



## *Relationship between Lean and Green buildings in Egypt*

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### **Abstract**

There is a lack of awareness about the added environmental value of the integration between Lean and Green building design. This study is investigating the relationship between Lean and Green building design represented in the Egyptian rating system (Green pyramid).

The research clarifies Lean Construction concepts and principles which reduce waste and increase the quality through enhance building performance. Also, focuses on analyzing the Egyptian rating system (Green Pyramid) which was established to ensure sustainability in Egypt, reduce the environmental impact of construction and raising the awareness toward the importance of green buildings to the Egyptian environment.

Based on analyzing previous concepts, studying literature review and considering the principles of Lean Construction with the criteria of Green Pyramid for certification of environmental performance of buildings for understanding the results of their integrations and proposing recommendations to be added at the Green pyramid Egyptian rating system as approach for green building design in Egypt.

**Keywords:** Lean, Green pyramid, Relationship, green design

## 1. Introduction

Discussing the concept of the Lean began in 1992, when Lauri Koskela published a work titled “Application of the New Production Philosophy in the Construction Industry”, focused on communicating the production flows that define the concept of value because of the search for quality. According to Koskela, the goals of the Lean philosophy can be achieved by following the eleven principles He described it through his work, and presented it later in this paper.

At the same time, various environmental rating systems have been established in several countries to evaluate the sustainable building and encourage the building sector all over the world to go more sustainable, such as: Building Environmental Performance Assessment at Canada (BEPAC), developed in Canada; Building Research Establishment Environmental Assessment Method (BREEAM), issued in the United Kingdom, Leadership in Energy and Environmental Design (LEED) certification at United States, and (Green Pyramid) in Egypt.

Based on these concepts, this research aims to analyze the integration between the Lean Principles and the Green Pyramid Criteria for Egypt by building a matrix of interaction between them as a guideline for the Green Pyramid Certification and the LEAN Principles.

## 2. Research methodology

This paper draws a proposal for understanding the interrelations of applying Lean principles on all the criteria of Egyptian green rating system based on the literature and the authors' arguments. This relation is figured out from a matrix that connects Lean principles and Green Pyramid criteria, establishing theoretical relations to identify the constructive interactions between them as shown in Figure 1.

In alignment with the goals of the research, during the development of the work, the following steps were followed:

- a) Literature review involving the Lean principles based on the work of Koskela and the Green Pyramid criteria.
- b) An interaction matrix concluded the relationship between Green pyramid criteria and the principles of LEAN
- c) Matrix evaluation of a direct relation between Lean principle and Green Pyramid criteria
- d) Concluding the relation between them, clarify the impact of the interaction of each principle in relation to the criterion is analyzed, discussing the correlation found, and searching for the complementary relation between the Lean principles and green criteria.

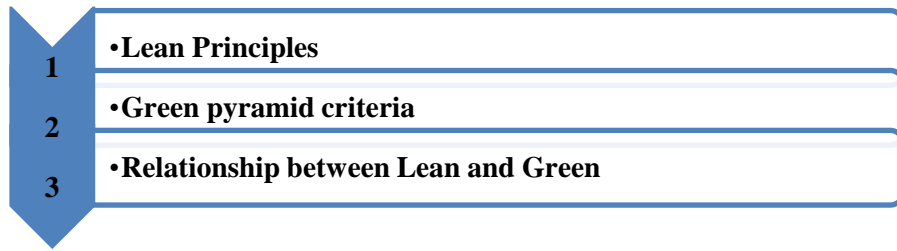


Figure 1: Research Methodology, Source: Authors

### 3. Literature review

#### 3.1. Lean Construction

Lean Construction aims to eliminate waste in construction with an effective technique. The goal of Lean Construction is to achieve customer satisfaction by using a little bit of everything for example materials, money, and resources. This construction method is most suited for complex and fast projects.

##### 3.1.1 Lean definition.

Lean defined in different ways as Koskela et al mentioned that Lean Construction is about creating the most value possible by reducing waste of materials, time and efforts, Abdelhamid et al. conclude Lean definition as all project participants (owner, contractors, facility managers, end-user) must collaborate to achieve project goals in the early stages of the project, and Lichtig recognized Lean Construction that desired ends affect the means to achieve these ends, and that available means will affect realized ends.<sup>1</sup>

At the end, Lean can be defined as a method to generate the maximum possible amount of value by minimizing waste of materials, time, and efforts. Lean Construction is a new form of management concept into construction which easier to (manage safe, quick completion, reduced cost, and appreciable quality) in construction projects. It uses the same principles of Lean production to increase productivity, efficiency, and reduce waste in the construction process.

##### 3.1.2 The Lean Construction Principles

In this research, the traditional list proposed by Koskela of the Lean process's principles is used. The application of these principles is the key to transforming the traditional concept of production, through evidence of the need to increase value generation and improve flow activities. (Table 1) These principles were chosen, cause they are derived from the basic principles of Lean, and are the ones that will be used to find the relationship between Lean and Green Pyramid,<sup>2</sup>

The eleven principles are explained as follows:

**Reduce the share of non-value-adding activities:** The activities can be as value adding and non-value-adding which based on the information requested by the client. All activities consume time and resources, but the conversion activities are responsible for

adding value as opposed to waiting, moving and inspecting activities. Therefore, the three later should be minimized.(Figure 2)



Figure 2: Two principally different ways of classifying non-value added activities

**Increase output value:** It is necessary to consider the requirements of customers in each phase and evaluate them. Value in construction is like value in any business: It is a return on your investment. Adopting Lean principles is an investment in the future of the project, which will reap benefits and give a solid return on investment. (Figure 3).

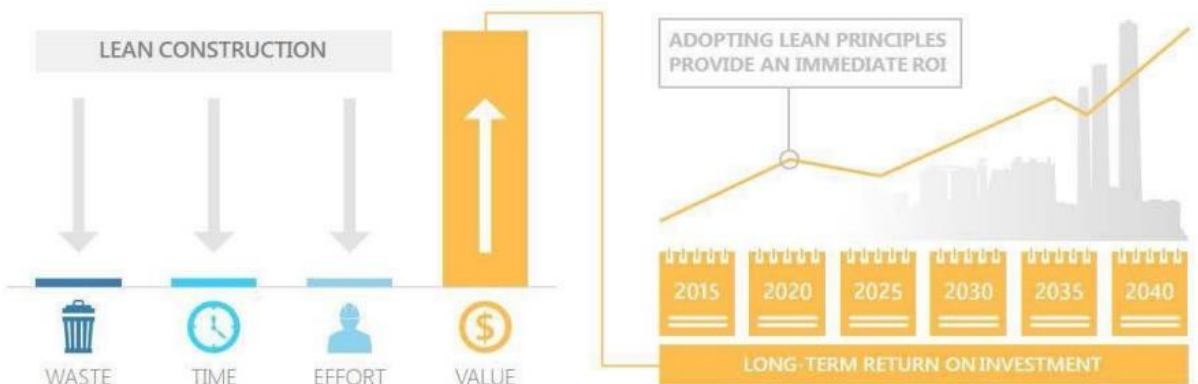


Figure 3: The way to increase output value

**Reduce variability:** Reducing output variability will improve performance and guarantees better quality. The variability increases the volume of non-value-adding activities so that, it is important to sort out the activities according to their sequence of development. <sup>4</sup>

**Reduce the cycle time:** Time is considered the main metric system for the flow process. Therefore, reducing cycle time reduces interruptions of the production process, eases management, and accelerates delivery work to the customer.

**Simplify by minimizing the number of steps and construction parts:** This principle works by simplifying the production process by reducing the number of the construction components, the number of steps in the flow of information and material and eliminating non value-adding activities.

**Increase output (products) flexibility:** an expression of the physical or real volume of output related to the physical or real quantities of input (e.g. labour, capital and energy) by Involving the production of a modularized product and the minimization of the lot sizes, to allow its easy customization at the end of process and the reduction of difficulties on changeovers.

**Increase process transparency:** Transparency is one of the main excellences in manufacturing and a fundamental step to construction companies searching for excellence in their construction projects. Therefore, it defends the process and layout organization, the implementation of informational and signaling systems and the use of visual controls. Through the increase of transparency in inspection operations, increase the tendency to errors and reduce the motivation for improvement.

**Focus control on the complete process:** Conducted by the responsible professional, Supports the evaluation and control of the process.

**Build continuous improvement into the process:** The responsibility for this principle’s fulfillment involves all employees to improve control by setting stretch targets, measuring, and monitoring improvement.

**Balance flow improvement with conversion improvement:** More controlled flows support the improvement of conversions, ensuring greater efficiency and less variability. So that the more complex the production process, the greater the impact on the flow. <sup>5</sup>

**Table 1. Lean construction principles**

Author’s	L.C Principles
Koskela	<ul style="list-style-type: none"> <li>- Reduce non-value-adding activities</li> <li>- Increase output value</li> <li>- Reduce variability</li> <li>- Reduce cycle time</li> <li>- Minimize the number of steps, parts and linkages</li> <li>- Increase output flexibility</li> <li>- Increase process transparency</li> <li>- Focus control on the complete process</li> <li>- Build continuous improvement into the process</li> <li>-Balance flow improvement with conversion improvement</li> <li>- Benchmarking</li> </ul>

### 3.2 Green Pyramid Rating System (GPRS)

The Egyptian Green Pyramid rating system or the system that Known as GPRS was introduced for the first time by the “Housing and Building National Research Center” in Egypt at 2009 when it was essential to propose an Egyptian rating system to the local building sector, and the main objectives were raising the awareness of the adopted national sustainable vision 2030 and guiding the local market to take steps toward sustainable and green buildings, in addition to decreasing the impact of building sector on the Egyptian environment.

Green Pyramid Rating System (GPRS) focus on assessing a new construction building at their post construction stage and design stage. The evaluation methodology is based on scoring system divided under seven aspects.

The evaluation system certificate buildings with four levels and they are certified (40-49 points), Silver Pyramid (50-59 points), Golden Pyramid (60-69 points) and the highest level is the Green Pyramid (above 70 points).

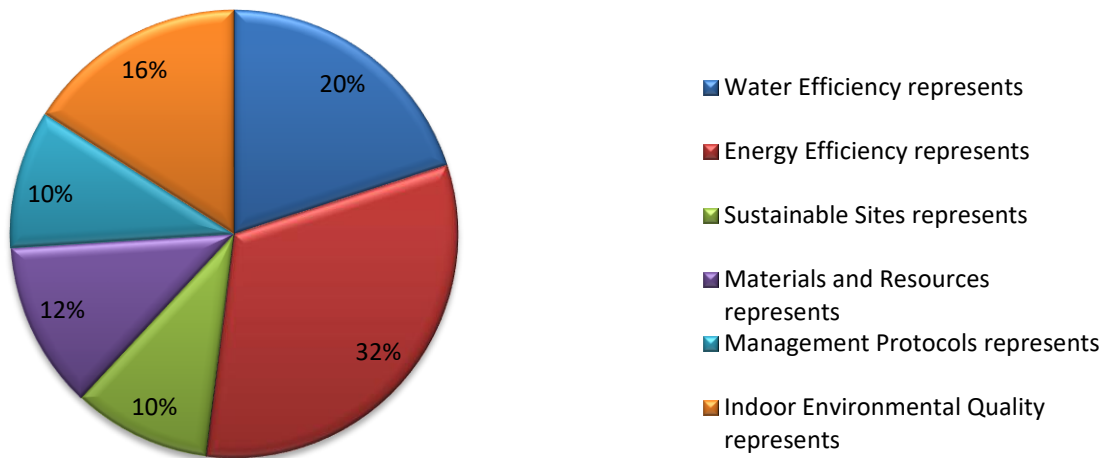


Figure 4: Green Pyramid Rating System (GPRS), Source: A

Each category has its own requirements, and score will be rewarded if they are integrated into the design.

The evaluation criteria are divided into two parts:

- **Perquisites Elements:** The project must fulfill all the requirements or mandatory elements to obtain classification and certification by the GPRS evaluation system, and failure to meet these mandatory requirements will prevent the project from obtaining the classification.
- **Credits:** The project does not have to achieve all credit points for these areas, but enough credit points must be achieved to obtain the required level.

The following is a brief explanation of each category of evaluation for this system, in addition to the elements and points of evaluation for these categories. <sup>7</sup>

- **Sustainable Sites:** this category is encouraging the development in desert areas, develop slums and avoid projects that negatively affect the environment, also, accessibility to reduce traffic congestion, and encouraging the usage of public transportation to reduce carbon emissions and conserve energy. As well as, achieving an environmental balance to reduce the negative impact of the project on the environment of the site and its surrounding areas.
- **Energy Efficiency:** this category is targeting reducing energy consumption and carbon emissions, optimizing the selection of electrical and mechanical equipment, evaluate the energy and carbon stocks for each developed system in electrical and mechanical engineering, and to reduce its negative impact on the environment, recording and monitoring building energy performance.
- **Water Efficiency:** encourage reducing water consumption inside and outside buildings, reducing the use of potable water for other purposes by encouraging the use of gray water or avoiding the use of potable water as possible and reducing wastewater generation.
- **Materials and Resources:** focus on the selection of materials with low costs and environmental impact, selection of regional local materials to reduce the negative environmental impact caused by transportation, selection of recycled materials, and choosing high-efficiency materials to reduce the need for maintenance, construction energy, or manufacturing skill, or choose materials that are easy to reuse.

- **Indoor Environmental Quality:** this category to prevent exposure of building occupants to the harmful effects of tobacco smoke, encouraging the use of low-toxic finishing material, enhancing thermal light and acoustic comfort for building occupants.
- **Management:** this category is focusing on adopting the site in order to encourage development in desert areas, redevelop slums, and avoid projects that negatively affect archaeological, historical and protected areas, study the environmental impact of the site in order to reduce the negative effects of construction operations and providing the user's guide for the building.
- **Innovation and Added Value:** this bounce category is rewarding designs that are distinguished in giving a reflection of the national and regional heritage with a positive contribution to the environmental performance of the building, initiatives that demonstrate additional environmental benefit beyond the current standards established in the Green Pyramid rating system, and innovation design initiatives and construction practice that have a measurable environmental benefit and that are not awarded points in the rating system.

#### 4 - Relationship between Lean principles and Green Pyramid Criteria

This Research study relation between Lean principles and Green Pyramid criteria as approach for efficient evaluation system of green building in Egypt. An interaction matrix concluded the relationship between Green pyramid criteria and the principles of LC in columns – compulsory elements of the Green pyramid were reduced to (52) by grouping criteria with similar intentions, such as:

- Developing desert areas - Redeveloping nonofficial areas- Developing polluted areas - integration with national development plan) under site selection
- Access to public transportation- Availability of services to remote areas - Alternative transportation) under Site Accessibility
- At energy efficiency category (Minimum energy performance - Enhance energy efficiency- Reduce energy load- Ideal balance between energy and performance) to be merged into Minimum energy performance &energy efficiency
- Avoid Ozone depletion and energy and Co2 emissions will be merged into Environmental impact
- Vertical movement system merged into Equipment low energy consumption
- At Water efficiency category (Water usage efficiency - Water usage enhancement - Water features efficiency - Efficient water usage during) will be merged into Water usage efficiency &enhancement.

#### 4.1 Matrix analysis & Results:

This matrix is measuring the integration between Lean principles and Green pyramid criteria as shown in (Table 2)



**Table 2:** Matrix between Lean principles and Green Pyramid, Source: Authors

Green & LEAN in CONSTRUCTION		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
		Reduce non-value-adding activities	Increase output value	Reduce variability	Reduce cycle time	Minimize the number of steps, parts and linkages	Increase output flexibility	Increase process transparency	Focus control on the complete process	Build continuous improvement into the process	Balance flow	Improvement with conversion
Sustainable sites	A- Site Selection											
	B- Site Accessibility											
	C- Environment											
	Protecting the surrounded environment Respecting the historical and cultural locations Limit construction pollution	*	*	*		*				*	*	*
Energy Efficiency	Minimum energy performance & energy efficiency		*	*						*	*	
	Monitor energy consumption and report it							*	*	*		
	Thermal comfort strategy		*							*	*	
	Equipment low energy consumption		*							*	*	
	Renewable energy		*				*			*	*	*
	Environmental impact	*	*	*		*	*			*	*	*
Water efficiency:	Operation and maintenance	*	*	*		*	*		*	*	*	*
	Water usage efficiency & enhancement		*						*	*	*	
	Water usage observation		*					*	*	*		
	Efficient water-cooling system		*							*		
	Water leaking detection		*					*	*	*		
Materials and Resources	Gray water management	*	*	*					*	*	*	*
	Inventory of materials used in construction	*	*	*	*	*			*	*	*	*
	Avoid toxic materials		*									
	Local materials	*	*									
	Fabricated construction materials	*	*	*	*	*	*			*	*	*
	Renewable materials											
	Recycled materials											*
	Light materials		*									
	Efficient materials		*									
Indoor Environmental Quality	Materials LEAN analysis		*									*
	Ventilation and indoor air quality in closed places		*						*	*	*	
	Smoke control		*						*	*		
	Control health risk		*	*					*	*		
	Ventilation quality		*						*	*	*	
	Building emissions control		*	*					*	*		
	Thermal comfort		*							*		
Management	Visual comfort		*							*		
	Acoustics comfort		*							*		
	Complementary building site plan	*	*					*			*	*
	Obligation of safety site roles	*	*		*			*				*
	Demolition statement		*									
	Achieve minimum water usage efficiency	*	*							*		
	Water usage observation	*	*	*		*	*	*	*	*	*	*
	Waste container at construction site	*	*		*	*				*	*	
	Employ workers for site waste recycle	*	*		*	*			*	*		
	Accessibility for trucks, equipment and tools	*	*	*	*	*	*	*	*	*	*	*
	Separated and specific locations as storage	*	*		*	*			*	*		
	a- Special standards for site environment											
	Project waste management plan	*	*	*	*	*	*	*	*	*	*	*
	Integrating specialized company in material recycle	*	*	*	*	*	*	*	*	*	*	*
	Protect water resources from pollution	*	*		*	*			*	*	*	*
	Mixing equipment waste management	*	*	*	*	*	*	*	*	*	*	*
	Emissions control	*	*		*	*	*	*	*	*	*	*
b- Special standards for building usage												
Availability of building user guide	*	*		*	*		*				*	
Availability of periodic maintenance schedule	*	*		*	*					*	*	
Innovation and Added Value:	Cultural heritage		*							*		
	Innovation		*									



In the interaction analysis, the relationship of each Lean principles to the Green Pyramid criteria was described in a general way, as shown in Table 2.

The results of this evaluation were divided into two groups: 1- Principles that effect. 2- Principles that do not affect

- Lean principles have weak effect on Sustainable site category, as Lean principles have no effect at all on site selection and have 35% on site accessibility, also for environment it effects only on limit construction pollution by 54.5%.
- Lean principles have effect on Energy Efficiency category, as monitor energy consumption and report it, thermal comfort strategy and equipment low energy consumption affect by 27%, Minimum energy performance & energy efficiency effect by 36.3%, Renewable energy effect by 45.4%, environmental impact affected by 54.5%, and operation & maintenance have the highest effect score which is 81.8%.
- Lean principles have low to medium effect on Water Efficiency category and Indoor Environmental Quality categories, as all credits are affected by less than 50%
- Lean principles have low effect in all materials and resources credits except Inventory of materials used in construction and Fabricated construction materials that being affected by 81.8%.
- Lean principles have effect on management as (Accessibility for trucks, equipment and tools- Project waste management plan - Integrating specialized company in material recycle- Mixing equipment waste management) affected by 100%.
- Lean principles have effect on management as (Waste container at construction site - Employ workers for site waste recycle-Separated and specific locations as storage-Availability of building user guide-Availability of periodic maintenance schedule) affected by 54.5%
- Lean principles have effect on management as (Water usage observation - Emissions control) affected by 81.8%
- Lean principles have effect on management as (Demolition statement) affected by 9%.
- Lean Principle 2 and 9 are the most integrated and interacted principles with green building design,

#### 4. Conclusion

This research is developing a correlation matrix between Lean principles and Green building design represented in Green Pyramid criteria to highlight their

integration. Evaluating their integration by matrix lead to define the level of integration if it high or medium or low .

Sustainable sites criteria has low level of integration or does not affected by Lean Principles especially at some elements like; Reducing cycle time - Increasing output flexibility-Increasing process transparency- Focusing control on the complete process-Benchmarking.

Energy Efficiency criteria is affected in a medium level by Lean principles especially Lean principle of “Building continuous improvement into the process” which must be considered but Reducing cycle time is not affected.

Water efficiency criteria is affected especially by Lean principle “Increasing output value and Building continuous improvement” into the process but does not affected by other Lean principles like; Reducing variability, Reducing cycle time, Minimizing the number of steps, parts and linkages, Increasing output flexibility, and Benchmarking which concluded that it has Weak effect on Lean principles

Materials and Resources have affected by Lean principle “Increasing output value” but has weak affect with the other principles.

Indoor Environmental Quality have a strongly affected by “Increasing output value and Building continuous improvement into the process” but the rest of the principles are weak or no effected with it.

Management is the highest criteria which affected and integrated with Lean principles due to the strong and mutual relationship between them.

Also, the Innovation and Added Value have highly affected also with Lean principle “increasing output value” but the other principles not affected with it.

Finally, LEAN can contribute to green building in a significantly way, because it interferes in the three spheres of sustainability: economic, environmental, and social and the two philosophies can be used in a complementary manner. Their application in conjunction can add value to customer, optimize resources and bring improvements to building.

As for future work, this research suggests the validation of the interaction matrix in a case study involving construction enterprises that intend to apply the green criteria and Lean principles.

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