

INTEGRATING LEAN AND GREEN CONCEPTS: SRI LANKAN CONSTRUCTION INDUSTRY PERSPECTIVE

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ABSTRACT

Construction industry developers and project teams usually struggle to associate the concept of Green on building projects since it is generally resulting in high initial investment cost. Although this cost of investment can be saved back through operational stage, the current building project delivery methods implemented by most project teams are often laden with non- value adding activities. Lean construction principles have been convinced to eliminate flow activities and improve construction process performance in highly complicated building construction projects. Hence, the aim of this research is to explore and develop a framework to integrate Lean and Green concepts to the Sri Lankan construction industry.

At the outset, the key features and principles of Lean and Green construction were identified to build the conceptual relationship between the two concepts. Subsequently, a qualitative research approach was adopted through the means of expert opinion survey with unstructured interviews involving ten number of local expert professionals who have experience and exposure to both of these concepts. The findings were analysed through content analysis.

The perception of the Sri Lankan stakeholders towards the application of integrated Lean-Green concepts is focused on a positive direction. The identified enablers to implement the integrated concept supersede the barriers by confirming the appropriateness of the application in the local construction industry. The Green concept was integrated into the activities that are implemented under each Lean construction principle. Finally, a framework was developed through the findings to guide the implementation of integrated Lean- Green application in Sri Lankan context.

Keywords: *Flow Activity Elimination; Green Construction Process; Integrated Lean-Green Application; Lean Construction Principles.*

1. INTRODUCTION

The construction industry contributes to the economic growth, both by its direct and indirect activities through the provision of buildings and infrastructures for the undisturbed functioning of businesses (Peng & Pheng, 2011). However, construction activities are also creating broader problems and issues affecting the environment, including global warming, climate change, ozone depletion, soil erosion, desertification, deforestation, eutrophication, acidification, loss of diversity, land pollution and consumption of valuable resources such as fossil fuels, minerals and gravels over their entire lifecycle (Ahn & Pearce, 2007).

With the emerging recognition of negative environmental impacts, the construction industry is pushed to take environmental considerations into the decision making processes (Yates, 2007). Hence, the industry is constantly being forced to minimise its large amount of energy consumption, raw material and water usage (Low et al., 2012).

Construction companies from various regions around the world are controlling the impact to the environment by integrating Green concept into their construction plans (Hwang & Tan, 2012). Many efforts have been undertaken such as process and technology innovation (Spence & Mulligan, 1995), adopting low carbon fuels

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(Hendriks et al., 1998), identifying alternative low carbon raw materials (Gartner, 2004) and CO₂ capture and sequestration (Herzog, 2001) to achieve long term sustainable development by reducing carbon emission.

Other than for the above discussed issues, construction industry is well known for low productivity, poor safety, inferior working conditions and insufficient quality. A number of solutions such as industrialization, computer integration and automation have been offered to control these problems (Koskela, 1994). Furthermore, the Lean construction can be utilized to minimise the overall cost while maintaining the quality standards and reducing cycle time (Womack & Jones, 1996).

Theoretically, Green construction focuses on reductions in building energy use, water consumption, materials employed and pollution (Abidin & Jaapar, 2008). On the other hand, Lean construction emphasizes on eliminating unnecessary activities while reducing waste in the processes used to design and construct buildings (Koskela, 1994). Although these two concepts have two different goals, it is clear that both the concepts exhibit significant synergies on minimizing resources use (Jamil & Fathi, 2016). The journey towards greener operations and products has pushed companies to search alternatives to balance efficiency gains and environmental friendliness in their operations and products. The exploration of the sequential or parallel deployment of Lean and Green concepts is the result of this balancing action. Further, the Lean concept's alignment with the Green paradigm, and its methods and tools seem natural as it aims on eliminating waste (Garza-Reyes, 2015).

As a result, Lean and Green relationship has the potential to bring in benefits in terms of positive environmental and economic outcomes to Sri Lankan construction industry. Yet, no investigations have been done to investigate the effectiveness of integrating those two concepts in the Sri Lankan construction industry. Thus, an attempt of integrating Lean concepts with the Green concepts seems an appropriate and effective effort which needs an in-depth investigation. Therefore, it is a timely need to carry out a comprehensive study on integrating Lean and Green concepts from the Sri Lankan construction industry perspective. Hence, the research was undertaken to explore and develop a framework to integrate Lean and Green concepts to Sri Lankan construction industry.

2. LITERATURE REVIEW

2.1. CONCEPT OF LEAN

Lean is a well-known philosophy originated from the Toyota production system, that targeted on eliminating all the expenditures on resources which do not create a value to the end customer (Čiarnienė & Vienažindienė, 2015; Ohno, 1988). The process of eliminating non-value-added activities, reduces the costs and cycle time which increases the customer responsiveness as well as the effectiveness and the competitiveness of the organization (Alukal, 2003).

The Lean production system categorize all the activities of the production system in to two main categories, based on the value that they are creating on the end product or process. Thereby the value adding activities referred to as Conversion activities while non-value adding activities which consumed resources and time, referred to as Flow activities (Koskela, 1992). To create an environment where Flow and Conversion activities were treated separately, Lean production system improved the Conversion activities and eliminated the Flow activities (Peng & Pheng, 2011).

According to Koskela (1992), eleven basic principles to Lean construction to be implemented to the total flow process and its sub process in the construction industry are; (1) reduce the share of non- value adding activities, (2) increase output value through systematic consideration of customer requirements, (3) reduce variability, (4) reduce the cycle time, (5) simplify by minimizing the number of steps, parts and linkages, (6) increase output flexibility, (7) increase process transparency, (8) focus control on the complete process, (9) build continuous improvement into the process, (10) balance flow improvement with conversion improvement and (11) benchmark. Moreover, these principles are under the core principle of eliminating non- value adding flow activities and increasing value adding conversion activities. Thus, the adoption of the core principle supports the adoption of sub principle without any extra effort.

2.2. CONCEPT OF GREEN

Industrialisation and globalisation have greatly influenced the global eco system when the agriculture based society transformed into an industrial society. Further, the improvements in the global economy have increased the use of energy level while exploiting the natural resources. Subsequently, such actions have led to an increase in the atmospheric concentration of carbon compounds and also phosphate and nitrogen concentration in soil and water at an aggressive rate. Moreover, this has caused in loss of biodiversity, soil erosion and other environmental degradation (Amiolemen et al., 2012).

Green is now a major concept in development thinking at all levels. Over the last few decades there has been an increasing understanding of the world and its occupants as a single system and of the requirement to integrate two key universal aims in the development of human activities: to eliminate the depletion of the resources and biological systems of the planet for the future generation's needs while at the same time to expand human development, specially in the underprivileged countries and to remove the inequities prevail in the world today (Spence & Mulligan, 1995).

The construction industry and building sector have a considerable contribution towards numerous negative environmental impacts (Illankoon et al., 2017). According to Pink (as cited by Illankoon et al., 2017), construction industry considered as one of the major industries which emits greenhouse gases significantly while contributes about 26% of waste. Further, Pulselli et al. (2007) revealed that construction industry exploits almost 40% of the world's consumption of materials. In addition, with the growing recognition of global climate change, there is a huge pressure on the construction industry to take environmental parameters into the daily decision making processes (Peng & Pheng, 2011).

Green construction could be identified as an integrated framework of design, constructions, operations, maintenance and demolition processes that consider the environmental, social, and economic effects of the construction projects (Li et al., 2015). Green construction recognizes the interdependence of built and natural environment while associating energy efficient products and renewable energy such as solar, biomass, wind, hydropower, biodiesel and geothermal into the projects (Ali et al., 2016). According to the U.S. Environment Protection Agency (EPA) (as cited by Illankoon et al., 2017), green buildings reduce the overall effects of the built environment on natural environment and human health by efficient use of water, energy and other resources, protecting occupant health and improving employee productivity while eliminating pollution, waste and environmental deterioration.

2.3. LEAN AND GREEN INTEGRATION INTO THE CONSTRUCTION INDUSTRY

The journey towards greener operations and products has pushed companies to search alternatives to balance efficiency gains and environmental friendliness in their operations and products. The exploration of the sequential or parallel deployment of Lean and Green concepts is the result of this balancing action (Garza-Reyes, 2015). Bergmiller and McCright (2009) suggested that the parallel implementation of two concepts create more chances to be successful by minimising cost and waste. Lean management creates positive effects on environmental management, which itself has a favourable impact on operational performance (Jabbour et al., 2013). Meanwhile, Dües et al. (2013) identified Lean as a catalyst for the implementation process of Green in manufacturing companies and that Green supports in return to manage best practices in Lean.

Lean construction and Green construction practices are generally considered as two different independent strategies where Lean process aims on increasing economic standards while Green aims on improving environmental objectives. Through number of researches and industry practices it was proven recently, that the two practices are interdependent and shares the exact basics of waste reduction (Khalfan et al., 2001). Moreover, Koranda et al. (2012) stated that the concepts of Green construction and Lean construction are similar because both the concepts aim to reduce waste during construction. Therefore, Meng (2012) and Smith (2003) suggested that the Green construction components can be integrated into the concept of Lean construction to improve and preserve environment, natural resources and economic growth.

3. RESEARCH METHODOLOGY

The research was aimed at exploring and developing a framework to integrate Lean and Green concepts to Sri Lankan construction industry. At the outset, a literature survey was carried out to identify the key features and

principles of Lean and Green construction to recognise the conceptual relationships between the two concepts. To fulfil the aim of this research, it was required to investigate the perception of the construction stakeholders and expert's opinions, experiences and knowledge. Despite the fact that the quantitative studies deliver more reliable and unbiased results, it requires large number of respondents to carry out the study. Since the Lean and Green concepts are new to the Sri Lankan construction industry, only a few number of experts were identified. Therefore, the research ultimately dealt with qualitative data as the study can be carried out with a lesser number of respondents. The purposive sampling method was used through to identify professionals with both Lean and Green awareness and experience. As a result of that, ten experienced industry professionals with more than ten years of experience who have engaged in large scale construction projects in Sri Lanka were selected as the interviewees to carry out the expert opinion survey. To get a wide range of responses, interviewees were selected from both the consultant and contracting fields with some managerial responsibilities. All of them were having experience with projects that have implemented Green concept. The experience and exposure of the interviewees with related to the Lean and Green concepts were given in the Table 1.

Table 1: Composition of Respondents

No	Designation	Industry experience	Level of awareness		Level of experience in practice	
			Lean	Green	Lean	Green
(1)	Site engineer	Above 15 years	Moderate	High	Moderate	High
(2)	Planning engineer	Above 15 years	High	High	High	High
(3)	Managing engineer	Above 10 years	High	High	High	High
(4)	Architect	Above 10 years	Moderate	High	Moderate	High
(5)	Project Manager	Above 15 years	High	High	Moderate	High
(6)	Quantity Surveyor	Above 10 years	Moderate	High	Moderate	High
(7)	Quantity Surveyor	Above 25 years	Moderate	High	Moderate	High
(8)	Project manager	Above 15 years	High	High	Moderate	High
(9)	Project manager	Above 20 years	High	High	High	High
(10)	Architect	Above 15 years	Moderate	High	Moderate	High

Unstructured interviews were carried out with open-ended questions. Code-based content analysis was selected as the data analysis technique as it allows convenience by minimizing data to be analysed which gathered through the interviews. For coding and simplifying the collected data, computer software N-Vivo 11 was used in this study with graphical presentation of interpreting relationships, combined with descriptive analysis where appropriate.

4. RESEARCH FINDINGS AND DATA ANALYSIS

4.1. SRI LANKAN STAKEHOLDERS' PERCEPTION TOWARDS THE LEAN- GREEN APPLICATION

Investigating the perception of the Sri Lankan construction stakeholders towards the Lean- Green application is critical before its introduction to the industry. Therefore, the contribution of Lean concept to the Green construction, the applicability of Lean- Green approach and enablers and barriers for its implementation were thoroughly investigated from the view point of Sri Lankan construction stakeholders.

4.1.1. CURRENT STATUS OF LEAN AND GREEN APPLCATION IN SRI LANKAN CONSTRUCTION INDUSTRY

Green concept; Even though it was proved that the concept of Green would bring out number of advantages to the construction industry, without practicing this concept none of these returns can be gained. All the respondents without any contradictory opinions exposed that the current performance of Green building delivery process is in an unsatisfactory level. Out of the ten responderespondts nine stated 'material and technology deficiencies' as an major issue that need to be addressed immediately. It was also revealed that the number of Green professionals that can be assigned in to Green projects is not sufficient in local context. Therefore, the respondents suggested 'improving sustainable education and training of the construction professionals' as an important solution which will favourably change the Green building delivery process.

However, few respondents expounded some managerial issues relating to the 'low effectiveness connected with the Green building delivery process'. According to those respondents, the Green construction process needs a set of principles which is compatible with Green aspects and increases the efficiency level of the delivery process. The findings emphasised the need of the Sri Lankan construction industry to seek out an effective set of principles that can be conveniently used in a Green construction project. This view has supported the aim of this research and proved the importance of using performance improving principles compatible with the Green aspects. The respondents were also emphasised 'the deficiencies in the green building certificate process' and 'contractor's lack of knowledge on their contribution to the Green building delivery' as concerns in implementing Green concept in construction industry.

Lean concept; The adoption of integrated Lean- Green approach is highly influenced by the present Lean application level in the industry. A high level of practice would be helpful to introduce the new approach since the industry know the benefits associated with it. However in terms of local context, the respondents highlighted that the application level of the Lean construction principles are in a moderate level but most of the time it is applied unconsciously without a complete knowledge on the subject area. Therefore, this unconscious implementation would not bring all the benefits to the projects. Out of ten, nine respondents emphasised, 'the insufficient knowledge relating to the Lean concept' as the main reason for the lack of application of the concept in the Sri Lankan construction industry. Other reasons such as misconception, implementation issues, insufficient management support and resistance to change are occurred due to the inadequate knowledge were also pointed out by the respondents. Therefore, to improve the current Lean application level in Sri Lankan construction industry these issues need to be addressed immediately. Respondents also highlighted 'the hierarchical project organisation structures' as an issue to implement some of the Lean construction principles. Therefore, it was proposed to adopt self-directed work teams in construction project management to deliver maximum benefits of the Lean construction principles.

4.1.2. CONTRIBUTION OF LEAN CONCEPT TO THE GREEN CONSTRUCTION

With the performance deficiencies embodied in the Green building delivery process, the industry is in a status quo to find out a method to overcome this issue. Therefore, the opinions of industry experts on the contribution of Lean concept to the Green construction is important to a great extent with the aim of evaluating perception on integrated application. Majority (8 out of 10) of the respondents identified Lean as a means of reducing wastage through the elimination of non-value adding activities which is beneficial in maintaining the environmental standards. Further, Lean was recognised as a concept that helps to maintain the site in a clean and orderly manner which will indirectly contribute to eliminate accidents on site and thereby increases the social value of the project. Lean provides the platform to maintain the machines, tools and equipment in a way that improves its efficiency level. Such performance increments result in economical benefits to the project. Aforementioned economical, social and environmental benefits that were identified by the Sri Lankan construction experts proves that Lean implementation is capable to deliver important Green impacts to a project. Most of the respondents agreed that there will be an enormous contribution if Lean is exercised along with the Green concept. Yet, experts disclosed that the compatibility of each principle needs to be analysed before its application in a Green building project.

4.1.3. ENABLERS AND BARRIERS IN IMPLEMENTING LEAN- GREEN APPLICATION

All the respondents had unanimously agreed that there are enablers available in the construction industry which will support the implementation of Lean-Green application. They also highlighted the importance of strengthening these enablers in order to accelerate the process. Majority (8 out of 10) of the respondents identified 'the opportunities available to increase the knowledge level relating to Lean and Green' as an enabler. The contribution of the consultants towards the Lean-Green application was intensified by most of the respondents (7 out of 10). Research findings explicated that the influences of the consultant can play a major role to upgrade the quality of the project through introducing new concepts. The Government involvement was also identified as an enabler which can positively influence the implementation of integrated approach.

All the respondents highlighted that the retarders of the implementation process of integrated approach is an amalgamation the barriers of implementing individual concepts. However, it was also identified that the integration may lead to overcome the each other's barriers. For example, the high initial cost of the Green concept implementation can be economised with the integration of the Lean construction principles. Lack of professionals, high initial cost of Green construction and lack of knowledge about the integrated approach

were recognised by the most of the respondents as the barriers to the integrated approach. However, the respondents further exposed that strengthening the available enablers that accelerate the implementation process will help to overcome those barriers by ensuring the successful execution of the Lean- Green approach.

4.2. INTEGRATED LEAN- GREEN APPROACH

4.2.1. THE DEVELOPMENT OF THE INTEGRATED LEAN AND GREEN FRAMEWORK

The findings related to the Lean principles revealed some relationships in between those principles. It was clearly observable that all the Lean construction principles have a contributory relationship with eliminating flow activities and improving conversion activities. Some of those relationships were having direct contribution while others were having indirect relationships. These indirect and direct relationships are illustrated in the Figure 1. Four principles were identified as indirectly influencing principles towards the elimination of flow activities. It was also observable that these principles directly influence the implementation of other principles, which directly contribute to the flow elimination. For example, benchmarking does not directly eliminate the flow activities and improve the conversion activities, but does direct influence to improve the construction process continuously which would be resulted in flow elimination. Therefore, benchmarking could be included or integrated under the principle of build continuous improvements.

Identification of social and environmental requirements along with the customer requirements was proposed by the respondents as a means of achieving variability reduction in the Green building delivery process. Therefore, ‘requirements consideration’ can be implemented under the principle of ‘variability reduction’.

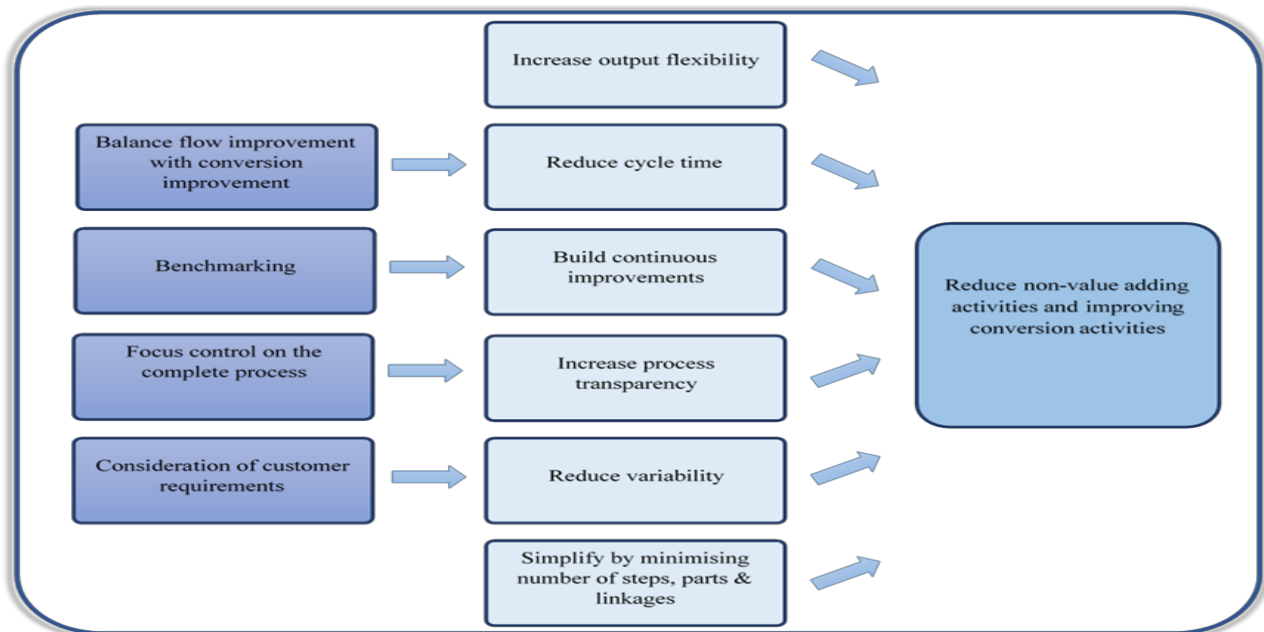


Figure 1: Relationships Among Green Integrated Lean Construction Principles

The respondents’ opinions related to the cycle time reduction intensified the necessity of considering the environmental and social aspects. This has forced to keep a balance in between the flow elimination and conversion improvements to minimise the negative environmental and social impacts. Therefore, the principle of ‘balancing flow improvement with conversion improvement’ can be implement under the principle of ‘cycle time reduction’ in order to achieve Greener results.

According to the opinions of the respondents, the transparency of the construction process can be increased through the holistic controlling of the complete construction process. Using self-directed teams and flat organisation structures to execute the construction work increases the flow of information within the project and allow to reach only the information that are relevant. Therefore, the principle of ‘holistic controlling’ can be implemented under the principle of ‘increasing process transparency’.

The research findings have set the path to identify the relationships between the Lean principles when the concept of Green is integrated. Among the interactions, the framework was built upon the relationship that the principles are having with flow activity reduction. Framework will mainly address the flow and conversion activities associated with the Green construction process. It provides a platform to eliminate flow activities and to improve conversion activities in a way that it facilitates the Green concept. Six main aspects of the Green construction process namely; process variability, cycle time, transparency, simplicity, flexibility and continues improvements are focussed to make the process more productive and economical. Giving prominence on those aspects would result in reduction of flow activities and improvement in conversion activities.

4.2.2. INTEGRATED LEAN AND GREEN FRAMEWORK

Lean construction and Green construction practices are ordinarily considered as two different independent approaches where Lean focuses on improving economic measures while Green aims on advancing environmental objectives. The implementation of Lean has indirect positive Green impacts but it can have negative impacts as well. If it is possible to set environmental and social issues as values to achieve at the beginning of Lean implementation, issues can be addressed and Green products will be delivered in an effective way. The integrated Lean- Green framework was developed based on this phenomenon where it will set the path to achieve a Green facility effectively by eliminating current pessimisms. The developed integrated Lean-Green framework based on the findings is illustrated in Figure 2. The given activities are prioritised based on the response rate of the relevant activities since it was assumed that the highly influential activities were the mostly suggested activities by the respondents. All the dotted activities that are shown in the framework do not have any negative impact on the Green concept. The activities that are shown in italic will have positive impact if those activities can be implemented along with the aforementioned activity. The barriers and enablers of the integrated Lean-Green application are demonstrated in the priority order to highlight the most influencing factors.

5. CONCLUSIONS

The ultimate aims of Green and Lean concepts are different since they are aiming on improving different aspects of construction projects. Yet based on the principles and key areas, the study exposed that a relationship can be established since both the concepts are focusing on improving the standard of the construction projects. The findings also revealed that the high initial cost of the Green concept implementation as the major concern addressed with the use of Lean concept. The eleven Lean construction principles identified act as the means of economising the cost of Green building construction process and increasing the performance level. Further, it was identified that the exclusive implementation of Lean concept may not be compatible with the Green standard of the project, since Lean does not take social and environmental aspects into the consideration. Therefore, the importance of implementing Lean concept integrated with the Green concept was recognised. Sri Lankan construction stakeholders have acknowledged the contribution of the Lean concept to the Green building delivery, which is the key governing factor to decide their perception in relation to the Lean- Green application. The implementation process is associated with numerous enablers and barriers where the barriers can be mitigated through strengthening the enablers. The integrated Lean- Green framework will allow to adopt a consistent construction process which would bring productivity to the project. The framework is based on six filtered Lean aspects of the construction process, namely process variability, cycle time, transparency, simplicity, flexibility and continues improvements. Moreover, the framework allows the Sri Lankan construction industry to improve its efficiency while adopting to Green considerations.

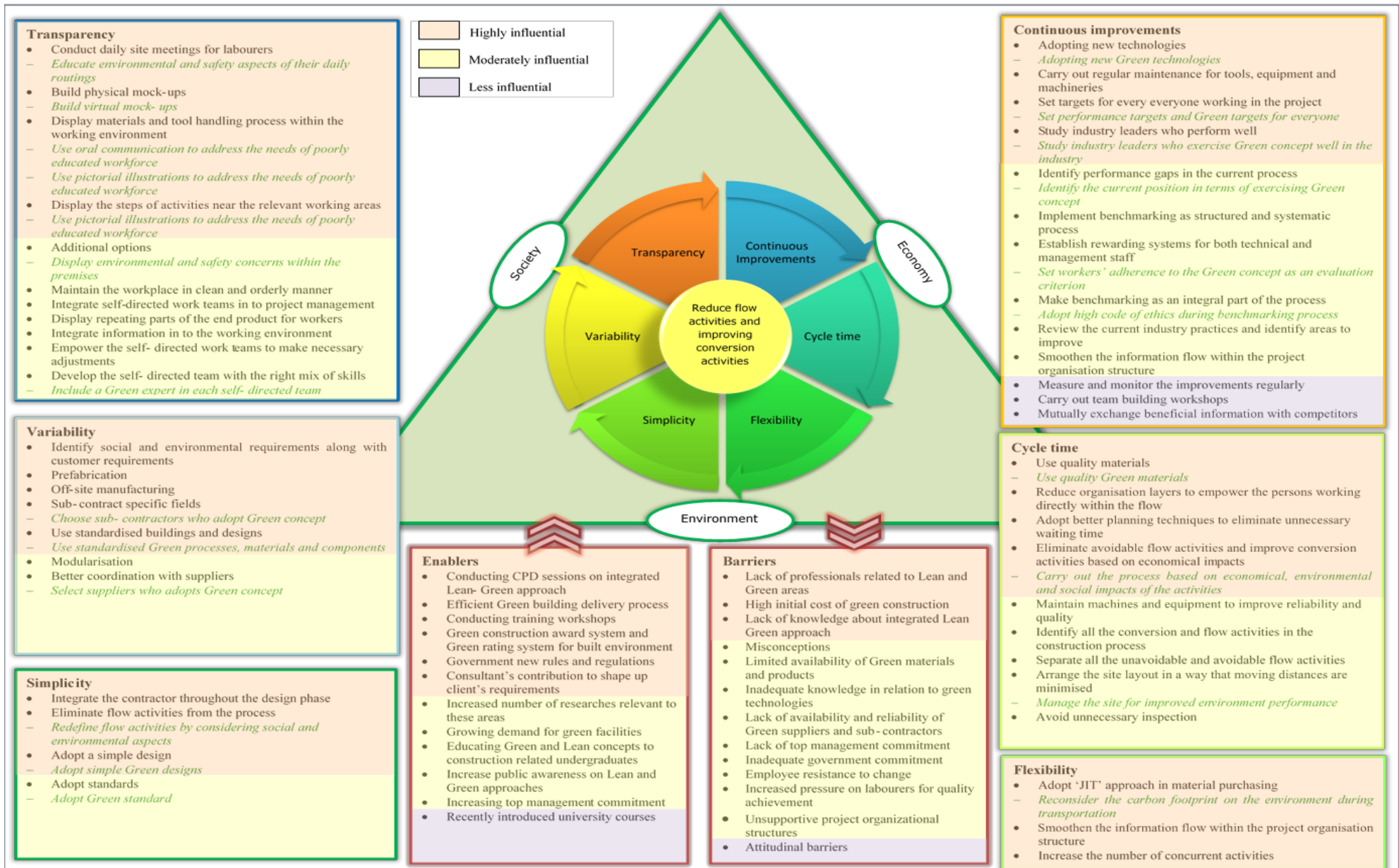


Figure 2: Integrated Lean- Green Framework

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