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Developing a Framework for Implementing Green- Lean Construction Techniques

تطوير هيكلية تطبيق تقنيات الاستدامة والبناء السلس في قطاع الإنشاءات

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أنا الموقع أدناه مقدم الرسالة التي تحمل العنوان:

Developing a Framework for Implementing Green- Lean Construction Techniques

تطوير هيكلية تطبيق تقنيات الاستدامة والبناء السلس في قطاع الإنشاءات

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بناءً على موافقة شئون البحث العلمي والدراسات العليا بالجامعة الإسلامية بغزة على تشكيل لجنة الحكم على أطروحة الباحثة/ **سماح رفعت سلامة أبو مسامح** لنيل درجة الماجستير في **كلية *الهندسة* قسم الهندسة المدنية– إدارة المشروعات الهندسية** وموضوعها:

تطوير هيكلية لتطبيق تقنيات الاستدامة والبناء السلس في قطاع الإنشاءات

Developing A Frame Work for Implementing Green- Lean Construction Techniques

وبعد المناقشة العلنية التي تمت اليوم السبت 09 ربيع الثاني 1438هـ، الموافق 2017/01/07م الساعة العاشرة صباحاً في قاعة المؤتمرات بمبنى اللحيدان، اجتمعت لجنة الحكم على الأطروحة والمكونة من:

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واللجنة إذ تمنحها هذه الدرجة فإنها توصيها بتقوى الله ولزوم طاعته وأن تسخر علمها في خدمة دينها ووطنها.

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نائب الرئيس لشئون البحث العلمي والدراسات العليا

أ.د. عبدالرؤوف علي المناعمة

ABSTRACT

It is recognized that the traditional construction life cycle has waste in time, materials, cost and quality issues as well as polluting materials. The main objective of this research is to propose a framework that integrates the traditional techniques into green-lean, to improve economic and environmental performance of the construction.

The assessment was performed through using Analytical Network Process (ANP) and Zero One Goal Programming (ZOGP). These methods suggest a close to the optimum arrangement to reach green-lean framework in different scenarios.

The researcher found that 47.7% of concrete works and blockworks time is wasted while 56.6% of the work steps are waste. This indicates a wide range of modifications that could be done with traditional construction.

This research is concerned with building projects only from experts' point of view who are more than 10 years experienced to analyze value; non-value added activities and steps in the design and construction phases and focuses in developing a realistic green-lean framework that could be concluded in solving the conflicts on the concurrent drawing, expand the use of the different energy and water systems, thinking about using renewable materials and re-using the wasted in construction during the design phase, without exceeding the deadline or sacrificing customer satisfaction.

In addition to that the research concluded that going green is not necessarily expensive and with the right approach, going green can save time and money while keeping staff and buildings clean and safe. Improving air quality and reducing environmental impacts are just the start. Sustainability initiatives are about smart business and lean is a practice that helps businesses meet their bottom lines and protect physical and human assets. Over time, sustainable lean options often cost considerably less.

Keywords: Green, Lean, ANP, ZOGP

الملخص

ان دورة حياة المشروع التقليدية تتضمن هدرا للوقت والمواد والتكلفة ومشاكل بالجودة بالإضافة إلى استخدامها لمواد ملوثة. الهدف الرئيسي من هذا البحث هو تطوير هيكلية تدمج تقنيات الاستدامة والبناء السلس مع التقنيات التقليدية لتحسين الاداء الاقتصادي والبيئي لقطاع الانشاءات.

تمت عملية التقييم من خلال استخدام عملية التحليل الشبكي (ANP) والبرمجي (ZOGP)تقترح هذه العمليات ترتيبا أفضل للعمليات للوصول إلى منهجية خضراء ومرنة ضمن سيناريوهات مختلفة. ووجدت الباحثة أن 47.7٪ من وقت أعمال الخرسانة والبناء يعد مهدرا في نفس الوقت الذي يمثل فيه المهدر 56.6٪ من خطوات بناء على هذه المعطيات فإن هناك مجالا واسعا لإحداث تغييرات عملية تقلل الفاقد وتحسن استثمار الموارد المتاحة ببدائل أفضل ذات قيمة مضافة أعلى .

لقد تناول البحث مشاريع البناء من وجهة نظر خبراء التصميم والبناء الذين تزيد خبرتهم عن 10 سنوات لتحليل الأنشطة والمواد ذات القيمة في المشاريع الإنشائية في مرحلتي التصميم والبناء وركزت الدراسة علي تطوير هيكلية خضراء مرنة تتصف بالواقعية والتي خلصت الي اهمية مرحلة التصميم في حياة المشروع من دراسة التصميمات المترتبة علي بعضها البعض وحل الاشكالات فيما بينها مبكرا والتفكير في انظمة توفير الطاقة والموارد المائية في مرحلة التصميم ودراسة الاعتبارات التصميمية الخاصة بها والتفكير في استدامة المواد المستخدمة واعادة الاستخدام للهادر كل ذلك في مراحل التصميم الاولي لكن دون تجاوز موعد التسليم النهائي للمشروع او التضحية في رضي الزبون. هذا سيؤثر ايجابا على تقليل العيوب التي من المحتمل ظهورها خلال مرحلة البناء او فيما بعد بالإضافة لتقليل الزمن والمواد والأنشطة الملوثة ضمن الموازنة والزمن والجودة المحددة مع تحسين الاثر البيئي للمنشاة.

وخلصت الدراسة الى التقنيات الخضراء ليست بالضرورة مكلفة للغاية ومع التوظيف السليم، التقنيات الخضراء يمكن ان توفر الوقت والمال مع الحفاظ على العمال والمباني الخاصة بك نظيف وآمن. بالإضافة لتحسين تحسين نوعية الهواء والحد من الآثار البيئية هو البداية فقط.

مبادرات الاستدامة هي حول التوظيف الذكي والبناء السلس هي الممارسة التي تساعد الشركات على تلبية توقعاتهم وحماية الأصول المادية والبشرية. مع مرور الوقت، والخيارات المستدامة والبناء السلس في كثير من الأحيان تكلف أقل بكثير .

الكلمات المفتاحية: استدامة، بناء سلس، تحليل شبكي، تحليل برمجي

DEDICATION

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LIST OF ABBREVIATIONS

Abbreviation	The explanation
GB	Green Building
ANP	Analytical Network Process
ZOGP	Zero-One Goal Programming
LCA	Life Cycle Assessment
VSM	Value Stream Map
GC	Green Cake

Chapter 1: Introduction

Chapter 1 : Introduction

The construction faces excessive production of waste and natural resources, both of which could be highly decreased using green-lean techniques to meet the estimated budget, time and reduce the negative environmental impacts of construction activities. The next sections will illustrate the research aim and objectives, importance and shortly the used methodology to accomplish the research aim.

1.1. Background

Despite management efforts, construction industry faces many issues related to performance, productivity and impact on the environment (Ofori, 2000). The activities require prudent planning and efficient management. This was assumed due to the high volume of construction activities, the creation of poor-quality products and the harmful environmental impact (Koskela, 1992). Therefore, there is an urgent need to improve efficiency and effectiveness of management strategy during the construction cycle, to smartly balance between time, cost, quality, resources and its influence on the environment. The optimum solution is to achieve high quality with low cost within the time constraints, to use the resources without affecting the environment.

The overall goal of this research is to propose an integrated green -lean framework to improve the performance, efficiency and greenness of construction processes during the construction phase. In order to accomplish this goal, new techniques for lean and green construction will be discussed in different scenarios.

Thus, improving the traditional construction process can result in improvement related to economic, environmental and social views. As the construction, industry in Palestine is on increase, the need for identifying the factors that affect construction projects and how to use the proposed green -lean framework to improve construction management.

1.2. Problem statement

The construction industry faces many issues related to performance, productivity and impact on the environment despite management efforts. Therefore, this research proposed optimum framework based on literature review and expert views to improve the traditional construction life cycle.

Analyzing the construction process from an economic view to increase efficiency and effectiveness of the resources, labor, energy, and materials through minimizing waste and increasing productivity. Also, analyzing it from an environmental view to prevent potentially harmful impacts on the environment. Finally, analyzing it from a social view to fulfill the requirements of the stakeholders at whatever stage of participation in the construction process.

The lean techniques can help to improve the economic impact of the project and reduce the waste in the construction process where different studies from various countries have illustrated that the wastes in construction field equal approximately 47% of the total construction process (Aziz, Hafez, 2013). While green techniques mitigate the significant impacts of the construction on the economy, society and environment (Zuo, YuZhao, 2014), where, regarding to the World Business Council (WBC) for sustainable development, blocks in the construction consumes 40% of total construction energy (Zuo, et al., 2014).

1.3. Research aim and objectives

Suggesting a framework to promote conventional construction with green- lean construction techniques, to promote the economic and environmental performance of the construction through using

- Analytical Network Process (ANP) to priorities the sub criterions that affect the construction process.
- Zero-One goal programming (ZOGP) to suggest a realistic construction framework.

1.4. Research importance

The efficiency of the construction field is widely perceived as unsatisfactory when compared with many other industries (Pekuri, Haapasalo, Herrala, 2011). Therefore, this research provides a better understanding of green -lean techniques and their concepts such as waste definition, types, environmental consequences, and importance of quality, which will increase the productivity and reduce waste.

1.5. Research limitations

This research is concerned with building projects only from experts' point of view who are more than 10 years experienced.
This research is analyzing value; non-value added activities and steps in the design and construction phases.

1.6. Methodology

The following section briefly presents the methodology that has been followed:

Research strategy: Analytical Network Process (ANP) and Zero One Goal Programming (ZOGP) as analytical methods are used to propose the optimum framework to integrate the traditional alternative with more green- lean techniques in different scenarios. Furthermore, Quantitative and qualitative methods have been used in this research. Quantitative data were collected to measure the proportion of value added and the non-value added time and activities in the major process in construction. This has been done using Value Stream Map (VSM) tool and Life Cycle Assessment (LCA) tool assessed the environmental effects of the traditional construction.

Developing framework: Analytical Network Process (ANP) was used to prioritize the sub-criteria that generally affects the construction process, and then Zero One Goal Programming (ZOGP) was used to propose a realistic green-lean framework in different scenarios.

Case study analysis: was used to primarily test the resulted framework of this research on the concrete and block works through quantitative and qualitative analysis methods. Value Stream Map (VSM), Life Cycle Assessment (LCA) were used to analyze ability to allocate the waste in activities and steps, thus minimizing non-value added duration, polluting materials/activities and propose some environmental alternatives.

1.7. Research structure

In this research, semi-structured questionnaire and literature review are used to collect information. A framework has been proposed in order to understand how to integrate the conventional construction with green–lean techniques.

- The first phase includes defining the problem and study literatures on green and lean buildings to understand their concept, principles, design specifications.
- Identifying assessment criteria for the comparison between the traditional techniques that are Analytical Network Process (ANP) and Zero One Goal Programming (ZOGP).
- Design the questionnaire and define the most effective criteria and sub-criteria affecting implementation of green and lean construction.
- ANP analysis was used to priories the sub criterion and the two alternatives.
- Zero One Goal Programming (ZOGP) is used to suggest a realistic green- lean framework in different scenarios.
- Then a case study were analyzed to track the concrete and block work from the daily reports using Life Cycle Assessment (LCA) and Value Stream Map (VSM) lean tool.
- Conclusions and recommendations: The final phase of the research included the proposed green- lean framework.

Chapter 2: Literature Review

Chapter 2: Literature Review

The construction industry has changed rapidly all over the world and especially in Gaza Strip over the past years; companies are faced with a real issues regarding to performance, productivity and the construction impact on the environment. Green-lean framework can smartly balance between time, cost, quality, resources and the construction effect on the environment. The next sections will discuss the literatures point of view of green and lean buildings to understand their concept, principles and design specifications. In additional to that, the chapter will explain ANP, ZOGP and their programs.

2.1. Definition of Green Building (GB)

Green Building (GB) has become an essential issue in the sustainable evolution. GB concept is responsible for balancing long-term economic, environmental and social aspects. Different countries try to attain this concept in the construction process (Al nsairat, Ali, 2009) and they named this process "green building". Kibert (2016) defined the green building as "a healthy facility designed and built in a resources efficient manner and using ecologically based principles". The Office of the Federal Environmental Executive (OFEE) in U.S. defined green building as "the practice of increasing the effectiveness of the construction and the use of energy, water, materials in the construction through reducing the building impacts on human health and the environment by better siting, design, construction, operation, maintenance, and elimination of the building" cited in (Atsusaka, 2003). Robichaud and Anantatmula (2011) cited in Zuo and Yuzhao (2014) pointed out that green buildings are concerned with minimizing the effects on the environment, promoting the health conditions of the construction, the return on investment to contractors and the local community, and the life cycle analysis during the planning and construction process.

2.2. Principles of green buildings

Green principles focus on the environmental issues; they include eco-product design, environmental design, consider re-use principles of design for re-use, re-manufacturing and recyclability, and the use of environmentally friendlier materials (Dhingra, Kress, Upreti, 2014). Table (2.1) shows the green view from different aspects (environmental, economic and social aspects).

Table (2.1): The principles of green building (Sandler, 2011)

Environmental Aspect	Increase material effectiveness by reducing the demand of non-renewable goods.
	Promote the material recyclability.
	Control and reduce the toxic materials in construction.
	Reduce the needed energy for material movement on and to the site.
Economical Aspect	Examine life-cycle costs.
	Consider alternative financing techniques.
	Consider the cash impact on local structures
Social Aspect	Promote the participation of stakeholders in the construction process.
	Promote public involvement.
	Consider the social framework impact in the construction life cycle.
	Assess the effect on the health of occupants and worker life.

2.3. Green design specifications

Lauren and Vitta (2011) developed some considerations that should be followed when implementing a green construction project, which are to put smart specific sustainable goals, before initiating the design and construction process. Furthermore, to involve the project manager and the key persons of the project team in the early beginning of the project, to ensure collaboration between them.

Among the considerations, Lauren and Vittal (2011) suggested that the involvement of all the team members in the design phase, primary pricing estimation, preparation of construction document, incorporate bonuses for implementing sustainable practices and accomplishing sustainability goals. They also pointed out that it is very effective to provide training and efficient communications between the team members throughout the construction process by conducting monthly meetings with the project members and the entire site workforce to evaluate the continuity of the work.

2.4. Assessment tools for green buildings

There are many international tools to assess the green performance of the construction and its effect on the environment as shown in Table (2.2).

Table (2.2): Assessment tools for green buildings

Assessment method	Origin	Characteristics
ABGR: Australian Building Greenhouse Rating	(Ding, 2008)	Rating method, based on calculating the energy consumption on 12 months and present a national standard to measure greenhouse performance.
BEPAC: Building Environmental Performance Assessment Criteria	(Cole, et al., 1993)	A comprehensive method which uses points criteria for ranking.
CASBEE: Comprehensive Assessment System for Building Environmental Efficiency	(Japan Sustainable Building Consortium, 2007)	A cooperative system between government and industry, could be used in the pre-design phase, in buildings implementation, and/or in renovating a building.
CEPAS: Comprehensive Environmental Performance Assessment Scheme.	(Ding, 2008)	Could be applied to all types of new or present building.

GB Tool: Green building challenge	(Kim, et al., 2008)	The most comprehensive rating system which has four rating systems and it's used worldwide for more than 20 countries.
Green Star	(Australia, 2009)	It is used for commercial buildings exclusively and the classification system is from 0 to 6 stars
HKBEAM: Hong Kong Building Environmental Assessment Method	(Lee, et al., 2008)	Evaluate new buildings as 'as built' more than 'as designed'.
LEED: Leadership in Energy and Environmental Design	(Council, U. G. B., 2004)	It consists of five categories of sustainability and it is possible to be used in new and existing buildings, commercial, renovation buildings.
SBAT: Sustainable Building Assessment Tool	(Gibberd, 2001)	Focuses on the social and economic aspects and depends on the life cycle analysis for the building to attain the integration in all the construction parts.
BREEAM (Building Research Establishment Environmental Assessment Method)	(Crawley, et al., 1999)	A widely used tool to assess and evaluate the environmental performance of construction.
GBI (Green Building Index)	(Chua, et al., 2011)	Which was started in 2009 and it consisted of 6 key rating systems for green building in Malaysia. The system is based on the efficiency of energy, material and resources, sustainable site management and planning, water efficiency, and innovation.

Life Cycle Assessment tool (LCA)	(International Organization for Standardization, 1997, Banawi 2013).	A systematic set of procedures for compiling and examining the inputs and outputs of materials and energy and the associated environmental impacts directly attributable to the functioning of a product or service system throughout its life cycle (International Organization for Standardization, 1997). Banawi (2013) defined Life Cycle Assessment (LCA) as a green tool that systematically assesses and manages the environmental impact of a product, process, or service through its entire life cycle, from the material and energy used in the raw material extraction and production processes, through acquisition and product use, and continuing to final product disposal.

2.5. Sustainable energy performance indicators for green building

Regarding to the used energy, many strategies are substantial, including reducing energy demand, adopting passive systems and increasing energy efficiency (Robichaud and Anantatmula, 2010). Table (2.3) shows the key performance criteria for sustainable buildings.

Table (2.3): Key performance criteria for sustainable buildings

Criteria	Description	Criteria	Description
Site selection	It is important to take these guidelines through the site selection process. Among these guidelines the right selection for the site that reduce the expected pollution of the construction, for	Water efficiency	The efficiency of the water use, waste water treatment and conservation techniques are other tools to evaluate the green performance within the building (1,2,5).

Site selection	example, the waste produced from transport and implementation during and after the construction process. An efficient way to manage the site is to define the foreseeable construction activities to decrease pollution possibility (1,2,3,4).		
Economical	To judge the economic performance, it is essential to analyze the life-cycle cost, life-cycle profit and project budget (2,3,4,6,7) .	Material and resources	Which means to reduce the generated waste and to use renewable local material (1,2,3,5,6,7).
Energy efficiency	Which tracks energy performance, means to calculate the proportion of the used renewable energy in the construction and reduction of the greenhouse emission (1,6,7). Another indicator of energy efficiency is to control the performance of the building envelope, the used heating–cooling techniques and the energy saving systems (2,4,5,6).	Indoor environmental	Means an assessment of the quality of indoor air, outdoor air delivery and to control indoor pollution sources. In addition, the thermal comfort and noise control are substantial in the evaluation of the performance of indoor environment (1,2,3,6).
Social	Which means to analyze the aesthetic alternatives and its effect on local view (3,4,6,7).	Innovation	Innovation in design (1,2,3,5).

(1) LEED 2009; (2) Ali and Al Nsairat 2009; (3) ALwaer and Clements-Croome 2010; (4) Shen et al. 2011; (5) Kai Juan et al. 2010; (6) Mwasha et al. 2011; (7) Ying Chen et al. 2010.

2.6. Definitions and principles of lean construction

In fact, lean construction had many definitions, where Ohno (1990) defined it as a business system with a fundamental objective of eliminating waste, and he defined waste as "anything that does not add value." Value-added activities are the ones that the client is interested in paying for, the ones that help converting the product or service to new product, and the ones that must be done correctly the first time. Another definition given by the lean construction institute (2012) as a production management process to the final delivery. Lean production management has caused a revolution in manufacturing, design, supply and assembly (Lukowski, 2010). Also, Dhingra (2014) mentioned that lean philosophy is about reducing waste, increasing productivity and safety in accomplishing the client's needs in the construction field. While Issa (2013) defined it as a new concept in the construction production management. It produces a control tool with the goal of reducing the losses throughout the process. Another definition for lean described by Lim (2008) which is attaining a balanced use of works, materials and resources. This allows contractors to minimize costs, decrease the waste in the construction and deliver projects on time.

Aziz and Hafez (2013) showed that lean production aims to optimize performance of the production techniques to meet the optimum perfection of the client needs. The lean principles are summarized in the next paragraphs.

- **Value:** Womack and Jones (2003) emphasized that customer is the main person who is responsible to determine the needed value from the project. While Aziz and Hafez (2013) illustrated that the value determined from the client point of view which adds value to the end product.

- **Value Stream Map (VSM):** a well-known used lean tool, which is a technique that analyzes the materials and information through a process flow diagram. VSM uses a methodical approach, covering all activities needed to reach the final product or service. The flow diagram shows all the steps, shed the light on any ineffectiveness in the value stream (Ohno, 1990). Also, Womack and Jones (2003) emphasized that value stream can only be defined by particular activities needed to design, order and provide a particular product from concept to launch, order to delivery.

- **Flow:** which means the flow of both material and workers' movement. Materials flow includes the transformation and storage on the site. The worker movement is concerned with temporal and spatial flows of the team members in the construction site (Koskela, 1992)**.** Aziz and Hafez (2013) mentioned the flow analysis is on the value chain that connects the entire activities. The focus on the flow analysis is on the process itself, not the final product.

- **Pull:** Womack and Jones (2010) mentioned that pull means to imply the capability to design and make precisely what the client needs quickly and efficiently. Aziz and Hafez (2013) mentioned that pull means to produce accurately what the customer wants at the time he needs and always be prepared for the modification by the customer.

- **Perfection:** Aziz and Hafez (2013) defined it as deliver a product, which meets the client requirements, with optimum quality without mistakes and defects and within the agreed time. This could be done by having a close communication with the client and team members. Womack and Jones (2003) shows that pull can be defined by perfection with zero waste.

2.7. Criteria of lean construction

As Aziz and Hafez (2013) elucidated that having a customized product that fits its purpose and that could be supplied instantly is the core idea of the lean strategy. Having zero waste is a core quality at that matter as well. This by nature would differ according to the ability of individuals and organizations to apply it. The process, which should be implemented, is summarized in the following: The first step is to select the right suppliers who are motivated to adopt the lean project delivery. Second, is to analyze the project structure to define the activities that are worth directing the cash flow into to get the best project level returns.

Afterwards comes the process of defining and aligning the project scope, budget, and schedule. Then to explore the adaptation options and the methods development; decide between design alternatives explicitly according to the stated criteria. In the meanwhile it is advised to practice production control in accordance with lean principles to improve quality, safety and to implement lean methods, for example, Just in Time (JIT) to guarantee ending the project within timeframe and estimated budget (Aziz, et al., 2013).

Lean production management has caused a revolution in manufacturing design, supply and assembly (Lukowski, 2010). Also, Dhingra, (2014) shows that lean construction is about reducing waste, increasing productivity and safety in fulfilling the client's requirements in the construction industry (Dhingra, et al., 2014). The next section illustrate the waste definition and types.

2.8. Construction wastes

Lean aims basically to reduce the waste because several partial studies from various countries have confirmed that wastes in construction industry represent a relatively large percentage of production cost. The existences of significant number of wastes in the construction have depleted overall performance and productivity of the industry (Dhingra, et al., 2014).

Aziz and Hafez (2013) defined Waste as ''Anything different from the absolute minimum amount of resources of materials, equipment and manpower, necessary to add value to the product '' (Aziz, et al., 2013).

Also, any losses produced by activities that generate direct or indirect costs but do not add value to the product from the point of view of the client can be called ''waste''.

2.9. Classifications of the construction waste

Formoso ((sited in (Aziz, et al., 2013)) proposed the main classification of waste based on the analysis of some Brazilian building sites they had carried out as shown in Figure (2.1):

- Overproduction: related to the production of a quantity greater than required or earlier than necessary. This may cause waste of materials, man hours, or equipment usage. It usually produces inventories of unfinished products or even their total loss, in the case of materials that can deteriorate. An example of this kind of waste is the overproduction of mortar that cannot be used on time;

- Substitution: is monetary waste caused by the substitution of a material by a more expensive one (with unnecessary better performance); the execution of simple tasks by an overqualified worker; or the use of highly sophisticated equipment where a much simpler one would be enough;

- Waiting time: related to the idle time caused by lack of synchronization and leveling of material flows and pace of work by different groups or equipment. One example is the idle time caused by the lack of material or by lack of work place available for a gang;

- Transportation: concerned with the internal movement of materials on site. Excessive handling, the use of inadequate equipment or bad conditions of pathways, can cause this kind of waste. It is usually related to poor layout and the lack of planning of material flows. Its main consequences are as follows: waste of man hours, waste of energy, waste of space on site, and the possibility of material waste during transportation;

- Processing: related to the nature of the processing (conversion) activity, which could only be avoided by changing construction technology. For instance, a percentage of mortar is usually wasted when a ceiling is being plastered;

- Inventories: related to excessive or unnecessary inventories which lead to material waste (by deterioration, losses due to inadequate stock conditions on site, robbery, and vandalism) and monetary losses due to the capital that is tied up.

- Movement: concerned with unnecessary or inefficient movements made by workers during their job

- Production of defective products: it occurs when the final or intermediate product does not fit the quality specifications.

- Others: waste of any other nature than the previous ones, such as burglary, vandalism, inclement weather, and accidents.

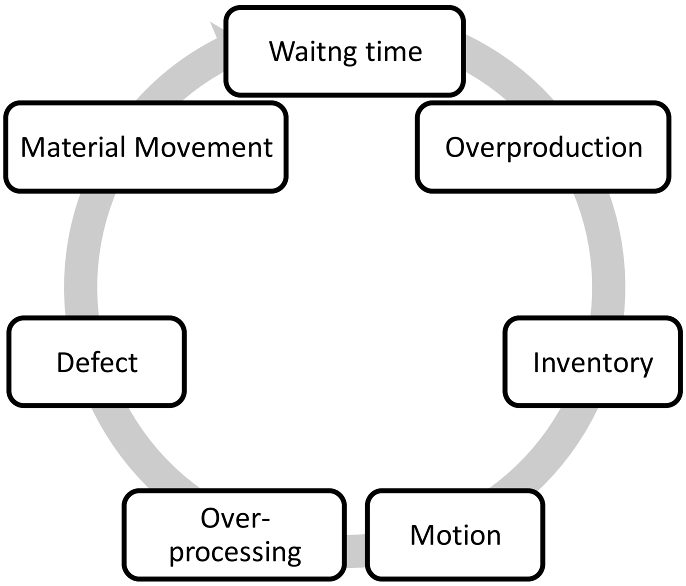

Figure (2.1) Classifications of the construction waste (Aziz, et al., 2013)

2.10. Relationship between green and lean

It is elementary that adopting green techniques lead to sustainability. This is not necessarily a vice versa relationship. The next paragraph would discuss the relationship the three levels of integration.

At the very beginning, planning with the environment in mind cannot be postponed from the design process or considered a luxury in lean thinking. On the other hand, applying green would be beneficial as it is automatically constrained with economic aspects (Dhingra et al., 2014).

When thinking sustainable, applying lean cannot be separated from applying green. This means that understanding economic, environmental, and social aspects are inevitable to correctly apply sustainability (Dhingra et al., 2014).

2.11. Analytic Network Process (ANP)

The Analytic Network Process (ANP) is a multi-criteria decision making tool used to derive relative priority scales of absolute numbers from individual judgments (Yazgan, et al., 2015)

The advantage of ANP is using the ratio scales to make accurate predictions and wiser decisions. This model is proven effective in many fields such as predicting sports results, economic fluctuations, business, and different events. The main feature that makes ANP unique is the ability to deal in a systematic manner with feedback and to define precisely the value from a customer's point of view in ratio numerical scale (Saaty, 2012).

ANP represents an enhanced version of Analytic Hierachy Process (AHP) that extends the interaction and feedback within and between the clusters. Feedback is a feature that traces the complex effects that may occur in the human society. ANP consists of a framework of clusters and nodes that are linked together in a manner that achieves ratio scales priorities. This ratio is derived from the interaction between the elements of the clusters. For what is aforementioned, the AHP is considered a special case of ANP. However, it is not advised to use ANP for the small scaled phenomenon's (Jayant, et al., 2014).

In other words, The Analytic Network Process (ANP) is a generalization of the Analytic Hierarchy Process (AHP) by considering the dependence between the elements of the hierarchy (Yazgan, et al., 2015).

The ANP method consists of two parts. The first is to build the hierarchy of criteria, sub-criteria, and alternatives. The second part is to build links and connections between these elements. Then defining the weight of each element and its rank among other elements. The main idea behind using the ANP approach is not to limit the human creativity into a mathematical shape. Rather, it resembles a natural flow of thinking. ANP provides a mathematical approach that is more effective that the probabilistic approach (Jayant, et al., 2014).

There are, however, some factors to take into consideration when using the ANP approach. On one hand, it is important to take in mind that every element might affect alower element and be affected by a higher element. On the other hand, the alternatives do affect both the criteria and sub-criteria. The feedback keeps us informed numerically about the present situation and future predictions (Hsu, et al., 2011).

The bottom line is that the ANP works with infinite loops while the AHP works in a linear way from top to bottom. The hardest part in the whole process could be determining the accurate weights of every element, the right connections between each node, and ensure the consistency of the expert's responses. This is particularly hard because of the nature of cycles of being infinite. Cycles are more data demanding than hierarchies (Yazgan, et al., 2015).

2.12. Super decision software:

The super decisions software is used for decision-making with and feedback. It implements the Analytic Hierarchy Process, AHP, and the Analytic Network Process, ANP. Both use the same fundamental prioritization process based on deriving priorities by making judgments on pairs of elements, or obtaining priorities by normalizing direct measurements. In the AHP the decision elements are arranged in a hierarchic decision structure from the goal to the criteria to the alternatives of choice, while in the ANP the decision elements are grouped in clusters, one of which contains the alternatives, while the others contain the criteria, or stakeholders or other decision elements (Hsu, et al., 2011).

Super decisions is a widely used piece of software for decision making and getting feedback. It utilizes the AHP (Analytic Hierarchy Process) and the ANP (Analytic Networking Process). Both of these methods use the same principle of judging based on pairwise comparison. ANP harnesses matrices advantages for prioritizing. The AHP methodology works from the top to bottom in the hierarchy of the decision structure. While the ANP works both ways from top to bottom and vice versa (feedback connection). Furthermore, ANP compares each criterion and gives a ranking for each. Moreover, it gives factors for the criterion in the decision structure, so that the decision maker could utilize in the decision making process (Yazgan, et al., 2015).

ANP consists of clustered network of elements, which are goal, criteria, sub-criteria, and alternatives. These clusters contain nodes are linked together, so that the software could prioritize them. The ANP is not limited by such assumptions. It allows for all possible and potential dependencies (Saaty, 2012). The prioritizing process depends on a series of pairwise comparison between the criteria sub-criteria, and alternative clusters. This also computes tangible and intangible criterion. ANP depends on feedback connections, which analyzes the effect of the alternatives on the criteria. The top to down approach that is used a typical AHP analysis has a goal on top and prioritizes criteria according to their importance to the goal using the pairwise comparison process. Consequently, the sub-criteria is prioritized according to their importance to the criteria. The same logic is inherently applied to the alternative cluster. Regarding Pairwise Comparison, it depends on two questions that are asked when interviewing experts to differentiate between elements. The first question is which criteria have more importance than the other does. The second question is what is the numerical value of this importance? (Cheng, et al., 2004).

After determining these values, these values are entered into the software and these results in the preference ranking for each node (Saaty, 2012). It is worth mentioning that the version that used in this research is ANP version 2.6.0-RC1.

2.13. Zero-One Goal programming (ZOGP):

This method deals with multiple objective problems that are classified as sophisticated problems. Many researches were conducted to test its efficiency and yielded in positive results (Steuer, 1986). The adopted method in this research is (ZOGP) which was developed by Charnes and Cooper (1961).

2.14. Lindo program:

Lindo platform is designed solely for solving optimization problems. Whether they are linear, integer, and non-linear etc. Its applications are, but not limited to, business, research, and governmental issues. This optimization process helps in getting the optimum value of profit, production, or even happiness. This is through getting the best utilization of funds, time, and labor (LINDO Systems, Inc., 2010).

This chapter discussed the definitions, principles, specifications and assessment tools of green and lean construction. Also, it discussed the details of the research assessment methods ANP, ZOGP, LCA and VSM and the operational program that implement each tool which will help priories the criteria (cost, quality, time and environment) and each sub-criteria of them.

Chapter 3: Methodology

Chapter Three : Methodology

This chapter discussed the research life cycle starting with explaining the research structure, the questionnaire design, content and the assessment tools mainly ANP and ZOG. In addition, this chapter defines the details of the analyzed criterion, sub-criterion and the steps of the analyzing process through super decision and Lindo programs.

3.1. Introduction

A comprehensive methodology was designed in order to develop a framework for integrating Green-lean techniques in construction industry. This chapter briefly discusses the methodological approaches, the details of the research methods that were used and finally the overall research design. Combinations of quantitative and qualitative methods are used in the research study, qualitative data were collected through semi-structured questionnaire with project managers and experts to understand the advantages of the traditional techniques and to priories the criterion that affect the construction process to be analyzed through Analytical Network Process (ANP) and Zero One Goal Programming (ZOGP). While quantitative data were used to measure the proportion of value added/ non-value added time and steps in each process of concrete and block works using Value Stream Map (VSM) then Life Cycle Assessment (LCA) assessed the environmental effects of the traditional materials.

3.2. Research design

A frame structure has been proposed in order to integrate green-lean techniques as shown in Figure (3-1) which summarizes the research design.

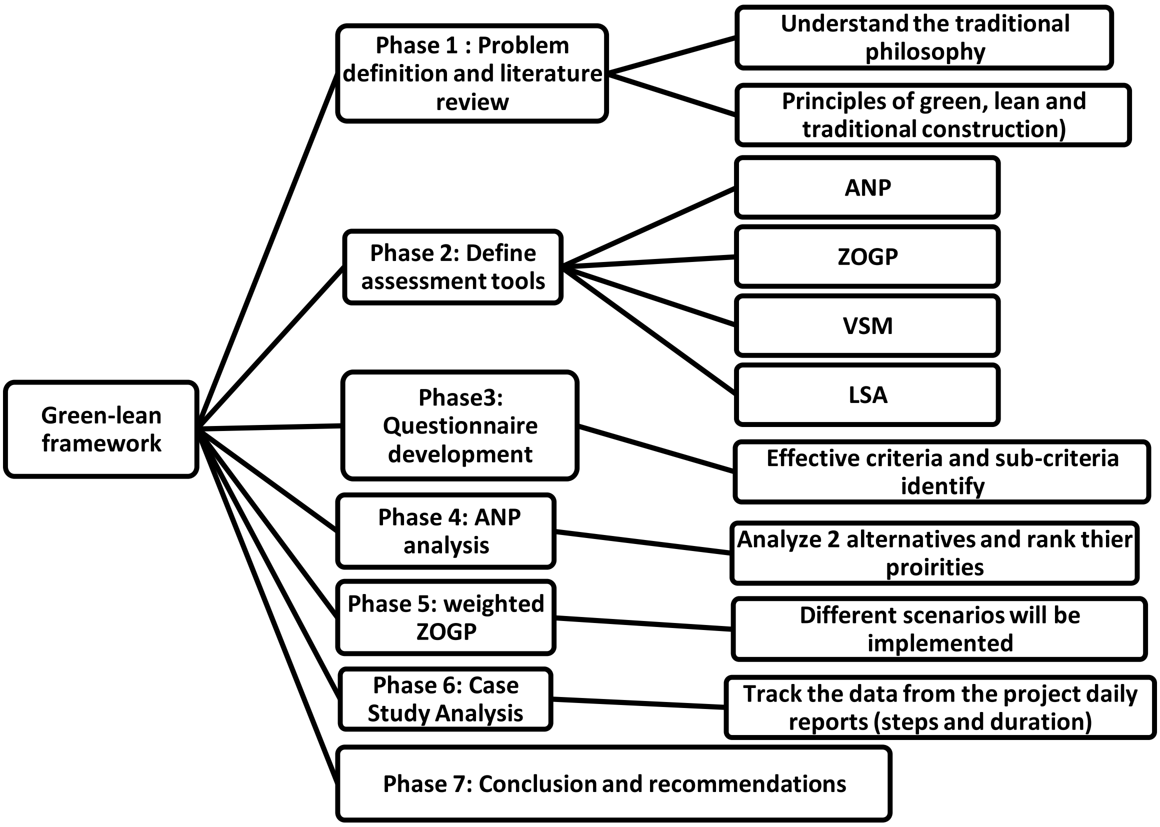

Figure (3.1): Framework of the research

The following paragraphs explain in details the various phases of the adopted methodology:

Phase 1: The first phase includes defining the problem and study the literatures on green and lean buildings to understand the philosophy, concept, principles, design specifications, their advantages and limitations.

Phase 2: Identifying an assessment criterion for the comparison between the traditional and green-lean techniques. The proposed a green-lean framework depended on Analytical Network Process (ANP) and Zero One Goal Programming (ZOGP). In this study, 19 sub criteria were identified for the comparison between traditional construction practices and green – lean techniques. Then, Value Stream Map (VSM) and Life Cycle Assessment (LCA) were conducted to allocate the waste in traditional construction.

Phase 3: The first step in this phase is to discuss the preliminary questionnaire with a pilot sample by inviting 2 professionals with more than 10 years of experience to discuss the criterion that affects the construction process and to develop the final questionnaire design. Here, there is no set order or wording of questions, purely exploratory to get as much as data about the problem and opinions of the respondents. This helped a lot at the next step of designing the final questionnaire to be answered from 10 different experts. It's advisable that in ANP analysis to look for highly qualified experts and to narrow the sample with no more than 10 experts.

Phase 4: ANP model was constructed and pairwise comparisons were added to the model depending on the experts' responses to calculate the priority of the criteria and sub-criteria. Then an analysis of these results, the weights of these criteria and sub-criteria and their relation to each other.

Phase 5: Weighted Zero-One Goal Programming (ZOGP) formula was constructed, the priorities derived using ANP in the previous phase were used as a coefficient in the objective function, where ZOGP can handle multiple objectives and seeks to minimize the total deviations from the desired goals.

Phase 6: Select an existing building as a case study to track the data of the project from the daily reports using (LCA) green tool. From the reports, analyzing for the concrete work steps and the sequence of the process for executing the project using (VSM) lean tool.

Phase 7: Conclusion results of the proposed framework were discussed different scenarios.

3.3. Questionnaire design and validation

The questionnaire consisted of six tables where the first table consisted of pairwise comparison for the main criteria, the second, third, fourth and fifth tables consisted of sub- criteria pairwise comparison and finally the sixth table designed to preform comparison for feedback connections between these sub-criteria. Figure (3.2) shows ANP model structure.

- Part 1: Pairwise comparison among the main criteria.
- Part 2: Pairwise comparison among the sub-criteria with respect to the main criteria.

- Part 3: Pairwise comparison for feedback connections.

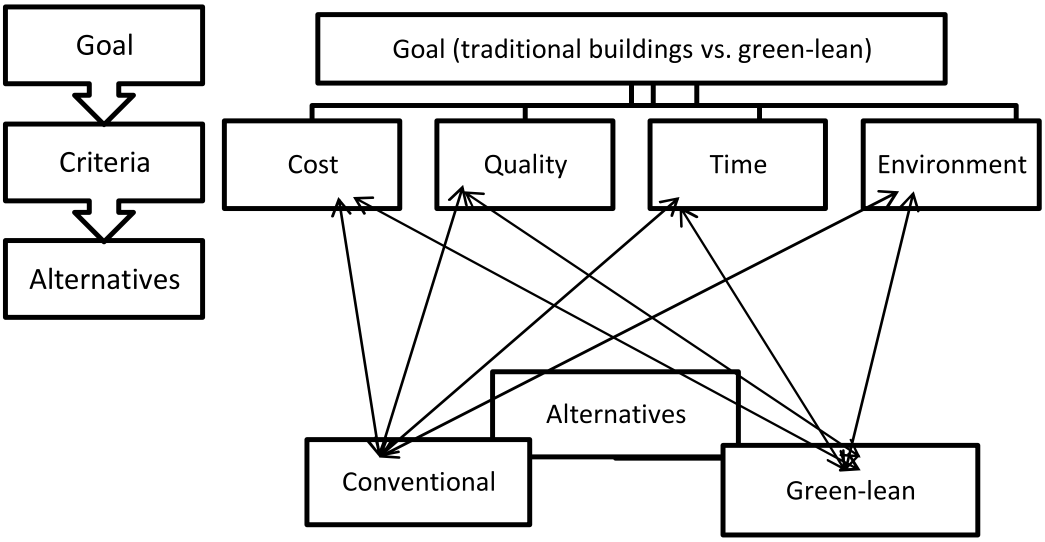

Figure (3.2): Analytical network analysis framework

To test the validity of the preliminary questionnaire, a pilot study was undertaken by inviting 2 professionals who have more than 10 years of experience. Respondents were requested to give their feedback on the criterion, questionnaire design and any suggestions for refining the questionnaire.

Minor modifications were made to the design of the questionnaire where the resources criteria were removed and included as sub- criteria. Also, some sub-criteria were found to be repeated, weak and not effective, so they were omitted as shown in Table (3.1) and (3.2).

Table (3.1): The criteria modification of the questionnaire criteria

Criteria	**Action**	**Final modified criteria**
Cost	Selected	Cost
Quality	Selected	Quality
Time	Selected	Time
Environment	Selected	Environment
Resources	Omitted	---------

Table (3.2): The sub-criteria modification of the questionnaire sub-criteria

	Sub-criteria	Action	Final modified criteria
Cost	Planning and design	Modified	Design cost
	Materials cost	Selected	Materials cost
	Operational cost	Selected	Operational cost
	---------	Added	Labor cost
	---------	Added	Machine cost
Quality	Reliability of the used material	Selected	Reliability of the used material
	Customer satisfaction	Selected	Customer satisfaction
	Construction defects	Selected	Construction defects
	Organize concurrent department's relationship	Modified	concurrent drawings relationship
	Material waste	Selected	Material waste
	Activities waste	Selected	Activities waste
Resources	Waste reduction	Omitted	---------
	Unit cost of the resource	Omitted	---------
Time	Time wasters	Selected	Time wasters
	Project duration	Selected	Project duration
	Adhere to deadline	Selected	Adhere to deadline
Environment	Polluting materials	Selected	Polluting materials
	Polluting activities	Selected	Polluting activities
	Gray water	Modified	Water systems
	Renewable energy tools	Selected	Renewable energy tools
	Renewable material use	Selected	Renewable material use

3.4. Assessment tools

Several tools were used in this research to analyze the status of the traditional construction techniques, priories the criterion that affects the construction and propose the interaction process from green- lean point of view. These tools included Analytical Network Process (ANP) and Zero One Goal Programming (ZOGP), Value Stream Map (VSM) and Life Cycle Assessment (LCA); the next section will discuss every tool separately.

3.5. Value Stream Map (VSM):

Well-known and commonly used lean tool is Value Stream Mapping (VSM), which is a technique that creates a process flow diagram of materials and information. VSM uses a systematic approach, covering all activities required to bring the product or service to completion, and shows all the steps, highlighting any ineffectiveness in the value stream (Lee, et al., 2010).

VSM depicts each of the process steps in the value stream, including both value-added and non-value-added. Also, VSM reveals process statistics, including cycle time, number of operators, quantity of inventory, and number of pieces.

3.6. Life Cycle Assessment(LCA)

Although lean has the potential to identify the waste in the process, lean does not quantify the environmental impact of waste in the construction process. Therefore, in this research, Life Cycle Assessment (LCA) was used in conjunction with lean to allow evaluation of material environmental impact of construction process during the construction phase.

Life Cycle Assessment (LCA) is a green tool that systematically assesses and manages the environmental impact of a product, process, or service through its entire life cycle, from the material and energy used in the raw material extraction and production processes, through acquisition and product use, and continuing to final product disposal (Rebitzer, et al., 2004).

3.7. Analytical Network Process (ANP)

ANP represents an enhanced version of AHP that extends the interaction and feedback within and between clusters. The ANP method consists of two parts. The first is to build the hierarchy of criteria, sub-criteria, and alternatives. The second part is to build links and connections between these elements.

Within the ANP procedure, some essential steps have to be followed, starting with defining the structure of the problem. This will help to develop the ANP hierarchy to perform the pairwise comparison. Next, the relative weights would be estimated from the experts' feedback on the questionnaire. The model checks the consistency and finally obtain the overall rating.

3.7.1 Developing ANP model

- First, define and structure the problem: in this step the understanding of the goal, criteria and the alternatives should be stated clearly. In the questionnaire, the main goal is to compare between the conventional building practices and green- lean techniques to identify the critical criteria and sub-criteria that may heavily affect in promoting the traditional construction to be more green – lean.

- Second, developing the ANP network and determining the relationship between the criteria (environment, quality, cost and time) and sub- criteria that affect the goal as shown in Table (3.3).
- Third, pairwise comparisons preformed for each criteria and sub-criteria on the network.

Table (3.3): The sub- criteria

	Environment	**Quality**	**Cost**	**Time**
Sub-criteria	Polluting materials	Material reliability	Design	Time wasters (activities)
	Polluting activities	Customer satisfaction	Materials	Project duration
	Water systems	Defects	Labor	Adhere to deadline
	Renewable energy	Concurrent drawings	Machines	
	Renewable material	Material waste	Operational	
	Energy systems	Activities waste		

3.7.2 Identification of criteria and sub-criteria

The next section explained the meaning of the criteria and sub-criteria terms, mentioned in Table (3.3).

A. The environmental criteria

This research sheds the light on the environmental impacts of construction activities and material during the construction and post construction phases. For more description of environmental criteria and sub-criteria, more details will be given in the following:

1. For **renewable material sub-criteria,** it has high effect the energy consumption of the building and its influences on the environment. The renewable materials include Green cake (GC) block, watershed block, composite, polystyrene foam, blended cement, green concrete and geo-polymer concrete, so it is expected that the performance will be much better in the long term when using renewable materials instead of traditional ones.
2. As for **energy systems sub-criteria,** from the experts point of view, using appropriate energy systems (photovoltaic, thermal, biomass and wind) can decrease the nonrenewable energy consumption in the building which will affect greatly the building performance, especially that Palestine is a developing country that suffers from major problems of energy due to poor resources of energy, inefficient use and the increase in it is generated pollution.
3. Regarding to **polluting material sub-criteria,** includes conventional blocks, limestone, asphalt (bitumen) and cement. So, this sub-criteria is concerned with protecting the environment through eco-design, design, design for re-use, reduction of toxic materials, and the use of greener materials.
4. As for **polluting activities sub-criteria,** means to enhance the health conditions of the labor who work on construction, occupants of the facility and decrease un healthy materials/ activities. For example, to use polystyrene foam instead of bitumen. There is a strong evidence for the carcinogenicity of steam-refined bitumen's, air-refined bitumen's and pooled mixtures of steam. Also, waste gases from an asphalt plant contains hydrocarbons, tars and hydrogen sulfide (Wess, 2005).
5. For **water systems sub-criteria,** Gaza strip suffers from the lack of water resource, so we need other strategies to secure the water resources. This includes using gray water system, wastewater treatment and conservation.

B. The quality criteria

There is an urgent need to improve our management strategies to smartly balance between time, cost, resources and their influence on the environment to give the optimum level of quality. The green-lean technique helps to manage this urgent need and facilitates it to different tasks to guarantee the expected quality. It is known that the customer always needs to guarantee reasonable quality of the work.

1. For **concurrent drawings sub-criteria,** which means taking into consideration the right design principles and solve the conflicts among the different (architect, civil, mechanical, electrical) specializations in the design phase. This will highly minimize the defects and misunderstanding.
2. As for **the activity and materials waste sub- criterion**, it is known that the construction is a challenging industry, where activities need careful management because of the high volume of construction activities, the creation of poor-quality products and harmful environmental impact. The construction field is faced with excessive production of waste and natural resources. Decreasing these sub-criteria will highly affect the construction performance.
3. Regarding **construction defects sub-criteria,** which occur due to the lack of experience of the labor, misunderstanding of the design drawings, vandalism, inclement weather, and accidents. The green- lean techniques aim to reduce the defects to its lowest percentage.
4. For **customer satisfaction sub-criteria,** many experts ensure that the customer needs must be met. So, the research aims to maximize the satisfaction of the customer, by focusing on main value that the customer wants, and decreasing the non- value added activities or materials. Green–lean techniques help to define value added activities and materials that benefit the construction projects in the short and long terms.
5. Regarding the **material reliability sub-criteria,** which means the probability that the material will perform its function under standard conditions and warranty period. Green-lean techniques encourage the use of new materials, especially if this material decreases the negative impact on the economic, environment, social life cycle of the construction.

C. The cost criteria

The budget of the project determines many serious limitations, for example, the area of the building, materials in the project, types of equipment in implementing the project, which heavily affects the decision of using a green-lean technique or not, as it needs a little higher initial cost.

The cost can be divided into the following:

1. For **operational cost sub- criteria,** the research analyzed the relationship between the sub-criteria that affect the cost through the project. Minimizing the operational cost will affect the flow of the steps in the project, determine the possible green cost savings and control the expected defects on the projects. However, this minimization should not affect the sustainability of the building.
2. For **machine cost sub-criteria,** means to determine the needed machines and equipment in the early beginning of the project, to help in reducing the total construction cost. This process enables the contractor to allocate his resource in the near optimum way to make profit.
3. As for **material cost sub- criteria,** materials are significant in saving cost and time in construction process which means to reduce waste generation, use renewable and local material**.**
4. In regard to **design cost sub-criteria,** the design cost is less than 10% of the total cost of the construction process, so its effect would be very little on life cycle cost of the project. However, taking into consideration this sub-criteria will reduce the defects and enhance the innovation of creative green solutions. So, it is known that reducing this sub-criteria shouldn't affect the sustainability of the life cycle of the project.
5. For **labor cost sub-criteria,** means that the cost spent on the worker and human participation weight regarding to the other sub-criteria.

D. The time criteria

Despite management efforts, construction field faces a lot of affairs related to proper time management. The construction projects rarely finish within time. Therefore, there is a need to improve efficiency and effectiveness of the management strategy, to smartly balance between time, cost, quality, resources and their influence on the environment.

1. **Adhere to deadline sub-criteria,** which means to complete the project in the scheduled time. This will reflect positively on the economic and social aspects of the project and save the contractor from the penalty cost.
2. In regard to **project duration sub-criteria,** this sub-criteria is important due to the fact that contractors usually wont to end on time, for example, the case that the project faced unpredicted circumstances, that effect its performance and can't solve it without exceeding the deadline.
3. For **time wasters sub-criteria,** the performance of the construction field is described as unsatisfactory when compared to other industries (Song,Liang, Javkhedka, 2010), especially the time wasters which present relatively 57% of the total construction process (Aziz, et al., 2013). It is widely known that minimizing time wasters can help to improve the economic impact of the project and reduce the waste in the construction process.

3.7.3 Analytical Network Process ANP model:

The model consists of four levels. The first one is the goal cluster where the goal (conventional vs. green-lean comparison) is determined as a node. The second level is the criteria cluster where four nodes were used on it (environment, quality, cost and time) as shown in Figure (3.3).

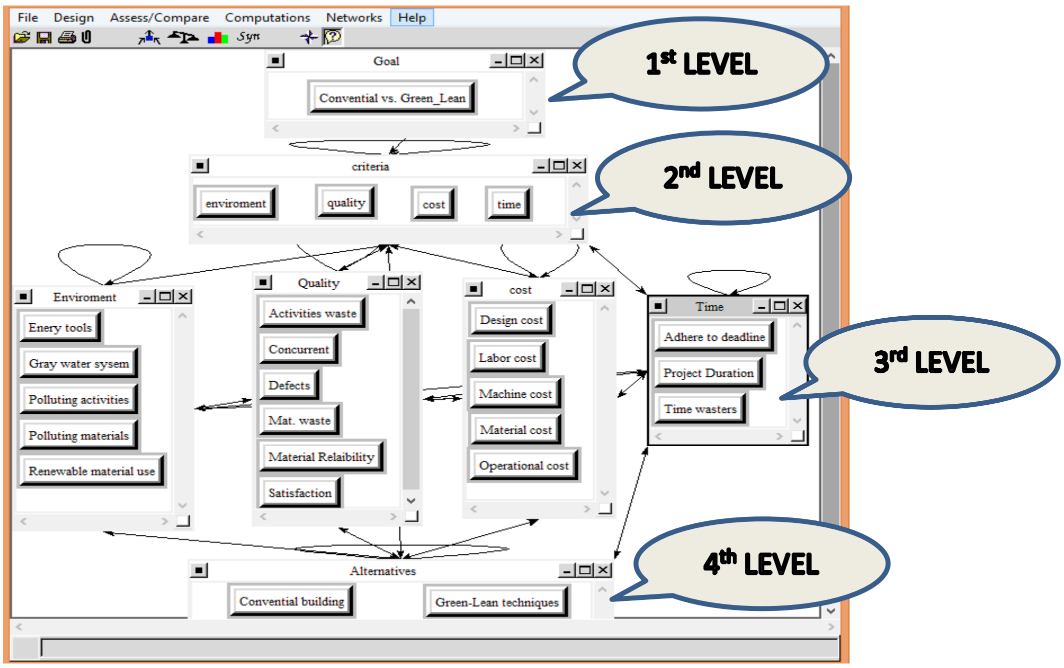

Figure (3.3): ANP model framework

The third level is the sub-criteria clusters where environment cluster contains polluting materials, polluting activities, efficient water systems, renewable energy, renewable material use and energy systems nods. The quality cluster contains material reliability, customer satisfaction, construction defects, concurrent design drawings, material and activities waste nods. While cost cluster contains design, materials, labor, machines and operational cost nods. Finally, time cluster contains time wasters, extend the project duration in case of need and adhere to deadline nods.

The fourth level is the alternatives cluster contains two nods the conventional and green-lean construction alternatives as shown in Figure (3.3). It is worth mentioning that to complete the model a connection between the nods must be done according to the relation between these sub-criteria and nods. The next step is to enter the average of the experts' responses to the pairwise comparison. The idea of pairwise comparison will be discussed in the next section.

3.7.4 Pairwise comparison process

This process is used to make tradeoffs among criterion and sub-criteria, the judgments are usually made numerically as a score, which is a reciprocal pairwise comparison in a carefully designed scientific way.

Table (3.4) shows the fundamental judgments scale. In his process, the judgments are first given verbally, this judgment represents as indicated in the scale Table (3.4). The vector of priorities is the principal eigenvector of the matrix. This vector gives the relative priority of the criteria measured on a ratio scale.

Table (3.4): Fundamental Scale (Saaty, 2008)

1	Equal importance
3	Moderate importance of one over another
5	Strong or essential importance
7	Very strong or demonstrated importance
9	Extreme importance
2,4,6,8	Intermediate values
Use reciprocals for inverse comparisons	

Associated with the weights there are an inconsistency. The Consistency Index (C.I.) of a matrix is given by CI.= (λ-N)/(N-1). The Consistency Ratio (C.R.) is obtained by forming the ratio and the appropriate one of the following set of numbers shown in Table (3.5), each of which is an average random consistency index computed for N<10. They create randomly generated reciprocal matrices using the scale 1/9, 1/8,…, 1/2, 1, 2,…, 8, 9 and calculate the average of their eigenvalues. This average is used to form the Random Consistency Index (R.I).

Table (3.5): Random index (Saaty, 2008)

Order	1	2	3	4	5	6	7	8	9	10
R.I.	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

The priorities derived from pairwise comparison matrices are entered as parts of the columns of a super-matrix. A super-matrix one of it is general entry matrices is shown in Figure (3.4). The component C1 in the super-matrix includes all the priority vectors derived for nodes. Figure (3.5) gives the super-matrix of a hierarchy and Figure (3.6) shows the k_{th} power of that super-matrix which is the same as hierarchic composition in the (k,1) position.

The Super-matrix of a network

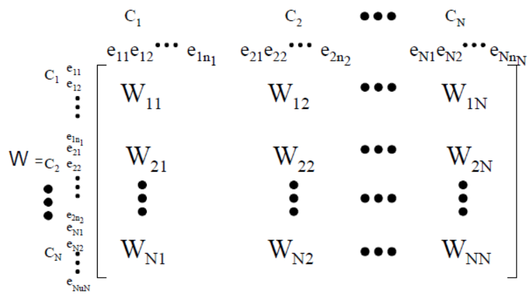

Figure (3.4): The Super-matrix of a network and detail of a component in it super-matrix of a hierarchy

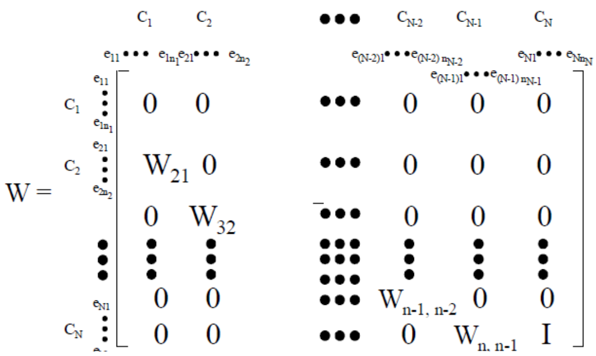

Figure (3.5): The super-matrix of a hierarchy

$$W^k = \begin{bmatrix} 0 & 0 & \cdots & 0 & 0 & 0 \\ 0 & 0 & \cdots & 0 & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & \cdots & 0 & 0 & 0 \\ W_{n,n-1}W_{n-1,n-2}\cdots W_{32}W_{21} & W_{n,n-1}W_{n-1,n-2}\cdots W_{32} & \cdots & W_{n,n-1}W_{n-1,n-2} & W_{n,n-1} & I \end{bmatrix}$$

Figure (3.6): The limit super-matrix of a hierarchy

In the ANP, we look for steady state priorities from a limit super matrix. To obtain the limit, we must raise the matrix to powers. The limit of these powers is equal to the limit of the sum of all the powers of the matrix. The outcome of the ANP is nonlinear and rather complex. The limit may not converge unless the matrix is column stochastic that is each of its column sums to one (Saaty, 2012).

Compute the limit priorities of the stochastic super-matrix according to whether it is irreducible (primitive or im-primitive) or it is reducible with one being a simple or a multiple root and whether the system is cyclic or not. Two kinds of outcomes are possible. In the first all the columns of the matrix are identical and each gives the relative priorities of the elements from which the priorities of the elements in each cluster are normalized to one. In the second the limit cycles in blocks and the different limits are summed, averaged, and again normalized to one for each cluster. Although the priority vectors are entered in the super-matrix in normalized form, the limit priorities are put in idealized form because the control criteria do not depend on the alternatives.

Synthesize the limiting priorities by weighting each idealized limit vector by the weight of its control criterion and adding the resulting vectors. The alternative with the largest ratio is chosen. This will be illustrated in the next numerical example:

The answers of the experts are calculated in a matrix, and then following steps are analyzed as in the next example.

In the first step, each column is summed as in Equation (1), we do a vertical summation for the answers. Then, each value are divided on its correspondent total summation to end with the Equation (2).

	A	B	C
A	1	.33	.5
B	3	1	2
C	2	.5	1
TOTAL	6	1.83	3.5

.... Equation (1)

In the second step, we calculate arithmetic mean for every horizontal row this matrix is called synthesized matrix.

	A	B	C	Arithmetic mean
A	.16	.18	.14	.16
B	.5	.55	.57	.54
C	.33	.27	.28	.30
TOTAL				1

…………………….. Equation (2)

In the third step, we take the calculated arithmetic mean for every row in equation (2) and multiply its correspond matrix from equation (1) as shown in equation (3).

$$.16\begin{bmatrix}1\\3\\2\end{bmatrix} + .54\begin{bmatrix}.33\\1\\.5\end{bmatrix} + .30\begin{bmatrix}.5\\2\\1\end{bmatrix} =$$

$$\begin{bmatrix}.16\\.49\\.32\end{bmatrix} + \begin{bmatrix}.18\\.54\\.27\end{bmatrix} + \begin{bmatrix}.15\\.60\\.30\end{bmatrix} = \begin{bmatrix}.49\\1.62\\.89\end{bmatrix}$$

……………… Equation (3)

In the fourth step, we talk the resulted values from equation (3) and divide everyone to its corresponded arithmetic mean from equation(2).

$(0.49 \div 0.16 = 3.02)..(1.62 \div 0.54 = 3.02)..(0.89 \div 0.30 = 2.98)$……………. Equation (4)

The fifth step, is to calculate lambda, this process is done by summing all the values resulted from equation (4) then divide on the total number of the analyzed variables.

$$\lambda_{max} = \frac{3.02 + 3.02 + 2.98}{3} = 3.01$$ …………………. Equation (5)

In the sixth step, we calculate the consistency index. This is done by subtracting the total number of the values from lambda then divide it on (n-1).

$$\text{Consistency Index (CI)} = \frac{\lambda_{max} - n}{n-1} = \frac{3.01 - 3}{3-1} = .0041$$ …………… Equation (6)

The final step, is to calculate the consistency ratio as shown in equation (7). The result must be less than 0.1 to make sure that the process is right.

$$\text{Consistency Ratio} = \frac{\text{Consistency Index (CI)}}{\text{Ratio Index (RI)}} = \frac{.0041}{.58} = .007 < .1$$ …………. Equation (7)

It is important to define the details of the criteria and sub criteria. The model consists of four criteria ,which are cost, quality, duration and environment aspects and 19 sub-criteria as shown in Table 3.2.

The priorities derived from pairwise comparison matrices are entered as parts of the columns of a super-matrix. The weighted super-matrix is obtained by multiplying all the elements in a component of the un-weighted super-matrix by the corresponding cluster weight and the un-weighted super matrix is the one that contains the local priorities derived from the pairwise comparisons throughout the network. Pairwise comparison is added into the questionnaire panel in the model as shown in Figure (3.4). All the responses were added to excel sheet to calculate the average of the answer to obtain the super matrix then entered in the super decision model.
During entry data, it is very important to check the inconsistency of the answers to be less than 0.1 in the third panel (Results) as shown in Figure (3.4).

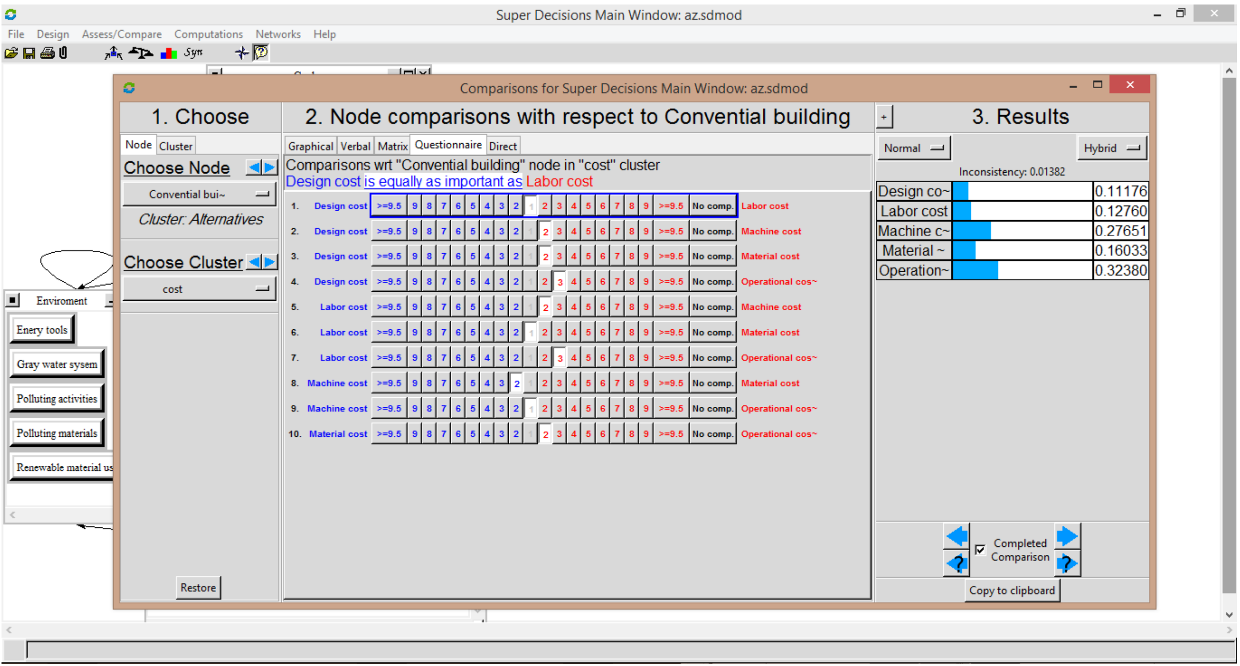

Figure (3.7): Super Decision Priorities

In the fourth step, super decision gives the priorities of criteria and sub-criteria and propose a preliminary order for the integrated green-lean framework as shown in Figure (3.5).

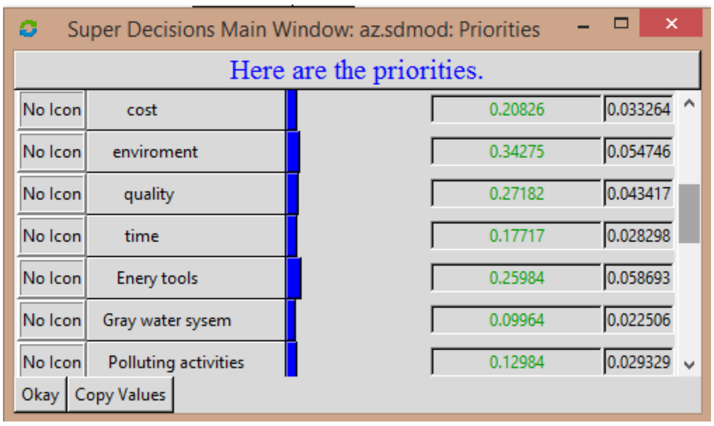

Figure (3.8): Super Decision Priorities

Analytical Network Process (ANP) is the first analyzing tool in the research, the next section discusses another tool which is Weighted Zero One Goal Programming (ZOGP) using the LINDO program, where more constraints were added to make the model more dynamic and realistic.

3.8. LINDO program analysis:

The weights of super decision where used as a coefficients for the objective value function in ZOGP model. Different scenarios were suggested to simulate real construction cases where one of the five cost sub-criteria (the operation, design, labor, machine and material) cost is fixed or all the sub-criteria were fixed as in real construction process. Table (3.6) shows that every sub-criteria is linked with a variable that indicated its condition whether it is minimized or maximized according to its negative or positive sign.

Table (3.6): The variable definition

	Criteria	Condition	Sign
X_1	Operation cost	Minimize	-
X_2	Machine cost	Minimize	-
X_3	Material cost	Minimize	-
X_4	Design cost	Minimize	-
X_5	Labor cost	Minimize	-
X_6	Renewable material	Maximize	+
X_7	Energy systems	Maximize	+
X_8	Polluting materials	Minimize	-
X_9	Polluting activities	Minimize	-
X_{10}	Water systems	Maximize	+
X_{11}	Concurrent design drawings	Maximize	+
X_{12}	Activities waste	Minimize	-
X_{13}	Materials waste	Minimize	-
X_{14}	Construction defects	Minimize	-
X_{15}	Customer satisfaction	Maximize	+
X_{16}	Materials reliability	Maximize	+
X_{17}	Adhere to deadline	Maximize	+
X_{18}	Project duration	Minimize	-
X_{19}	Time wasters in construction	Minimize	-

3.8.1 The formulation of the ZOGP:

The obtained weights from ANP are set as coefficients for objective function factors that should be maximized or minimized as shown in Table (3.6). The maximization process is given a positive sign while the minimization process is given a negative sign. The objective function is subject to the environment, quality, cost and time constraints. The detailed formulations are given the next paragraphs.

1. Objective function Minimize $\sum w_j d_i^+ + w_j d_i^-$

   Subject to :
2. $X_m - AY_m \geq 0$ X= cost variable, m=(1,2….5), A = amount in $
3. $Y_m + d_m^+ - d_m^- = 0$ m = 1,2,…..
4. $\sum_{m=5}^{1} Ym = 5$
5. $X_j + d_j^+ - d_j^- = 0$ j = 6, 7, ……19
6. $\sum_{j=19}^{6} Xj = B$ B= 5,6, ……19

The following paragraphs explain in details the previous equations

1. The first equation which is the objective value function

$$\text{Minimize} \quad \sum (w_j d_i^+ + w_j d_i^-) \ldots\ldots(1)$$

The maximization process is given a positive sign while the minimization process is given a negative sign.

- "w" : this is denoted by ANP weights and "j" : is the number of the sub-criteria except the fixed one that is the subject of the scenario.
- "d_1^+, d_1-" = the positive and negative deviation variables depending on its correspond condition in Table (3.6) for i= 1,2,….19 except fixed one that is the subject of the scenario.

2. The second inequality is :

$$X_m - AY_m \geq 0 \ldots\ldots(2)$$

- Where " X_m " is the variables of the cost sub-criteria as in Table 3.6, "m" is from 1 to 5
- "A" is for the paid money amount for the cost sub-criteria, which are \$2000 for the operational, \$4000 for the machine, \$180000 for the material, \$900 for the design and \$9000 for the labor costs in the concrete works.
- " Y_m " is variable of the sub-criteria except the excluded X_m which being analyzed in the scenario

$$Ym = \begin{cases} 0 & when\ the\ sub-criteria\ (m) are\ not\ selected \\ 1 & when\ the\ sub-criteria\ (m)\ are\ selected \end{cases}$$

3. The third equation is

$$Y_m + d_m^+ - d_m^- = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

- Where" Y_m " is variable of the sub-criteria except the excluded X_m which being analyzed in the scenario
- "m" is the numerical assumed number of the fixed sub-criteria correspond to Table (3.6).
- " d_m^+, d_m^- " = the positive and negative deviation variables of the fixed sub-criteria which is being analyzed in the scenario depending on its corresponding condition in Table (3.6).

4.The forth equation is

$$\sum_{m=5}^{1} Ym = n \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

- Where" Y_m " is a variable of the sub-criteria except the excluded X_m which being analyzed in the scenario
-
- "m" the assumed numerical number of the fixed sub-criteria in the scenarios correspond to Table (3.6).

5.The fifth equation

$$X_j + d_j^+ - d_j^- = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

- Where "X_j" is the integer variables of the sub-criteria except the fixed sub-criteria correspond to the given in table (3.6).
- "j" is the assumed numerical number of the sub criteria except the fixed sub-criteria correspond to the given in table (3.6).
- "d_j^+, d_j^-" = the positive and negative deviation variables of the sub-criteria except the excluded fix ones which are being analyzed in the scenario depending on its corresponding condition in Table(3.6), j= 1,2,….19 except fixed sub-criteria.

6.The sixth equation

$$\sum_{j=19}^{6} Xj = B \quad \text{……………………..........(6)}$$

- Where "X_j" is the variables of the sub-criteria except the fixed sub-criteria correspond to the given in table (3.6).
- "B" is the number of the sub-criteria that we want to work from 1 to 19 where "b" is control point that priories the sub-criteria to give the logical framework that we are looking for.

3.8.2 An example of Lindo format

In the case that the five cost sub-criteria are fixed X_1, X_2, X_3, X_4, X_5:

Minimize

$$12d_6^+ + 13d_7^+ + 14d_8^- + 15d_9^- + 16d_{10}^+ + 17d_{11}^+ + 18d_{12}^- + 19d_{13}^- + 20d_{14}^- + 21d_{15}^+ + 22d_{16}^+ + 23d_{17}^+ + 24d_{18}^- + 25d_{19}^- + 26d_1^- + 27d_2^- + 28d_3^- + 29d_4^- + 30d_5^-$$

Subjected to:

$$X_1 - 4000Y_1 \geq 0$$

$$X_2 - 8000Y_2 \geq 0$$

$$X_3 - 200000Y_3 \geq 0$$

$$X_4 - 500Y_4 \geq 0$$

$$X_5 - 6000Y_5 \geq 0$$

$$X_4 - 700Y_4 \geq 0$$

$$Y_1 + d_1^+ - d_1^- = 0$$

$$Y_2 + d_2^+ - d_2^- = 0$$

$$Y_3 + d_3^+ - d_3^- = 0$$

$$Y_4 + d_4^+ - d_4^- = 0$$

$$Y_5 + d_5^+ - d_5^- = 0$$

$$Y_1 + Y_2 + Y_3 + Y_4 + Y_5 = 5$$

$$X_6 + d_6^+ - d_6^- = 0$$

$$X_7 + d_7^+ - d_7^- = 0$$

$$X_8 + d_8^+ - d_8^- = 0$$

$$X_9 + d_9^+ - d_9^- = 0$$

$$X_{10} + d_{10}^+ - d_{10}^- = 0$$

$$X_{11} + d_{11}^+ - d_{11}^- = 0$$

$$X_{12} + d_{12}^+ - d_{12}^- = 0$$

$$X_{13} + d_{13}^+ - d_{13}^- = 0$$

$$X_{14} + d_{14}^+ - d_{14}^- = 0$$

$$X_{15} + d_{15}^+ - d_{15}^- = 0$$

$$X_{16} + d_{16}^+ - d_{16}^- = 0$$

$$X_{17} + d_{17}^+ - d_{17}^- = 0$$

$$X_{18} + d_{18}^+ - d_{18}^- = 0$$

$$X_{19} + d_{19}^+ - d_{19}^- = 0$$

$$X_6 + X_7 + X_8 + X_9 + X_{10} + X_{11} + X_{12} + X_{13} + X_{14} + X_{15} + X_{16} + X_{17} + X_{18} + X_{19} + Y_1 + Y_2 + Y_3 + Y_4 + Y_5 = B$$

INTE X_6 , INTE X_7, INTE X_8, INTE X_9, INTE X_{10}, INTE X_{11} , INTE X_{12} , INTE X_{13} , INTE X_{14} INTE X_{15} , INTE X_{16} ,INTE X_{17} , INTE X_{18} ,INTE X_{19} , INTE Y_1 , INTE Y_2 , INTE Y_3 , INTE Y_4, INTE Y_5

Chapter 4: Developing the green – lean frame work

Chapter 4: Developing the green – lean framework

In this study, a developed framework, which integrates green and lean techniques in the construction of the residential projects, were concluded. This developed framework would improve the economic and environmental performance of the projects.

The results of this study are reported in this chapter where the first section compares the weights of the main criteria (cost, quality, time and environment) and the sub-criteria for every main criteria, which concluded from the literature and experts point of view, followed by a sensitivity analysis of the criteria. The second section suggests a framework to implement the green-lean techniques in different scenarios.

4.1. Results of ANP model

In the ANP, the main goal is to prioritize the criteria and sub-criteria based on the analysis of the questionnaire answers, to find a reasonable green- lean framework through specific relationship and feedback between criteria and the sub- criteria given in this research. Through this chapter, an analysis will be done for the criteria, sub criteria and finally the alternatives weights as in Figure (4.1).

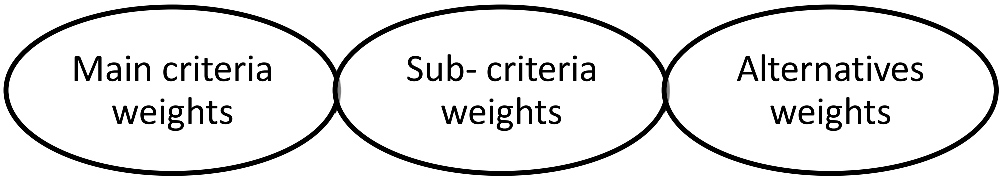

Figure (4.1): The sequence of the analyzing process through this chapter

4.2. Main criteria weights

This research analyzes the construction performance from four different aspects that formulate the main criteria of the research (environmental, quality, cost and time) criteria. Every criteria contain many sub-criteria, and through the analysis a study of the relation between these sub-criteria and their influence on each other were discussed and analyzed using analytical network process (ANP) as shown in the next sections.

Results indicate that the environmental criteria is the most important criteria that should be taken into consideration with a weight of 0.34. Quality and cost criteria weights are 0.27 and 0.21 respectively. Finally, the time criteria weighs 0.18 as shown in Table (4.1), which indicates that there is a tendency of experts to encourage promoting conventional construction to be greener and to focus the effort on the environmental side of the project and the high quality of the production even if it a bit little higher in the cost and takes more longer time than the traditional construction.

Table (4.1): Main criteria weights

Main criteria	Normal value	Limit super matrix
Environmental criteria	0.342	0.055
Quality criteria	0.271	0.043
Cost criteria	0.208	0.033
Time criteria	0.178	0.028
Total	1	

4.1.1 The environment sub-criteria weights

The environmental criteria weighs 0.34, which indicates that it is time to adopt new changes and make the construction process more sustainable, which will surely affect the construction environmental as shown in Table (4.2). The next paragraphs discuss the environmental sub-criteria result separately.

Table (4.2): Enviroment sub criteria weights

Environment sub-criteria	Normal value	Limit super matrix
Renewable material use	0.301	0.068
Energy systems	0.260	0.059
Polluting materials	0.211	0.048
Polluting activities	0.128	0.029
Water systems	0.099	0.022
Total	1	

1. As for the **renewable material use sub-criteria**, the results confirm that renewable material is an important sub-criterion weighs 0.068 as shown in Table (4.2). This highly affects the energy consumption of the building and its performance with respect to the environment.

2. When it comes to **the energy systems sub-criteria**, the results show that appropriate energy systems (photovoltaic, thermal, biomass and wind) weigh 0.058, which means that this sub-criteria should highly be taken into consideration, especially that Palestine is a developing country that suffers from energy problems and an increase in the pollution, poor resources of energy and inefficient use of them.

   The reason behind this high rank can be attributed to the absence of fossil fuel resources. Palestine imports all it needs of petroleum products from Israeli market and about 92% of electrical energy from the Israeli Electric Corporation (IEC). Indigenous energy resources are quite limited to solar energy for photovoltaic and thermal applications (mainly for water heating), and biomass (wood and agricultural waste) for cooking and heating in rural areas, while the potential of wind energy is relatively small but not yet utilized in Palestine.

3. It is found that **polluting materials sub-criteria** ranked third and weighs 0.047 as shown in Table (4.2). This sub-criteria is concerned with reducing the polluting materials in construction and encouraging the use of green materials instead, for example, replacing the asphalt with foam in the isolation work in construction. The main idea is to protect the environment through eco-design, design for the environment, design for reuse, remanufacture and recyclability, reduction or elimination of toxic materials, and the use of environmentally friendly materials (Dhingra, et al., 2014).

4. As for **polluting activities sub-criteria**, Table (4.2) shows that decreasing the polluting activities in the construction weighs 0.029, which reflects the need to be more careful when dealing with such activities. It is fundamental to enhance the health conditions, for the labors who work on construction and occupants who will use the facility.

5. **Water systems sub-criteria** weighs 0.022. This can be attributed to the fact that Gaza strip suffers from the lack of water resource, so we need to promote the efficiency of the water use, waste water treatment and conservation techniques in the building.

4.1.2 The cost sub-criteria weights

The research analyzes many cost scenarios that affect the proposed framework to integrate the traditional construction with green-lean techniques as shown in Table (4.4). This includes the design, labor, material, machine and operation costs.

Table (4.3): Cost sub criteria weights

Cost sub-criteria	Normal value	Limit super matrix
Operational cost	0.306	0.043
Machine cost	0.260	0.037
Material cost	0.172	0.024
Design cost	0.129	0.018
Labor cost	0.132	0.019
Total	1	

The budget of the project determines many serious limitations, for example, the area of the building, types of the used materials in the project, types of equipment, which heavily affect the decision of using green-lean techniques or not, as it needs a higher initial cost.

1. **The operational cost sub-criteria** ranked as the first cost sub-criteria with a weight of 0.043. Barrie, et al. (1992) illustrated that design fees are less than 10% of total construction costs, while construction costs are less than the operation cost. This means that the operational cost is the biggest cost during the life cycle of the building. So, studying carefully the value that the customer wants to achieve in the final product, will help the designer to prepare the building in the design phase for these values with the least possible cost savings and high ability to predict and control the expected defects on the projects, which minimize the total cost of the project.

2. **Machine cost sub-criteria** ranks as the second with a weight of 0.036, this high rank can be justified by the fact that machines save time, money and give a sequence reliable performance.

3. While **material cost sub-criteria** is the third, which weighs 0.024. It is reasonable that using new materials in construction, especially if these new materials reduce the negative impact of the construction project on the environment and society. The material cost has a higher weight than the labor cost due to the fact that the material cost is significant in the traditional cost when compared design and labor costs. On the other hand, the **labor and design cost sub-criterion**, ranked fourth with a weight of 0.018 as shown in table (4.2) for both which indicate that the contractors prefer to pay for using machines in the construction more than using the human labor force when compared to the weight of machine sub-criteria. When it comes to the design cost sub-criteria, even it is in the fourth rank; it is still important and has a high effect on the construction cost and duration.

4.1.3 The quality sub-criteria weights

When analyzing the quality sub-criteria (concurrent design drawings, activity waste, material waste, construction defects, customer satisfaction and reliability of the used material), the results show that solving conflicts between the concurrent drawings in the design phase before moving to the next step- real implementation – is in the highest rank with a weight of 0.044 as shown in Table (4.3). The next paragraphs will talk about each cost-sub-criteria separately.

Table (4.4): Quality sub criteria weights

Quality sub-criteria	Normal value	Limit super matrix
Concurrent drawings	0.248	0.045
Activities waste	0.230	0.042
Material waste	0.224	0.040
Defects	0.116	0.021
Satisfaction	0.103	0.019
Material reliability	0.077	0.014
Total	1	

1. **As for concurrent drawings sub-criteria**, it has the highest weight of 0.044. This can be attributed to the fact that solving the conflicts between the specialized drawings (architect, civil, mechanical, electrical) in the design phase, will highly minimize the defects and misunderstanding of the drawings and their implementation, which will directly affect the cost and duration of the construction project.

2. The weight of activities and material waste sub- criterion are 0.042 and .0.040, as shown in Table (4.2). It is obvious that construction is a challenging field, where activities require careful planning and effective management because of the high volume of construction activities, the creation of poor-quality products and harmful environmental impact; excessive production of waste and excessive use of natural resources. Also, the results show that reducing the material waste sub-criteria has a relative importance to concurrent drawings and activities waste sub-criteria due to the fact that the material occupies a large percentage of the construction cost.

3. For **defects sub-criteria**, it weighs 0.021, where the defects may occur when the final or intermediate product does not fit the quality specifications. This may be due to the lack of experience of the labor, misunderstanding of the design drawings, inclement weather, and accidents. It is known that decreasing these sub-criteria will increase the work quality, saves time and cost.

4. **In the customer satisfaction sub-criteria,** results show that the customer needs have to be met. So, the weight of committing to the customer requests is 0.018. This means that the designer should use his experience and convince the customer of using the value added activities and tools, for example, using the photovoltaic systems to generate the energy for the building even if its initial cost was a little more than usual and to convince him with the benefit in the long term.

5. For the **material reliability** sub-criteria, has the last rank even though this sub-criteria is responsible for a high percentage of the environmental impacts. The material reliability

weight is 0.014 indicating that the designers require using new materials in design, especially if these materials have environmental, economic and social advantages.

4.1.4 The time sub-criteria weight

The construction projects never end at the scheduled time. Therefore, the need to manage the time criteria weighs 0.18 as shown in Table (4.5). Further analysis of the sub- criteria weights will be discussed in the next paragraphs.

Table (4.5): Time sub criteria weights

Time sub-criteria	Normal value	Limit super matrix
Adhere to deadline	0.615	0.080
Project duration	0.238	0.031
Time wasters	0.147	0.019
Total	1	

1. **Adhere to deadline sub-criteria**, the results show that meeting the deadline is the most important time sub-criteria with a weight of 0.080. This could be justified due to many reasons, for example, the construction penalty payment and resources overload in case of delay.

2. **Project duration sub-criteria,** the results show that in case, the project faces unpredicted circumstances that affect its performance and cannot be solved without exceeding the deadline, the decision maker prefers to stick to the deadline, therefore the weight in a case like the mentioned above is 0.03 as shown in Table (4.2).

3. When it comes to **time wasters sub-criteria,** the results show that minimize time wasters sub-criteria weighs 0.019, where the time performance of the construction industry is perceived as un-satisfactory when compared to other industries (Song, etal., 2010). It is suggested to decrease the non- value added wasters in the activities or in the materials will improve the time performance. This sub-criteria has the lowest rank due to the fact studying the time wasters in a project and suggesting alternatives for it, then using it takes a lot of time and thinking while the project is highly time limited. So, some experts suggested that experts to

try and evaluate these new alternatives in academic projects and track its result before generalize the new methods in the construction projects.

4.1.5 Alternatives comparison

Alternatives performance with respect to the criteria and sub-criteria are given in Table (4.6) and (4.7), (4.8), (4.9), (4.10). Results show that in the green-lean alternative, the environmental criterion has the highest rank as it weighs 0.33. The second highest rank is the quality criteria 0.27, then the time criteria weighs 0.23 and finally, cost criteria, is in the last rank and weighs 0.17 as shown in Table (4.6).

On the other hand, in the traditional alternative, time criteria has the highest rank weighs 0.35. cost criteria is in the second rank and weighs 0.32 as shown in Table (4.6). The quality is in the third rank and weighs 0.19, while the environmental criteria is in the last rank and weighs 0.13.

Table (4.6): Alternatives performance with respect to the main criteria

Main criteria	Green – lean	Traditional
Environmental criteria	0.33	0.13
Quality criteria	0.27	0.19
Time criteria	0.23	0.35
Cost criteria	0.17	0.32

As for the performance of the two alternatives weights on the environment sub-criteria, renewable materials weighs 0.197 on the green-lean alternatives. For the energy system sub-criteria, the green-lean has a weight of 0.206 while traditional alternative weighs 0.227. For the polluting materials, activities and efficient water systems have the same weight of 0.199 in the green-lean alternative, the case is different in traditional alternative for the same sub- criterion with a weight of 0.264, 0.20 and 0.164 respectively as shown in Table (4.7).

Table (4.7): Alternatives performance with respect to environment sub-criteria

Environment sub-criteria	Green – lean	Traditional
Energy systems	0.206	0.227
Renewable material use	0.197	0.145

Polluting materials	0.199	0.264
Polluting activities	0.199	0.200
Water systems	0.199	0.164

For the quality criteria, it is obvious that green-lean focuses on decreasing the non-value added activities and materials, so it is not strange that decreasing the material waste in green-lean has the highest weight 0.184 in the quality criteria. Furthermore, decreasing this sub-criteria is very important in the traditional alternative too with a weight of 0.161 as shown in Table 4.8. This can be explained by the fact that decreasing the waste will directly guarantee a decrease in the total cost of the project, an increase in its quality and a decrease in the total project duration.

Table (4.8): Alternatives performance with respect to quality sub-criteria

Quality sub-criteria	Green – lean	Traditional
Material waste	0.184	0.161
Concurrent drawings	0.181	0.148
Activities waste	0.16	0.174
Material reliability	0.167	0.125
Satisfaction	0.155	0.219
Defects	0.153	0.174

In the cost sub-criteria, operational cost has the highest rank; it weighs 0.283 in the green-lean alternative, while it has the last rank and weighs 0.121 in the traditional alternative as shown in Table (4.9).

Table (4.9): Alternatives performance with respect to cost sub-criteria

Cost sub-criteria	Green – lean	Traditional
Operational cost	0.283	0.121
Machine cost	0.204	0.211
Labor cost	0.196	0.208
Design cost	0.167	0.217
Material cost	0.15	0.243

Weights are close for both alternatives green-lean and traditional for time sub-criteria, since both consider adhere to deadline sub-criteria have the highest rank that should be taken into consideration with a weight of 0.341 in the green-lean alternative and 0.344 in the traditional alternative.

Table (4.10): Alternatives performance with respect to time sub-criteria

Time sub-criteria	Green – lean	Traditional
Adhere to deadline	0.341	0.344
Project duration	0.318	0.338
Time wasters	0.341	0.318

4.3. Sensitivity analysis

In order to gain more insights into the problem and make the model more dynamic, sensitivity analysis was performed for the main criteria environment, quality, cost, and time, the next section show the results: Figure (4.2) shows the trend of conventional and green-lean where it is seen that any increase in the parameter value (the horizontal axis) increases the performance of green-lean and decreases the performance of the traditional alternative as in equation (1).

Parameter value = α * alternative (1) + (1- α) alternative (2) ………………(1)

Where, alternative 1: first alternative which is here (green – lean alternative) and alt 2 : second alternative which is (traditional/ conventional alternative).

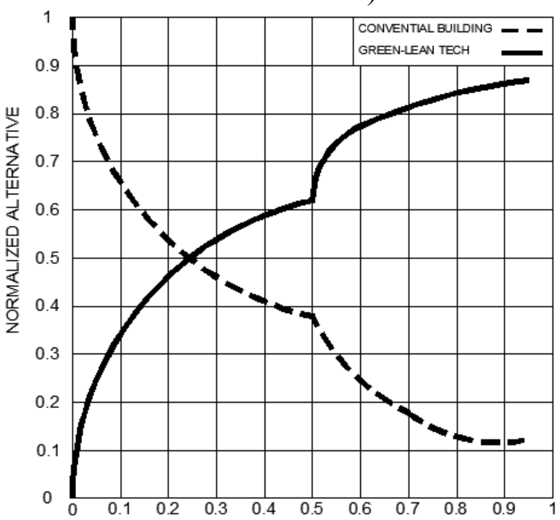

Figure (4.2): Sensitivity analysis of the alternatives performance

Normalized alternative (the vertical axis) represents numerically the integrated relation between the alternatives and the sub-criteria. This means that at the start of the project, there are two situations, in case the decision maker does or does not take any of the criteria and sub-criteria into consideration.

1. When the decision maker doesn't implement the green – lean criteria and sub-criteria, then α * alternative (1) = 0 , then the parameter value of green –lean alternative is zero and the traditional alternative (1- α) alternative (2) = is at it is highest value =1 and the green-lean alternative is at the lowest value zero as shown in Figure (4.2). As the sub-criteria are being taken into consideration, the preference of the traditional practices decreases, while the green-lean preference increases.
2. As the demand for fulfillment the sub-criteria increases (horizontal axis -parameter value), the traditional alternative fails in satisfying the sub-criteria in an optimum value as the green- lean does. The traditional normalized value decreases, while the green–lean increases, when considering the sub-criteria.
3. When the decision maker does implement all the green – lean criteria and sub-criteria, then its parameter value is approximately 0.98, while the traditional alternative is approximately 0.12. It is obvious from Figure (4.2) that the green – lean trend can't reach the value 1, also the tradition doesn't fall to a zero value. This is due to the fact the there is more criterion that has a small influence in the trend of the alternatives affects its values.

4.2.1 Main criteria**:**

For the environmental criteria, Figure (4.3) shows that green-lean practices are concerned with the environmental issues more than the traditional practices, where green-lean weight ranged from (0.767 to 0.863), while the traditional practices ranged from (0.137 to 0.233) as the importance of the environment criteria increases from (0 consideration to 1 fully consideration).

Figure (4.2) shows the trend of green- lean performance increases as the parameter in the horizontal axis increases (consideration of the environmental criteria in the project); also it shows that the performance of traditional practices decreases.

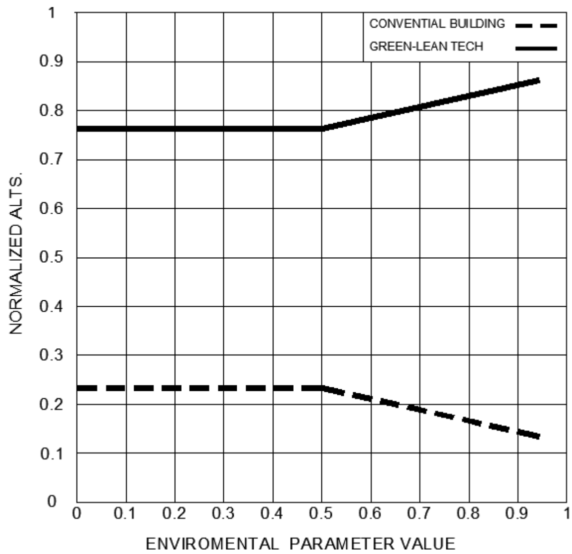

Figure (4.3): Sensitivity analysis of environment criteria

It is obvious from Figure (4.3) that the green-lean alternative performance is higher than that of the traditional, which reflects the need for promoting the environmental awareness in the construction works and the maintenance of building's impact on the environment. These works can cause irreversible changes in the climate of the all over world, atmosphere, and ecosystem. Buildings are a significant source of greenhouse gas emissions and in particular CO_2, and unless action is taken (Reeves, 2002).

The sensitivity analysis in Figure (4.4) shows that green-lean performance in respect to the quality criteria ranged from (0.766 to 0.863), while the traditional performance ranged from (0.234 to 0.137). This indicates that integrating the traditional alternative with green–lean construction will increase the quality of the construction project.

This trend could be explained by Dhingra, et al., (2014) that "green- lean construction is about reducing waste, increasing productivity and meeting the customer's satisfaction" which will improve the quality of the construction process.

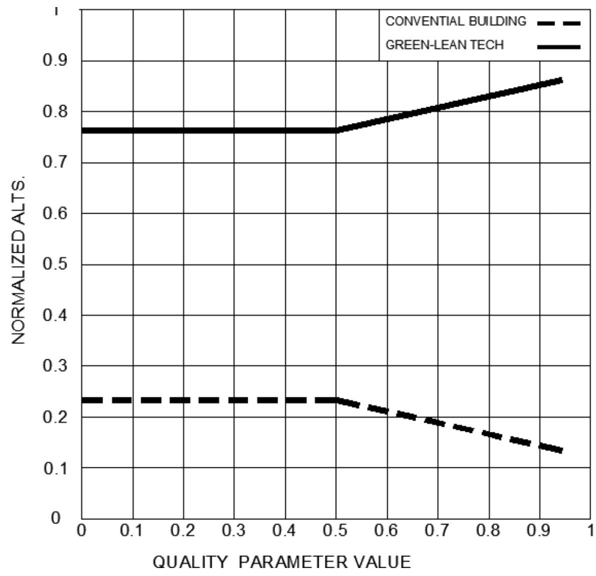

Figure (4.4): Sensitivity analysis of quality criteria

As for the cost criteria, Figure (4.5) shows an increase in the green-lean performance ranged from (0.766 to 0.863), while the traditional alternative decreases from (0.237 to 0.137). The results indicate that it are acceptable to increase the initial cost of the construction if its long-term life cycle benefits are more valuable than the traditional construction life cycle.

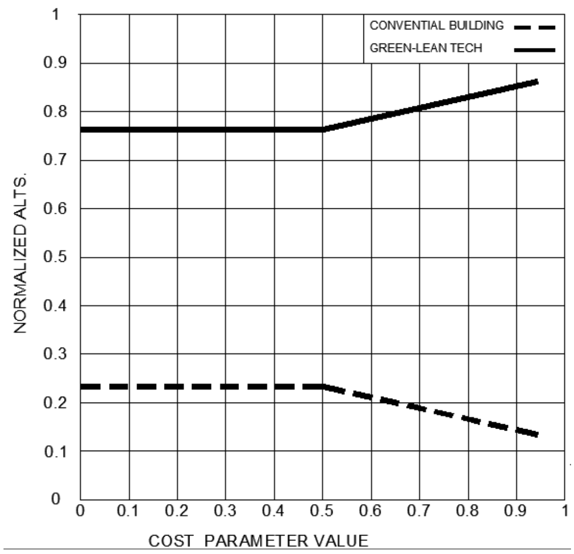

Figure (4.5): Sensitivity analysis of cost criteria

In regard to time criteria, Figure (4.6) shows an increase in the green-lean performance that ranged from (0.769 to 0.866), while the traditional construction performance decreases from (0.231 to 0.135). These values are similar to the cost sensitivity analysis, which indicates that there is a slight range of acceptance to increase the total project duration, if this increased duration affects positively on the environmental, economic and social performance.

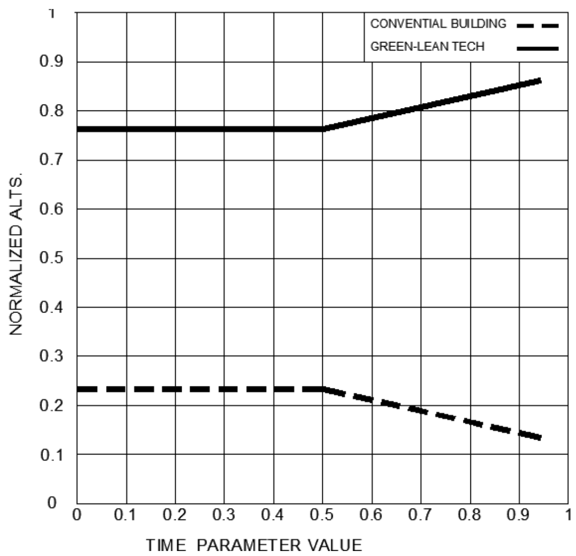

Figure (4.6): Sensitivity analysis of time criteria

4.4. Suggested framework using Zero- One Goal Programming

In order to provide a systematic approach to use the resulting ANP weights among multi – criteria and trade- off among objectives, a Zero- One Goal Programming (ZOGP) is used to handle these multiple objectives and seeks to minimize the total deviations from the desired goals. ZOGP determines near optimum and realistic framework in different scenarios.

The weighted goal-programming model considers all the goals simultaneously by forming an achievement function that minimizes the total weighted deviation from all the goals stated in the model. The weights are not preemptive but reflect the decision makers' preferences regarding the relative importance of each goal.

Steps to construct ZOGP model:

- The first step is to obtain the relative weights of the multi-criteria decision problem that we had, to determine the degree of impact or influence between the criteria, sub-criteria and alternatives, which has been done using (ANP).
- The second step is to use the obtained weights from the (ANP) to formulate (ZOGP) model. The solution to ZOGP will provide a framework that identifies and rank sub-criteria inclusion.

4.4.1 Formulation of zero- one goal programming:

The main idea of the model is to answer the question of " what is the near optimum framework to work on, when certain amounts of cost are assigned?".

4.4.1.1 First scenario:

Zero- One Goal Programming (ZOGP) model is used to identify which sub-criteria to work on to maintain the objective function in its near optimum value. The idea is to determine which sub-criteria should be taken into consideration in case of limited budget.

It is assumed that the operational cost = $20000, machine cost = $4000, material cost = $180000 design cost = $900 and labor cost = $9000, but it is worth mentioning that values are just indicators and do not restrict to the produced sub-criteria order. The used formulation are discussed in the methodology chapter and were applied in different scenarios as discussed in the following paragraphs.

In the first scenario, the five cost sub-criterion were assigned a fixed budget; these five different sub-criteria were excluded from the ordering process, to determine the priority for including the other sub-criteria as a shown in Table (4.11).

Table (4.11): Results of the first scenario

		6	7	8	9	10	11	12	13	14	15	16	17	18	19
6	Concurrent drawings														
7	Energy systems														
8	Water use														
9	Renewable material														
10	Material reliability														
11	Adhere to deadline														
12	Satisfaction														
13	Defects														
14	Polluting activities														
15	Time wasters														
16	Polluting materials														
17	Material waste														
18	Activities waste														
19	Project duration														

ZOGP analysis results showed that concurrent drawings sub-criteria is in the first rank to guarantee a green-lean process when the decision maker wants to apply just one criteria as shown in Table (4.11), this criteria means to identify the conflict that might appear between the different specialized drawings (architect, civil, mechanical, electrical) at an early stage. In addition to that, this criteria enables the decision maker to define the value added and non-value added materials and activities to ensure the near optimum allocation of the resources.

Energy systems sub-criteria comes in the second rank, this is reasonable due to the fact that green-lean construction is concerned with the overall life cycle of the construction. Therefore, the energy system decreases the life cost despite its high initial cost when compared to the traditional construction. The energy systems involved installing photovoltaic solar cells, replacing regular windows with double-glazed ones, replacing incandescent bulbs with compact fluorescent light bulbs, replacing traditional block with double wall from CEB blocks.

Water systems are in the third rank when the decision maker wants to work on three sub-criteria. Water systems are also very important sub-criteria, especially that Palestine is approaching the point where water demands would exceed supply. This situation will necessitate improved decision making for water resources planning, proper management of the demand is an important step to achieve the water balance and ensure that water use for a range of beneficial purposes is sustainable.

As the decision maker expands his needs and the implementation of green-lean techniques more sub-criteria keep appearing to open new ways to promote the traditional alternative to be more green- lean. When the decision maker wants to implement four sub-criteria, that means the previous three criterion should be adopted and also to employ the renewable material sub-criteria which is defined as sustainable materials, means according to the Rutgers University Center (RUC) for sustainable materials, the materials that do not use up non-renewable resources.

Material reliability and adherence to deadline are in sixth and seventh ranks when the decision maker needs to implement six or seven sub-criteria. This means that it is important for the decision maker to use reliable material and in case he uses new material as green–lean encouraged, then adherence to the deadline should be taken into consideration from the early start of the project.

Customer satisfaction is an important issue, but it does not come in the highest order due to the fact that green-lean techniques relies essentially on the requirements of the customer and define the value and outcomes of the project based on the customer needs from the start of the construction design process.

Defects could be a critical issue in the construction process; however, considering the previous sub-criteria will help a lot in avoiding the defects in the project. Therefore, if there are still defects, then the decision maker must consider fixing them. So, decreasing the defects comes as the eighth sub-criteria.

A summary of the previous discussion shown in Figure (4.7) where all the sub-criteria ranked according to their contribution to the total objective function value. It is worth mentioning that there are some sub-criterion have the same objective function value. This means, for example if the decision maker decided to use just one criteria to organize his work, he will get the same result -objective function value- if he employed 8 sub-criteria (concurrent drawings, increase the energy systems, efficient water use, renewable material, reliable material use, adhere to deadline, satisfaction, reduce defects). However, including more sub-criterion will increase the penalty of the project as shown in Figure (4.7).

Knowing that will encourage the decision maker to expand his promoting plan to be more green-lean plan. After the eight sub-criteria, the objective function value starts to increase.

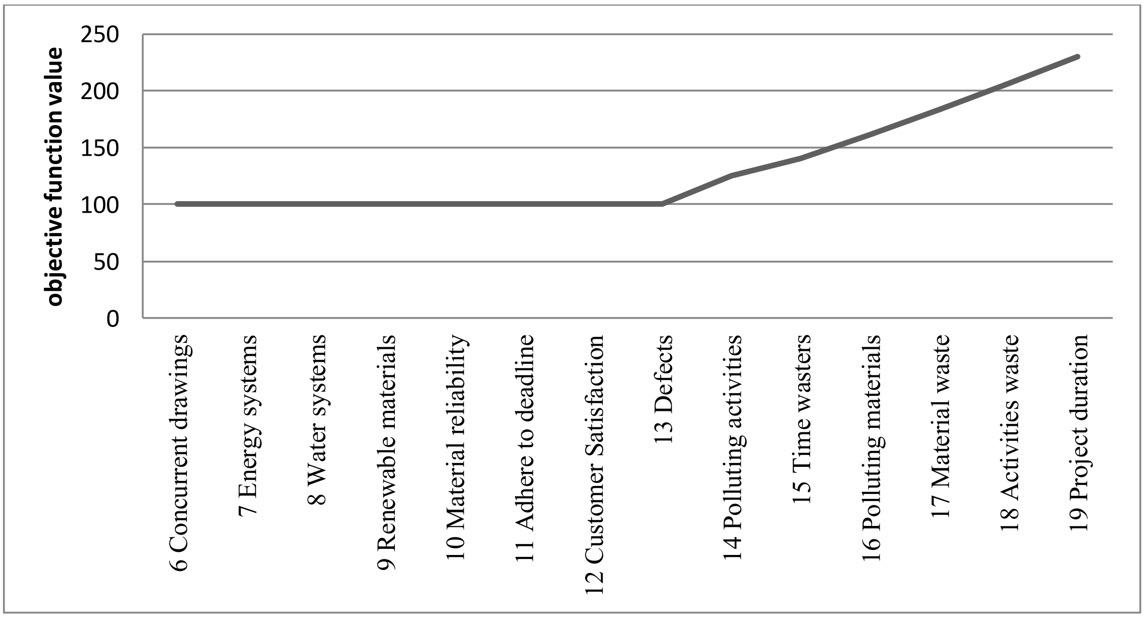

Figure (4.7): Relation between sub-criterion rank and Objectives function value where all cost sub-criterion is fixed(first scenario)

4.4.1.2 Comparison between ANP and ZOGP results:

The next results obtained when fixing the cost criteria, which means to determine a specific cost for design, material, machine, operational and labor sub-criteria. Table (4.12) shows the order of the sub-criteria. It is obvious that the order is not the same; this is due to the fact that ZOGP model has more constraints; makes the results more realistic.

Table (4.12): ANP and ZOGP ranking

	ANP rank	ZOGP rank
Material reliability	6	10
Satisfaction	7	12
Time wasters	8	15
Defects	9	13
Water systems	10	8
Polluting activities	11	14
Project Duration	12	19
Material waste	13	17
Activities waste	14	18
Concurrent drawings	15	6
Polluting materials	16	16
Energy systems	17	7
Renewable material	18	9
Adhere to deadline	19	11

According to ANP results, the material reliability has the first rank, this could be attributed to the fact that green-lean techniques suggest that the construction requires periodic update for the used material mainly if these materials have environmental, economic and social advantages.

On the other hand, ZOGP suggested more realistic framework where the concurrent drawings is in the first rank, a well preparing for the drawings, solving the concurrent conflicts, accurate bill of quantity will affect highly on project duration, quality and cost.

As shown in Figure (4.8), as more sub-criterion been taken into consideration, more positive performance is occurring. It is worth mentioning that ANP framework, classified the adhere to deadline sub- criteria in the last rank, which indicate that the project duration is important in green-lean construction, however, it is not a holistic and could be exceeded if this exceeds benefit the project in the long term.

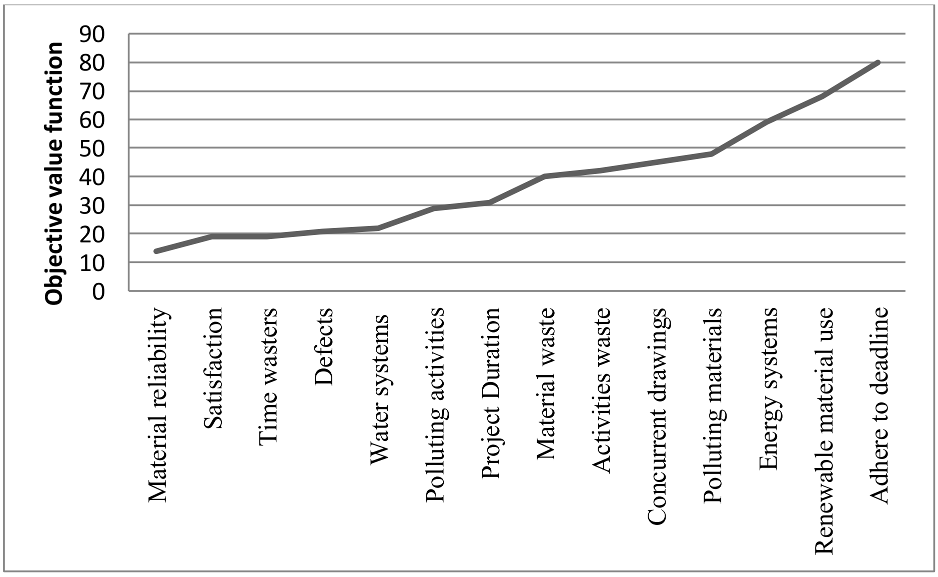

Figure (4.8): ANP ranking

Figure (4.8) shows the case when more constrains is added to the weighted rank of ANP in a shape of ZOGP analysis, this will produce a more realistic, stable and balanced green-lean framework.

A lot of modification occurred in the proposed framework as shown in Figure (4.8), where the concurrent drawings sub-criteria has the first rank-lean technique. This sub-criteria enables the decision maker to think more about the project in the design phase, reduce the conflicts between the concurrent drawings, decreases misunderstanding about the implementation process, to smartly balance between time, cost, quality and environment impact in the early start of the project and takes the needed modification with the least cost.

Energy systems sub-criteria is in the second rank to be taken into consideration in the early stages of the life cycle of the project, will highly improve the construction environmental and economic performance. This illustrates the important role of green-lean thinking from the early start of the project mainly in the design phase to maximize the gained benefit of the green-lean framework.

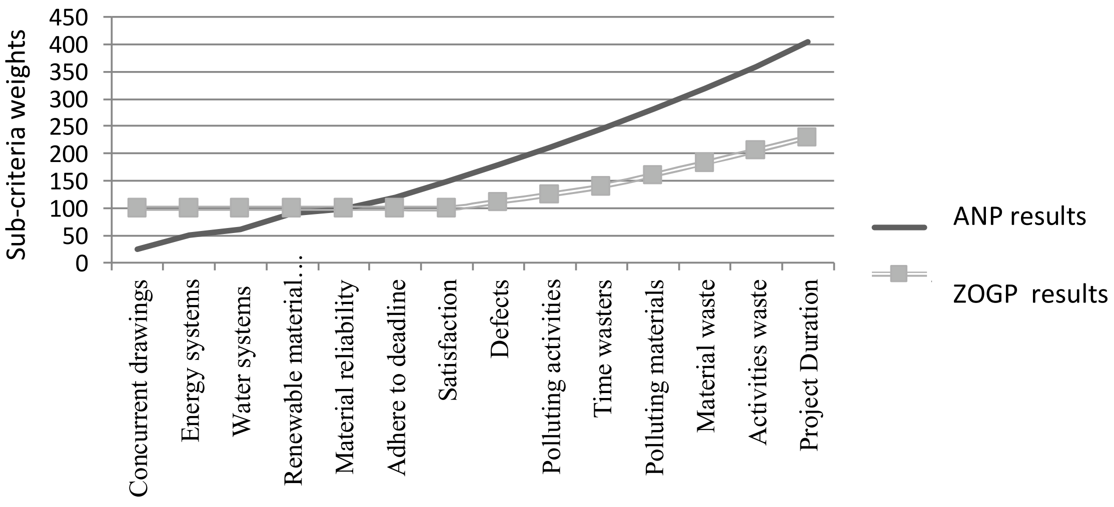

Figure (4.9): Comparison between ANP and ZOGP results

Figure (4.9) compares between the ANP and ZOGP results, where it's obvious that ANP and ZOGP improves the performance of traditional framework, however, ZOGP gives a more realistic framework that promote the economic and environmental performance with the same cost, time, quality, resource constraints. The results indicate that there are eight green –lean sub-criterion the decision maker can work on without exceeding the tradition construction constraints as occurs in the Figure (4.9) which are to solve concurrent drawings if the decision maker want to employ one sub-criteria. If he want to employ two sub- criteria then it's advisable to work on energy systems sub-criteria. The total cost of green-lean framework is the same cost of traditional construction for the first eight sub-criterion as in Figure (4.9).

Green – lean is not necessarily expensive, with right approach green-lean techniques can keep the construction process clean and safe without exceeding the cost and time limitations. It's all about smart managing for the sub-criterion that affects the construction to meet the decision maker requirements with close to optimum quality, efficient employing for the resources, respecting the deadline and the total cost of the project with clean innovations.

4.4.1.3 The second scenario:

The second suggested scenario is when the decision maker has a fixed budget for each of the cost sub-criteria, every case has its specialty and proposed order to implement the green-lean framework, where inequality (2) as in the explained formulation in chapter (3), were modified in the model

$$X_m + AY_m \geq 0.............(2)$$

- Where " X_m" is the variables of the cost sub-criteria as in Table 3.6, "m" is from 1 to 5
- "A" is for the cost sub-criteria, which are \$2000 for the operational, \$4000 for the machine, \$180000 for the material, \$900 for the design and \$9000 for the labor costs in the concrete works.
- " Y_m " is variable of the sub-criteria except the excluded X_m which being analyzed in the scenario

$$Ym = \begin{cases} 0 & when\ the\ sub - criteria\ (m) are\ not\ selected \\ 1 & when\ the\ sub - criteria\ (m)\ are\ selected \end{cases}$$

As shown in Table (4.13), for the fixed operational cost X_1 case, customer satisfaction has the first priority and the decision maker needs to make sure to use reliable materials that the materials he used will get the needed results taken into consideration adhering to deadline of the project to avoid penalty payments among other predicted problems.

Solving conflicts in concurrent drawings in the design before tender preparation stage will highly speed up the work and increase its quality and work performance.

The results indicate that if it is acceptable to work on more than five sub-criteria, it is worth working on improving water systems to promote traditional construction is in the sixth rank. Energy systems sub-criteria is added to the other previous sub-criteria when the decision maker wanted to work on seven green- lean criteria, working on this criteria will enable the construction process to be more sustainable and economical in the long term.

When the operational cost is fixed, the machine cost will be the last sub-criteria to be taken into consideration as shown in Table (4.13).

In the case of a fixed machine cost, the sub-criteria are the same as if the operational cost was fixed. However, in this order the operational cost is the last sub-criteria to be taken into consideration.

The fixed the material cost case, has the same results as in the fixed operational and material cost, the same criteria affects the objective function value (material cost, satisfaction, reliable material use, adhere to deadline, organize concurrent drawings, efficient water use, increase the energy systems and renewable material).

A slight difference appears in the order of reduce polluting activities and reduce material waste sub-criteria. Also, the order of the polluting material takes the order 14, reduce material waste at the order 15, reduce activities waste at the order 16, reduce total project time at the order 17 and finally the machine cost at the order 18.

In fixed the design cost X_4, the order of the sub-criteria changes from the other cases. It is very important to use reliable material that achieves the customer requirement at the least cost and time, using the energy systems (photovoltaic cells…….) will affect highly on the sustainability of the project.

As for a fixed labor cost X_5 is used, the new order is similar to the order of operational, machine cost and material cost.

Table (4.13): The effect of fixing cost X1, X2,X3,X4,X5 on sub- criterion rank

		Operational cost X_1	Machine cost X_2	Material cost X_3	Design cost X_4	Labor cost X_5
1	Operational cost	1	19	19	19	19
2	Machine cost	19	1	18	18	18
3	Material cost	14	14	1	13	13
4	Design cost	11	11	11	1	10
5	Labor cost	10	10	10	11	1
6	Renewable material	8	8	8	4	8
7	Energy tools	7	7	7	3	7
8	Polluting materials	15	15	14	14	14

9	Polluting activities	12	12	12	10	11
10	Water systems	6	6	6	8	6
11	Concurrent drawings	5	5	5	7	5
12	Activities waste	17	17	16	16	16
13	Material waste	16	16	15	15	15
14	Defects	9	9	9	9	9
15	Satisfaction	2	2	2	6	2
16	Material reliability	3	3	3	2	3
17	Adhere to deadline	4	4	4	5	4
18	Project duration	18	18	17	17	17
19	Time wasters	13	13	13	12	12

4.3.1.4 Effect of cost sub-criteria cases on the objective function value:

For fixed cost X_1, X_2, X_3, X_5 cases, Figure (4.10) shows that the first eighth sub-criteria have the same objective value function and wouldn't affects the regular construction cost. This encourages the decision maker to promote his construction process based on at least 8 sub-criteria which are satisfactory, material reliability, adhere to deadline, concurrent drawings, water systems, energy systems and renewable material. If the decision maker takes these sub-criteria into his consideration, a wide range of modification will appear in the construction process and tangible effects would be felt.

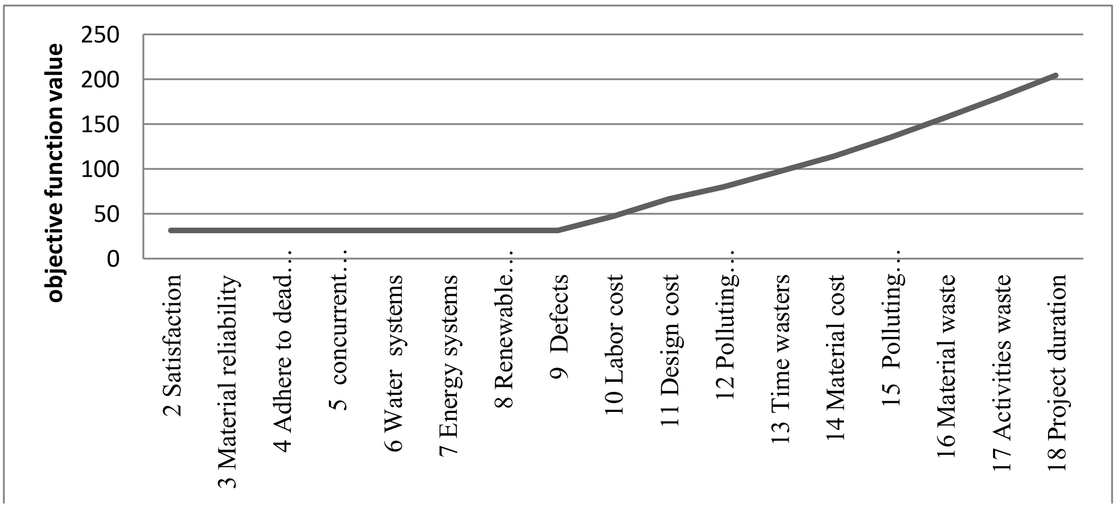

Figure (4.10): Relation between sub-criteria and Objective function value where the fixed value cost cases X_1, X_2, $X_3$and X_5were analyzed

When the design cost X_4 is fixed, Figure (4.11) shows the effects of the criteria on the objective value. It's obvious from the figure that X_4 has different sub-criteria arrange from the previous cases, this indicates to the strong relationship between the design cost and the period/ cost of the project. Having a good design cost/period leads to well-prepared design/drawings, mainly if green-lean techniques and the given framework were followed. These are eighth sub-criteria that have the same objective function value which are satisfactory, material reliability, adhere to deadline, concurrent drawings, water use systems, energy systems and finally renewable material use.

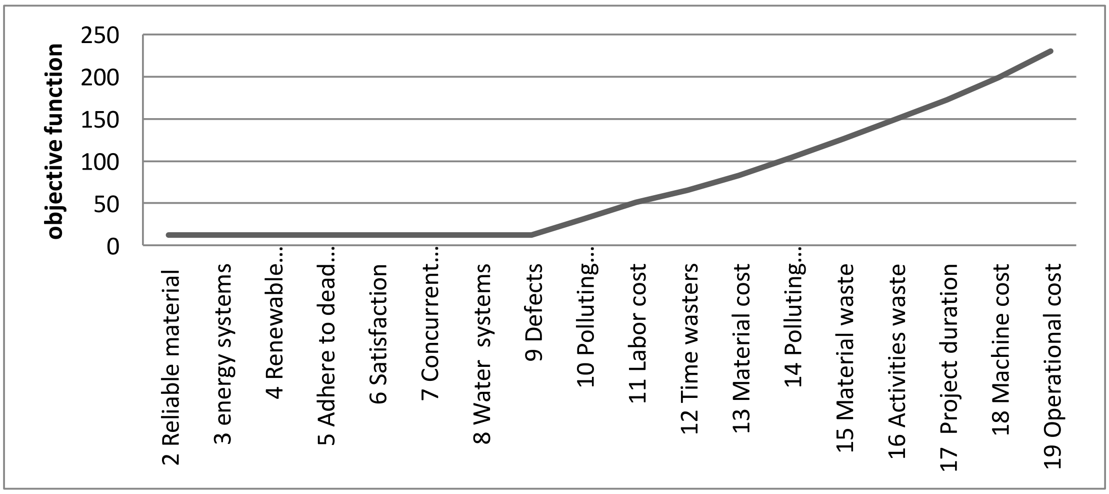

Figure (4.11): Relation between sub-criteria and Objective function value where fixed cost X4 were analyzed

Chapter 5: Case study

Chapter 5: Case Study

In this chapter, a primary implementation was done for the resulted framework through an analyzing for the value and non-value activities/ materials of the concrete and blocks works on an existed case study -Al-Qastal neighborhood- using Value Stream Map (VSM), and determination for the wastes/ harmful in the material and activities using Life Cycle Analysis (LCA) has been done.

To analyze the concrete and blocks flow in the case study, excessive tracking and analyzing for the drawings, quantities tables, actual quantities progress, general and special specification, supplies records, monthly and daily reports of the project, field visits, drawings checks has been done to implement the previous mentioned analysis tools VSM and LCA.

Also, a brief discussion about the harmful material used in the construction and some friendly environmentally alternatives has been done as an attempt to implement the suggested framework in this research in the case study.

5.1. Al-Qastal neighborhood project location

The project is located eastern Deir-Albalah, southern Salah El- Dain road - a major road in Gaza Strip- as shown in Figure (5.1) and the main features of the project are shown in Table (5.2).

Figure (5.1): Al- Qastal neighborhood location (Google Earth)

Table (5.1): Al-Qastal neighborhood description (Enfra Consultants)

Subject	Data
Project name	Al-Qastal neighborhood
Location	Eastern Deir-Albalah
Owner	The Ministry of Public Works and Housing
Contractor	A consortium of Alsarhad and Tasamoh for General Trading and Contracting.
Consultant	Enfra Consultants
Donor	Ministry of Foreign Affairs for the reconstruction of Gaza
Ground floor area	456 m^2
Typical floor area	543 m^2
No of typical floors	5
No of apartments / floor	4
Area of the apartment	120 m^2
Start date	1/10/2015
Finish date	1/10/2016
Estimated cost of project	$ 5,000,000

5.2. Analysis of Al-Qastal data

To explain the implementation of the framework in chapter 4, a review of each step in the concrete and blocks work of the construction process has been developed using LCA and VSM analysis tools:

- Value stream of the project: was developed in order to identify the waste activities/ time in mobilization, plain concrete, foundation, neck column, ground beam, column works, slabs and block work processes.
- Life cycle assessment: determines the environmental impacts of products, processes or services, through production and usage as shown in the next paragraphs.

In the analysis a tracking for the used material, required process time, and steps has been done. The line under each figure concluded the value added activities from lean point of view. Additionally, at the end of the line a summarize for value/on-value add time and activities.

1. **Mobilization and excavation:** Figure 5.2 shows that this process takes 30 hours to complete its 5 tasks, just two of them where value added activities corresponds to 40% of the total steps and value added time corresponds to 33% of the total time.

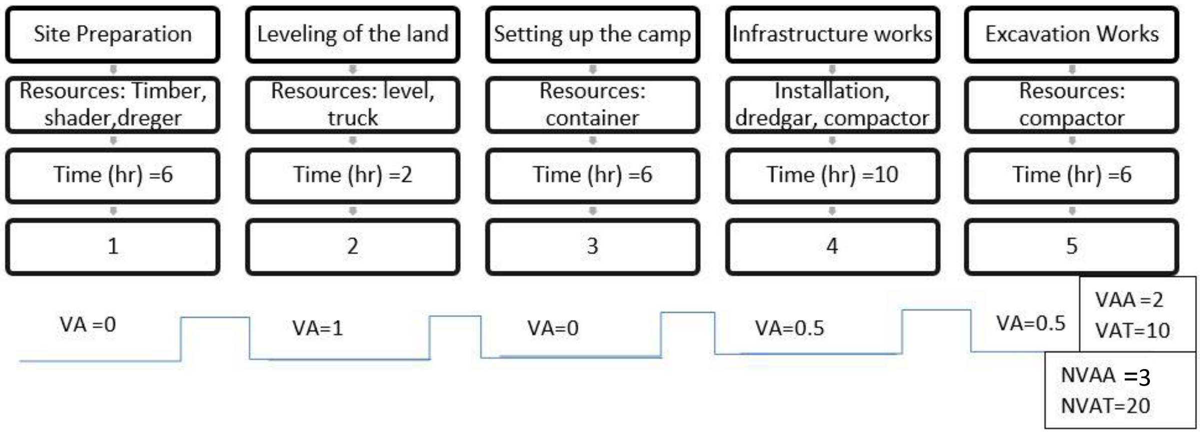

Figure (5.2): Mobilization and excavation analysis

2. **Plain concrete**: Figure 5.3 shows that this process takes 10 hours to complete its 2 tasks, just one of them was value added activities corresponds to 50% of the total steps and value added time corresponds to 20% of the total time.

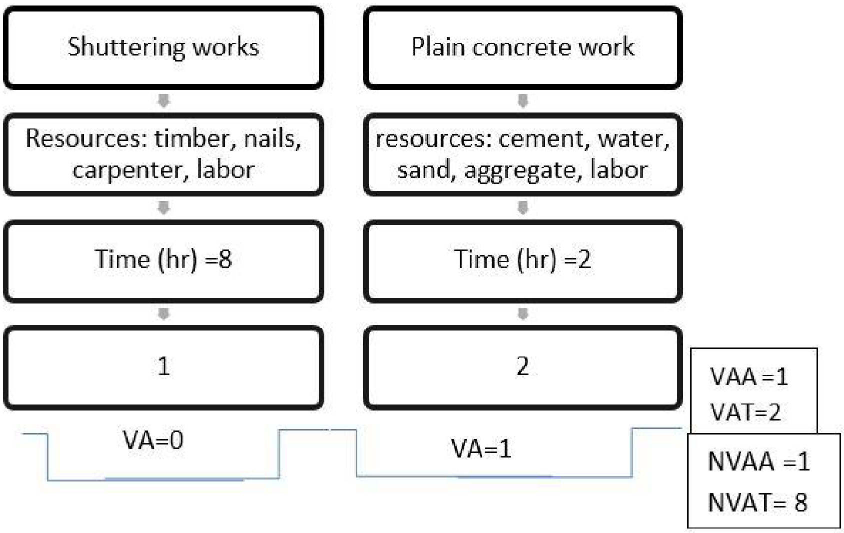

Figure (5.3): Plain concrete analysis

3. **Foundation**: Figure 5.4 shows that this process takes 35 hours to complete its 7 tasks, just three of them were value added activities corresponds to 43 % of the total steps and value added time corresponds to 28.5 % of the total time.

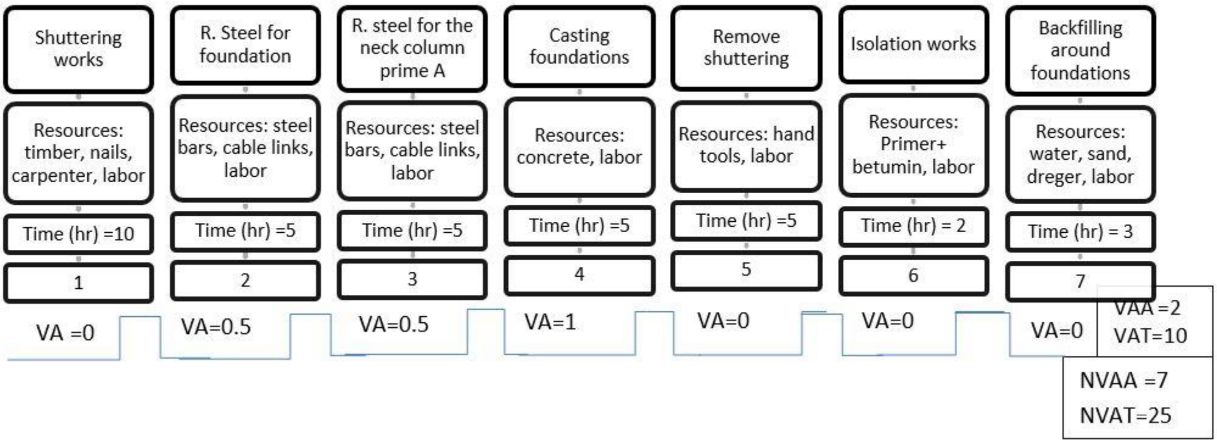

Figure (5.4): Foundation analysis

4. **Columns neck works**: Figure 5.5 shows that this process takes 20 hours to complete its 6 tasks, just 2 of them were value added activities corresponds to 33 % of the total steps and value added time corresponds to 25 % of the total time.

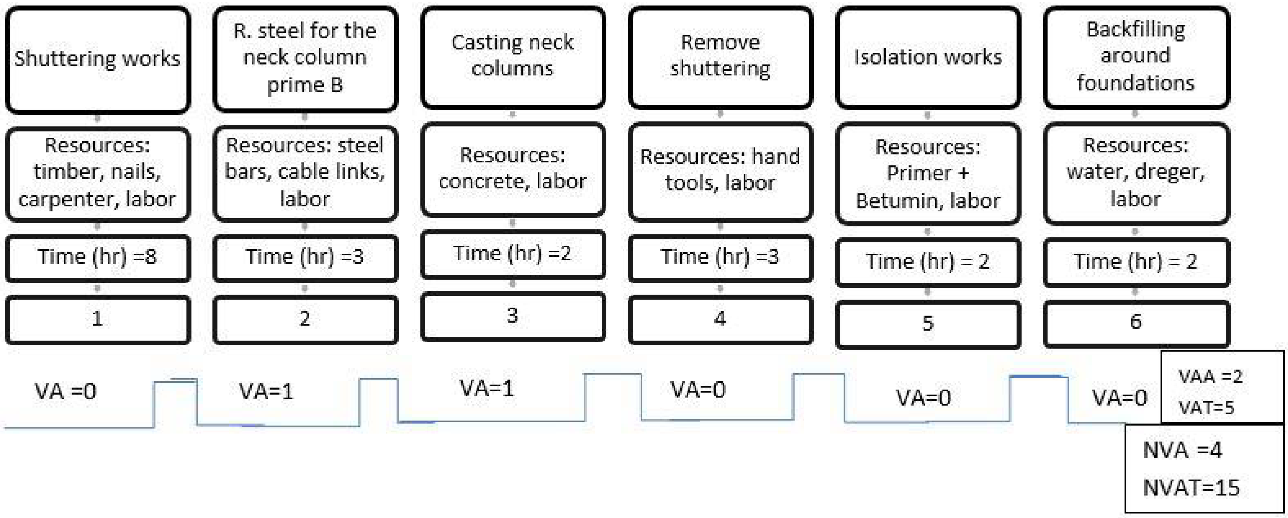

Figure (5.5): Columns neck works analysis

5. **Ground beam works:** Figure 5.6 shows that this process takes 40 hours to complete its 6 tasks, just 2 of them were value added activities corresponds to 33 % of the total steps and value added time corresponds to 45 % of the total steps.

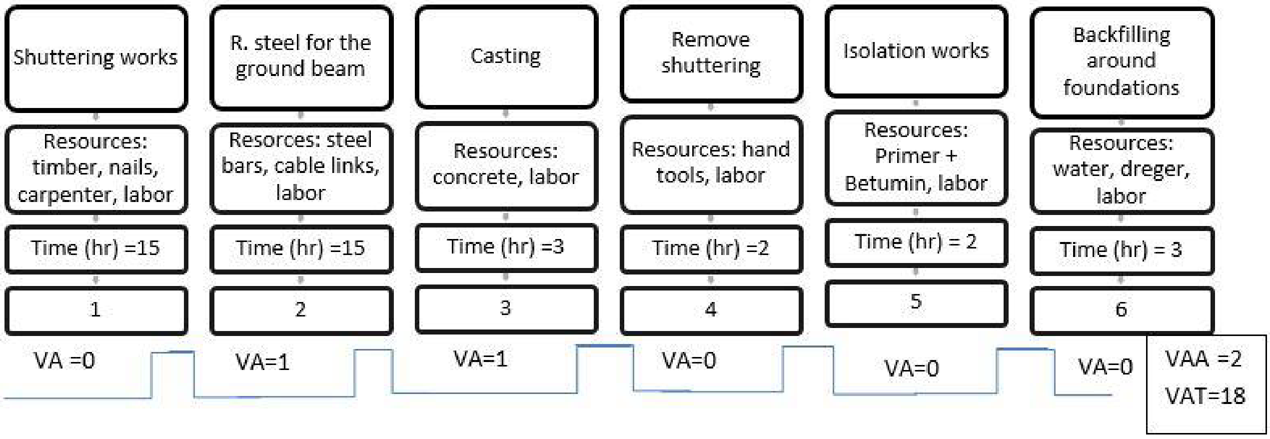

Figure (5.6): Ground beam works analysis

6. **Column for ground floor works:** Figure 5.7 shows that this process takes 20 hours to complete its 4 tasks, just 2 of them were value added activities corresponds to 50 % of the total steps and value added time corresponds to 60 % of the total time.

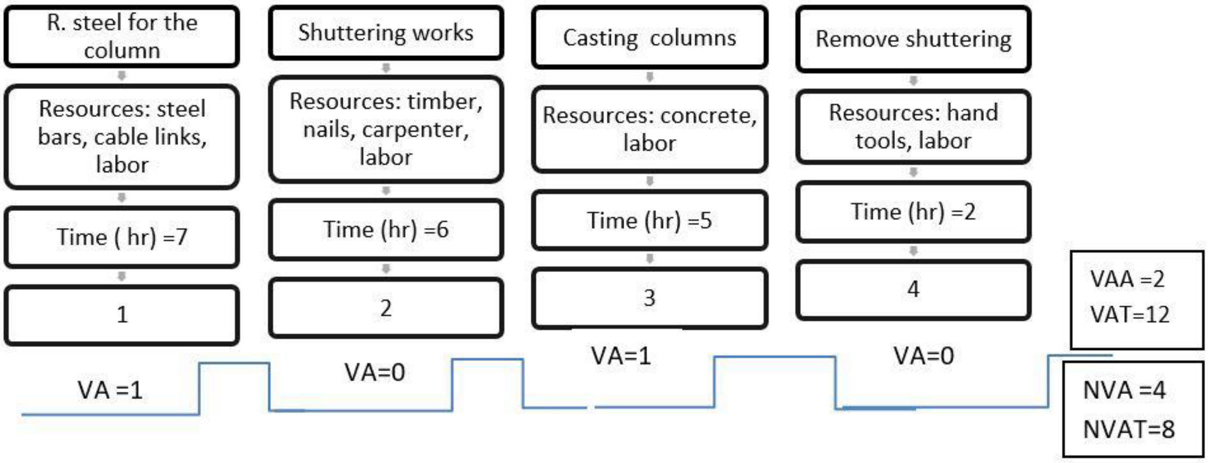

Figure (5.7): Columns works analysis

7. **Stairs works on the ground floor:** Figure 5.8 shows that this process takes 10 hours to complete its 4 tasks, just 2 of them were value added activates and time both corresponds to 50 % of the total steps/time.

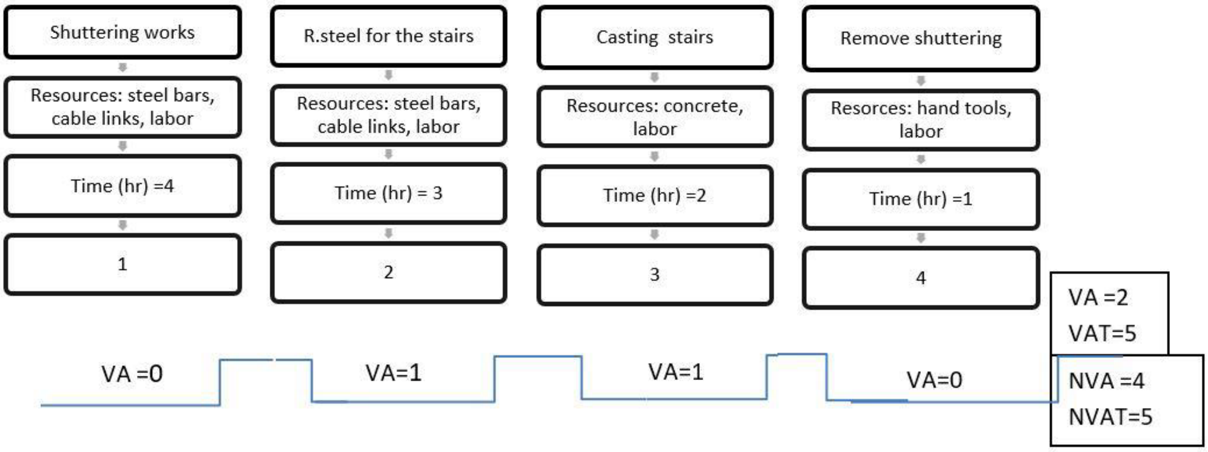

Figure (5.8): Stairs works on the ground floor

8. **Works for G. floor slab:** Figure 5.9 shows that this process takes 70 hours to complete its 4 tasks, just 2 of them were value added activities corresponds to 50 % of the total steps and value added time corresponds to 71 % of the total time.

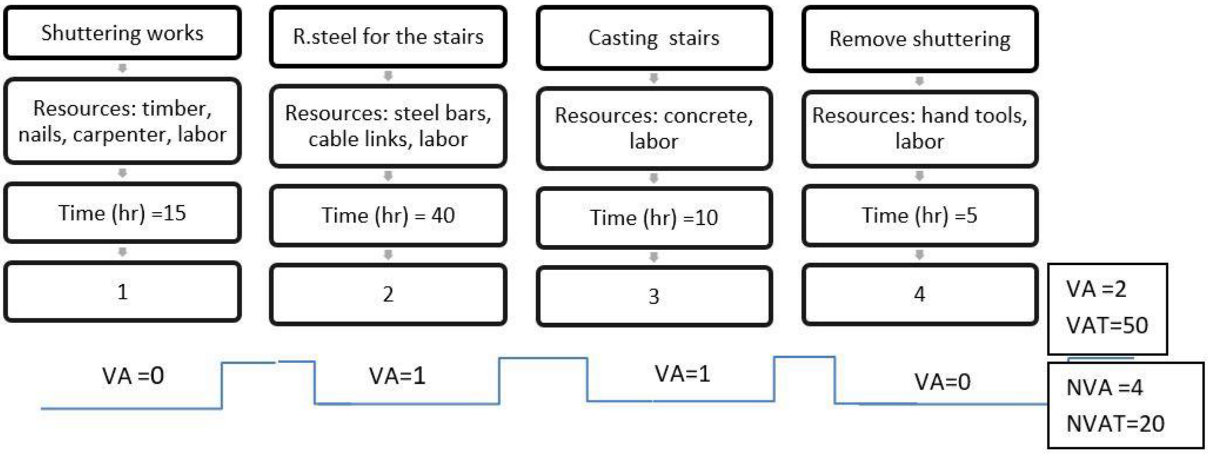

Figure (5.9): Works for G. floor slab analysis

9. Block for the 20 cm external wall works: Figure 5.10 shows that this process takes 20 hours to complete its 11 tasks, just 5 of them were value added activities corresponds to 45 % of the total steps and value added time corresponds to 50 % of the total time.

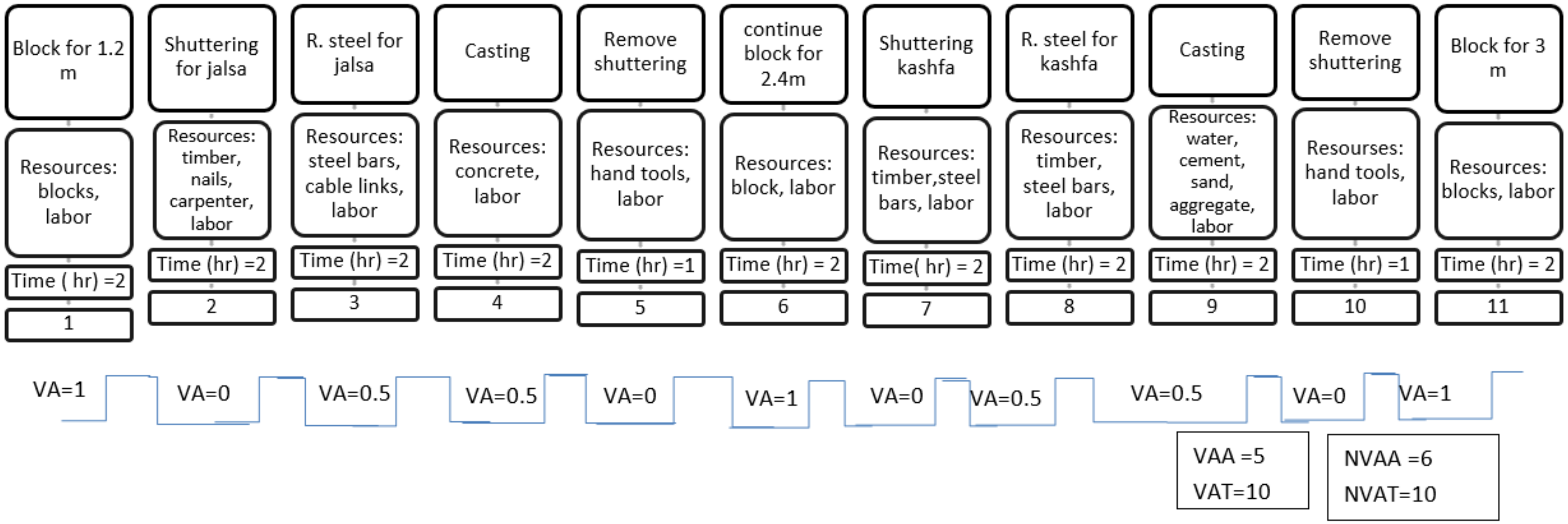

Figure (5.10): Block for the 20 cm external wall works analysis

10. Block for the 15 cm internal walls work: Figure 5.11 shows that this process takes 20 hours to complete its 11 tasks, just 5 of them were value added activities corresponds to 45 % of the total steps and value added time corresponds to 50 % of the total time..

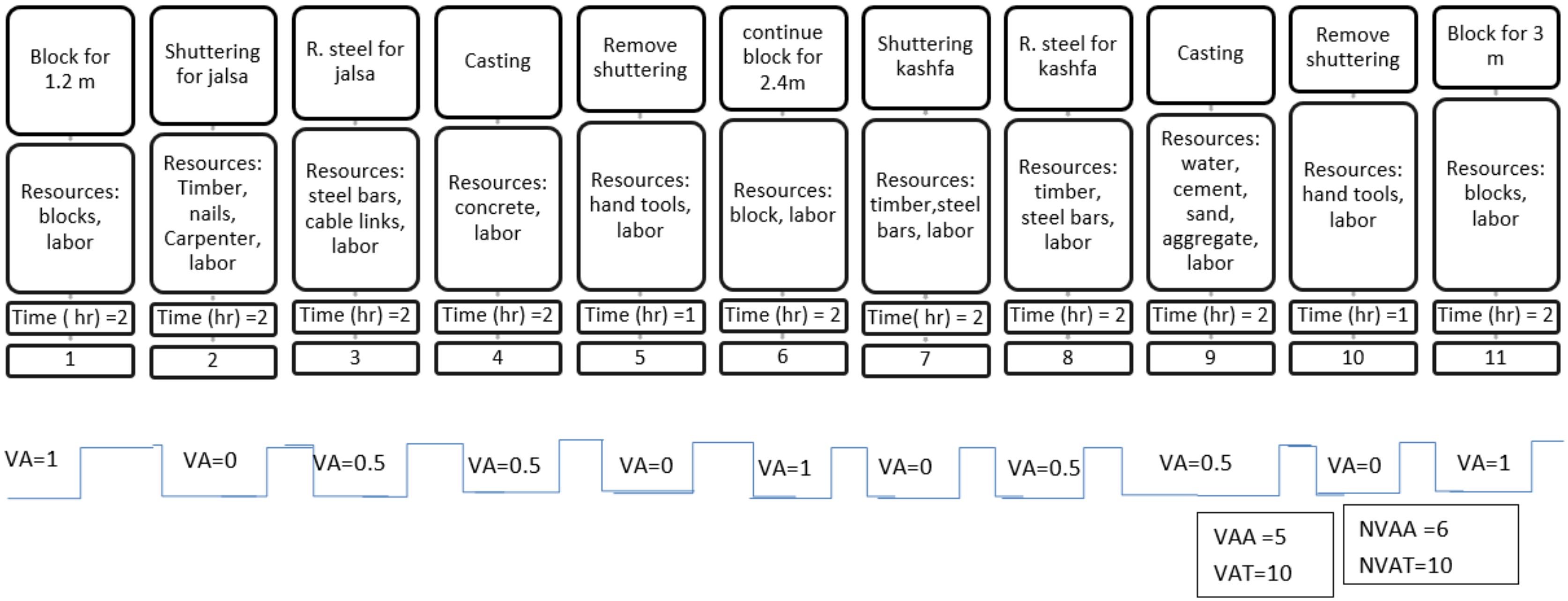

Figure (5.11): Block for the 15 cm internal wall works analysis

11. Block for the 10 cm internal walls work: Figure 5.12 shows that this process takes 38 hours to complete its 11 tasks, just 5 of them were value added activities corresponds to 45 % of the total steps and value added time corresponds to 58 % of the total time..

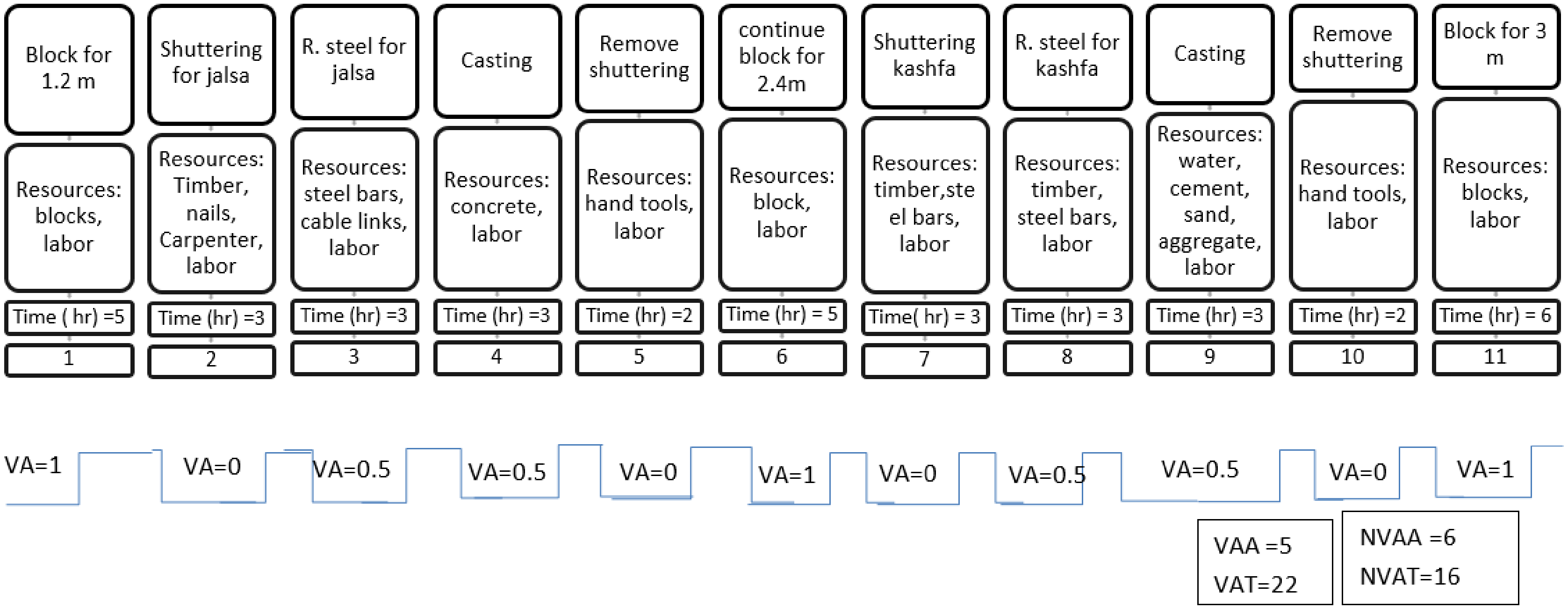

Figure (5.12): Block for the 10 cm internal wall works analysis

5.3. Al-Qastel concrete and block works analysis results:

As shown in Table (5.2) summarizes the analysis results of concrete and block works, the weighted average for value – added concrete and block works are 52.3 %, which means 47.7% of the concrete and blocks works time were waste, the same calculation applied for the concrete and block activities where 43.4% were value added activities while 56.6% were wasted. According to these results there is a wide range of modification which could be carried out to promote the tradition construction activities and decrease the wasted time in these activities with more value added ones.

The value added time weighted average were calculated be multiplying value added time percentage% in task duration (hr.), then divide it by the total task duration (hr.). The same rule applied to value- added activity, weighted average were calculated be multiplying value added activity percentage% in task steps, then divides it on the total task steps.

Table (5.2): Al-Qastel Analysis results

Task	Task duration (hr.)	Value added duration	Task steps	Value added steps	Value added time percentage%	Value- added activity percentage%
Mobilization and excavation	30	10	5	2	33	40
Plain concrete	10	2	2	1	20	50
Foundation	35	10	7	2	28.5	43
Columns neck works	20	5	6	2	25	33
Ground beam works	40	18	6	2	45	33
Column for ground floor	20	12	4	2	60	50
Stairs on the ground floor	10	5	4	2	50	50
Works for the ground floor slab	70	50	4	2	71	50
Block for 20 cm external walls	20	10	11	5	50	45
Blocks for 15 cm internal walls	20	10	11	5	50	45
Blocks for 10 cm internal walls	38	22	11	5	85	45
Total (weighted average)	313 hr.	154 hr.	71	30	52.3	43.4

From Table (5.2), the total task duration is 313 hr., and 119 are non – value added duration from lean – green point of view. These non-value added are in the site mobilization, sitting the camp, shuttering, remove shuttering and isolation work. Also, the block work were classified as a polluting material due to the cement percentage in the block.

5.4. The environmental effect of some of the used material in AL-Qastel project:

At this stage, after defining the value added and non-value added activities/ time, an analysis of used construction materials is done.

In the developed countries, the construction sector is responsible for a high proportion of environmental impact. Approximately 40% of total environmental burden are due to the construction in the European Union (Khasreen, et al., 2009). In a previous study, Ashland Inc. (2011) found that building process consumes a large of amount of resources to construct and operate as shown in Figure (5.13). Figure (5.14) shown the estimated saving in many resources.

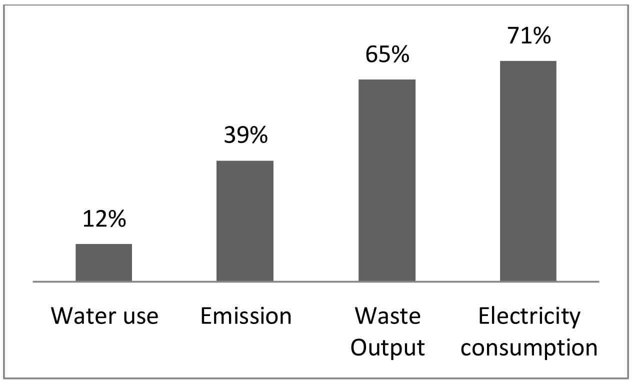

Figure (5.13): Building consumption of natural resources (Ashland Inc., 2011)

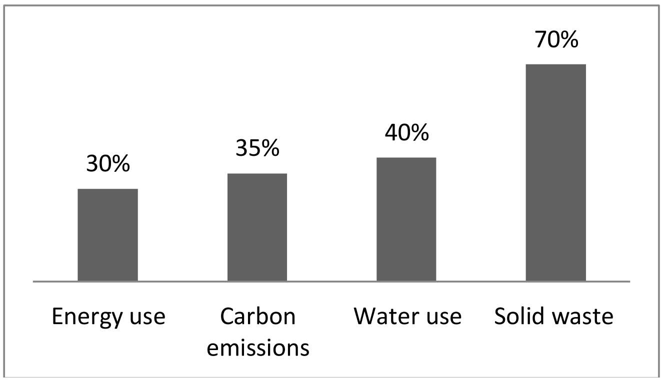

Figure (5.14): Green building savings of natural resources (Ashland Inc., 2011)

The next section discusses some of environmentally harmful materials and proposes some green alternatives have been discussed:

- **Conventional blocks**

Concrete block is a vital in the construction process, which consisted of cement (ordinary Portland cement), aggregate (sand, gravel) and water. The concrete blocks can be produced manually or mechanically with a large variety of sizes and shapes.

The economic advantages of conventional blocks are its little capital cost and less working time regarding to the production of the fired blocks (Skat, 2012). However, it has some limits of production, for example, raw materials must be locally available and a large amount of cement is required. It is worth mentioning that cement has a harmful effect on the environment. Finally, the production process needs a special knowledge and experience. Due to the fact the cement has a harmful effect to the environment, some alternatives are discussed in the next paragraphs:

- **Block alternatives:**

The environmentally-friendly material, are more desirable and needed nowadays, therefore Green Cake block (GC) which made of ash and cement and isolates sound, extreme temperatures and fire appears to be a good alternative.

The brick is light weight, sound and heat proof, environment friendly and cheap. With such type of brick it can be an alternative of heavy brick made of cement. It is made of coal burning for electricity generation at a cost of 25 per cent less than the commonly used ones in Gaza.

- **Asphalt (Bitumen)**

Another toxic material is bitumen, which is complicated mixture of various chemical compounds. According the US Coast Guard Emergency Response Notification System (ERNS), asphalt is one of the most commonly spilled petroleum products the U.S. (Roy, et al., 1997).

Bitumen occur naturally or separated from petroleum chemicals. Asphalt contains aliphatic hydrocarbons in addition to the mononuclear aromatic and polycyclic aromatic hydrocarbon (PAH) mixtures found in both asphalt and tar (Irwin, et al., 1997).

There is sufficient evidence for the carcinogenicity of extracts of steam-refined bitumen's, air-refined bitumen's and pooled mixtures of steam, waste gases from an asphalt plant contained hydrocarbons, tars, hydrogen sulfide and mercaptans.

In the manufacture process, asphalts are heated to vapors then it cooled to condense. These vapors are fortified with volatile ingredients that are expected to be chemically and potentially toxicological distinct from the parent material.

During the burning process, asphalt vapor does not condense all at once, so the workers are exposed not only to asphalt fumes but also to vapor's. Many studies show that the cancer risk increases among the workers who expose to asphalt vapors (Wess, 2005).

- **Polystyrene foam**

Polystyrene (PS) foam can be used as sustainable isolation material that replaces asphalts. PS foam is a light light- rigid plastic insulation material. It is obtainable either as EPS (Expanded Polystyrene, produced from polystyrene beads) or as XPS (directly Extruded Polystyrene). PS foam have been widely used for many decades in the construction and building industry.

Among the technical versatility of PS foam that it is lightweight, hard, easy to handle, long life cycle over 50 years, good thermal insulation, resistant to water absorption and mechanical loadings, high compression strength

From the health and safety side, polystyrene foam does not need for special handling or consideration, there is no dust during installation and use, no chemical binders and safe for consumers - no exposure to harmful substances during service life.

Regarding to the environmental performance, PS is recognized by it is constancy and strength, low environmental effect during production and installation.

The intervention at stage is suggested to be on the block and in the isolation asphalt works. Table (5.3) shows one of the interactions that could be done to improve the green- lean performance of traditional construction for Al-Qastel neighborhood, the interaction was done on non-value added materials and activities (block 20 cm, block 15 cm, block 10 cm, shuttering wood, nails, isolation base, asphalt) to be replaced with Green Cake block (GC block) 20 cm, GC block 15 cm, GC block 10 cm, shuttering wood, polybead and foam). The replaced materials were more friendly environment and dropped the total cost of the concrete and block works with a percent of 2.8%.

Table (5.3): Comparison between traditional material and suggested green-lean materials

Traditional material	Unit	Number	Price/ NIS	Total cost for traditional	Green- lean alternative	Price/ NIS	Total cosr green- lean alternative
Block 20 cm	block	158,000	3.5	553,000	GC Block 20 cm	3.2	505,600
Block 15 cm	block	15,300	3	45,900	GC Block 15 cm	2	30,600
Block 10 cm	block	130,000	2.5	325,000	GC Block 10 cm	2.8	364,000
Isolation base	liter	700	20	14,000	Polybead	14	9,800
Asphalt	kilo	9,000	5	45,000	Foam	5	45,000
Total (3)				**982,900**			**955,000**

Chapter 6: Conclusion and Recommendation

Chapter 6: Conclusion and recommendations

6.1. Proposed framework for green-lean construction:

Figure (6.1) shows framework to integrate the green-lean techniques in case that a fixed cost were used in the project like a real construction project. The first rank was to solve the conflicts of the concurrent drawings to insure the smooth flow in the construction process which affects the project duration and cost. In the second order comes the energy system. It is very helpful to use efficient energy system for example, photovoltaic cells in the early start of the project mainly the design phase. Then the use of efficient water systems like gray water re-use, should also be considered at an early stage of the project, these two sub-criteria classified as green techniques in additional to renewable material use and reuse of the material in the site.

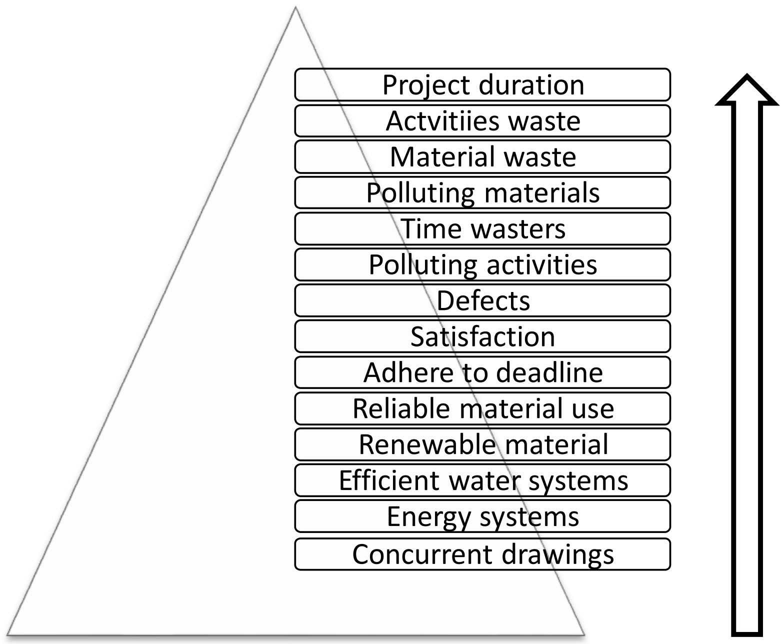

Figure (6.1): Framework for green-lean construction

Renewable material in the fourth rank will highly affect the economic and environmental effect of the project, for example, using Compressed stabilized earth block technology (CSEB) will reduce the harmful effect of the conventional block on the environment. This sub-criteria strongly related to the next sub-criteria in the fifth rank which is the reliability of the used material mainly if it used for the first time in construction.

Regarding to the material reliability, some experts proposed that to try and evaluate these new materials in academic projects and track its result before generalize the new material as a construction material.

In the sixth rank comes adhere to deadline sub-criteria as shown in Figure (6.1), almost all the projects delayed behind the scheduled timetable, this force the contractor to pay a delay penalty and affect the value that the owner tries to accomplish. Lean concept concentrates on the idea that the project must be studied precisely to come up with a detailed implementation plan to guarantee the ability to finish the project on time.

Satisfaction sub-criteria is in the seventh rank because its main principle in lean techniques to be taken into consideration during the design process, so its anticipated that the satisfaction would be guaranteed in the construction phase. Defects sub-criteria is in the seventh rank, which might appear due the lack of experience of the labor, misunderstanding in the design drawings, inclement weather or accidents and all these must be considered and be prepared for it from the early start of the project.

After the seventh criteria, the total cost of the project will increase more than the one in the traditional construction. It would be very good to implement the next sub-criteria as in Figure (6.1), but the initial cost will increase gradually.

6.2. Green – lean sub-criteria relationship

Its previously mentioned that lean technique leads to green effects, in the framework 8 sub-criteria were lean and the first step in the framework is a lean sub-criteria. On the other hand, the framework contains 5 green sub-criteria were distributed through the framework. The main criteria that consider as green-lean is satisfaction sub-criteria, can't be omitted from the scope of either lean or green as shown in Figure (6.2).

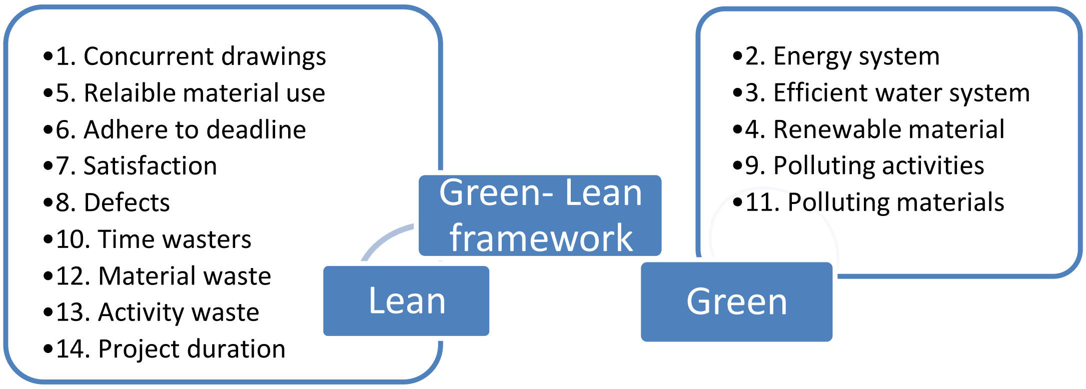

Figure (6.2): Green – lean sub-criteria relationship

6.3. In the case the decision maker has a fixed operational, machine, material and labor cost X_1, X_2, X_3, X_5

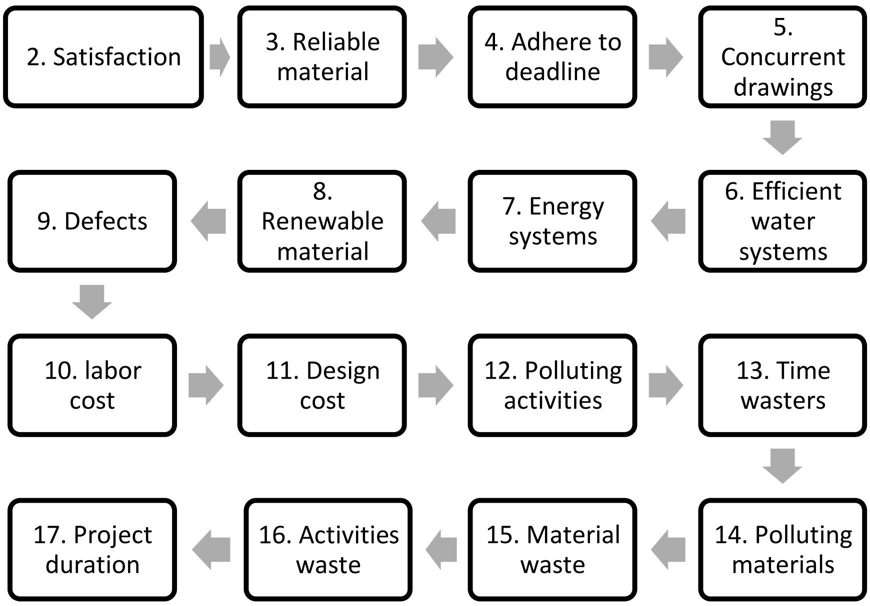

Figure (6.3): The optimum order of sub-criteria in case of X_1, X_2, X_3, X_5

In case like this the satisfaction of the owner is in the first order, then using a reliable material in the construction that meets the results that the owner need without exceeding the deadline, the order of other sub-criteria shown in Figure (6.3). The cost of the process will increase after the sixth sub-criteria (energy systems use). Almaty, the same frame if a fixed labor cost (X_5)were used, at least for the first seven sub-criteria which will keep the planned cost as the cost.

6.4. In the case of fixed design cost X_4:

In the case of fix design cost, the priority is for using reliable materials to accomplish the project and enhancing the project energy with green technology to save power and cost in the long term. These and other sub-criteria orders is shown in Figure (6.4).

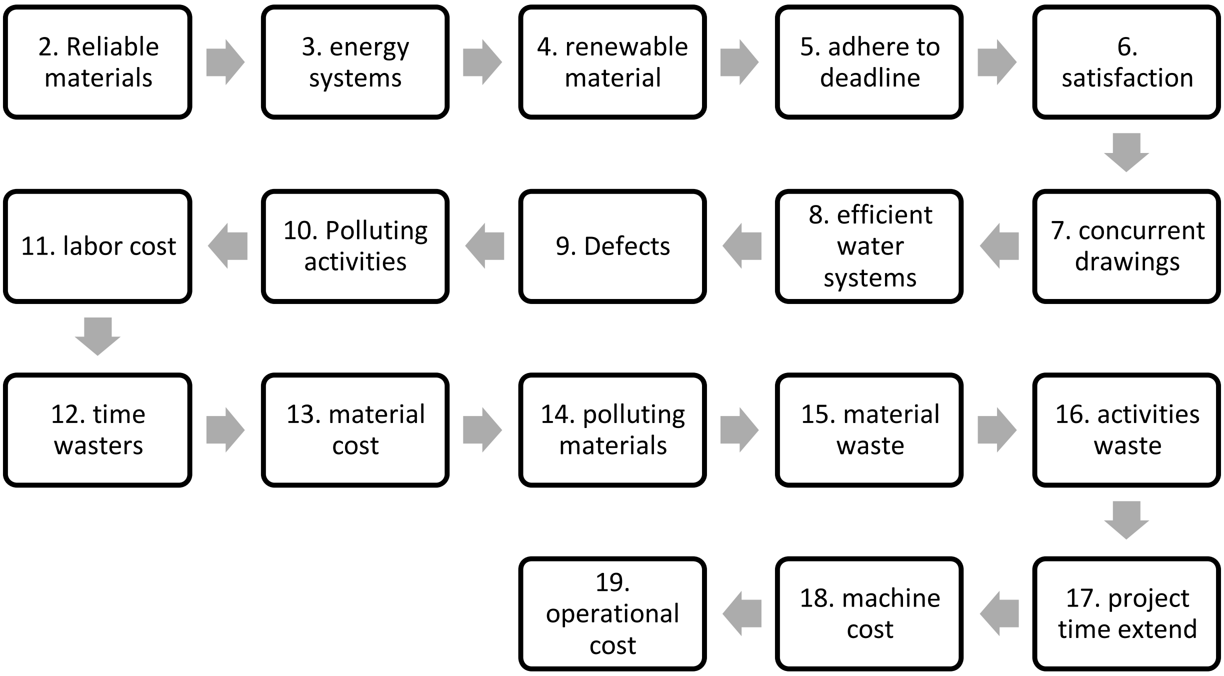

Figure (6.4): Fixed design cost X_4

6.5. Recommendations:

1. It is recommended for the future researchers to improve new formulas for green concrete to be used instead of traditional one and to be efficient in cost and manufacturing.
2. It is recommended to concentrate the effort in the design phase and to give the designer an optimum duration to improve his designs and integrate it periodically with innovated solar and water energy alternatives.
3. To find new value-added activities/ materials to replace non-value ones.
4. Encourage designers to use modern analyzing tools, mainly in the design phase to study the environmental impact of the construction and promote it in the early start with innovative alternatives like shading elements, panels and skylight and water treatment strategies. It is not essential to use expensive tools to grantee the thermal satisfaction, it could be done with simple modification in the ventilation, orientation and location of the construction.
5. Analyzing the needed activities in an early start of the project that will help to release the right work at the right time the right people at an optimum price.

References

References

Ali, H. H., & Al Nsairat, S. F. (2009). Developing a green building assessment tool for developing countries–Case of Jordan. *Building and Environment, 44*(5), 1053-1064.

Al-Tamimi, N. A. M., Fadzil, S. F. S., & Harun, W. M. W. (2011). The effects of orientation, ventilation, and varied WWR on the thermal performance of residential rooms in the tropics. *Journal of Sustainable development, 4*(2), 142.

Alwaer, H., & Clements-Croome, D. J. (2010). Key performance indicators (KPIs) and priority setting in using the multi-attribute approach for assessing sustainable intelligent buildings. *Building and Environment*, *45*(4), 799-807.

Asfour, O., & Kandeel, E. (2016). The Potential of Thermal Insulation as an Energy-Efficient Design Strategy in the Gaza Strip. *Journal of Engineering Research and Technology, 1*(4).

Australia, G. B. C. (2009). Green Star. *Green Building Council of Australia (2013).*

Aziz, R. F., & Hafez, S. M. (2013). Applying lean thinking in construction and performance improvement. *Alexandria Engineering Journal, 52*(4), 679-695.

Banawi, A. A. (2013). *Improving construction processes by integrating lean, green, and six-sigma*. University of Pittsburgh.

Binh, N. T. (2015). Application of Lean Construction in Quality Management of Highway Projects in Vietnam. *Innovative Journal of Business and Management, 4*(6), 118-119.

Biswas, T., Krishnamurti, R., & Wang, T. H. (2009, April). *Framework for sustainable building design*. In Proceedings of the 14th International Conference on Computer Aided Architectural Design Research in Asia/Yunlin (Taiwan) (Vol. 22, pp. 43-52).

Brioso, X. (2015). Teaching lean construction: Pontifical Catholic University of Peru training course in lean project & construction management. *Procedia Engineering, 123*, 85-93.

Chen, Y., Luh, P. B., Guan, C., Zhao, Y., Michel, L. D., Coolbeth, M. A., ... & Rourke, S. J. (2010). Short-term load forecasting: similar day-based wavelet neural networks. *IEEE Transactions on Power Systems*, *25*(1), 322-330.

Cheng, E. W., & Li, H. (2004). Contractor selection using the analytic network process. *Construction management and Economics*, *22*(10), 1021-1032.

Chiarini, A. (2014). Sustainable manufacturing-greening processes using specific Lean

Production tools: an empirical observation from European motorcycle component manufacturers. *Journal of Cleaner Production, 85*, 226-233.

Chua, S. C., & Oh, T. H. (2011). Green progress and prospect in Malaysia. *Renewable and Sustainable Energy Reviews*, *15*(6), 2850-2861.

Cole, R. J., Rousseau, D., & Theaker, I. (1993). BEPAC: Building Environmental Performance Assessment Criteria. *University of British Columbia, Vancouver.*

Council, U. G. B. (2004). Leadership in energy and environmental design. *Building Design and Construction, version, 4.*

Crawley, D., & Aho, I. (1999). Building environmental assessment methods: applications and development trends. *Building Research & Information*, *27*(4-5), 300-308.

Crow, J. M. (2008). The concrete conundrum. *Chemistry World, 5*(3), 62-66.

Dahmen, J. (2014). Preliminary Comparison of Environmental Impacts: Watershed Block vs. Conventional Concrete-Based Masonry. Sustainability, 5, 55-48.

Dhingra, R., Kress, R., & Upreti, G. (2014). Does lean mean green? *Journal of Cleaner Production, 85*, 1-7.

Ding, G. K. (2008). Sustainable construction—The role of environmental assessment tools. *Journal of environmental management*, *86*(3), 451-464.

Education, N. A., Program, P., Lung, & Asthma, B. I. S. E. P. o. t. M. o. (1997). *Expert panel report 2: guidelines for the diagnosis and management of asthma*: DIANE Publishing.

El aydi, H. A. Q., Zaki M. . (2013). Energy efficient sustainable buildings: case study Irada building at IUG. *Journal of Natural Studies*, *80*, 220-223..

Fulford, R., & Standing, C. (2014). Construction industry productivity and the potential for collaborative practice. *International Journal of Project Management, 32*(2), 315-326.

Gautam, N., Krishna, V., & Srivastava, A. (2014). Sustainability in the concrete construction. *Int. J. Environ. Res. Dev., 4*(1), 81-90.

Gibberd, J. (2001). The sustainable building assessment tool—assessing how buildings can support sustainability in developing countries. *Continental shift*, 11-14.

Goulding, J., Lewis, J. O., & Steemers, T. C. (1992). *Energy in architecture: the European passive solar handbook*: BT Batsford for the Commission of the European Communities, Directorate General XII for Science, Research and Development.

Hamdani, M., Bekkouche, S. M. E. A., Benouaz, T., & Cherier, M. K. (2014). A New Modelling Approach of a Multizone Building to Assess the Influence of Building Orientation in Saharan Climate. *Thermal Science*, *40*(2), 20-30.

Hart, S. L. (1995). A natural-resource-based view of the firm. *Academy of management review, 20*(4), 986-1014.

Hostetler, M. (2010). Beyond design: The importance of construction and post-construction phases in green developments. *Sustainability, 2*(4), 1128-1137.

Howell, G., & Ballard, G. (1998, August). *Implementing lean construction: understanding and action*. In Proc. 6 th Ann. Conf. Intl. Group for Lean Constr.

Hsueh, S.-L., & Yan, M.-R. (2013). A multimethodology contractor assessment model for facilitating green innovation: the view of energy and environmental protection. *The Scientific World Journal, 2013*, *80*(2), 40-48.

Hsu, P. F., & Kuo, M. H. (2011). Applying the ANP model for selecting the optimal full-service advertising agency. *International Journal of Operations Research*, *8*(4), 48-58.

Irwin, R., Mouwerik, M., Stevens, L., Seese, M. D., & Basham, W. (1997). Environmental contaminants encyclopedia, naphthalene entry. *National Park Service*.

Issa, U. H. (2013). Implementation of lean construction techniques for minimizing the risks effect on project construction time. *Alexandria Engineering Journal, 52*(4), 697-704.

Japan Sustainable Building Consortium. (2007). CASBEE (comprehensive assessment system for building environmental efficiency) for home and urban development technical manual.

Jayant, A., Paul, V., & Kumar, U. (2014). Application of Analytic Network Process (ANP) in business environment: A comprehensive literature review. *International Journal of Research in Mechanical Engineering & Technology*, *4*(3), 29-37.

Jepsen, M. T., Mathiesen, D., Munch-Petersen, C., & Bager, D. (2001, October). *Durability of resource saving "Green" type of concrete*. In Proceedings of FIB-symposium on Concrete and environment, Berlin.

Jin, V. L. A. (2008). *Lean construction: knowledge and barriers in implementing into Malaysia construction industry.* Universiti Teknologi Malaysia.

Jong-Jin, K., & Rigdon, B. (1998). Qualities, Use, and Examples of Sustainable Building Materials. *National Pollution Prevention Centre for Higher Education*.

Jorgensen, B., & Emmitt, S. (2008). Lost in transition: the transfer of lean manufacturing to construction. *Engineering, Construction and Architectural Management, 15*(4), 383-398.

Juan, Y. K., Roper, K. O., Castro-Lacouture, D., & Ha Kim, J. (2010). Optimal decision making on urban renewal projects. *Management Decision, 48*(2), 207-224.

Kats, G. (2003). Green building costs and financial benefits: Massachusetts Technology Collaborative Boston, USA for *Massachusetts Technology Collaborative*, *200*(4), 100-150.

Khasreen, M. M., Banfill, P. F., & Menzies, G. F. (2009). Life-cycle assessment and the environmental impact of buildings: a review. *Sustainability, 1*(3), 674-701.

Kibert, C. J. (2016). *Sustainable construction: green building design and delivery*: John Wiley & Sons.

Kim, S. S., Yang, I. H., Yeo, M. S., & Kim, K. W. (2005). Development of a housing performance evaluation model for multi-family residential buildings in Korea. *Building and environment*, *40*(8), 1103-1116

Koskela, L. (1992). *Application of the new production philosophy to construction* (No. 72). Stanford, CA: Stanford University.

Kurdve, M., Zackrisson, M., Wiktorsson, M., & Harlin, U. (2014). Lean and Green integration into production system models–Experiences from Swedish industry. *Journal of Cleaner Production, 85*, 180-190.

Lajevardi, A., Endut, I. R., & Paydar, S. (2011, December). *Application of lean model to reduce waste of time in construction Case study of concreting task in Malaysia*. In Humanities, Science and Engineering (CHUSER), 2011 IEEE Colloquium on (pp. 345-350). IEEE.

Lee, M. C., & Chang, T. (2010). Developing a lean design for Six Sigma through supply chain methodology*. International Journal of Productivity and Quality Management*, *6*(4), 407-434.

Lee, W. L., & Burnett, J. (2008). Benchmarking energy use assessment of HK-BEAM, BREEAM and LEED. *Building and Environment*, *43*(11), 1882-1891.

Lehman, T., & Reiser, P. (2004, July). *Maximizing Value & Minimizing Waste– Value Engineering & Lean Construction.* In SAVE International 44th Annual Conference Proceedings.

Li, S., & Zhu, K. (2008, December). *Research on multi-objective Optimization of lean construction project.* In MultiMedia and Information Technology, 2008. MMIT'08.

International Conference on (pp. 480-483). IEEE.

Li, Y. Y., Chen, P.-H., Chew, D. A. S., Teo, C. C., & Ding, R. G. (2011). Critical project management factors of AEC firms for delivering green building projects in Singapore. *Journal of construction engineering and management, 137*(12), 1153-1163.

Jin, V. L. A. (2008). *Lean construction: knowledge and barriers in implementing into Malaysia construction industry* (Doctoral dissertation, Universiti Teknologi Malaysia).

LINDO Systems, I. (2010). LINDO API 6.1 (user manual).

Ling, C. S., Ahmad, M. H., & Ossen, D. R. (2007). The effect of geometric shape and building orientation on minimising solar insolation on high-rise buildings in hot humid climate. *Journal of Construction in Developing Countries, 12*(1), 27-38.

Lukowski, J. (2010). Lean construction principles eliminate waste. Power, 154(8), 65-67.

Maini, S. (2005). Earthen architecture for sustainable habitat and compressed stabilised earth block technology. *The Auroville Earth Institute, Auroville Building Center-India.*

Manalo, A., Aravinthan, T., Karunasena, W., & Ticoalu, A. (2010). A review of alternative materials for replacing existing timber sleepers. *Composite Structures, 92*(3), 603-611.

Mapp, C., Nobe, M., & Dunbar, B. (2011). The cost of LEED—An analysis of the construction costs of LEED and non-LEED banks. *Journal of Sustainable Real Estate, 3*(1), 254-273.

Marhani, M. A., Jaapar, A., & Bari, N. A. A. (2012). Lean Construction: Towards enhancing sustainable construction in Malaysia. *Procedia-social and behavioral sciences, 68*, 87-98.

McLeod, R. S. (2005). Ordinary portland cement. *BFF Autumn, 30*, 33.

Muhaisen, A. S., & Abed, H. M. (2015). Investigation of the Thermal Performance of Building Form in the Mediterranean Climate of the Gaza Strip. *IUG Journal of Natural Studies, 21*(1).

Mwasha, A., Williams, R. G., & Iwaro, J. (2011). Modeling the performance of residential building envelope: The role of sustainable energy performance indicators. *Energy and buildings, 43(9),* 2108-2117.

Nayak, J., & Prajapati, J. (2006). Handbook on energy conscious buildings. *Prepared under the interactive R & D project*(3/4), 03.

Obla, K. H. (2009). What is Green Concrete? *The Indian Concrete Journal, 24*, 26-28.

Ofori, G. (2000, November). *Challenges of construction industries in developing countries:*

Lessons from various countries. In 2nd International Conference on Construction in Developing Countries: Challenges Facing the Construction Industry in Developing Countries, Gaborone, November (pp. 15-17).

Ohno, T. (1988). Toyota production system: beyond large-scale production: crc Press.

Osso, A., Walsh, T., Gottfried, D., & Simon, N. (1996). Sustainable building technical manual. *Public Technology Inc., New York, 10*(2).

Parrish, K. (2012, December). *Lean and green construction.* In 20th Conference of the International Group for Lean Construction, IGLC 2012.

Platt, B., Lent, T., & Walsh, B. (2005). Guide to Plastic Lumber. *The Healthy Building Network, Washington, DC.*

Rebitzer, G., Ekvall, T., Frischknecht, R., Hunkeler, D., Norris, G., Rydberg, T., ... & Pennington, D. W. (2004). Life cycle assessment: Part 1: Framework, goal and scope definition, inventory analysis, and applications. *Environment international*, *30*(5), 701-720.

Reed, W. G., & Gordon, E. B. (2000). Integrated design and building process: what research and methodologies are needed? *Building Research & Information, 28*(5-6), 325-337.

Riza, F. V., Rahman, I. A., & Zaidi, A. M. A. (2010, December). *A brief review of compressed stabilized earth brick (CSEB).* In Science and Social Research (CSSR), 2010 International Conference on (pp. 999-1004). IEEE.

Robichaud, L. B., & Anantatmula, V. S. (2010). Greening project management practices for sustainable construction. *Journal of Management in Engineering, 27*(1), 48-57.

Rosenlund, H. (2000). Climatic design of buildings using passive techniques. *Building Issues, Vol 10.*

Saaty, T. L. (2005). *Theory and applications of the analytic network process: decision making with benefits, opportunities, costs, and risks*: RWS publications.

Saqfelhait, M. A. S. (2012). *Construction Contracts in Palestine from Engineering and Legal Perspectives* (Doctoral dissertation, Faculty of Graduate Studies, An-Najah National University).

Sarhan, S., & Fox, A. (2013). Barriers to implementing lean construction in the UK construction industry. *The Built & Human Environment Review, 6*(1).

Serpell, A., Venturi, A., & Contreras, J. (1995). Characterization of waste in building construction projects. *Lean construction*, 67-77.

Song, L., Liang, D., & Javkhedkar, A. (2008). A case study on applying lean construction to concrete construction projects. *A Case Study, University of Houston, Texas Tech University, FMC Technologies, Houston, Texas.*

Srinivas, M., & Jayaraj, S. (2013). Investigations on the performance of a double pass, hybrid-type (PV/T) solar air heater. *Journal homepage: www. IJEE. IEEFoundation. org, 4*(4), 687-698.

Standardization, I. O. f. (1997). *Environmental Management: Life Cycle Assessment: Principles and Framework* (Vol. 14040): ISO.

Helden, W. G., van Zolingen, R. J. C., & Zondag, H. A. (2004). PV thermal systems: PV panels supplying renewable electricity and heat. *Progress in Photovoltaics: Research and Applications, 12*(6), 415-426.

Wang, W., Rivard, H., & Zmeureanu, R. (2006). Floor shape optimization for green building design. *Advanced Engineering Informatics, 20*(4), 363-378.

Waziri, B. S., & Lawan, Z. A. (2013). Properties of Compressed Stabilized Earth Blocks (CSEB) For Low-Cost Housing Construction: A Preliminary Investigation. *International Journal of Sustainable Construction Engineering and Technology, 4*(2), 39-46.

Womack, J. P., & Jones, D. T. (2010). *Lean thinking: banish waste and create wealth in your corporation*: Simon and Schuster.

Womack, J. P., Jones, D. T., & Roos, D. (1990). *Machine that changed the world*: Simon and Schuster.

Yazgan, E., & Üstün, A. K. (2015). Application of analytic network process: weighting of selection criteria for civil pilots. *Journal of Aeronautics and Space Technologies*, *5*(2), 1-12.

Zhu, K., & Li, S. (2008, December). *Study on the cooperation and credit mechanism of lean construction.* In MultiMedia and Information Technology, 2008. MMIT'08. International Conference on (pp. 476-479). IEEE.

Zuo, J., & Zhao, Z.-Y. (2014). Green building research–current status and future agenda: A review. *Renewable and Sustainable Energy Reviews, 30*, 271-281.

Appendix

Appendix

Questionnaire survey about: Developing a Frame Work for Implementing Green- Lean Construction Techniques (Analytical Network Analysis ANP approach)

Research aim: Promote the implementation of green – lean techniques by analyzing conventional building practices and compare it with green- lean techniques to improve the economic and environmental performance of the construction process.

This questionnaire consists of three parts as in figure 1;

- **Part 1:** Pairwise comparison among the main criteria.
- **Part 2:** Pairwise comparison among the sub-criteria with respect to the criteria.
- **Part 3:** Pairwise comparison for feedback connections.

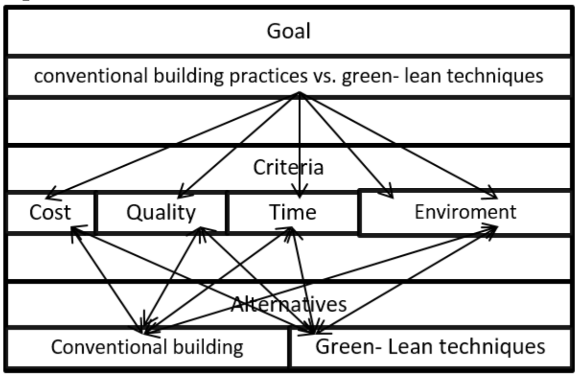

Figure 1 : analytical network analysis approach

Example :

	Minimize total cost	Maximize quality	Adhere to deadline	Optimum resource use	Environment aspects
Minimize total cost	**1**	1/2			
Maximize quality		**1**			
Adhere to deadline			**1**	2	
Optimum resource use				**1**	
Environment aspects					**1**

- In the first example select which is more important node than the other (minimize the cost more than maximize the quality)
- As in the giving example minimizing the total cost is half as important as maximize the quality of the project so we put ½ in the cell and in the second example adhere to deadline is twice as important as to use the resources optimally so we put score 2 in the cell.

Many thanks to all who will help to complete this research work, and thank for carefully answering the questionnaire.

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Part 1: Pairwise comparison among the main criteria

At the beginning, select which is the more important node than the other, and then select the level of importance through its score.

	Minimize total cost	Maximize quality	Adhere to project duration	Environment aspects
Minimize total cost	**1**			
Maximize quality		**1**		
Adhere to project duration			**1**	
Environment aspects				**1**

Part 2: Pairwise comparison among the sub-criteria with respect to the criteria.

Decide the importance factor towards **cost aspect**

Compare between each pair of factors 1=Equal importance, 3= Moderate importance, 5= Strong importance, 7= Very strong importance, 9= Extreme importance, (2, 4, 6, 8= Intermediate values between adjacent scale values)

	Reduce design cost	Reduce material cost	Reduce labor cost	Reduce machines cost	Reduce operational cost
Reduce design cost	1				
Reduce material cost		1			
Reduce labor cost			1		
Reduce machine cost				1	
Reduce operational cost					1

Decide the importance factor towards **quality aspect**						
Compare between each pair of factors 1=Equal importance, 3= Moderate importance, 5= Strong importance, 7= Very strong importance, 9= Extreme importance, (2, 4, 6, 8= Intermediate values between adjacent scale values)						
	Reliability of the used material	Customer satisfaction	Reduce construction defects	Organize concurrent drawings relationship	Reduce material waste	Reduce activities waste
Reliability of the used material	1					
Customer satisfaction		1				
Reduce construction defects			1			
Organize concurrent drawings				1		
Reduce material waste					1	
Reduce activities waste						1

Decide the importance factor towards **time aspect**			
Compare between each pair of factors 1=Equal importance, 3= Moderate importance, 5= Strong importance, 7= Very strong importance, 9= Extreme importance, (2, 4, 6, 8= Intermediate values between adjacent scale values)			
	Reduce time wasters	Project duration	Adhere to deadline
Reduce time wasters	1		
Project duration		1	
Adhere to deadline			1

Decide the importance factor towards **environment aspect**					
Compare between each pair of factors 1=Equal importance, 3= Moderate importance, 5= Strong importance, 7= Very strong importance, 9= Extreme importance, (2, 4, 6, 8= Intermediate values between adjacent scale values)					
	Reduce the use of polluting materials	Reduce the polluting activities	Gray water use	Renewable energy tools	Renewable material use
Reduce the use of polluting materials	1				
Reduce the polluting activities		1			
Gray water use			1		
Renewable energy tools				1	
Renewable material use					1

Part 3: Pairwise comparison for feedback connections

Comparing the Green- Lean techniques factors according to their groups Compare between each pair of factors 1=Equal importance, 3= Moderate importance, 5= Strong importance, 7= Very strong importance, 9= Extreme importance, (2, 4, 6, 8= Intermediate values between adjacent scale values)	Minimize total cost	Maximize quality	Adhere to project duration	Friendly environment aspects	Reduce design cost	Reduce material cost	Reduce labor cost	Reduce machines cost	Reduce operational cost	Reliability of the used material	Customer satisfaction	Reduce construction defects	Organize concurrent drawings departments relationship	Reduce material waste	Reduce activities waste	Reduce time wasters	Total project duration	Adhere to deadline	Reduce the polluting materials	Reduce the polluting activities	Gray water use	Renewable energy tools	Renewable material use	Traditional practices	Green- lean techniques
Minimize total cost	1																								
Maximize quality		1																							
Adhere to project duration			1																						
Friendly environment aspects				1																					
Reduce design cost					1																				
Reduce material cost						1																			
Reduce labor cost							1																		
Reduce machines cost								1																	
Reduce operational cost									1																
Reliability of the used material										1															
Customer satisfaction											1														
Reduce construction defects												1													

Organize concurrent design drawings relationship													1												
Reduce material waste														1											
Reduce activities waste															1										
Reduce time wasters																1									
Total project duration																	1								
Adhere to deadline																		1							
Reduce the use of polluting materials																			1						
Reduce the polluting activities																				1					
Gray water use																					1				
Renewable energy tools																						1			
Renewable material use																							1		
Traditional practices																								1	
Green- lean techniques																									1