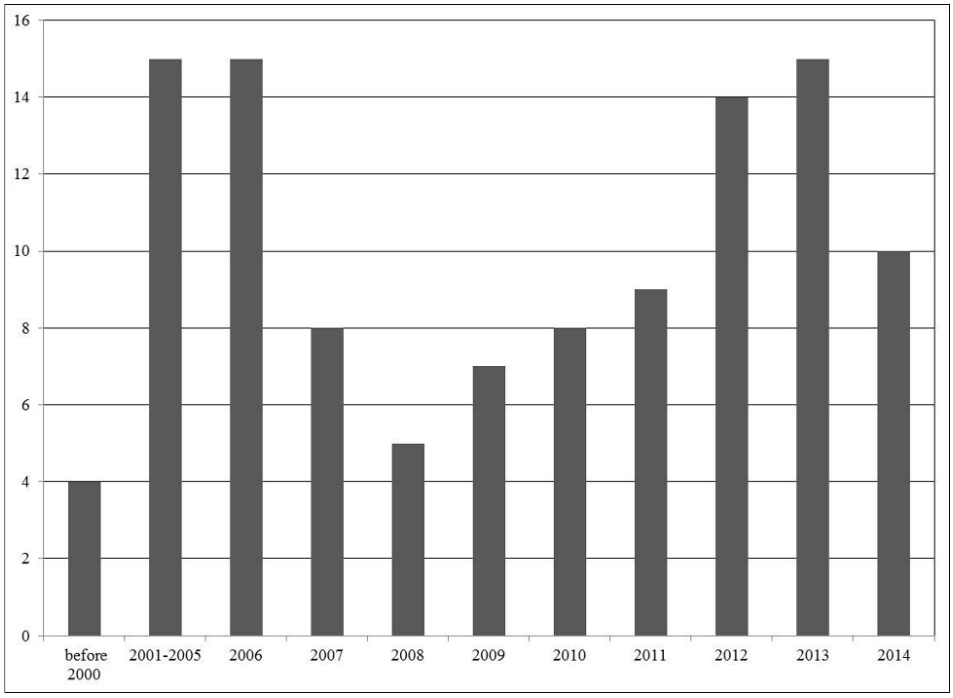
challenge to all countries. This means the sustainable issue has become an important issue from micro level (supporting sectors of human life) to macro level (all countries). The development of sustainable issue can be seen from year to year based on publications done by researchers. Fig. 1 shows the research in sustainable issue has been started before the year of 2000, precisely in the year of 1987 through various scientific publications.



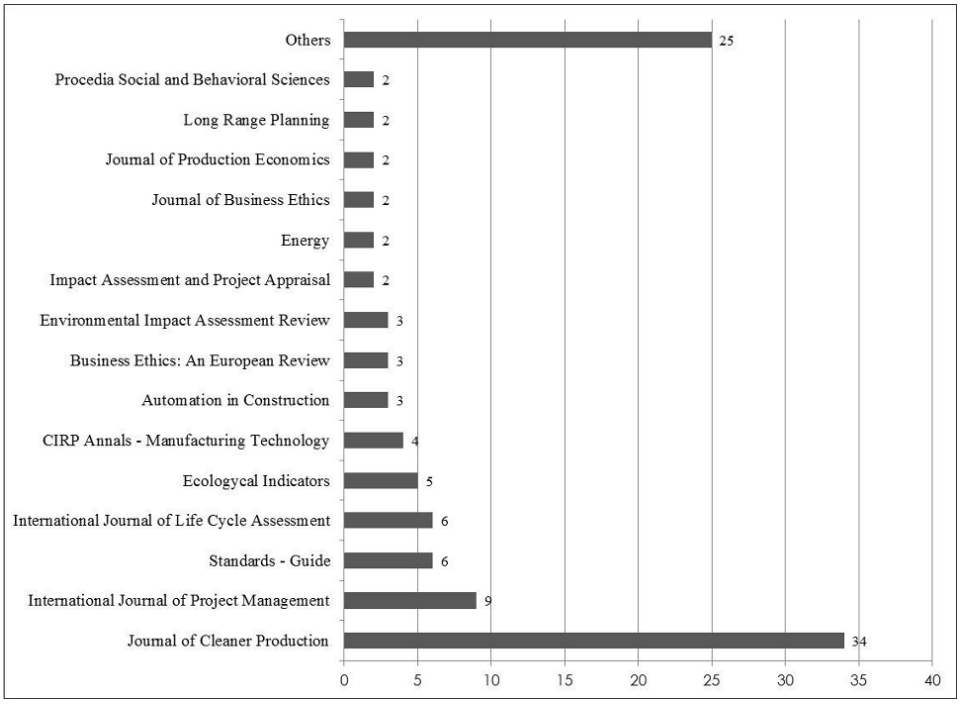


Fig. 1. The distribution of sustainable issue research based on time and publication [2]

As described in the previous section that the sustainable issue has become a challenge to all countries, including developing countries. In this context, the challenge faced by developing countries is how to provide their infrastructure development needs. In other words, the sustainable issue becomes a concept which underlies a sustainable development especially in providing the infrastructure. The availability of adequate infrastructure will boost the economic growth [3]. Yet, factors such as poverty alleviation priority, human resources strengthening, capacity building, socio-cultural and environment can't be ignored in the attempt to boost the economic growth. Therefore, the implementation of sustainable infrastructure should have an element of harmonization with other factors. Likewise Indonesia as a developing country, the sustainable infrastructure matter also becomes a challenge. There are two main challenges to implement the sustainable infrastructure in Indonesia. First of all, as being part of the world we are responsible in taking care of the environment especially in the relation of global warming. It means that the implementation of sustainable infrastructure should be able to reduce the greenhouse gas effects, one of which is reducing carbon dioxide (CO_2) emission. The other challenge is to accelerate the economic growth through MP3EI and Nawa Cita which become the vision of the Indonesian government.

Table 1. The needs of infrastructure investment in Indonesia.

No.	Economic corridor	Investment (IDR Billion)
1.	Sumatera	474.964
2.	Jawa	798.235
3.	Kalimantan	127.357
4.	Sulawesi	68.451
5.	Bali – Nusa Tenggara	43.210
6.	Papua – Kepulauan Maluku	161.627

Source: MP3EI, Coordinating Minister for the Economy, 2011

2. Literature study

2.1. The sustainable development concept

The construction industry which is part of a sector that supports economic growth is also faced to the sustainable development challenge. Started in the year of 1987 on Bruntland Comission Report, the concept of sustainable development becomes popular in construction industry [3]. Then it is followed up in the international conference of Rio de Janeiro Summit in 1992. The conference produces a resolution known as Rio Declaration on Environment and Agenda 21. This meeting is resumed in international conferences such as in South Africa Summit in 2002. Through meetings and conferences held in several countries, it is concluded that the sustainable development becomes a necessity to all countries mainly because it will affect a country's competitiveness [4]. The relationship between sustainable development and country's competitiveness is: the proper designed of environmental standards can trigger innovations that lowered the total cost of a product or improve its value. Such innovations allow companies to use a range of inputs more productively from raw materials to energy to labor e thus offsetting the costs of improving environmental impact and ending the stalemate. Ultimately, this enhanced resource productivity makes companies more competitive, not less. Fig. 2 shows the relationship between sustainable development and country's competitiveness into a model.

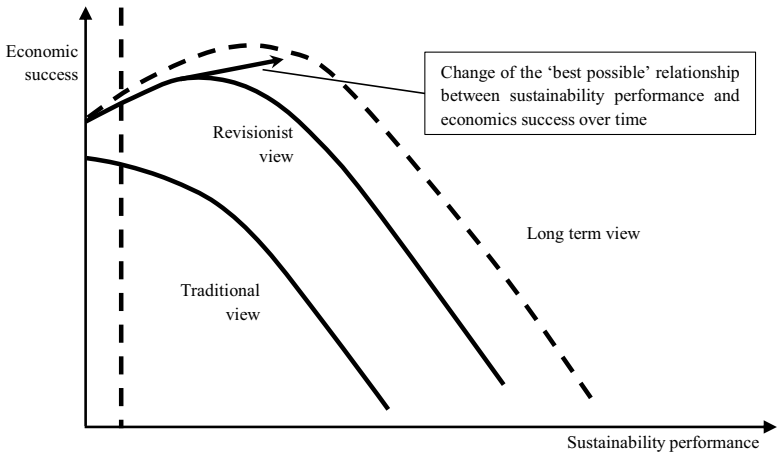


Fig. 2. The phenomenological relationship between sustainability performance and economic success [5]

Traditional view assumes that a development which seeks to prevent environmental. The above model shows there are 2 (two) kinds of view in this matter, traditional and revisionist view. The damage will reduce its profit and the presence of regulation as an attempt to protect environment will cost the development. While the revisionist view assumes that a sustainable development will benefit the development. This revisionist argument is improved by researchers to implement the sustainable development concept.

The sustainable development concept then also becomes important for construction industry as a part which becomes the infrastructure provider. The sustainable development concept has been adopted in construction industry since 1994. The ground of sustainable development in construction industry is based on 2 (two) aspects, which are efficiency in the use of resources and ecological principles [6]. Yet, not all parties involved in construction industry have performed the practice of sustainable development concept. The implementation is still weak actually [7]. The biggest challenge of sustainable development practice in construction industry is a matter of material, technique, skill, innovation and management practice which related to construction supply chain [8]. An attempt to perform practice of sustainable development in construction industry is developed into various models and instruments. As for some models were developed in order to develop the practice of sustainable development in construction industry can be seen in Table 2.

Table 2. Model and criteria of the sustainable development practice in construction industry [9]

Objectives	Criteria	Metrics
1. Operational Environmental performance (ENV)	1.1. Carbon footprint index (CFI)	cf_1: Total amount of greenhouse gas (GHG) emissions caused by energy consumption of the housing unit and expressed in CO_2 equivalent emissions (CO_2e)
	1.2. Water usage index (WTI)	wt_1: Total amount of housing water consumption (US gal)
2. Social quality of life (SQOL)	2.1. Thermal comfort index (TCI)	tc_1: Predicted percentage of dissatisfied (PPD) index (%)
	2.2. Indoor lighting quality index (LQI)	lq_1: Annual average daylighting illuminance (Lux) lq_2: Total hours exceeding glare comfort level in a year (hours)
	2.3. Indoor air quality index (AQI)	aq_1: Points achieved by performing the EPA recommended air quality caused by ventilation rate (%) aq_2: Percentage of dissatisfied people (PD) from indoor air quality by ventilation rate (%)
	2.4. Neighborhood quality index (NQI)	nq_1: Education level (%) nq_2 : Safety level (%) nq_3: Health conditions (%) nq_4: Economic conditions (%) nq_5: Environmental conditions (%)

3.	Life cycle cost (LCC)	3.1. Life-cycle cost (LCC)	lc_1: Initial investment cost (US $) lc_2: Operation and maintenance cost (US $) lc_3: Energy and utility cost (US $) lc_4: Capital replacement cost (US $) lc_5: Residual value (US $)

Table 2 shows a carbon footprint is one of the model which can be used to modeling the sustainable development practice in construction industry. The carbon footprint is a total amount of carbon dioxide (CO_2) emissions produced from activities within construction industry. Those carbon dioxide (CO_2) emissions would have a domino effect. It means that each stage of the construction industrial activity contributes to the size of carbon dioxide (CO_2) emission to be produced. Therefore, if carbon dioxide (CO_2) emissions from each construction industrial activity starting from upstream to downstream are summed, it will obtain the carbon footprint. This provides information that a project management will impact to the carbon footprint. As previously described, the project management especially supply chain practice is also becomes the part which contributes to carbon footprint. Modeling the carbon footprint requires an instrument that functions in accessing the size of carbon dioxide (CO_2) emission from each activity in construction supply chain. One of the instrument used is a life cycle analysis (LCA). The LCA has been used in construction industry, especially to analyze a building's life cycle [10].

2.2. The carbon footprint

A footprint concept is pioneered by Wackernagel, and Rees, (1996) [11] in Columbia University, which aims to explain the impact of human activity. In its development, the footprint concept is used as an embryo of carbon footprint. The footprint phrase is very wide and used in various sectors such as transportation, urban, university's activity, infrastructure, and construction. Some definitions of carbon footprint taken from several sources are as follows [12].

- BP, 2007 defines a carbon footprint as the amount of CO_2 produced from daily activities.
- a carbon footprint is a methodology to estimate the greenhouse total effects, one of it is CO_2 from the entire cycle of a product which is started from raw material extraction used to create certain product in manufacturing process,
- a carbon footprint is a technique to identify and quantify the greenhouse gas effects from each individual activity in every process of supply chain in producing product,
- a carbon footprint is a size of greenhouse gas effects from the impact of human activities on environment which is equivalent into ton of CO_2,
- a carbon footprint is a size of CO_2 amount produced by direct or indirect combustion
- a carbon footprint is the total amount of CO_2 and other gases from greenhouse gas effects produced from a product's cycle as a whole. The size of CO_2 is expressed in gram of CO_2 equivalent per kilowatt hour per kilowatt hour (gCO_2eq/kWh), for each gas produced from greenhouse gas effect.

Based on the definitions of carbon footprint, it can be obtained keywords as an attempt to measure the amount of CO_2 from each activity. Thus, it can be concluded back that a carbon footprint is a measurement of the total amount of CO_2 caused by an activity, either directly or indirectly. The carbon footprint size of an activity is greatly influenced by the length of process occurs in the activity.

2.3. The supply chain

The complexity of parties involved in construction project requires a management of the planning stage to the implementation stage. This complexity started from the upstream to the downstream parts. There's a construction material industry that functions as a supplier at the upstream part. While at the downstream part, there's a construction project as a customer / user of construction material. Besides, other parties such as planner, contractor and owner are involved in its process. Therefore, it appears that the construction project will always consist of a lot of varied and complex participants.

The number of parties involved in construction project can be described into a network called supply chain. The characteristic of supply chain in construction involves dozens and even hundreds of parties started from construction material supplier and service which support the project realization [13]. Fig. 3 describes the complexity of construction's supply chain involving a lot of parties such as the service provider which consists of financier, structure service provider, mechanical, electrical, architecture, and the material provider which consists of building material / product supplier and subcontractor.

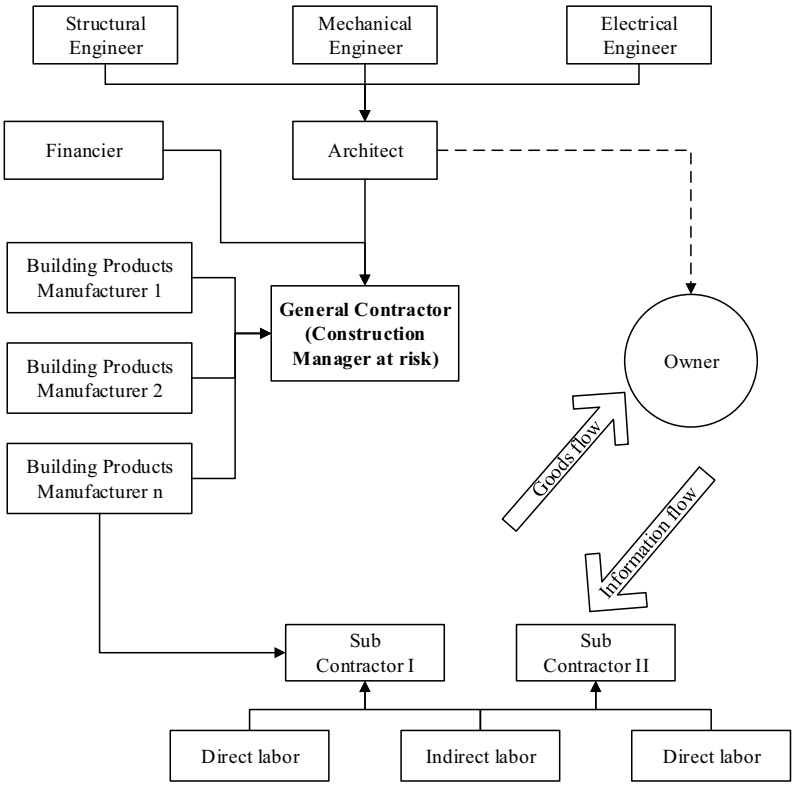


Fig. 3. Construction supply chain [14]

The principles revealed in Fig. 3 can be detailed into the concept of supply chain in construction project which is described in Fig. 4. The supply chain in construction project is a relatively new concept that is more recognized in the manufacturing industry. In its development, due to the numbers of parties involved, the supply chain in construction project needs to be controlled. The control is certainly based on the triple constraints in construction project, which are cost, quality and time. So that, if the supply chain is not being controlled, then the supply chain design will potentially increase the project's cost by 10% [15].

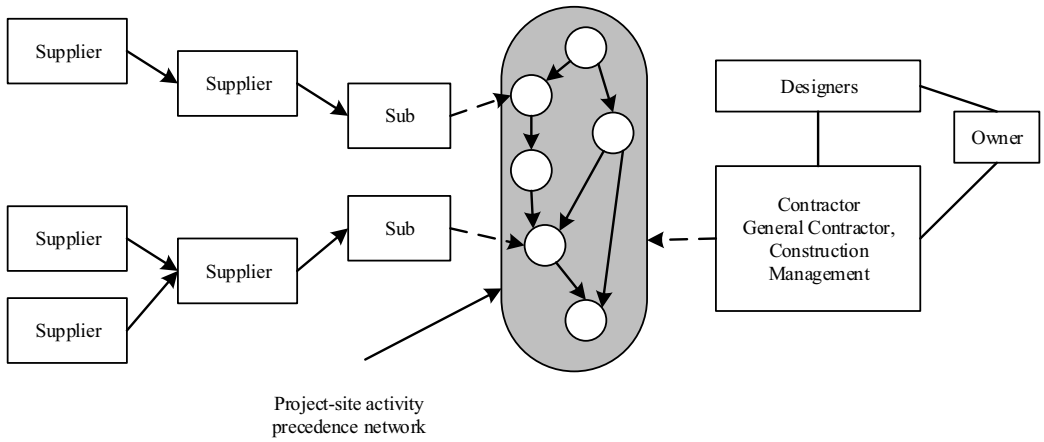


Fig. 4. The conceptual of supply chain in construction project [16]

As the presence of global warming becomes a challenge either to any sectors or to all countries, the supply chain in micro level also has the same challenge. There are some relevancies between supply chain and global warming, which are (a). transportation modes used in the distribution line of one party to another produces exhaust gases. One of these gases is carbon dioxide (CO_2) emission which is very significant to the escalation of global warming as it's part of the greenhouse gas effect; (b). energy / fuel is required in each stage started from the upstream to the downstream part. The used of energy / fuel will produce various greenhouse gases such as carbon dioxide (CO_2), methane (CH_4), nitrogen dioxide (N_2O), hydrofluorocarbon (HFCs), perfluorocarbon (PFCs) and sulphur hexafluoride (SF_6) [17].

On the other hand, the global warming issue can not be stopped, giving an understanding that the supply chain owned by the construction project must be designed and controlled with the ultimate goal to reduce greenhouse gas effects especially carbon dioxide (CO_2) emission [18]. One attempt to do so is by identifying every line which has the potentials to produce carbon dioxide (CO_2) emission. Of course it needs supports from the decision maker and regulation, so that the role of construction supply chain can reduce the carbon dioxide (CO_2) emission.

2.4. Life cycle analysis

ISO 14040 [19] defines a life cycle analysis as a technique to do the assessment of environmental aspect and potential impact related to a product by compiling or inventorying inputs and outputs which are relevant to the produced product, making an evaluation to the environmental impact potencies that related to the product's inputs and outputs; and interpreting the analysis and assessment result of impact from every stage related to the study object. The life cycle analysis studies the environmental aspect and impact potencies of the product cycle from raw material, production process, product usage and product disposal.

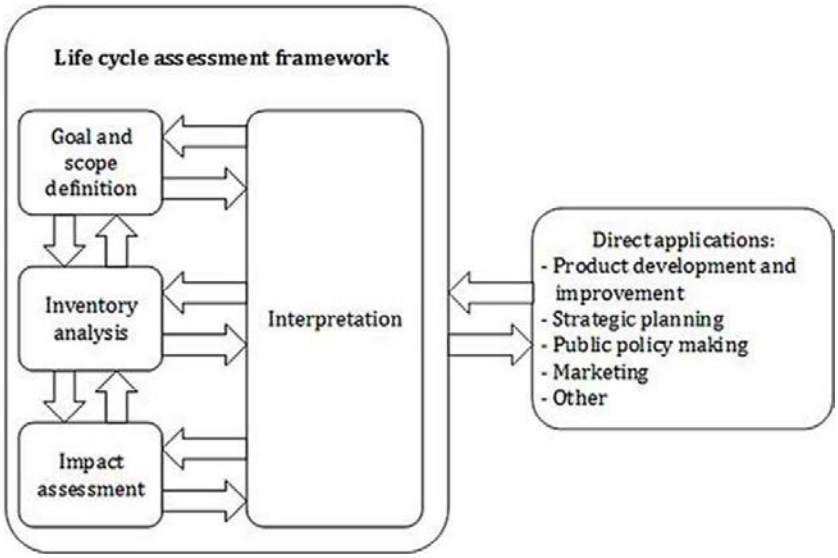
Fig. 5 shows the stage of life cycle analysis which divided into four stages, which are:

- objective, scope and definition
  the first stage of life cycle analysis is defining the scope of study including the function of each part, study limitation, detail of each level and environmental burden that will be allocated in each level.
- inventory analysis
  the second stage of life cycle analysis is making an inventory of input and output related to the study scope.
- impact assessment
  at this stage, the evaluation to the environmental impact potency is done by using the life cycle inventory result and providing information to interpret the final phase.
- interpretation
  the final stage of life cycle analysis provides conclusion, recommendation, and decision making based on the

study limitation which has been set at the first stage.

The scope of life cycle analysis can be divided into four kinds of scope, which are [20]:

- Cradle to grave, the scope is started from the raw material to the product operation.
- Cradle to gate, the scope of life cycle analysis is started from the raw material to the gate before the operation process.
- Gate to gate is the shortest scope of life cycle analysis because it only observes the nearest activity.
- Cradle to cradle is a part of life cycle analysis that shows the scope from the raw material to the material recycle.



- Fig. 5. The stages of life cycle analysis [19]

3. Discussion

The sustainable development practice certainly has to involve all parties in the construction industry. Parties involved in the construction industry are influenced by the conducted supply chain, which in present paper is starting at the upstream part which is the industry that produces construction material and at the downstream part which is the user of construction material. Therefore, there's a new paradigm in the sustainable development concept that says a project's level of success is not only determined by quality, cost and time. Thus the environmental factor also becomes its parameter [21].

The following are some examples of existing sustainable development practice using the carbon footprint model.

- The carbon dioxide (CO_2) emission and carbon footprint model. The first stage conducted by [22] is compiling a work breakdown structure (WBS) which is divided into 3 level that are input, process and output. At the input section, the construction project is divided into several works such as preparation work, sub structure work and several other works. Those works are outlined under the resource needs, then the resource is mapped into direct and indirect emission and cost needs. The direct emission defines by [22] is an emission produced directly on-site as a result of the diesel and electricity fueled equipment usage. While the indirect emission is an emission produced from activity out of on-site such as manufacturing and transportation used for delivery. Based on this description, an estimation framework of carbon dioxide (CO_2) emission and carbon footprint can be described as shown in Fig. 6.

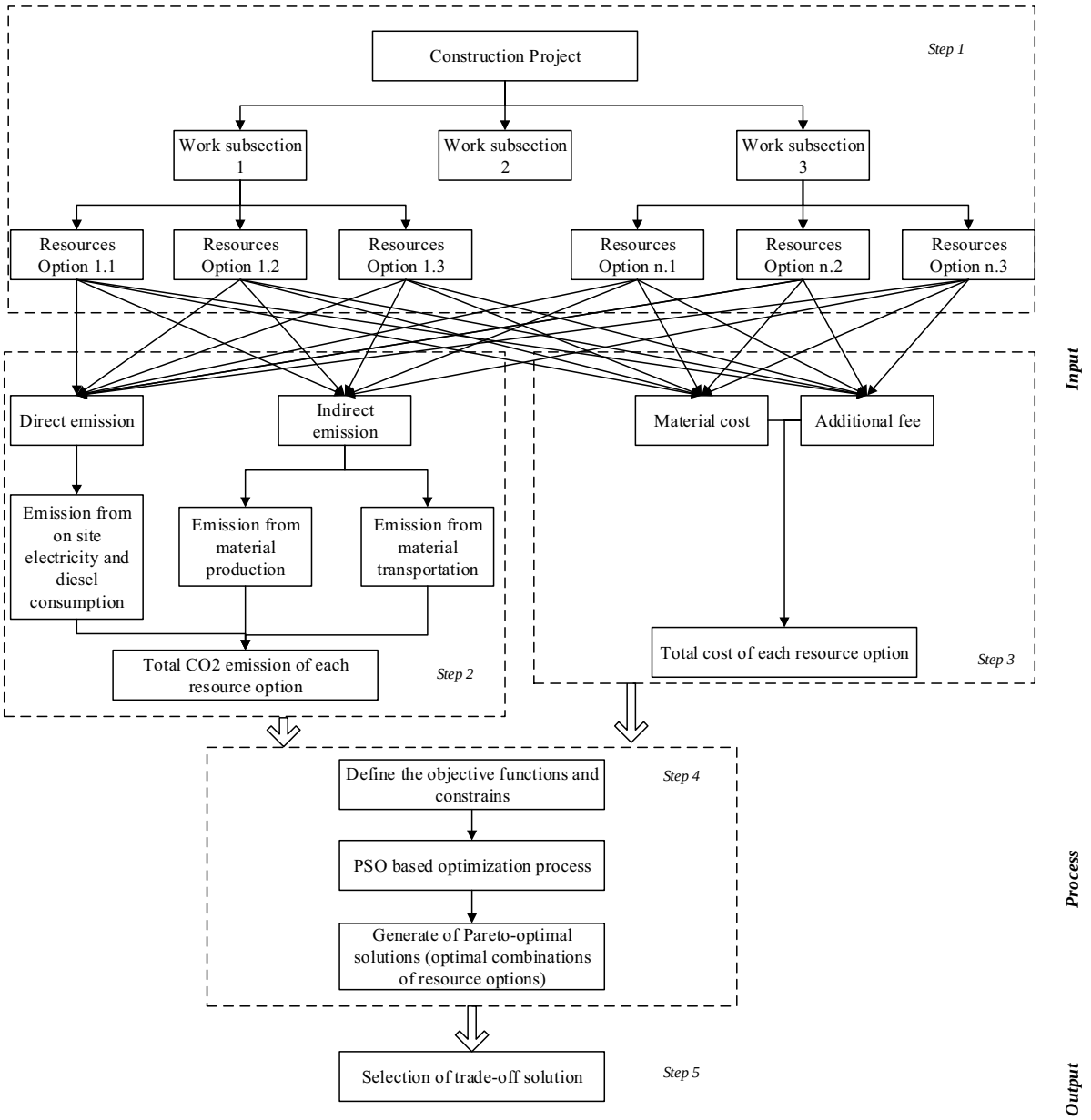


Fig. 6. The carbon dioxide (CO2) emission and carbon footprint model [22]

- The implementation of carbon footprint modeling in concreting work of high rise building construction in Indonesia [23]. Some of the running research is modeled as in Fig. 7, which is the carbon dioxide (CO_2) estimation modeling in concrete casting work using a tower crane.

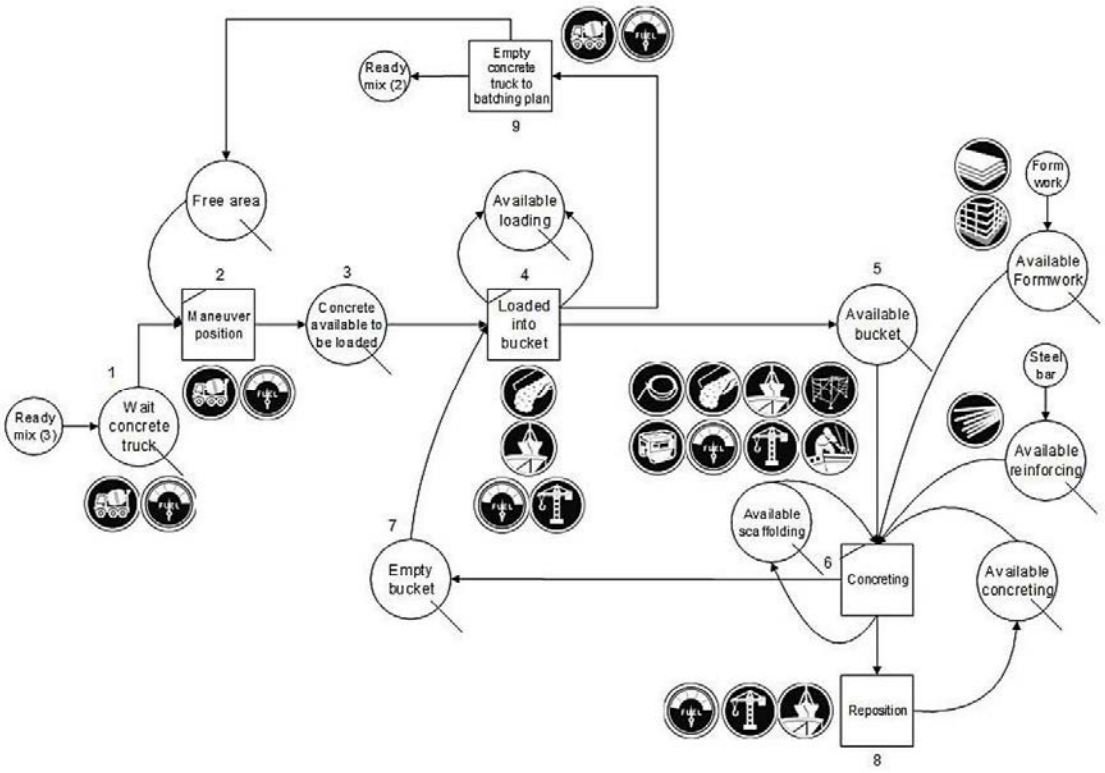


Fig. 7. The carbon footprint estimation model of casting work using a tower crane [23]

4. Conclusions

Based on description above, it can be concluded that:

a. The implementation of sustainable development requires a synergy between all parties involved in construction industry.
b. Industrial activities at the upstream part need a government regulation which related to the use of raw material and environment friendly material. The government regulation can be formed as a joint regulation from various ministries such as the ministry of industry and trade, the ministry of public works, the ministry of environment. The joint regulation is expected to affect the construction supply chain so it can reduce the greenhouse gas effects especially carbon dioxide (CO_2).
c. The construction implementations at the downstream part -which involves parties such as planning and contractor- need awareness to the sustainable development concept.

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