IMPROVING PROJECT PERFORMANCE AND WASTE REDUCTION IN CONSTRUCTION PROJECTS: A CASE STUDY OF A GOVERNMENT INSTITUTIONAL BUILDING PROJECT

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ABSTRACT

The construction industry plays an important role in establishing the infrastructure required for socio-economic development and directly contributes to economic growth. On the other side, it also generates severe impacts on the environment. The construction industry is one of the biggest environmental polluters and it also consumes large quantities of raw materials. Value Engineering originates from the manufacturing industry in order to deliver higher value and quality to a product by means of an increase in efficiency. 'Lean Construction' (LC) concepts emerged as a consequence of the application of VE philosophy, specifically for construction industry. LC extends from the objectives of a lean production system – to maximize value and to minimize waste – in relation to specific techniques and then applies them conceptually in a new project delivery process. The aims of this paper are to present practical examples of the application of Value Engineering and Lean Construction concepts within a green building construction project and to qualitatively assess its benefits in terms of environmental impact and waste minimization. A detailed case study was conducted for project execution of a new multi-storey government institutional building in the Jakarta central business district. This project adopts a Green Building and a Green Site concept in order to reduce potential environmental impact during the construction phase itself and during the occupancy phase of the building. The case study primarily concerns issues such as water consumption, power usage, etc. This project is a perfect example for the application of Value Engineering and Lean Construction philosophies in order to deliver better quality, faster completion, environmentally friendly practice, and less waste generation. The adoption of environmental awareness in the context of building design, the application of alternative and/or recycled/environmentally friendly materials, along with a number of "green" technologies and building systems featured in this building concept will deliver greater value without jeopardizing the ecology. Meanwhile, the adoption of prefabrication construction methods, intelligent excavation works, 'Reduce-Reuse-Recycle' principles, and simple 'environmentally-aware' on-site practices can minimize the waste produced and the local environmental impact emitted during project execution.

Keywords: Environmental; Green building*;* Lean construction; Value engineering; Waste minimization

1. INTRODUCTION

The construction industry plays an important role in establishing the infrastructure required for socio-economic development and it directly contributes to economic growth. On the other hand, it also generates severe impacts on the environment (Bossink & Brouwers, 1996). Problems related to environmental performance concern environmental problems associated with construction activities (Shen et al., 2005; Tam & Le, 2007; Ekanayake & Ofori, 2004,

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Gangolells et al., 2009). The construction industry is associated with high energy consumption, resource depletion, and a large amount of waste generation (Kim et al, 2005). The industry is one of the biggest environmental polluters (Yahya & Boussabaine, 2006). The construction industry also consumes large quantities of raw materials. As stated by Firmawan (2006), "…the most influence indicator of the cause of the deviation of the material cost is the purchase process, (besides transportation, storage or use of the material in the process.)" This explains also that the management of materials becomes the most pertinant source of construction waste. The type of materials produced to serve the industry range from raw goods such as sand, aggregates, soil and water to manufactured goods such as bricks, cement, plasterboard, metals (steel and iron), timber, concrete, cement, and plaster. As a consequence of a high rate of consumption of these materials, waste is generated in large quantities, which can have significant impact on the environment.

Meanwhile, construction waste is an undesirable or leftover material from construction activities which is generated in large quantities and it poses extensive environmental impact. A number of studies have developed some methods for environmental impact assessments in order to identify effective measures in mitigating impacts associated with construction activities, such as waste generation, noise pollution, water pollution and air pollution (EPD, 2003). Major sources of construction waste consist of, namely, road work material, excavated material, demolition waste, site clearance and renovation waste (EPD, 1992; Poon et al., 2001). A study by conducted by Graham and Smithers (1996) found that significant factors causing construction waste generation within the project life cycle include those occurring during the design stage, and procurement of materials. Masudi et al., (2011) reported that the type of building, design, and size of project and site management are the main factors for construction waste generation.

Studies found that there is a relatively low awareness of waste management among contractors in Malaysia which is reflected by lack of waste record-keeping and illegal waste dumping practices (Masudi et al., 2011; Begum et al., 2009). Contractors consider cost and duration as the most important priorities and waste & environmental impacts as the least important ones (Poon et al., 2004). Alwi (2003) found that one of the main problems suffered by Indonesian construction industry is productivity, particularly waste management. Alwi (2003) added that characteristics of contractors, such as inadequate management strategy and lack of organizational focus are the key contributing factors. Meanwhile, Siagian (2005) stressed that the lack of utilizing environmentally friendly construction materials resulted in poor sustainability in the Indonesian construction sector. Moreover, Suprapto and Wulandari (2009) concluded that the current status of waste management in the Indonesian construction industry is limited primarily to disposal only practices. Minimum efforts were made to actually manage, reuse, and recycle waste materials. Green construction practices seem to be the solution for problems associated with waste generation (Ervianto et al., 2011).

Value Engineering (VE) originated from manufacturing industry in order to deliver higher value and quality to a product by means of a higher level of efficiency. Value Engineering (VE) is an intensive, interdisciplinary problem solving activity that focuses on improving the value of the functions that are required to accomplish the goal, or objective of any product, process, service, or organization. The main idea is the systematic application of recognized techniques which identify the functions of the product or service, establish the worthiness of those functions, and provide the necessary functions to meet the required performance at the lowest overall cost (Bryant, 1998). VE methodology involves the flow chart described in Figure 1.

From Figure 1, the core VE study consists of the following steps:

Information Phase:
To clearly identify the problem(s) to be solved, and to gather information on the background, functions and requirements of the project.

Functional Analysis:
Identification of project's purposes. Identification of functions and how they are related.

Creativity Phase:
Brainstorm ideas on how to improve the high cost, broken, or inadequately performed key functions.

Evaluation Phase:
Screen ideas for acceptance, score remaining ideas on a scale and group ideas into categories. Develop design scenarios, and selection criteria. Rate and rank ideas.

Development Phase:
Plan how to sell ideas to management, identify key recommendations, and plan management presentation.

Reporting Phase:
Present oral presentation to management or develop written report.
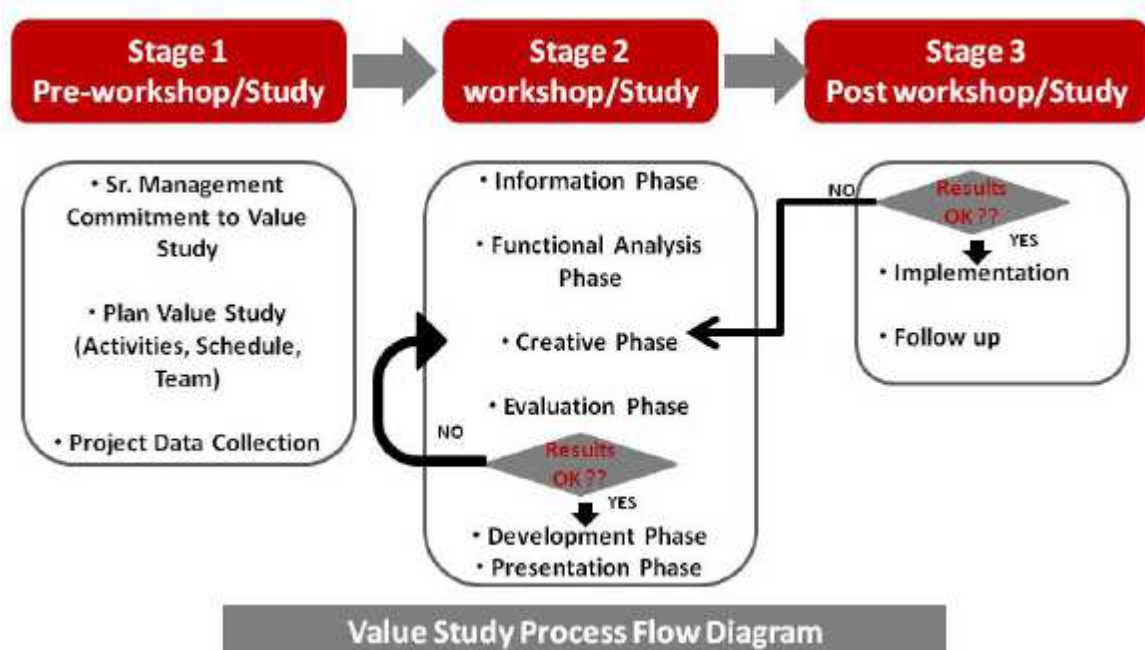

Figure 1 Value study process flow diagram (Bryant, 1998)

Alternative materials and techniques usually are the ultimate means for achieving VE by using decision matrix which involves cost, value, and score comparisons. For example, Roudebush (1998) found that implementing commercial plywood as a substitute for regular plaster for tile protection could save cost and deliver higher quality finishing. Roudebush (1998) also found that construction waste material based on EMERGY calculations result in the agricultural product EMERGY equivalent of one cubic yard (1100 lbs) of construction waste. An application of Environmental Value Engineering can be used to assess the waste generated during construction for an alternative process in the built environment. Environmental value

engineering is an environmental life cycle assessment methodology that can be used to assess EMERGY equivalents towards sustainable development, (Roudebush, 1998).

The 'Lean Construction' (LC) concept emerged as a consequence of the application of VE philosophy, specifically for the construction industry. Lehman and Riser (2000) define Lean Construction (LC) as, "a production management-based approach to project delivery - a new way to design and build capital facilities. LC changes the way work is done throughout the delivery process. LC extends from the objectives of a lean production system - maximize value and minimize waste - to specific techniques and applies them in a new project delivery process." (Lehman & Riser, 2000). Creative ideas and innovation are most of the time required to deliver a leaner project (less consumption, less waste, higher quality, higher value, higher constructability, and faster completion) rather than sticking to conventional practices. The ideal in both Value Engineering and Lean Construction is to maximize value and minimize waste by systematically applying a method to a process or service to provide the customer with an enhanced product or service that fulfills their needs in a cost effective and timely manner. Lean Construction practices do not compete with Value Engineering; it is intended to complement Value Engineering. Although there are many similarities, especially regarding measurable results and benefits in terms of resources, dollars, and time, Lean Construction has its own set of specific project tasks intended to maximize value and minimize waste (Lehman & Riser, 2000). The aforementioned authors concluded that the Lean Construction Ideal is "a custom product, delivered instantly, without waste". Lean construction goals include:

- Deliver products or services that enable customers to better accomplish their goals,
- Deliver products or services on time and within budget,
- Minimize direct costs through effective project delivery management,
- Make well-informed business decisions at all project levels,
- Minimize risk and maximize opportunity,
- Inject reliability, accountability, certainty, and honesty into the project environment,
- Reduce system noise,
- Improve project delivery methods,
- Promote continuous improvement in project delivery methods through lessons learned, and
- Deliver a custom product, instantly, without waste.

The aims of this paper are to present practical examples of the application of Value Engineering methodology and Lean Construction concepts within a green building construction project and to qualitatively assess its benefits in terms of environmental impact and waste minimization.

2.   METHODOLOGY

The Value study utilized during design phase entails implementing a FAST (Function Analysis System Technique) method. Function Analysis is widely regarded as being one of the three cornerstones of VM together with the Job Plan and the use of Multi-Disciplinary Teams (Gronqvist et al., 2006). Developed by Mr. Charles W. Bytheway in 1964, and first presented as a paper to the Society of American Value Engineers conference in 1965, FAST contributed significantly to perhaps the most important phase of the Value Methodology (VM) – function analysis.

The most common method of Function Analysis is that a function is expressed in as concise a phrase as possible, ideally one comprising just an active verb followed by a noun. Passive verbs include 'provide' and 'allow' whereas active verbs are, for example, 'protect', 'hold', 'attract', and 'enclose', since they are, in effect, more descriptive. The technique of stating a function

using 'verb-noun' syntax helps to reduce a problem into its fundamentals (Gronqvist et al., 2006). The advantages of the approach are (Dell'Isola, 1982):

Forces conciseness. If you cannot define a function in two words, you do not have enough information or understanding about the problem, or you are trying to define too large a segment of the problem. Avoids combining different functions and ensures that only one function will be defined at one time. Facilitates the task of distinguishing between primary and secondary functions because it helps to identify each function as specifically as possible. Aids in achieving the broadest level of disassociation from specific designs or previous solutions.

The Technical FAST technique follows a few basic rules (Norton & McElligott, 1995). As the name implies the technique is well suited to depicting the technical performance requirements of a problem. It also takes into account the time element, to a degree. The How/Why method for testing the logic of the resulting diagram is used. This study shall implement the How/Why method in formulating the FAST diagram.

 A detailed case study based on a Value study was conducted during evaluation and project execution phases of a new multi-storey government institutional building in the Jakarta central business district. This project adopts a Green Building and a Green Site concept in order to reduce potential environmental impact during the construction phase itself and during the occupancy phase of the building, which primarily concerns issues such as water consumption, power usage, etc. Occasional site visits, analytical observations, and data collection were carried out during the on-going project phase. Basic project data such as contract value and size of building, and essential data such as detailed building specifications, construction techniques and other on-site control practices were collected and recorded. Some interview sessions with key personnel such as the Project Manager, the Head of Development and Implementation from the government institution were also performed during occasional site visits. Qualitative assessment was undertaken to compare that the so called 'green specifications' of the building that are in-line with environmental Value Engineering and Lean Construction concepts.

3.   RESULTS AND DISCUSSION

A new multi-storey government institutional building in the centre of Jakarta was selected for case study of value engineering concept. This project adopts environmentally-friendly a Green Building concept. Project summary and detailed value engineering features are presented below.

3.1. Project profile (information phase)

Project Name	:	Building Construction Project of Ministry of Public Works Republic of Indonesia
Project Duration	:	371 days
Contract Sum	:	Rp 358 Billion (Approx. RM 120 Millions/ USD 37.9 Millions)
No of Floor	:	17-storey plus 1 semi-basement with an average distance between floors of 4.15 m
Parking Building	:	12-storey plus 1 semi-basement with an average distance between floors of 3 m

This building shall be considered as a national landmark and benchmark as the basis of green building concepts in Indonesia, specifically for government institutional buildings.

3.2. Functional analysis phase

FAST (Function Analysis System Technique) was conducted during the functional analysis phase by applying a comprehensive FAST diagram as proposed by Grönqvist et al., (2006). Critical functions were identified for green design features and on-site practices which maximize the Lean Construction concept, compared to conventional construction. The FAST diagram for this green building is described in Figure 2, as follows.

From Figure 2, it can be concluded that the main objectives of LC are to maximize value and minimize waste. Since the purpose of a green building concept is to create sustainable construction, thus, protecting the environment shall be considered as the highest order function. Therefore, the major path of this exercise shall be divided into two separate issues, which are lean construction practices and green design. Lower order functions from both critical issues are elaborated on the far right, which further highlights the main features of this building.
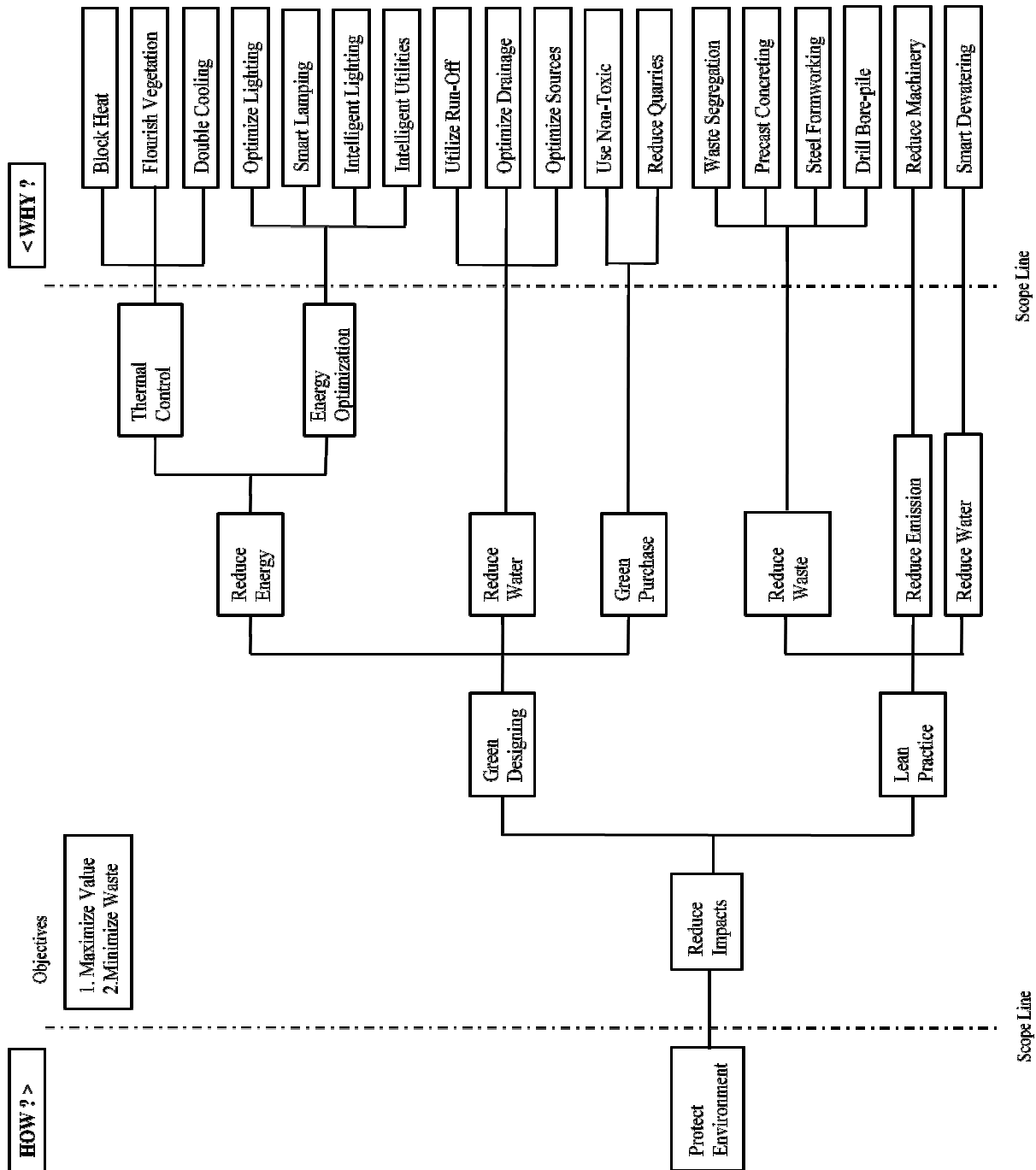
Figure 2 FAST diagram for green building

3.3. Evaluation and implementation phase

Based on the functional analysis phase described in the FAST chart, the evaluation and implementation phase is divided into two sections, green design features and on-site construction practice. Functional solutions/outcomes based on further and detailed site visit/data collection processes include:

No.	A. Building Value Engineering Features
1	Zero run-off concept. The purpose was to minimize water drains from rain to areas outside of building vicinity by designing retention ponds/ swale, local absorbent areas, and optimization of perimeter drainage systems.
2	Thermal control or microclimate systems by patterned arrangements and selection of suitable vegetation; designing naturally flowing air circulation; and O_2/CO_2 management with bulky and dense plants.
3	Utilization of environmentally friendly construction materials by minimizing the use of natural products or selecting of non-toxic products, and providing facilities for pedestrians and disabled individuals.
4	'Recycle, Reduce, and Reuse' by application of reliable soil absorption and water source systems, and minimizing the use of supplied water.
5	Efficient power usage by optimizing natural lighting, selection and installation of low energy-consumption lamps (LEDs) and sensors.
6	Implementation of waste segregation for organic, non-organic, and hazardous waste.
7	Usage of at least 30% of ISO 14001-certified construction materials with an emphasis on local manufacturers. Products from vendors shall fulfill 'Greenship' material requirements with greater emphasis given for green-certified materials. Questionnaires were sent to suppliers for control of recycled materials.
8	The engineered equipment shall be calibrated and validated prior to installation. Moreover, indicators and meters must be permanently fixed within the equipment. Therefore, all used equipments shall be properly monitored.
9	Air conditioning needs shall be fulfilled and supported by two cooling systems such as: a water cooled chiller and a Variable Refrigerant Volume (VRV) system. VRV system will be installed in certain rooms such as data rooms in order to avoid running central air conditioners at night, which consumes high amounts of energy. Chillers shall use high efficiency water cooled screw chiller systems with 300 TR capacity and R-134A refrigerant which is ozone-friendly. The cooling tower shall use the Cross Flow Closed System type for efficient water usage. Ducting shall utilize environmentally friendly and air-tight materials, such as polyurethane, which will minimize the loss of conditioned air.
10	Clean water shall be supplied from local water Supplier Company and deep wells. Meanwhile, used water from toilets and condensation from air conditioners shall be circulated for toilet flushing and plant watering usage requirements, etc.
11	The Lighting installation shall utilize an Intelligent Lighting Control System, which is a control system for indoor building lighting. This system shall be fully capable of controlling ON/OFF/dimming for every group of lamp nodes. This is an implementation of minimizing power consumption for artificial indoor lighting. It was found that electrical consumption shall be reduced by 44%.
12	The Elevator system shall utilize Variable Voltage Variable Frequency (VVVF) which features soft-starting motors and lower in-rush current for low energy consumption. Elevators shall be equipped with regenerative converter and during usage; a traction machine can function as generator when the elevator is descending, therefore generating electricity. This system could minimize energy consumption by 35%.
13	During project execution, contractor shall comply with any environmental requirements by monitoring noise levels and pollutants. A special task force from the corporate decision making level shall be assigned periodically to monitor and audit of all HSE-related aspects.

No.	B. On-Site Value Engineering Practices
1	Two back hoe excavations were carried out, each with a capacity of 30 m^3 per hour and 10 hours of work duration per day. Volume of excavation for main building reached 7,469 m^3 which were divided into three excavation zones. Meanwhile, the volume of excavation for parking building was 8,909 m^3 which was divided into two excavation zones.
2	These buildings shall utilize a bore pile type foundation with varied depths. For the piling method, innovations were made in order to excavate until pile cap level. After digging, drilling for foundation is then carried out. The objective and purpose of this method is to minimize waste resulted from cutting of bore piles. This system, however, will face some challenges during monsoon season due to formation of retaining ponds. Therefore, effective drainage system is essential which provided with open drain pits.
3	To anticipate rainy water filling up the excavation area, drain pits were made to accommodate water pumping and water removal operations Prior to further excavations, dewatering was conducted by pumping out settled water which shall be processed in some simple purification ponds. Thus, purified water from the dewatering processed can be consumed for daily project usage.
4	For excavation works, the number and capacity of heavy machinery equipment shall be considerably minimized according to necessity only in order to mitigate emissions generated from project.
5	To reduce waste generated from formwork activities, the construction system in this project will optimize the utilization of precast concrete elements, such as beams and slabs.
6	A steel formwork panel system was also utilized. Formwork panels are adjustable in order to cast different sizes and shapes of structural elements and these are highly suitable for repeated use. These panels were pre-fabricated prior to the initiation of the project. By adopting this construction method, no timber cut offs were produced on site due to installing/detaching conventional timber formwork. Steel panel formworks and metal decks (for slabs) can save valuable time during concrete casting, especially for beams and columns. Thus, it would lead to faster completion rate, significantly less waste & concrete spillage, and better quality control, compared to conventional timber formwork.
7	Insulation used a recycled material with special additives to be applied on building facades and structures. This insulation can absorb some of the heat radiated from direct sun light, thus will keep the indoor cool.
8	Car stopper blocks in parking building were made of leftover concrete spillage from casting works for an efficient use of concrete.
9	Office rooms for the project team are committed to save energy from the use of air conditioners and lighting. Food for construction workers was supplied by subscribed caterer, instead of being supplied with box/ packaging in order to minimize domestic waste produced by workers on site. Drinks were served using glasses rather than using plastic bottles. Tissues were replaced by wash cloths.
10	A designated shelter was provided for smokers.
11	Meanwhile, large machinery equipment must be properly cleaned before coming out from project site.

From site practices it is clear that by implementing simple modifications in piling and excavation methods, adapting prefabrication and metal formwork construction methods, instead of conventional timber formworks shall resulted in faster completion and significantly less wastage. These are aligned with the objectives of LC, which are maximizing value and minimizing waste. The VE method, by using a common FAST diagram, would help brainstorming and decision making processes to achieve LC goals.

4. CONCLUSION

This project exhibits a well-considered example for the application of Value Engineering and Lean Construction philosophies in order to deliver better quality, faster completion, environmentally friendly practices, and less waste generation. The adoption of 'environmentally-aware' building designs, the application of alternative and/or recycled/environmentally-friendly materials, a number of "green" technologies and building systems featured in this building concept deliver more value without jeopardizing the ecology. Meanwhile, the adoption of prefabrication construction methods, intelligent excavation works, 'Reduce-Reuse-Recycle' principles, and simple 'environmentally-aware' on-site practices can minimize waste produced and local environmental impacts emitted during project execution. Green building design shall encompass Value Engineering and Lean Construction concepts in order to modernize the Indonesian construction sector to achieve a sustainable construction industry. This project can be regarded as a benchmark for sustainable building project for the future.

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