Rule Based DSS in Controlling Construction Waste

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Abstract: This paper presents the concept and the protocol in developing a Decision Support System (DSS) in which the system enables to trigger the construction waste generation factors. Once these factors are determined, the system will be able to provide options for controlling the generation of the waste. The system applies the rule-based reasoning in deciding right output for a specific input to the system. The proposed DSS will use VB.net software package together with SQL Server for the database of the system. This system will help the practitioners and the government agencies in triggering the factors of construction waste generation and also for finding the possible controlling actions with their level of effectiveness. This will be useful for selecting the most suitable method for construction waste control.

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1. Background

Construction waste is classified in two types as (i) Physical waste which reflect waste generated in the form of materials; (ii) Non-physical waste also known as Non-value adding activities which can be reflected as time and cost waste. Non-physical waste also includes undesired activities which can cause physical waste also such as rework, unnecessary material movements [Nagapan et. al. 2012].

It is a worldwide phenomenon where amount of construction waste generated in the urban areas is increasing [Nazech et. al. 2008]. The waste gives negative impact to the environment, cost, productivity, time, social and economy of the construction industry [Osmani 2012, Wang et. al. 2008]. Improving the quality and efficiency of the construction industry is one way of waste at all stages of the construction process [Egan, 1998].

Besides the concerned of physical waste, the construction industry has also experiencing non-physical construction waste generation where most of the projects experience poor time and cost performance. This poor performance is described as the inability to complete projects within time and budget which is experienced worldwide and is becoming very critical. In assessing cost overrun issues, Flyvbjerg (2003) had studied 258 projects in 20 nations which approximately US$90 billion worth of project with a size ranging from US$1.5 million to $8.5 billion. They found that the cost escalation happened to almost 9 out of 10 projects with an average of 28% higher than forecasted costs. Their study indicated that cost performance has not improved over the time and its magnitude has not changed for the past 70 years. The problem of time and cost overrun is a common issue in both developed and developing countries.

In Malaysia also, construction waste has become a prominent issue where huge amount of material waste is dumped into landfills and a significant number of projects are facing time and cost overrun [Aziz et. al. 2012]. Material waste in Malaysia has resulted in causing illegal dumping nationwide. A study carried out in Klang Valley showed that a majority of C&D waste dumps to the private land or illegal dumpsites while only 20% of them is disposed in legal landfills [Begum et. al. 2008]. The result also showed that 88% of the C&D waste generated is from residential buildings while 9% from commercial and 3% from government buildings resulted from increased demand of housing and commercial buildings. The largest components of C&D waste are concrete; aggregate and rubbles followed by soil, wood, metals and roofing materials. Nagapan et. al. (2012) in a research which consisted with three construction sites found that the timber waste was the dominant waste produced at all three sites which is followed by bricks, packaging waste and concrete. Another study conducted by Foo et. al. (2013) revealed that total waste generated at two sites of housing project was 154.31 m^3 and major component of waste was timber with 49% of total waste.

From non-physical waste i.e. time and cost waste perspective, various researchers have highlighted seriousness of the problem. Malaysians Auditor General 2008 report as summarized by Khamidi et. al (2011) showed that the completion of electrified double track project between Rawang and Ipoh resulted in a cost overrun of RM 1.43 billion.

Endut et al. (2009) analyzed cost overrun problems by investigating 308 public and 51 private projects (a total of 359 projects). They found that only 46.8% and 37.2% of public sector and private sector projects completed within the budget respectively with average cost deviation of the project was 2.08%. The maximum deviation was found as 80.76% of project cost. Further, in MARA large construction project, research conducted by Abdullah et al. (2009) revealed that more that 90% of large MARA construction project experienced delay since 1984 with major effects of time and cost overrun. Later on, in qualitative study of project performance of D&B project through eight case studies Potty et. al. (2011) found that seven projects were facing cost overrun; however, the risk of these overruns was borne by contractors as the projects were awarded on fixed price conditions. Sambasivan and Soon (2007) also mentioned that Malaysian construction projects are facing problem of construction delay and 17.34% projects were considered sick which were abandoned. Further, the recently similar problem of time and cost overrun issue happened in the construction of Kuala Lumpur International Airport 2 (known as KLIA2). This project was targeted to be opened in September 2011 but the opening was then moved to 28th June 2013. Because of the delay, project expected the cost overrun run of about RM500 million [Sidhu 2013]. Issues related to construction waste generation including physical and non-physical i.e. material, time and cost in some of the countries are summarized in table 1.

Table 1. Waste Generated Worldwide

Origin	Reference	Issues
Malaysia	Begum et. al. 2010, Foo et. al. 2013, Sambasivan and Soon 2007, Noor et. al. 2013, Rahman et. al. 2013, Auditor General Report 2012	Construction waste is not well managed in Malaysia where huge amount of materials is deposited into the landfill, and most projects are delayed with significant amount of cost overrun. It was reported that, in Klang Valley, 88% of the C&D waste is contributed from residential buildings and majority of C&D waste is dumped to the private land or illegal dump sites while only 20% of them is disposed in legal landfills. Besides this, 17.34% of government contract projects were considered sick i.e. delayed for more than 3 months or abandoned. In a survey amongst the practitioners, 89 of respondents highlighted that their projects often face cost overrun. A recent project of KLIA2 was delayed for more than 2 years and exceeded cost drastically.
Thailand	Kofoworola et. al. 2009	Construction waste is a significant issue where an average of 1.1 million tons of construction waste generation was recorded annually during the period of 2002 – 2005. Further, about 7.7% of the total amount of disposed waste disposed in landfills and open dumpsites annually was contributed from construction waste.
Indonesia	Intan et. al. 2005	Annually about 3 million ton (which contained 50% earth/sand and 50% contributed from buildings) of waste generation was recorded from existing C&D landfill sites in Kuwait. Authors highlighted that the demolition work produced waste at an average rate of 1.5 ton/m^2, at rate of 1.45 ton/m^2 generated waste was residential, and waste from industrial work was generated at rate of 1.75 ton/m^2. Further, other construction works generated waste of about 45 kg/m^2 of constructed flooring.
Kuwait	Kartam et. al. 2004	Waste generation of materials was amounting 9% of the totally purchased material for the projects studies.
China	Lu and Yuan 2011	The study investigated Waste Generation Rate (WGR) by conducting on-site waste sorting and weighing in four ongoing construction projects in the Shenzhen city of South China revealed that WGRs ranged from 3.275 to 8.791 kg/m^2.
India	Doloi et. al. 2012, Pai and Bharath, 2013	Construction projects experience huge amount of delay and cost overrun where only 60% of the construction project were completed on estimated time. Average amount of time overrun is recorded as 40%. Approximately 70% projects have faced overrun in cost with maximum of 65% - 70%. Besides this, Bandra Worli sea link project faced delay of 5 years with heavy cost overrun.
Zambia	Kaliba et. al. 2009	It was reported that only 30.77% and 46.15% of road projects were completed on time and within budgeted cost with a maximum amount of time overrun as 69.23% and cost overrun of 53.85%.
Egypt	Marzouk and El-Rasas, 2012	Around 25% of building construction projects faced time overrun with a minimum amount of time overrun was 24.59%.

This issue of construction waste is caused by various factors such poor site management, design changes, lack of experiences, poor coordination between parties, slow information sharing and others as identified from various research works. To overcome this issue of construction waste, several approaches had been proposed by researchers and practitioners such as waste management strategy, advanced techniques, quality control system and others. However, in this paper the authors have proposed a dynamic technique known as Decision Support System (DSS) for proposing suitable corrective actions in controlling the factors generating construction waste.

2. Decision Support System Concept

Decision Support System (DSS) is developed using Expert System (ES) in assisting decision making by asking relevant questions and explaining the reasons for adopting certain actions. Expert System is an efficient computer program which provides the solution of problems based on task specific knowledge and inference techniques at the level of a human expert [Bollojua et. al. 2012]. Expert systems are developed from the study of artificial intelligence (AI), which is a field of computer science and aims to transfer human brain power into the machines [Tripathi 2011]. An expert system is used to extract the information of a human expert within a specific domain and makes this knowledge available to less experienced users through a computer coded program [Dogantekin et. al. 2010].

Expert system is developed to imitate the human expert's decision making ability in a particular domain such as construction management or any other field of knowledge where there is a shortage of comprehension engineers or experts and can also give advices and explanations [Shiue et. al. 2008]. Fundamentally, it comprises of some representation of expertise, or a problem to be solved, and some mechanisms to apply the expertise to a problem in the form of rules [Omran et. al. 2005].

A typical DSS consists of several components which include database, the reasoning engine and graphical user interface. The structure of the DSS is shown below in figure 1. Among the components of DSS, database is considered as the heart of DSS; it consists of facts and rules which provides all the knowledge and information about the problem domain. Data base is warehouse of the domain where specific knowledge captured from the human expert through knowledge acquisition is stored. It contains both factual and heuristic knowledge and represents that knowledge in the form of production rules, logic etc. Factual knowledge is a widely shared knowledge obtained from text books and journals. Heuristic knowledge is rarely discussed because it is less rigorous, more experiential and judgmental [Shen et. al. 2010].

An inference engine implements the reasoning process of artificial intelligence; which is an analogy to human reasoning [Prasad et. al. 1996]. Its role is to work with the available data from the system and the user to derive a solution to the problem. The purpose of an inference engine is to extract information from the data base for the provision of answers, predictions and suggestions just like a human expert.

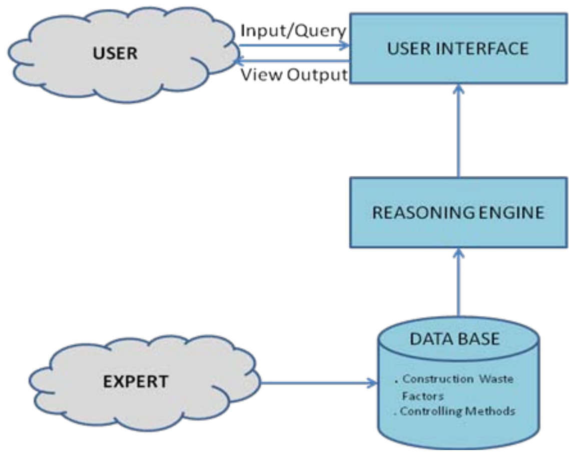


Figure 1. Structure of Decision Support System

User interface manages the dialog between the user and the system. It provides facilities such as menus, graphical interface etc. Thus; it is an intermediary that allows communication between the user and the system. The function of the user interface is to ease the usage of an expert system by developers, users and administrators [Daniel et. al. 1997].

For developing the rules, various types of reasoning are applied depending on the purpose of DSS. Some of the vastly adopted reasoning are rule-based reasoning, case based reasoning, model based reasoning and neural network. Rule based reasoning acquaints the knowledge in the form of rules such as IF–THEN [Xu et. al. 2007] and has been applied in various areas of study such as state transition analysis, psychiatric treatment, production planning, advisory system, teaching, electronic power planning, automobile process planning, etc [Liao 2005].

Case-Based Reasoning (CBR) is Artificial Intelligence (AI) technique to support the capability of reasoning and learning in decision support systems [López et. al. 2005]. CBR helps in solving the new problem by adapting the solutions used to solve previous problems. Artificial neural network is a form of artificial intelligence, which attempts to simulate the biological structure of human brain and nervous system by means of their architecture [Gupta et. al. 2006]. Neural network is widely applied in DSS for prediction in several areas such speech synthesis, diagnostic problems, medicine, business and finance, robotic control, signal processing, computer vision, mitigation process control and biomedical application [Takagi 1997, Chua and Yang 1988, Fu 1998].

In this study, the aim of DSS is to assist decision making by asking relevant questions and explaining the reasons for adopting certain actions. Hence, for practical application, rule based reasoning is adopted.

3. Development of Proposed DSS

A procedural framework to develop an application for controlling construction waste is divided into 2 states as shown in figure 2.

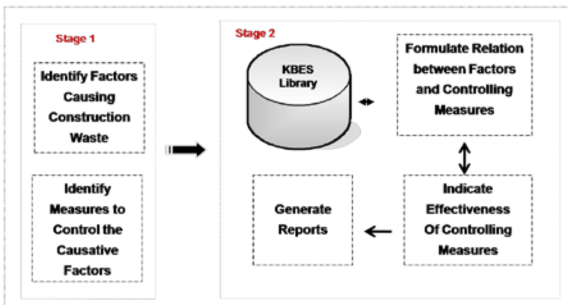


Figure 2. Architecture of the Proposed DSS

As seen from figure 2, stage 1 aims to understand and uncover the factors causing construction waste and possible controlling measures in controlling the factors. This involves a qualitative approach to understand the perception of construction's professionals in Malaysia. For this, initial identification of common factors of construction waste generation and possible controlling measures involves the review of published literature worldwide. These identified factors need detailed investigation for confirming their relative occurrence within Malaysian construction environment. Further, these factors are classified based on probability of occurrence in various phases of a construction project life cycle. In this study, life cycle of a construction project is divided into 4 phases i.e. planning, designing, construction and finishing as shown in figure 3 where Planning (P) phase emphasize developing clear and complete plan for the project. It involves describing the scope, purpose and objectives of the project and also estimation of resources, time and cost. This is to ensure that the project executions can be completed within the desired time frame and budget.

Design (D) phase involves preparation of detailed plan and drawings for the entire project. Designers are responsible for providing drawings according to owner requirements and any changes can be made before it is approved. Construction (C) phase is a major part of project lifecycle where actual project execution is done. This phase involves the execution of the project plan, communication between other parties, report the project progress, and control the time, cost and quality of work. Finishing (F) phase is the concluding stage of construction work. It involves the finishing work for the entire structure or building

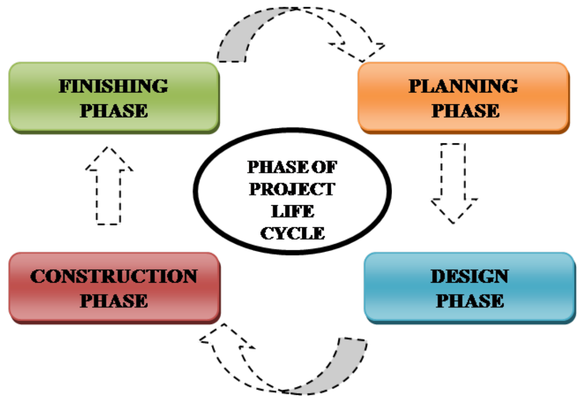


Figure 3. Phases of Project Lifecycle

For this study, initially a total of common factors 34 factors are listed through literature review. A total of 5 experienced personal were interviewed to park these factors into various phases of project lifecycle based on the frequency of occurrence and severity level in causing construction waste. Based on the interviews, the factors classified into various phases of project life cycle are summarized in table 1.

Further, in identifying the possible measures for controlling construction waste, initially a total of 282 measures were identified. These measures were reviewed carefully to correlate with the identified factors which resulted in reducing the measures to 106 and a correlation matrix showing the factors and relative measures of control were presented to the interviewed panel for confirmation of the applicability of suggested measures for identified factors.

Based on the identified factors and controlling measure, stage 2 work i.e. development of DSS was carried out to facilitate the practitioners for decision making to control the contributing factors through visualization, as well as preparation of the required report in this context. For this, database library is a compulsory component. Data Base Library was developed with SQL server computer language which contains information about factors, description, controlling the method, project lifecycle phase, effectiveness level of each controlling method and other necessary information. The front end application for controlling construction waste was developed by using a computer program of VB.net.

Table 1. Causative Factors of Waste Generation throughout Project Lifecycle

Causative Factors	Phases			
	P	D	C	F
Poor site management and supervision			√	√
Incompetent subcontractors			√	√
Schedule delay			√	√
Inadequate planning and scheduling	√	√	√	√
Lack of experience	√	√	√	√
Inaccurate time and cost estimates			√	√
Mistakes during construction			√	√
Inadequate monitoring and control			√	√
Frequent design changes	√		√	√
Mistakes and errors in design			√	√
Incomplete design at the time of tender		√	√	√
Poor design and delays in Design		√	√	√
Delay Preparation and approval of drawings			√	√
Cash flow and financial difficulties faced by contractors			√	√
Poor financial control on site			√	√
Financial difficulties of owner			√	√
Delay in progress payment by owner			√	√
Delay payment to supplier /subcontractor			√	√
Contractual claims, such as, extension of time with cost claims			√	√
Lack of coordination between parties	√	√	√	√
Slow information flow between parties	√	√	√	√
Lack of communication between parties	√	√	√	√
Labour productivity			√	√
Shortage of site workers			√	√
Shortage of technical personnel (skilled labour)			√	√
High cost of labour			√	
Labour absenteeism			√	
Shortages of materials			√	√
Late delivery of materials and equipment			√	
Equipment availability and failure			√	
Poor project management			√	√
Change in the scope of the project	√	√	√	√
Delays in decisions making	√	√	√	√
Inaccurate quantity take-off			√	√

This system is developed based on rule based reasoning approach to suggest the controlling methods. A rule-based reasoning is defined as a system containing information obtained from a human expert and representing that information in the form of rules, such as IF–THEN. The rule can then be used to perform operations on data to inference in order to reach appropriate conclusion [Kishan et. al. 2012, Abraham 2005]. A rule-based system consists of a bunch of facts, and an interpreter controlling the application of the rules, given the facts. These if-then rule statements are used to formulate the conditional statements that comprise the complete knowledge base. A single if-then rule assumes the form 'if x is A then y is B' and the if-part of the rule 'x is A' is called the antecedent or premise, while the then-part of the rule 'y is B' is called the consequent or conclusion [Abraham 2005]. The matching of the rule IF parts to the facts produce inference chains. The inference chain indicates how an expert system applies the rules to reach a conclusion [Rebizant et. al. 2011]. In essence, a rule-based system is based on sets of rules that are used to make decisions.

In proposed system, the factors of waste generation are following "If" condition. For each "If" condition, the controlling measure as "Then" are suggested. The methods for controlling factors are proposed based on expert opinion and questionnaire survey. The system also suggests a level of effectiveness for each controlling method.

3. Protocol of DSS

Procedural framework for applying DSS in the industry follows a stepwise approach, facilitating user friendly approach as highlighted in figure 4.

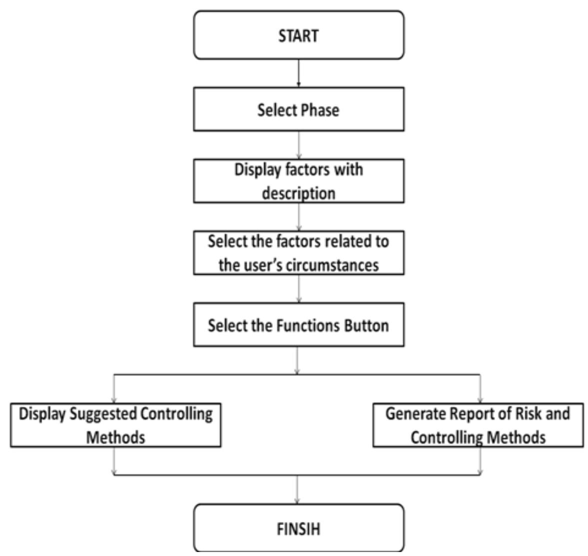


Figure 4. Procedural Framework of Developed DSS

In accessing developed DSS, the first step is to get input from the user. For this, when the user starts the program screen will be opened where user has to select the phase of the project as shown in the screenshot given in figure 5.

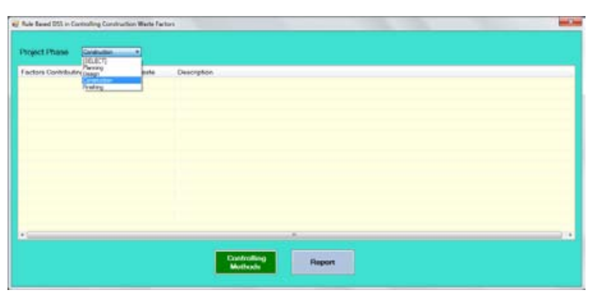


Figure 5. Screenshot for Phase Selection

When the user selects the phase, all possible factors of construction waste which can be occurred in that particular phase will be displayed. Also, the explanation of all the factors is appeared on the same screen as shown in the screenshot in figure 6.

Figure 6. Screenshot of Display of Factors and their Description

From displayed factors, user will select the contributing factors based on the prevailing circumstances and problems being faced in his projects. For the select factors, user has to process for computational work. It depends on the requirements of the user. Current system allows seeing suggested possible controlling methods for each factor together with the level of effectiveness in controlling construction waste. The user can also print controlling method by selecting the button report. The screen shots of all three functions of the system are shown in figure 7 and figure 8.

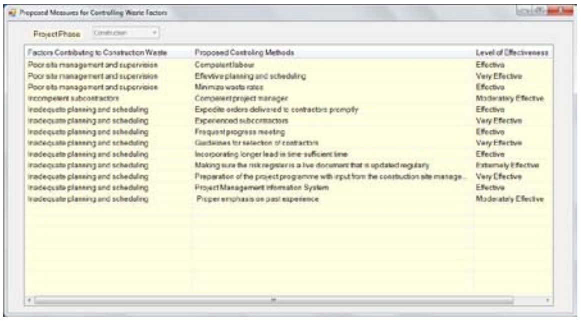
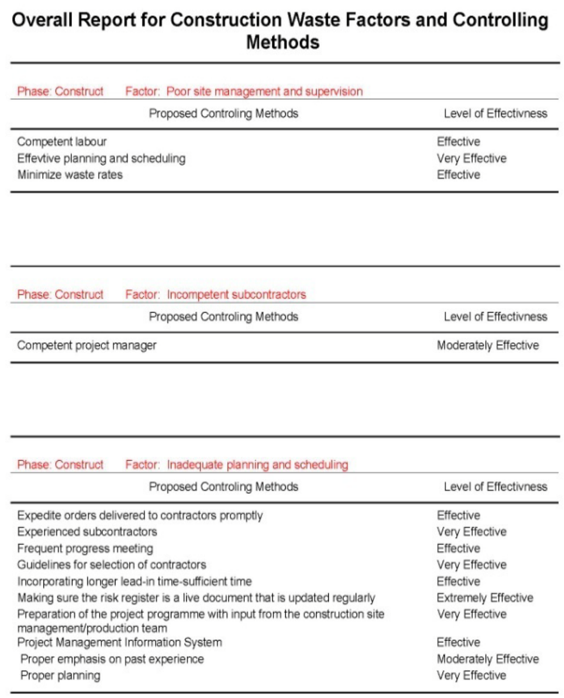


Figure 7. Screenshot of Displaying Suggested Controlling Methods



Overall Report for Construction Waste Factors and Controlling Methods

Phase: Construct Factor: Poor site management and supervision

Proposed Controling Methods	Level of Effectivness
Competent labour	Effective
Effevtive planning and scheduling	Very Effective
Minimize waste rates	Effective

Phase: Construct Factor: Incompetent subcontractors

Proposed Controling Methods	Level of Effectivness
Competent project manager	Moderately Effective

Phase: Construct Factor: Inadequate planning and scheduling

Proposed Controling Methods	Level of Effectivness
Expedite orders delivered to contractors promptly	Effective
Experienced subcontractors	Very Effective
Frequent progress meeting	Effective
Guidelines for selection of contractors	Very Effective
Incorporating longer lead-in time-sufficient time	Effective
Making sure the risk register is a live document that is updated regularly	Extremely Effective
Preparation of the project programme with input from the construction site management/production team	Very Effective
Project Management Information System	Effective
Proper emphasis on past experience	Moderately Effective
Proper planning	Very Effective

Figure 8. Example of Report Showing suggested controlling methods

7. Conclusion

Construction waste has becoming a phenomenal issue worldwide which need creative way to lessen or resolve the issue. This dynamic system is able to assist the construction community to anticipate and also to control the waste generation. The system works based on rule based reasoning principles with IF-Then logic. For every “If” condition i.e. factors of waste generation, “then” i.e. suitable controlling measures are suggested which will be very useful and helpful in assisting the practitioners for controlling waste generation.

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