# LEAN THINKING AND THE DELIVERY OF SUSTAINABLE CONSTRUCTION PROJECTS

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The construction industry is affected by factors that are forcing change. The demand for 'sustainable' construction was brought to the forefront by the adoption of the Kyoto protocol and the Brundtland report, both of which force an appraisal of the energy efficiency and sustainability of materials selected for use within buildings. Moreover, the demand for competence, as outlined in the Egan Report with its focus on progress in the areas of time, cost and quality of the construction process, is pushing the building industry towards the use of lean construction techniques. The main objectives of this research are to develop a methodology that links the principles of sustainable construction together with the principles of lean thinking into one strategic approach to the control of waste in the construction process. The extent to which sustainability and lean thinking are mutually exclusive is explored in this paper. Then, the possibility of merging lean thinking and sustainability to the benefit of productivity in construction projects is introduced.

Keywords: lean construction techniques, sustainable construction,

## INTRODUCTION

The Kyoto protocol (1987) aims to reduce energy consumption as part of an overall strategy to reduce the extent of damage done to the environment via continuously growing economic activity. Buildings are among the most significant consumers of energy, both in terms of their initial production and in terms of their use over a life cycle, which may range from twenty to over one hundred years. The Latham (1994) and Egan (1998) reports pose challenges to the current driving forces for innovation in the construction industry as a whole. These reports are concerned with the efficiency of building project delivery processes and they advocate the philosophy of lean production. As a result, there is much use of the term lean construction at the present time.

According to the Egan report, there is a need for the UK construction industry to identify a system capable of integrating change so as to make better profits for clients. This point was emphasised by the Chairman of the Royal Institution of Chartered Surveyors (RICS):

> *"Pressure on the construction industry to introduce methods and design to conserve and make best use of our natural materials has never been greater and will increase as more evidence of depleting natural resources is identified. One aspect of conservation is to increase the use of reclaimed or recycled materials, the major source of which is from demolitions" (RICS 2002).*

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Bidarianzadeh, G R and Fortune, C J (2002) Lean thinking and the delivery of sustainable construction projects. *In:* Greenwood, D (Ed.), *18th Annual ARCOM Conference*, 2-4 September 2002, University of Northumbria. Association of Researchers in Construction Management, Vol. 2, 567-76.

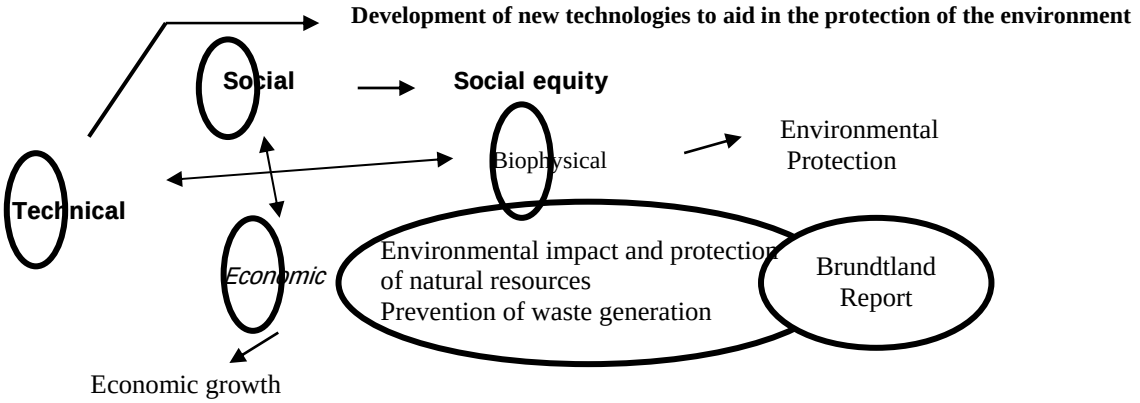
Specifically, this research looks at whether lean thinking principles can influence the establishment of sustainable forms of construction, and if so whether it is possible to integrate lean and sustainable construction concepts within the same project. However, the combination of lean and sustainable processes as they pertain to the elimination of waste in an environmentally sound manner will only become central to the success of projects when architects, suppliers and construction managers become aware of the potential benefits. Project advisors have a responsibility to look for improvement and embrace change in an effort to increase client satisfaction. This ongoing research looks at the potential integration of lean and sustainable technologies.

This research firstly considers literature on the concepts of lean and sustainable construction processes. It looks at the nature of sustainable development and how it relates to the construction industry i.e. sustainable construction. It then goes on to present the case for lean thinking in construction, reviewing relevant recent literature in the area in an effort to give an overview of the nature of this concept. Having established a foundation for the two concepts - sustainable construction and lean construction - the research sets out to find common ground as well as conflicts that may be inherent in the two approaches. A future phase of research would be to illustrate in the form of examples from areas such as recycling, supply chain management, waste management etc, these common points and conflicts.

## SUSTAINABILITY

The 'Brundtland Report' (WCED, 1987) defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". The idea is not a new one. Indeed, as early as the middle of the 20$^{th}$ century people were starting to doubt whether or not the earth had the capacity to sustain the lifestyle to which people in the developed world had become accustomed (Hill and Bowen 1997: 224). Gradually, more and more attention was paid to conservation, environmental issues and the impact that modern and material development had on them. This is not to say that everyone was in favour of conservation or the protection of the environment to the detriment of modern development. However, the debate of the 1970's and 1980's, where development and environment were seen as being polar opposites, has been replaced by a general consensus that "uncontrolled exploitation of natural resources is not beneficial to human kind in the long term" (Hill and Bowen 1997: 225). For the purposes of this research, however, Hill and Bowen's (1997) detailed concept of sustainable construction will be considered. Four 'pillars' of sustainable construction, 'social', 'economic', 'biophysical' and 'technical', form the basis of their definition. Figure 1 illustrates these four pillars of sustainability and the issues that they share in common with the Brundtland report. As illustrated, the aims of the biophysical and economic pillars as well as of the Brundtland report are to come to an understanding about the impact the construction industry has on the environment and to work towards waste prevention and disposal.

Figure 1: Areas shared by pillars of sustainability and Brundtland report.




This research is primarily concerned with the 'biophysical' and the 'economical' aspects of this definition. One of the main points of 'pillar two' or 'economic sustainability' is that financial affordability for the intended beneficiaries should be ensured (Hill and Bowen 1997: 228). The biophysical' pillar considers issues related to "the atmosphere, land, underground resources, the marine environment, flora, fauna and the built environment" (ibid. 229). Further practitioners should attempt to "maximise resource reuse, and/or recycling as this leads to a reduction in waste thereby prolonging the life of landfill facilities and reducing the need to select new landfill sites" (ibid. 230). In addition, such practice would reduce the need for raw materials and thus contribute to a reduction in resource consumption - a central point in achieving biophysical sustainability.

The construction industry, undeniably, has a huge impact on the environment and the term 'sustainable construction' may seem to contain an oxymoron. How can an industry such as construction, traditionally so thoroughly dependent on the use of nature's resources and concerned primarily with creating new structures, answer increasing societal and, in turn, governmental demands for a sustainable industry? According to the Construction Industry Research and Information Association (CIRIA), the amount of waste produced by the construction industry is immense. For instance in 1999 it was estimated that:

> *"72.5 million tonnes of construction and demolition waste, including clay and subsoil, are produced annually; this represents some 17.5% of the total waste produced in the UK. Construction is also a huge consumer of resources. Every year approximately 260 million tonnes of minerals are extracted for use as aggregates and raw materials for construction. In the UK approximately 13 million tonnes of construction materials are delivered to site and thrown away unused every year"* (CIRIA.2002).

Such practices are clearly not sustainable. It is clear that something needs to be done within the framework of the construction industry in order to deliver sustainability to building projects. The idea of sustainability as it pertains to construction has been described in various ways and interest in the field is growing. International organisations such as the International Council for Research and Innovation in Building and Construction (CIB) and governmental departments such as the UK's DETR devote much time and energy to pursuing the goal of 'sustainable

construction.' According to Hill and Bowen, "the term 'sustainable construction' was originally proposed to describe the responsibility of the construction industry in attaining sustainability" (Hill and Bowen 1997: 225). In general, the term is used to describe the construction process from the design phase until after the construction team has left the site. For Wyatt (1994, cited in Hill and Bowen 1997: 226), the term refers to a comprehensive appraisal including "managing the serviceability of a building during its lifetime and eventual deconstruction and recycling of resources to reduce the waste stream usually associated with demolition". According to RICS, if the construction industry wants to build a better quality of life and save money they should promote sustainable buildings (RICS 2002). Further, scholars such as Kohler (1999) see sustainable construction, at least in advanced industrialised countries, in terms of a shift from new construction to works of maintenance and repair. According to Kohler, rather than constructing additional new buildings, the existing stock of buildings should be improved indeed he commented that:

> *The objective is not to continuously expand the stock, but to improve qualitatively the stock without growth, which means that we reduce the material throughput and improve the functional quality and the durability* (Kohler 1999:317).

## LEAN CONSTRUCTION

The principles of lean construction call for systems to be set up to ensure that issues such as minimisation of waste going to landfill sites, saving of money spent on transportation and disposing of landfill, reduction of pollution impacts of travelling and providing of benefits to communities and environment are addressed. Lean thinking is the general term for the application of the principles of lean production first made popular by Toyota (Womack *et al.*, 1996). Following the publication the Egan Report (1998), the policy shaping bodies for the UK construction industry such as the Construction Clients' Forum (CCF), the Construction Industry Board (CIB) and the Government Construction Clients' Panel (GCCP) have embraced lean thinking principles (Green 1999). Lean construction has the goal of better meeting customer's needs while using less of everything (Howell 1999). Howell and Ballard describe the main goals of lean thinking as:

> *"Redefine [ing] performance against three dimensions of perfection: a uniquely custom product, delivered instantly, and with nothing in stores. This is an ideal that maximises value and minimises waste. The goals demand a new way to co-ordinate action, one that is applicable to industries far removed from manufacturing"* (Howell and Ballard 1998: 2)

Figure 2 illustrates how elements of Howell and Ballard's definition of lean principles work together towards the desired outcome of value maximisation and waste minimisation.

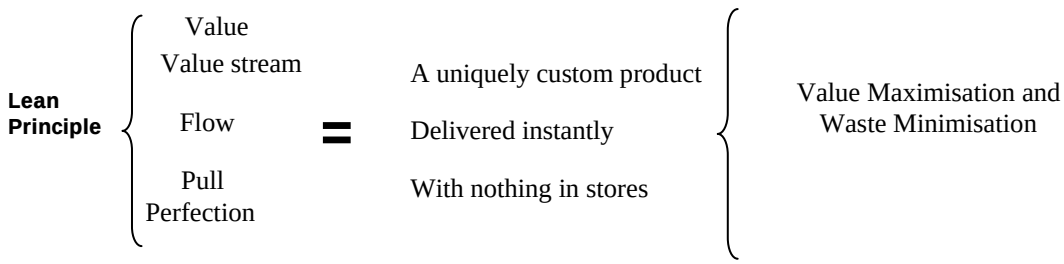



Figure 2: The definition and aims of lean construction

Howell and Ballard (1998) continue by stating that not only does lean thinking continually redefine perfection but also that implementing such a practice would require changing the way we think about and do construction. According to Eaton (1994: 274), two types of lean production are recognised: conversion activities - which add to the materials or piece of information being transformed into a product, and flows – such things as inspection, waiting, and moving through which bind the conversion activities together but which do not add value. Figure 3 illustrates the main process for analysing construction projects according to lean principles, it gives the basic outline for lean thinking as a design production system, a system that has impact from instruction to production and delivery and at the same time aiming at the complete elimination of waste.

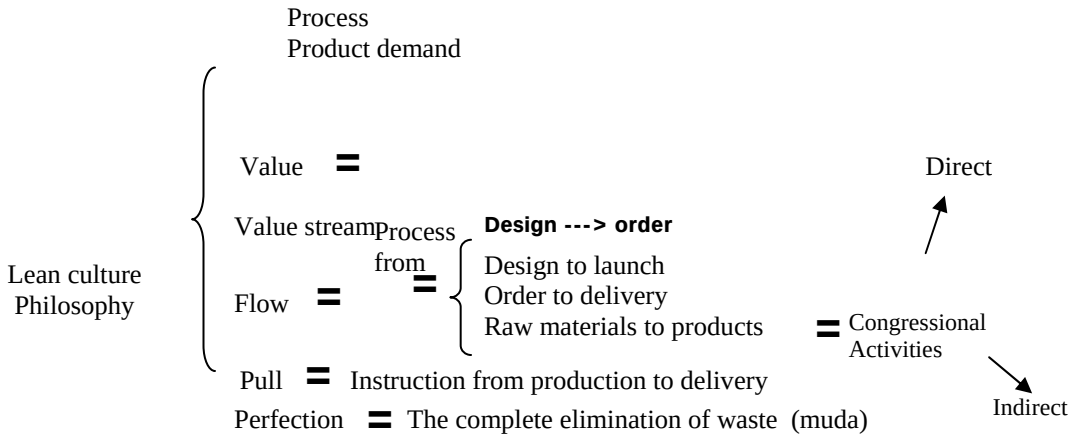



Figure 3: Introducing lean as a system

Lean thinking is spreading to different economic sectors (Flavio and Picchi 1999). Indeed, several authors have focused on the interpretation of this approach for the construction sector (Koskela and Huovila 1997; Egan 1998; Howell 1999; Koskela *et al.* 1999). Others see lean construction as essentially about improving the reliability of the planning process (Seymour *et al.* 2000).

Flavio and Picchi discuss the five lean principles suggested by Womack and Jones (1996); i.e. value, value stream, flow, pull and perfection and some specific construction characteristics. They propose three main flows for the analyses of construction, namely business, job site and supply flows. The basic outline for lean thinking is to design a production system such as that presented by Howell (1999). Here, lean production is introduced as a system that will deliver a custom product instantly but maintain no intermediate inventories. Tyagi and Chua (2000) introduce and formalise a technique for minimising the share of non-value adding activities by improving the work flow reliability in construction processes. Controlling each activity in the construction process will reduce the cost and duration of each step and is the key to improvement. Lean is about identifying the nature of the project and its objectives and aims. Production is then managed by dividing the project into smaller parts and then putting them together again in a logical sequence.

In effect, lean thinking is a translation process in a logical flow that will generate value for clients. The lean revolution is essentially a conceptual revolution, at the heart of which are the flow and value models. The flow facilitates waste reduction and value maximisation. To date, according to the literature reviewed, most lean thinking in construction has been concerned with waste reduction. The use of lean value

principles is applied to waste reduction in order to identify the non-value adding activities and analyse the process. When applied to construction processes, according to Al-Sudairi, factors such as value specification, rethinking operating methods, focus on actual objects, releasing resources for delivery just when needed and quality or perfection in construction projects are of key importance (Al- Sudairi *et.al* 2000).

The literature review illustrates that the construction industry has been short sighted. To support this statement, Eaton (1994) addressed well-known chronic problems associated with the UK construction professions: low productivity, insufficient quality, poor co-ordination, high cost, etc. Moreover, if short-term financial benefits are not evident, projects are not undertaken. This is a mindset that may be environmentally unsustainable but at the same time difficult to change. Thus, there is a need to make environmentally sustainable construction projects also cost-effective. The case of reused or recycled brick is just one example that may be used to illustrate this claim. It is suspected that if the cost of using recycled brick exceeds the cost of using new brick then the construction industry will usually opt for using new brick, ignoring the benefits of using recycled brick. A number of solutions have been proposed to address parts of these problems. However, generally these solutions seem to be adaptations of procedures used in the manufacturing industry, which are then applied to the construction industry (Koskela 1997). It is thought that the implementation of lean thinking in the construction industry could be part of this solution especially in relation to the recycling of materials such as brick. Such a development will go a long way in combining the advantages of both sustainability and of lean principles.

## COMMON GROUND AND CONFLICTS IN APPROACHES

The construction industry is currently affected by two factors, which are forcing changes each in its own way. Firstly, the demand for environmentally friendly, "sustainable" construction is forcing an appraisal of the energy, economic efficiency and sustainability of buildings and the materials, selected for use within them. Secondly, the demand for efficiency as exemplified by the Egan task force with its focus on improvements to the time, cost and quality of the construction process, is forcing designers to use lean construction techniques. Unfortunately, the lean methods that have been adopted so far have tended to use high-tech, industrialized techniques with an emphasis on remote manufacture of finished components, which are then assembled on site. On the face of it, such methods may not be environmentally friendly or sustainable. Much of the work that has been undertaken in each of these two areas (as shown in Howell (1999), Hill and Bowen (1997) and Cooper (1999)) is mutually exclusive. This research attempts to address this issue by seeking to make a connection between the two fields and in so doing contributing to the development of both.

Much progress is currently being made in the fields of lean construction and sustainable construction. The work of the Building Research Establishment (BRE) in connection with the life cycle assessment of construction materials and components and environmental profiling is particularly important in connection with the proposed research. Additionally, academic work in the field of construction materials' life cycle assessment and sustainability is much in evidence and is demonstrated by the work of Hutchinson *et al.* (1998) amongst others.

If the construction industry wants to build a better quality of life and save money it must promote both lean and sustainable buildings. Sustainable development in construction and lean thinking are two different concepts. Where sustainable construction focuses on environmentally friendly issues, lean construction is a way of thinking logically in order to eliminate activities which cannot or do not add value to any given construction project. According to Eaton (1994), the lean production analysis of activities into flows and/or conversion can be used as an analytical tool that may create the opportunity for an alternative cost curve for some companies. Lean construction, however, is more a method for controlling activities in order to shorten the length and keep the cost of the project down.

According to IISD (2002) to the business principal for a sustainable and competitive future is to adopt the principle of life cycle management by applying sustainable criteria at every stage of the enterprise's activity. This applies to design for recycling and re-use, and the utilisation of raw materials and hazardous substances, production processes, transportation and distribution, sales and customer use, and ultimate disposal.

The limitation of our environment can be offset by technology or by recycling. According to the Brundtland Report the limitation can, only partially, be due to technology and recycling graft on new solutions without addressing the root of the problems the mentality that an economy can grow indefinitely.

Lean construction has the goal of better meeting customer needs while using less of everything, also rests on production management principles and the physics of construction. The result is a new project delivery system, which can be applied to any kind of construction but is particularly suited for complex, uncertain and quick projects. This system will deal with waste. Waste in lean methodology is defined by the performance criteria for production systems. Failure to meet the unique requirements of a client is waste, as is time beyond instant and inventory standing idle (Howell 1999).

Lean production can be understood as a new way to design and make things differentiated from mass and craft forms of production by the objectives and techniques applied on the shop, in design and along supply chains. In the light of all this how can lean thinking principles be incorporated into the establishment of sustainable forms of construction project delivery in the UK? The relationship between lean and sustainability needs to be quantified in order to provide guidance to the industry and to optimise the process such that both needs can be satisfied rather than solving one of the problems without addressing the other. The operational environment of the construction industry will need to be investigated, through the examination of the product value chain and its possible financial integration leading to the development of a sustainable project. In addition, a forum for ongoing research, to identify the best ways for developing sustainable projects integrating lean principles will need to be promoted.

Lean thinking will be used to develop more sustainable projects. This will lead to the identification of methods of improving strategic resource materials and methods of finance. It is clear that both sustainable and lean performances are working towards the improvement of the economic performance of the project through reducing energy consumption, reducing the extent of environmental damage and continuous economic activities. It has been previously stated that lean particularly by its nature is not to protect the environment. Because there is no confirmation that what is lean is also

sustainable. Therefore, any routine in this area should aim to establish the scope for mutual compatibility which is clearly an important strategic in the area of construction. Figure 4 identifies the link between sustainable development and lean construction principles and how they can be merged in order to work toward the complete elimination of waste.

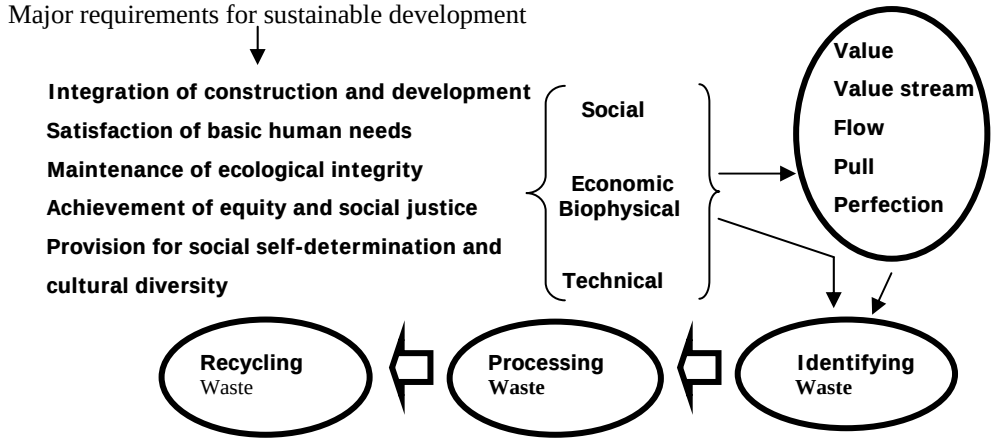



Figure 4: Link between lean objectives and sustainability

It is certainly true that lean is concerned with management philosophies, which, if applied in the construction context, are fundamentally concerned with the process rather than with the product. Waste, in lean thinking, refers to any activities that may appear to take unnecessary amounts of time such as materials, human error and activities. Lean involves increasing value for money by eliminating waste streaks for efficiency of building projects and delivery processes in order to achieve maximum value and minimal waste. So, targeting the elimination of waste in order to ensure improved value for money can merge the areas common to both sustainable development and lean. For instance, both concepts promote the reduction of waste but at the same time they are based on two different ways of understanding waste in construction. According to lean and its philosophy, any activities, processes or materials that do not add value, are activities consisting of conversions and/or flows. Waste in sustainable construction means also materials that would not be use and disposing them they may harm the environment. In lean philosophy if waste costs and does not add value to the process, it is uneconomical. However, within the core aim of lean production is the minimisation of waste in the use of production resources, whether human or material, and this clearly corresponds with the aims embodied within sustainability. What may be optimal from the lean perspective may or may not be optimal from the perspective of sustainability. Sustainable development and lean are both aiming for elimination of waste. Sustainable and lean concepts can be merged and commonalties are evident, recycling and reuse of brick is one example of the influence of process on product and serves to demonstrate how lean thinking can impact on construction technology. Combining lean techniques with recycling (i.e. sustainable practice) in order to reduce waste, both material and financial, is one way to make recycling more attractive for the construction industry

## CONCLUSION

This research has considered the sustainability of building as a concept that has been given much attention by several countries since the 1970s in an effort to find better building solutions now and in the future. Such solutions or building methods would protect us from environmental problems that have come to the attention of the world over several years**.** Through protection of the environment, the construction industry is one of many bodies responsible for contributing to the protection of the health and safety of future generations. Sustainable development is a process with both long and short-term objectives and includes four pillars: social, economic, biophysical and technical. In this research, the aim is to understand two of these four pillars or, specifically, the common ground shared by the economic and biophysical pillars in terms of lean philosophy. Investigation into opportunities for improving the leanness and sustainability of construction projects is undertaken. The aim is to determine whether or not there is a need to change the focus of attention on methods for assessing environmental projects. A link between sustainability and lean concepts is established in order to present the lean idea as a tool or a system to measure the financial and environmental impact on construction projects. The processes these two concepts may have in common and the implementation of lean philosophy as a system making up a part of sustainable projects were examined.

Lean philosophy has been introduced as a concept that eliminates all waste from a process while pursuing perfection in the finished product. Therefore, lean philosophy could be used as a control system to be implemented for sustainable projects. Such a control system would be based on progressive achievement and would reduce environmental impact. It is also introduced as a product policy that integrates economic variability and efficiency. Economic efficiency of reusing/recycling materials such as brick depends on choices made during the demolition process and its development phase. The basic principles of lean, such as flow and pull need to be implemented in areas such as the cleaning technology used for bricks. Progressive achievement includes value stream in such a way that stoppages and waste are excluded from processes such as the reusing/recycling of brick from demolition to delivery.

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