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EXPLAINING SUCCESS IN GREEN BUILDING PROJECTS USING TRANSFORMATION-FLOW-VALUE-GENERATION THEORY

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Abstract- Green Buildings (GBs) are construction projects developed on the principles of sustainable development. Project success in GBs is an important concept to determine their performance. This concept is operationalized by success factors which affect the performance of a GB project and success criteria based on which a project's performance can be determined. Previous studies on GBs are limited in providing an interpretation of the Success factors and Success criteria in terms of the theories related to construction. This lack of interpretation has constrained the development of theory as well as research on GB project success. With a focus towards Green Buildings, this paper aims to explore the use of the Transformation-Flow-Value-generation (TFV) theory for interpreting success factors and success criteria. Upon analysing a few examples of Success factors and criteria, it is realized that the TFV theory can interpret GB project success. The findings presented in this paper have theoretical implications as these can inform research in construction projects in general and GB projects in particular. For future research on GB project success, the TFV theory can be used as a theoretical framework.

Keywords- Green Building, Transformation-Flow-Value-generation theory, Waste, Success factors, Success criteria

1 INTRODUCTION

Building projects are associated with negative environmental effects and Green Buildings (GBs) can help reduce these. Since buildings fulfil the requirements of human life on a daily basis in terms of living and working, they are extremely important part of the built environment. However, services from buildings come at a cost as the building and construction sector tend to consume large amounts of resources. For instance, the buildings and construction sector in 2018 accounted for 39% of energy and process-related carbon dioxide (CO_2) emissions and 36% of final energy use [1]. To mitigate these environmental effects, Green Buildings have been proposed. Compared to traditional buildings, GBs have considerations towards socio-economic and environmental aspects, and this increases their market demand [2]. GB projects are becoming increasingly popular in society and this signifies the need for effective development practices regarding these projects.

1.1 Green Building project success

For theory and practice of GB development, the concept of GB project success has much importance. To conceptualise project success, it is necessary to answer two key questions: 'what' is project success and 'how' to achieve project success. Success criteria and Success factors are the answer to these questions. Success criteria help conceptualise 'what' project success is. These are the principles or standards by which project performance can be evaluated. For instance, quality performance is a criterion on which project performance is determined. Once Success criteria applicable to a certain project type are determined, it is possible to conduct intermediate or post-completion audits to identify the reasons for project success or failure. Based on the acquired knowledge, remedial actions can be taken for a project or the learnt lessons can be applied to future projects [3]. Success factors help conceptualise 'how' project success is achieved. These are circumstances, facts, or influences to facilitate or impede project success [4]. For instance, project team collaboration facilitates project success and is, therefore, a Success factor. If success enabling conditions are ignored during the project

development, a multitude of problems can result, and project performance may be detrimentally affected. Similar to any other project, success of GB projects can be conceptualised using success factors and success criteria.

Success criteria in case of GB projects include Project Management-related criteria such as Schedule, Cost, and Quality Performance [5-10]. Since GB projects are developed on sustainable development principles their success criteria also include: Environmental sustainability performance (such as water consumption, energy consumption, and consumption of resources and materials) [5, 9-14]; Economic sustainability performance (such as life cycle cost and business performance) [5, 6, 11]; Social sustainability performance (such as indoor environmental quality, owner and end-users' satisfaction, acoustic quality, and thermal comfort) [5, 9, 10, 12]; and performance in Green certifications [7-10, 15]. The factors enabling success (i.e. success factors) in GB projects include effective team communication, commitment of all project participants, support from senior management, skillfulness of project participants, and early involvement of key project participants in GB development [10, 16].

1.2 Research gap and significance

Previous studies have identified Success factors and criteria of GB projects. Besides the identification of factors and criteria, it is also important to rationalize and explain the significance of Success factors and criteria for GB projects. This is possible if a relevant theory is used to interpret Success factors and criteria. Previous studies are limited in explaining the Success factors and criteria in terms of the theories related to construction. This lack of interpretation has constrained the development of theory as well as research on GB project success. For instance, 'Reducing environmental impact of construction' is a success criterion and 'effective team communication' is a success factor. A theory needs to explain the importance of such success factors and criteria for a GB project. Since GBs are essentially construction projects, their Success factors and criteria can be interpreted by a theory developed for or related to the construction industry.

Theories are formulated to predict, explain, and understand phenomena [17]. Theoretical framework is a structure that holds or supports a theory of a research study. A theoretical framework describes the theory which explains why the research problem under study exists. Previous studies on GB project success are limited in the use of theoretical frameworks for interpretation of findings and this has constrained the understanding and explanation of Success factors and criteria. Transformation-Flow-Value-generation (TFV) theory developed to explain construction projects can explain the development of GB projects. Based on this theory, the development process of a GB project can be defined in terms of Transformation (that is the transformation of inputs into outputs), Flow (that is the flow of materials involving transformation, inspection, moving and waiting), and Value-generation (that is value creation for the customer). With a focus on Green Buildings, this paper aims to explore the TFV theory as a theoretical framework for interpreting Success factors and Success criteria. In this paper, first the TFV theory of production is explained which is followed by the interpretation of GB success factors and criteria using the TFV theory.

2 TFV THEORY OF PRODUCTION

For construction projects, Koskela [18] found that the mismatch between the observed reality and conceptual models underscored the lack of robustness in existing theories. While realising the need for a theory of production in construction, Koskela developed an overarching production management paradigm for construction projects. In developing this theory Koskela used the ideal production system embodied in the Toyota Production System. Koskela's understanding of construction was founded in the same ideas as that for manufacturing, where the nature of the production was seen from three viewpoints: as a flow of work, as a chain of transformations, and as a generation of value for the customer. Upon identifying these viewpoints, Koskela used them to explain the construction process. The TFV theory of production in construction proposed by Koskela can explain the development of GB projects and interpret Success factors and criteria for GB projects.

The three concepts or views (i.e. Transformation, Flow, Value-generation) encompassed in the TFV theory are not competing or alternative theories, but rather partial and complementary. Each view in the TFV theory has certain assumptions, principles, and contributions as shown in Table 1. Each of these views addresses certain aspects of the production phenomenon [18]. The development of a construction project can be conceptualised by collectively considering these three views and their associated principles as an integrated theory of production. For a research inquiry of project success, the significance of the TFV theory is that it explains how the goals of production in a construction project can be achieved. While the goal of getting the intended products ready is realised by task management, the goals of production related to external customer are achieved by value management.

Table 1: Integrated TFV view on production (Source: Koskela [18])

	Transformation view	**Flow view**	**Value-generation view**
Conceptualisation of production/ Assumptions	As a process in which inputs are transformed into outputs	As a flow of materials, composed of transformation, moving, waiting, and inspection	As a process where value for the customer is created by fulfilling his/her requirements
Main principles	Getting production achieved efficiently	Elimination of waste (non-value-adding activities)	Eliminating value loss (achieved value in relation to the best possible value)
Practical contribution	Taking care of what has to be done	What is unnecessary is done as little as possible	Ensuring the fulfilment of customer requirements in the best possible manner

The Transformation, Flow, and Value-generation views can interpret Success factors and criteria of GB projects. As compared to the existing theories, a much wider framework is provided by the TFV theory of production, since it provides the flexibility to perceive construction projects collectively from three viewpoints instead of only one viewpoint. Some Success factors and criteria may associate with all three views, some associate with two views, while the rest associate with one of the three views. Since Success criteria are directly and indirectly related to meeting project stakeholders' expectations, Value-generation view in the TFV theory, which explains the value created for project stakeholders, is particularly relevant in interpreting Success criteria. GB Success factors which result in eliminating or reducing non-value adding activities may be interpreted using the Flow view. Success factors which help realise the efficient development of a project may be interpreted using the Transformation view. Success factors which are about the elimination of value loss can be interpreted using the Value-generation view. Hence, the three views within the TFV theory can provide the theoretical interpretation of GB Success factors and criteria.

2.1 Green Building development from the Transformation view

According to the Transformation view in the TFV theory, GB project development can be considered as a transformation of labour, information, equipment and materials into a sustainable building. The intellectual origins of Transformation view are in economics, where it remains unchallenged to this day [19]. The Transformation view of production has remained dominant throughout the twentieth century. According to this view, production is about transforming inputs into outputs [18]. Production management in this viewpoint equates to decomposing the total transformation into elementary transformations and tasks, acquiring the inputs to these tasks with minimal costs, and executing the tasks as efficiently as possible [18].

The main principle of transformation is to get production achieved efficiently [18]. Principles of production in transformation suggest hierarchically decomposing the total transformation into smaller transformations (that is tasks), and minimising the cost of each task independent of the others. The Transformation view has much importance in discovering the tasks needed in a production undertaking and in achieving those tasks [19]. For instance, planning GB project development is an aspect strongly associated with the Transformation view. This is because project planning involves breaking the overall transformation (i.e. project) into a number of component transformations (i.e. activities) which are individually optimised for cost, time, and resources.

There are two main deficiencies related to the Transformation view of production: first, it does not recognise the phenomena in production other than transformations, and second, it fails to recognise that it is not the transformation itself that makes the output valuable, but, instead, the value is a result of output conforming to the customer requirements. The issue of avoiding the waste of resources and meeting customer requirements are not addressed well by the Transformation view and these aspects are explained by the Flow and Value-generation view respectively [19].

2.2 Green Building development from the Flow view

In the Flow view, the GB project development is a flow of resources (such as people, material, and information) to result in a sustainable building. The early framework of industrial engineering introduced production in terms of the Flow view. The Flow view of production, first described in scientific terms by Gilbreth and Gilbreth [20], has provided the basis for Just-In-Time and lean production. According to the Flow view, production is a flow of materials involving transformation, inspection, moving and waiting [18]. Flow can be defined as "movement that is smooth and uninterrupted, as in the 'flow

of work from one crew to the next' or the flow of value at the Pull of the customer." The basic thrust in the Flow view is to eliminate waste from the flow processes, promoting such principles as variability reduction, lead-time reduction, and simplification [19]. The main principle of the Flow view is the elimination of waste, that is non-value-adding activities. The triumph of Just-In-Time and lean production based on the Flow view has practically proven the power of this concept [18].

GB Success factors such as 'effective team communication' can be well interpreted by the Flow view. This is because these Success factors help reduce non-value-adding activities and strongly influence project development in terms of the flow of materials, resources, and labour. Even though the Flow view explains how to avoid waste, it does not particularly address the issue of meeting customer needs. The Value-generation view considers this aspect to explain project development.

2.3 Green Building development from the Value-generation view

The GB project development, according to the Value-generation view, is a process of producing a sustainable building which meets the client's requirements. The view of production as Value-generation was articulated in the 1930s with the basic goal of achieving the best possible value for the customer [19]. Production management according to the Value-generation view is to accurately translate customer needs into a design solution, and then developing products which conform to the specified design [18]. Value can be about the usefulness, functionality, utility, and benefit of a product. According to this view, the ultimate goal of the production process is the intended use of a product by the customer. Value for the customer is, therefore, the dominant value perspective in the TFV production theory by Koskela. Within this tradition, the definition of value can, therefore, be specified as an output of production required by the customer [21]. The main principle of the Value-generation view is to eliminate the value loss, that is reducing the gap between the achieved value and the best possible value [18].

GB Success factors such as those related to defining project goals and project design development can be well interpreted by the Value-generation view. This is because these Success factors are about capturing project requirements, converting these requirements into a workable plan (that is design), and therefore creating value for the project client. Moreover, the Value-generation view is also well-suited to interpret GB Success criteria. This is because most of the GB Success criteria such as achieving green certifications are about meeting the requirements of the project client or creating value for the client.

In high-performance buildings, the environment is elevated to be a key stakeholder of the building alongside that of the customer (that is building owner or user) [22]. Conventional projects set objectives for the building owner and user, but rarely address the needs of the environment explicitly. The disclosure of environmental objectives required in case of high-performance buildings makes those activities critical that were otherwise thought as marginal (that is wasteful), for example, energy modelling and life-cycle cost analysis [23]. Hence, by acknowledging the environment as a stakeholder in the Value-generation view, the TFV theory can explain why the particular steps taken and activities performed in GBs are important for the success of these projects. While the Transformation, Flow, and Value-generation views in the TFV theory can explain GB project success, the concept of waste defined by the TFV theory can also explain GB Success factors and criteria.

2.4 Waste defined by the Transformation, Flow, and Value-generation view

According to the TFV theory, in a GB project waste is the loss of materials, time, or value during project development. The Waste concept can be embedded in the TFV theory to provide an enriched interpretation of the Transformation, Flow, and Value-generation view. Waste (loss of material, time, or value) is an important aspect for interpreting GB project success because of two reasons. First, waste in the project development process reduces the potential of successfully achieving project outcomes, an aspect directly related to project success. Second, waste in the end-product and the production process is in direct contrast with sustainability goals, an aspect related to sustainable development. The TFV framework helps conceptualise waste in the process of project development and the waste related to the end-product (such as building project). All three views of the TFV theory (that is Transformation, Flow and Value-generation) are important for developing a comprehensive understanding of waste. In this paper, waste is not considered as a separate theoretical construct but as a concept strongly embedded in the TFV construct. Alongside the principles of Transformation, Flow and Value-generation, the waste definitions by the TFV theory can also be used in interpreting GB Success factors and criteria as shown in Figure 1.

In the Value-generation view, waste implies value loss, for instance, a situation where the product is not used as intended. Waste according to this view also means that "part of value (is) not provided even if potentially possible" [18]. According to Womack and Jones [24] waste also means the delivery of a wrong product or service. The concept of value loss can be adopted to refer to the part of value not provided even if potentially possible. This concept can also be used to measure value in relative terms [18]. When analysing value, Rooke, et al. [25] distinguished outputs from outcomes. Based on this distinction it can be said that in the Value-generation view, waste is a situation where the outputs of production do not equate to outcomes [21]. This can be because the product does not meet the client's requirements, could have met the requirements in a better way, or is not used as intended. These are the reasons related to a product coming out of production; however, the unwanted outcomes are not limited to the (main) product, they also include unwanted by-products of the production process. While the wastes related to the main product are in terms of the lack of quality (including defective product) and the lack of intended use, the waste related to by-products can be injuries, harmful emissions, and work-related sickness [21].

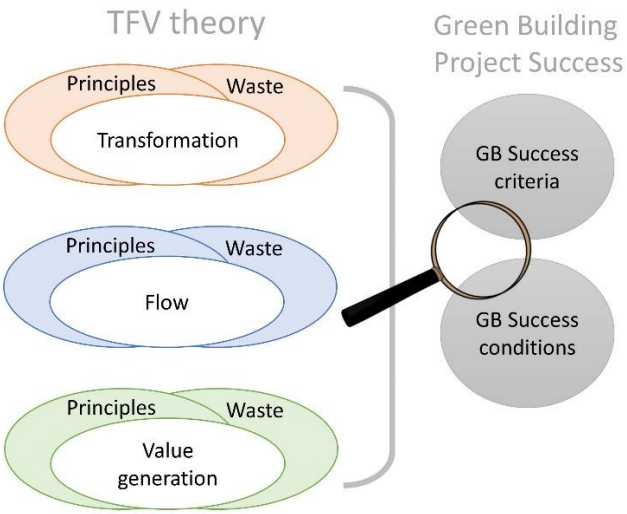

Figure 1: Interpretation of Success factors and criteria by the principles and waste definitions related to the Transformation, Flow, and Value-generation views

When considering the Transformation view, production can be seen as the conversion of component parts and raw materials into products using machinery, labour and energy. Waste in this view implies the use of more production resources than needed [21]. The Flow view recognises non-value adding activities in a project as waste [18]. Waste is the expense of labouring force which does not produce value [26].

Table 2: Taxonomy of the Wastes of production in construction (Source: Bølviken, et al. [21])

	Transformation	**Flow**	**Value**
Production resource	Machinery, materials, energy, and labour	Time	
Type of waste	Material loss	Time loss	Value loss
Wastes	Material waste Non-optimal material use Non-optimal use of machinery, energy, and labour	*In the workflow* Unnecessary work Waiting Unnecessary movement of people Inefficient work *In the product flow* Space not being used for work Unnecessary material transportation Materials not being processed	*Main product* Lack of intended use Lack of quality *By-product* Harmful emissions Injuries and work-related sickness

Ohno [27] identified seven sources of waste. Among these, the five sources refer to the flow of material, including (1) the waste of overproduction, (2) the waste of correction, (3) the waste of material movement, (4) the waste of processing, and (5) the waste of inventory. Two waste sources referring to work of men are also identified and these are the waste of waiting, and the waste of motion. Bølviken, et al. [21] realised that the classical list of wastes provided by Ohno was context-specific (that is related to mass production) and a list specific to construction was required. A taxonomy related to the waste of production in construction was provided based within the TFV framework (Table 2).

3 INTERPRETATION OF GREEN BUILDING PROJECT SUCCESS

This section provides the interpretation of GB Success factors and criteria using the principles and Waste concept related to the TFV theory. The potential of the TFV theory to interpret GB Success is shown by a few examples of Success factors and criteria in Table 3.

Table 3: Interpretation of Green Building Success factors and criteria in terms of the TFV theory

		Can be interpreted in terms of …				**The condition/criterion can be associated with the Waste concept since it prevents…**	**Why related to TFV principles or Waste concept**
		T	**F**	**V**	**W**		
Success criterion	Reducing environmental impact of construction	×			×	Material loss	*Interpretation by Transformation view*: Fulfilling this criterion means that there is an efficient transformation of inputs into outputs.
	Achieving Green certifications			×	×	Material loss	*Interpretation by Value-generation view*: Fulfilling this criterion means that the client's aspiration of Green certification is met. Hence, value is created.
Success factor	Effective team communication		×	×	×	Material loss. Time loss	*Interpretation by Flow view*: This condition reduces the various non-value adding activities associated with the lack of project information. *Interpretation by Value-generation view*: This condition reduces the risk of not meeting project requirements hence contributing towards the value for project client.
	Early involvement of project team		×	×	×	Material loss. Time loss	*Interpretation by Value-generation view*: As a result of this condition possibility of meeting project requirements increases hence contributing towards the value for project client. *Interpretation by Flow view*: Project information available for decision-making because of early team involvement leads to effective decision-making reducing non-value adding activities. associated with the lack of project information.

***Note**: T=Transformation view; F=Flow view; V=Value-generation view; W=Waste concept*

GB Success criteria can be interpreted using the principles and Waste concept related to the TFV theory. Some of the Success criteria related to GB projects include achieving Green certifications [15] and reducing the environmental impact of construction [5, 14]. The interpretation of these Success criteria in terms of the TFV theory (shown in Table 3) is as follows,

- 'Reducing environmental impact of construction' is a criterion strongly associated with the concept of Waste reduction. Reduction in greenhouse gas emissions, embodied energy, waste, and water usage means that the waste of resources occurring in the development and operation of a building is reduced. Since this criterion is also about preventing material waste during construction, fulfilling this criterion means that there is an efficient transformation of inputs (that is construction materials) into outputs (that is building).
- Achieving Green certifications is a criterion associated with both the Value-generation and the Waste reduction concept. Since GB certifications can lead to sustainable project development these criteria add value for a client. Green certification of GB projects (such as Leadership in Energy and Environmental Design (LEED) certification) is the desired outcome for many clients. The energy waste is also reduced because of Green certifications since for fulfilling certification requirements the building performance is optimised and the environmental footprint of construction is reduced.

Some of the Success factors related to GB projects include effective team communication and early involvement of key project participants (that is project team) in GB development [16]. The interpretation of these Success factors in terms of the TFV theory (shown in Table 3) is as follows,

- 'Effective team communication' implies a smooth flow of information among the project team and across project stages. This can reduce the various non-value adding activities (for example, inefficient design and construction) associated with the lack of information. Moreover, smooth information flow also reduces the risk of not meeting project requirements hence contributing towards value for the client. Because of effective communication, the risk of rework in the project (such as redesign and rework on construction site) is mitigated and hence the material and time-related wastes are prevented.
- 'Early involvement of project team' implies that different parties with relevant expertise in project development are available during the decision-making process. This means that well-informed decisions regarding project development can be made. This increases the possibility of meeting project requirements, therefore, easing the generation of the project value. By virtue of early project team involvement, opportunities for a more efficient development (for example, reduced labour, cost, and material resources) are created, therefore reducing the non-value adding activities (for example, redesign of the project, and rework on construction site).

The above-mentioned examples demonstrate that the principles of the TFV theory and the Waste concept based in the TFV theory have much relevance in providing a theoretical interpretation of GB Success factors and criteria.

4 CONCLUSION

For developing research in GB project success, a construction-related theory needs to interpret GB Success factors and criteria. The contribution of this paper is that it explores the potential of the TFV theory to interpret Success factors and criteria of GB projects. Upon analysis of few examples of Success factors and criteria, it is realized that the principles of Transformation, Flow, and Value-generation, and the concept of waste defined by the TFV theory can interpret GB Success factors and criteria. The findings presented in this paper have theoretical implications as these can inform research in construction projects in general and GB projects in particular. In practical terms, the better understanding of project teams and clients regarding GB Success factors and criteria, by virtue of the theoretical framework proposed in this study, will lead to better performance in GB projects. For future research on GB project success, the TFV theory can be used as a theoretical framework. Future research on construction projects other than GB projects can also explore the relevance of the TFV theory in explaining project success.

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