

AN INVESTIGATION INTO THE DISSEMINATION OF
LEAN PRINCIPLES IN THE IRISH CONSTRUCTION
INDUSTRY

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**An investigation into the dissemination of lean principles in
the Irish construction industry**

Abstract

Lean Construction offers a new construction project procurement and delivery format which can address the fragmentation, inefficiencies, and wastes which prevail in traditional construction methods. This is achieved by building on the principles of a lean production system aimed at maximising value and minimising waste.

With a return to growth following a significant downturn, the Irish construction industry is now looking to new project procurement and delivery formats, such as Lean Construction, to try to avoid repeating the mistakes of old. However, the Lean Construction concept has only recently been introduced to Ireland and there is limited information available on its adoption and implementation.

To try to address this, research was carried out in the form of a detailed literature review and a survey of Irish construction companies to gauge the level of dissemination of lean principles in the Irish construction industry.

The research found a broad understanding of lean principles and concepts in the Irish construction industry and the adoption rates of lean tools and techniques to be quite high. However, the findings also identify that the Irish construction industry is still dominated by traditional project procurement, planning and management methods and that the use of newer, leaner methods is the exception rather than the norm.

In general there are some very positive signs that there is an ever increasing rate of adoption and, on average, the Irish construction industry has fared better than other countries previously studied. There appears to be a very good foundation already established for the future development and expansion of lean principles in the Irish construction industry and the participants in the survey certainly believe that lean represents the future of construction in Ireland.

Declaration

I, Kevin O'Brien, declare that the work being submitted for examination is wholly my own work and that all materials consulted and ideas garnered in the process of researching the dissertation have been properly and accurately acknowledged.

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Chapter 1 – Introduction:

The construction industry is historically very fragmented, notoriously conservative, slow to adapt, and slow to embrace change (Latham, 1994). Nowhere is this more obvious than in Ireland where, despite huge growth in the construction industry during the boom years of the Celtic Tiger, the methods used by contracting companies to run and complete construction projects have seen little change (Stewart, 2013). Project procurement and delivery formats have remained the same for decades, and inefficiencies and waste were seen as acceptable by-products of a booming industry.

Success during the construction industry boom years both in Ireland and elsewhere masked the massive inefficiencies which were endemic in the industry as a whole (Hore, 2006). The construction industry in the US for example had a negative annual productivity growth rate for 30 years up to 2004 (Diekmann et al, 2004). Conversely, during that same period of time significant productivity gains were achieved in the manufacturing industry. If the manufacturing industry can make such significant productivity gains, then why not the construction industry? The reason, according to Stewart (2013), is “the construction industries lack of integration, inability to embrace IT advancements, low off site fabrication, fragmentation of professional services and protectionist stances from vested interests”.

During the 1990's, the UK industry was also suffering with massive inefficiencies and zero growth. To try to understand why, the British government commissioned an investigation into the causes and possible solutions for this issue. The results of this investigation were the Latham report (1994) and the Egan report (1998). These seminal reports highlighted the inefficiencies, wastes and failures that were endemic in the construction industry. They also put forward recommendations for improvements in the industry through the elimination of waste or non-value-adding activities from the construction process.

The concept of Lean Construction (LC) offers perhaps the greatest potential for such improvements. According to the Lean Construction

Institute (LCI), LC is the elimination of waste and inefficiencies from the process of designing and constructing buildings. This is achieved through using a production management-based approach, building on the principles of a lean production system and applying them to a new project delivery process. The concept of LC has been around for the past 20 years and has been developed through organisations such as the International Group for Lean Construction (IGLC) and the aforementioned LCI. Research has identified that since the formation of the LC concept, a number of studies have investigated the adoption and implementation of LC in countries such as the UK (Common et al, 2000), the Netherlands (Johansen et al, 2002) and the US (Gilbert, 2008).

However, this research also shows that a very limited amount of information is available on LC in the Irish context. This is despite the fact that recently, the concept of LC has been introduced to the Irish construction industry, primarily through the efforts of the Lean Construction Institute (Ireland), which was founded in 2014. There is currently a return to significant growth in the Irish construction industry, with the most recent CSO figures (Q1, 2016) showing a 13.6% year-on-year increase in the Irish construction sector output to Q1 2016, including a 4.2% increase on the preceding period. With this return to growth, and in light of the waste and inefficiencies which prevailed during the boom years, industry players are keen not to repeat the mistakes of old. They are now looking to new project procurement and delivery methods to ensure that history does not repeat itself. LC is perhaps the most significant development in this respect but the lack of information available on LC in the Irish context is potentially an issue and may act as a barrier to adoption.

Therefore, now is an opportune time to carry out research into LC in the Irish context with the objective of addressing this research gap. A survey of Irish construction companies will be conducted to determine the level of dissemination of lean principles in the Irish construction industry. This research will also try to gain some insight into the current understanding of

lean, and attitudes to lean in the Irish industry. The survey will also enable Irish industry to be compared to other industries by benchmarking the survey results against the results of the existing research which has been carried out in the field of LC.

Chapter 2 – Literature Review

2.1 Lean Production

The origins of Lean Production can be traced back to the foundation of the Toyota Motor Corporation by Kiichiro Toyoda in 1937, who wanted to manufacture cars for the domestic Japanese market (Liker, 2004). The subsequent outbreak of the Second World War left Japan facing an economic crisis by the mid-1940's which forced Toyota to focus their efforts on production efficiency improvements in order to overcome problems such as:

- A shortage of raw materials
- A lack of financial resources
- Scarcity of land in their small island nation
- Lack of industrial development, particularly compared to the Western world

The task of finding these improvements in production efficiency fell to Taiichi Ohno, an engineer who had worked with Kiichiro's father, Sakichi, since 1932. Ohno's focus on efficiency led to the development of the Toyota Production System (TPS). The TPS looked at the overall production system, rather than focusing specifically on craft production i.e. the worker, or mass production i.e. the machine, and was primarily based around the principle of doing the right things (Modig & Ahlstrom, 2013).

Ohno built on the production management system developed by Henry Ford, but adapted it to cater for specific customer orders, and developed a set of objectives which should be used when designing a production system as follows:

- Create a product to meet specific customer requirements
- Deliver the product instantly
- Have no stock inventory

Ohno defined any failure to meet these objectives as waste. By applying these objectives to the mass production systems used in the US automotive industry, Ohno identified the high levels of waste which existed in that industry. The focus on maximising the output of each machine and keeping the production line moving resulted in excessive inventories and overproduction in the US industry. The pressure to keep the production line moving resulted in defects not being addressed as and when they were identified i.e. they were moved down the line to be resolved, thereby creating a bottle-neck, or worse still, they were not resolved at all and resulted in a defective finished product.

In order to address this issue and streamline the workflow, Ohno instructed his line workers to stop the production line once a defective part had been identified, and to investigate the cause of the defect so that it could be addressed and resolved (Liker, 2004). This decentralising of the decision making process was also applied to the inventory control system by the introduction of a distributed pull system to replace the traditional centralised push system (Howell, 1999). This was achieved by the use of an empty bin to identify a downstream demand to the upstream station which resulted in reduced work in progress. This in turn reduced the cost of defects due to the reduced number of parts affected. This is known as the Kanban production control system and is a cornerstone of the just-in-time or JIT production system (Askin and Goldberg, 2002).

Ohno also promoted transparency in the production process to improve not only the process itself, but also the finished product (Liker, 2004). Transparency involved ensuring that all production system information was available to all parties involved in the production process, thereby facilitating more informed decision making and further reducing the reliance on centralised management. This demand for transparency was also extended to the supply chain where information sharing was not only encouraged, but expected.

The term lean production was first used in in the 1988 Sloan Management Review article titled *Triumph of the Lean Production System*, by John

Krafcik (Modig & Ahlstrom, 2013). In this article, Krafcik challenged the idea that productivity was created by economies of scale and demonstrated that systems which employed low inventories, low buffers and simple technologies (such as TPS) were much more efficient and delivered higher quality.

However, despite the benefits of the TPS, and the success it had brought to the Toyota Motor Corporation, the system was largely dismissed outside of Japan until the publication of *The Machine That Changed the World* in 1990. This publication, by Womack, Jones & Roos, identified that the Japanese automotive industry and Toyota in particular, were leagues ahead of their European and American competitors in terms of productivity and quality and stated that this was a result of the implementation of systems such as Toyota's TPS.

Womack and Jones continued to develop the lean concept and their 1996 book, *Lean Thinking*, introduced five key principles of lean in order to assist with the implementation and application of the lean production concept:

- Identify and deliver value to the customer
- Remove anything that does not add value
- Ensure production is organised into a continuous flow
- Ensure that the inventory control system is driven by the downstream pull
- Pursue perfection to drive continuous improvement

Lean production is summarised by Howell as aiming to “optimise performance of the production system against a standard of perfection to meet unique customer requirements” (Howell, 1999).

2.2 Lean Construction

According to the Lean Construction Institute (LCI), LC is a “production management-based approach to project delivery -- a new way to design and build capital facilities.” (LCI, 2016). When applied to construction project design and delivery, Lean changes the way work is done throughout the delivery process by building on the principles of a lean production system i.e. to maximise value and minimise waste, and applying them in a new project delivery process. As a result:

- The construction delivery process is incorporated into the design to better support customer purposes.
- Work is structured throughout the process to maximise value and minimise waste.
- There is a focus on improving total project performance.
- The performance of the planning and control systems are measured and improved.

The concept of applying lean production methodology to the construction industry was initially put forward by Koskela in his 1992 paper *Application of the New Production Philosophy to Construction*. Koskela believed that if applied to the construction process, lean production principles will improve the efficiency of the process and will ultimately improve the quality of the end product by focusing on flow and value considerations (Koskela, 1992).

This view went against the prevailing form of activity centred construction management which broke a project down into its component parts, or activities, which are scheduled and managed separately, but as part of the overall construction project. With this methodology, each activity is controlled by monitoring it against its cost and schedule projections. Activities that are not in line with these projections are dealt with on an individual basis, sometimes at the expense of a downstream activity. Howell argued that this focus on activities “conceals the waste generated

between continuing activities by the unpredictable release of work and the arrival of needed resources” (Howell, 1999).

This move away from activity focused management was developed by Howell and Ballard in their 1998 paper *Implementing Lean Construction: Understanding and Action*, where they coined the phrase “project-as-production system” to highlight that the total project cost and duration are more important than the cost or duration of a single activity (Howell and Ballard, 1998). With LC, the entire construction project is viewed as a production system as opposed to a combination of individual activities, with work flow and added customer value as the primary objectives.

According to Howell, the features of LC include a “clear set of objectives for the delivery process, aimed at maximising performance for the customer at project level, concurrent design of product and process, and the application of production control throughout the life of the project from design to delivery” (Howell, 1999).

2.3 Tools for the Implementation of Lean Principles in Construction

Although LC is, in theory, identical to lean production, the reality is that in practice it is very different. Therefore, the successful implementation of lean principles in the construction industry required a new set of tools and techniques to be developed. The implementation tools which were used in lean production, such as total quality management and six-sigma, were adapted for use in lean construction, and other tools such as the Last Planner System and the Lean Project Delivery system were specifically developed to facilitate lean construction implementation. According to Aziz and Hafez (2013), some of these implementation tools can be described as follows:

2.3.1 Concurrent Engineering:

Concurrent engineering is the simultaneous execution of various tasks by multidisciplinary teams with the objective of increasing productivity and producing a higher quality end product. Concurrent engineering relies heavily on teamwork, knowledge sharing and communication.

2.3.2 Last planner:

The Last Planner System (LPS) is a short-term project planning system which is used to plan activities as close as possible to the actual activity being carried out in order to reduce activity uncertainties caused by upstream process issues (Ballard, 2000). With the LPS, the planning & sequencing of activities is refined to task execution level meaning that the construction trades are part of the activity planning. The LPS is regarded as the principle tool used in the lean construction system.

2.3.3 Daily huddles:

Daily huddles provides a platform for the team members to share their views and to discuss any problems they are facing during the production process.

2.3.4 The Kanban System:

A Kanban is an empty card or box which replaces centralised inventory control with a signal system which alerts the upstream workstation of a demand in the downstream workstation. This system changes the inventory control system to a distributed pull instead of the traditional centralised push (Howell, 1999), thereby lowering the work-in-progress and in turn the costs due to a reduction in the scale of potential impacts to production.

2.3.5 Plan Conditions and Work Environment in the Construction Industry (PCMAT):

PCMAT is a means of building a health and safety plan into the overall project execution plan, thereby enabling any potential schedule impact as a result of the health and safety activity to be evaluated and mitigated.

2.3.6 Quality Management Tools:

Ensuring quality at source enables workers to focus on the execution of planned activities instead of quality corrections.

2.4 Implementation of Lean Concepts in Construction

The successful implementation of lean principles in the construction industry requires a significant change in mentality and a shift away from the traditional methods of the industry as a whole. It also requires the adoption and implementation of new tools and techniques for project procurement and delivery. However, the construction industry is historically very fragmented, notoriously conservative, slow to adapt and slow to embrace change. This unwillingness and/or inability to adapt and change has resulted in the construction industry being left behind in terms of gains in productivity, particularly when compared to other industries such as manufacturing. In fact, in many instances productivity growth has been in decline for many years.

This decline in productivity is highlighted by Sveikauskas et al. (2014). Their paper on productivity growth in the US construction industry between the years of 1958-2010 shows that “productivity growth was negative from 1967 to 1987, close to zero from 1987 to 1997, but has been substantially negative since then”. This paper followed research into productivity in the Japanese construction industry carried out by Teicholz (2004) which identified a productivity decline of over 25% in the Japanese construction industry over the period of 1990-2004. Going back even further to 1997, an investigation carried out on a number of UK mechanical & electrical (M&E) projects by Hawkins (1997) for the Building Services Research and Information Association (BSRIA) found an overall productivity rate on these projects of only 37%. This research covers a period of almost 20 years and shows that, during a period of significant gains in productivity in the manufacturing industry, there was a worldwide productivity decline in the construction industry.

The reasons behind this, at best, stagnation in productivity growth rates in the construction industry are “the industries lack of integration, inability to embrace IT advancements, low off site fabrication, fragmentation of professional services and protectionist stances from vested interests” (Stewart, 2013). This rigidity which is endemic in the industry was also alluded to by Howell & Ballard who stated that “one has to accept the deep resistance to decentralised decision making” (Howell & Ballard, 1998)

There are real benefits to lean construction which offer perhaps the greatest potential for improvements in outdated project procurement and delivery methods, and a solution to the stagnation in productivity growth rates identified above.

2.5 Benefits of Lean Construction:

The real benefits from the adoption of lean principles are clear to see from the productivity gains experienced in the manufacturing industry, and the acceptance, adoption and implementation of lean principles, tools and techniques also offers the construction industry many potential benefits. As stated by Ebbs (2011) “Lean Construction principles can not only succeed, but can without doubt improve the Irish Construction Industry”.

Developments in the area of information technology offer perhaps the greatest potential for the advancement of construction project delivery methods. One such development and probably the most significant lean construction tool is Building Information Modelling (BIM) which is “a digital representation of physical and functional characteristics of a facility. It is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition” (nationalbimstandard.org).

Stewart (2013) states that it is clear that BIM “has dramatic potential benefits to all stakeholders involved in the construction industry”. Collaboration is one of the cornerstones of the lean construction philosophy, and the integrated nature of BIM enables a constant sharing of information among all users, resulting in them realising the maximum benefits available from IT. Other information technology tools which facilitate collaboration for construction team members are cloud computing and software as a service. Both of these have been facilitated by improvements in broadband networks, and can keep all members of the project team connected, ensuring that the latest project information is available as and when required.

Along with collaboration, another core component of the lean construction philosophy is innovation, and in his BSRIA report on Innovative M&E Installation, Wilson (2000) concluded that the use of innovative M&E installation techniques will bring substantial changes to the construction industry, claiming that the industry will see a reduction in inefficiencies and

waste, potential reductions in installation labour of up to 90% and potential reductions in installation costs of up to 70% (Wilson, 2000).

Leagility is one such innovation and was discussed by Court et al. (2006) in their paper on the design of a lean and agile construction system. Leagility builds on the leagile concept from the manufacturing industry which was based on the coupling of lean and agile manufacturing. The authors wanted to see how the leagile concept could be built upon for the development of a lean construction system. The leagility concept is to pre-assemble as much as possible off-site, deliver to site just-in-time to be incorporated into the assembled systems, move as many people as possible off site and to provide those remaining with good ergonomics, appropriate working tools and a good working environment (Court et al, 2006). The lean construction system developed as part of this research leans heavily on the concept of modular assembly or modularity. According to Fredriksson (2006) modularity is the “ability to pre-combine a large number of components into modules, for these modules to be assembled off-line and then brought onto the main assembly line and incorporated through a small and simple series of tasks”.

In 2007 & 2008, Court, Pasquire, and Gibb had the opportunity to put the lean and agile mechanical and electrical construction system they had developed in 2006 into practice on a case study project in the UK. This system was designed to improve efficiency and productivity by overcoming the traditional problems and issues faced by the mechanical and electrical contracting companies operating within the UK construction industry. Their 2009 report on this case study project (Court et al, 2009) indicated that when compared to traditional methods, the new construction system resulted in a 37% reduction in onsite labour numbers and a 7% reduction in overall labour. Significantly, the report also highlighted an overall productivity rate of 116% on the case study project which is a significant improvement on the 37% overall industry productivity rate identified by Hawkins (1997).

Regardless of whether or not it is wrapped up in the leagility concept, off-site pre-assembly or pre-fabrication of component parts into modules is another key principle and philosophy of lean construction. Sparkman et al. (1999) identified the general advantages of off-site pre-fabrication including reductions in labour, waste, and installation time; increases in quality and efficiency; and improved productivity, control, cost and performance.

Based on the benefits identified above, it would be safe to assume that there is widespread implementation of lean principles in the construction industry. In order to investigate this assumption, research was conducted which identified that a number of studies have already been carried out on the adoption and implementation of lean construction in countries such as the UK, Germany, the Netherlands, and the US, as discussed below.

2.6 Dissemination of Lean Construction

In 2000, shortly after the aforementioned Egan Report (1998), Common, Johansen and Greenwood carried out research among UK based construction companies to “test the transfer of lean principles to construction by investigating their penetration into large construction companies in the UK”. The research was carried out in the form of a survey, sent to 100 large construction companies, with the aim of establishing the extent to which these companies applied lean construction techniques. The survey had a 35% rate of return and the results showed that there was a “distinct lack of understanding and application of the fundamental techniques required for a lean culture to exist”, and that while there had been some adoption of LC, it was in conjunction with traditional project delivery methods. The research also found “great variation” in the survey groups’ perception of LC and how LC had been embraced by the industry (Common et al, 2000).

The research carried out in the UK by Common et al (2000) was developed further by Johansen, Glimmerveen, and Vrijhoef in 2002 when they carried out a similar survey among Dutch construction contractors

using the same questionnaire as had been used in the UK survey in 2000. As with the UK survey their aim was to determine the level of dissemination of LC within the Dutch industry and also to investigate how the Dutch results compare against the results from the UK survey. The questionnaire was distributed to 60 medium to large contracting companies, and at the second attempt, a 20% rate of return was achieved. The results of this research showed that penetration of LC in the Dutch construction industry was very low. In fact, it was even lower than in the UK construction industry when compared to the original research carried out by Common et al. (2000). The research also highlighted a high lack of understanding of the concept of lean and suggested that most construction companies have no interest in adopting lean concepts (Johansen et al, 2002).

In 2007, Johansen, who had been involved in both the original UK study and the subsequent Dutch study, along with his colleague Walter, carried out research on the dissemination of LC among construction contracting companies in Germany. They used the same questionnaire as had previously been used in the UK & Dutch research. The authors updated their questionnaire to take account of the developments in LC in the 5 years since the Dutch research was carried out and in order to assist with the formulation of the questions, they utilised a questionnaire developed by Diekmann et al. (2004) to investigate the application of lean manufacturing principles to construction.

As with the previous research, the objectives of this study were to “establish how lean techniques have been disseminated among construction companies, how lean thinking has penetrated the industry, and how lean concepts are being understood” (Johansen & Walter, 2007). The questionnaire was distributed to 61 construction contracting companies and a 28% rate of return was achieved which is in line with the low rates of return achieved in both the UK and the Netherlands. The results of this research suggest that there was “little awareness of lean in the German construction industry” and that “no more than a few lean

concepts are occasionally applied within the industry.” The research also indicated that there was little belief in the German construction industry that LC is beneficial, and that there was a lot of scepticism regarding the “transferability of lean principles to the construction industry.” Similar to the aforementioned research by Howell & Ballard (1998), the authors conclude that the biggest barrier to the adoption of lean principles was the construction industries unwillingness to change their mentality or open their minds to new ideas (Johansen & Walter, 2007).

Gilbert (2008) carried out research on the deployment of lean methods in the US construction industry. This study, while independent of the studies carried out in the UK, the Netherlands, and Germany, sought to answer similar questions to those studies, and to establish an understanding of the dissemination of lean principles in the US construction industry. In order to achieve this, the author developed a questionnaire and distributed it to 113 construction contracting companies who were represented at the 2008 University of Florida spring career fair. Forty-four of the contracting companies responded to the questionnaire, giving a 39% rate of return which is the highest achieved in the four studies reviewed so far in this paper.

The results of this study indicated that there was little dissemination of lean principles in the US construction industry and highlighted that only 23% of respondent organisation were familiar with lean construction. This lead the author to conclude that “most of general contractors, specialty contractors, and construction management firms in the construction industry are unfamiliar with the term lean construction as an approach to managing the construction process” (Gilbert, 2008). There does however seem to be at least some adoption of lean principles among larger companies surveyed (200+ employees), and the answers received indicated that those companies who were familiar with the concept of lean construction and who had adopted at least some of the methods and techniques “believe that it is beneficial” (Gilbert, 2008).

While this study was carried out in the University of Florida, the author is very non-specific regarding the nationality of the organisations surveyed or where they actually conduct their business. The author states that the survey was distributed to “some of the world’s top contracting companies” (Gilbert, 2008), but does not give any indication of where these companies are from. It is not clear whether these organisations were US-based or international, and the study is therefore limited in terms of being representative of the US construction industry as a whole. The results however are consistent with the Dutch, German and UK studies regarding the low dissemination rates of lean construction.

An analysis of lean construction practices in the Abu Dhabi construction industry was carried out by Al-Aomar in 2012. Like the aforementioned research carried out by Gilbert (2008), this study was independent of any which had gone before, and sought to investigate, amongst other things, how familiar the Abu Dhabi construction industry is with lean construction concepts and methods (Al-Aomar, 2012). Of the 60 companies surveyed, 28 responded giving a 47% rate of return which is significantly higher than any of the studies previously identified in this paper. The study found that 32% of the organisations surveyed are familiar with the lean construction concept and methods and that only 15% are regularly using lean techniques as part of their project executions. The study also identified that those organisations that are familiar with and using lean techniques have only been doing so for a relatively short period of time i.e. <5 years.

An awareness rate of 32%, despite being perceived by the author as low, shows a significant increase in awareness of lean construction when compared to the previously identified studies. Perhaps significantly, this study identified that the adoption of lean techniques has only occurred in the 5 years prior to the study. This, combined with the increased awareness rates would indicate a growing international awareness of lean construction in the 4 year period between the US and Abu Dhabi studies. The Abu Dhabi study is limited however in that it was confined to the

residential and commercial construction industry and therefore may not be representative of the Abu Dhabi construction industry as a whole.

In 2013, McGraw Hill Construction conducted a study into lean practices in the US construction industry among both general and speciality contractors. This quantitative survey yielded responses from 193 contractors comprised of two groups i.e. construction contractors that were members of the Lean Construction Institute (37%) and construction contractors that were not members of the Lean Construction Institute (63%). The authors do not indicate how many organisations were asked to participate in the study so there is no information available on the rate of response. Of the non-LCI member organisations, 28% had implemented at least one lean practice, 35% were familiar with lean construction but had not implemented any lean practices, and 37% were not familiar with lean construction at all.

This study indicates that 63% of construction contractors were familiar with lean construction which is a significant increase on the other studies referenced in this paper e.g. 23% awareness in the 2008 US study (Gilbert) and 32% in the 2012 Abu Dhabi study (Al-Aomar). However, less than half of those organisations familiar with lean construction had actually implemented a lean practice. Nevertheless, this study does indicate a growing move towards lean construction, particularly when compared to the previous study carried out in the US by Gilbert (2008) where significant increases in awareness, adoption and implementation can be seen.

2.7 Challenges of Lean Construction:

Despite the growing trend towards the adoption and implementation of lean construction as demonstrated in the aforementioned research studies, the level to which lean tools and techniques are being used are not what one would expect based on the obvious potential benefits. This lack of dissemination would suggest that the acceptance, adoption and implementation of LC is not without its challenges. The successful implementation of lean principles in the construction industry requires a

significant change in mentality and a shift away from the traditional methods of the industry as a whole, and the adoption and implementation of new tools and techniques for project procurement and delivery. However, as aforementioned, the construction industry is historically very fragmented in the way it operates and is notoriously conservative, slow to adapt and slow to embrace change. As Howell and Ballard (1998) put it, there is a “deep resistance to decentralised decision making”.

Developments in the area of information technology have not been embraced by the construction industry as readily as in other industries despite offering perhaps the greatest potential for the advancement of construction project delivery methods. Stewart (2013) states that it is clear that BIM “has dramatic potential benefits to all stakeholders involved in the construction industry”. However, in the same paper he states that there are significant issues with the adoption of modern technologies. This in turn is resulting in reduced productivity in the construction industry and the author states that “industry analysts place these results squarely at the construction industries lack of integration, inability to embrace IT advancements, low off site fabrication, fragmentation of professional services and protectionist stances from vested interests”. According to Aziz & Hafez (2013), the reason that these new technologies have not been fully embraced by the construction industry, is that new technology cannot alone reduce the cost of design and construction, and also improve the management of the construction process. They state that contemporary management concepts need to be used in conjunction with these new technologies in order to improve the efficiency of construction projects, and identify lean construction as the contemporary management process which is most complimentary to the new technologies (Aziz & Hafez, 2013).

Off-site fabrication is a central philosophy of lean construction and offers huge potential for the advancement of construction project delivery methods. In their 2002 paper, Pasquire and Connolly identify that lean production has made “significant improvements” in productivity in the

manufacturing sector and point to factory-based fabrication as a “logical method for incorporating lean production in construction project delivery (Pasquire & Connolly, 2002). The benefits of off-site fabrication and pre-assembly have also been identified by Gibb (1999), however the research carried out by Pasquire and Connolly identified that incorporating off-site manufacturing into the construction process has met “significant resistance from both clients and their advisors”. This theory was put to the test by Pasquire and Connolly on a case study project, and while they found that the use of off-site fabrication resulted in some significant benefits, particularly with labour savings, there are still significant hurdles to overcome. They state that “there is little understanding within the construction industry of the process of putting parts of construction into manufacturing”, and that “design consultants have little understanding of the differences in designing for manufacture and assembly from designing for insitu assembly” (Pasquire & Connolly, 2002). It seems that in order for there to be any significant adoption of off-site fabrication, a major re-think of traditional methods is required. When this is combined with other issues such as increased capital cost, there is a significant challenge to face to try to increase the adoption rates.

Collaboration and integration are another key philosophy of lean construction, and increased collaboration amongst project teams offers potentially substantial benefits to the whole construction project. However, the construction industry is historically very fragmented and in their 2001 paper on the problems in the interface between design and construction, Miles and Ballard state that “design and construction are insufficiently integrated in all forms of project delivery currently on offer”, and consequently there is “tremendous waste on projects” (Miles & Ballard, 2001). According to the authors, the solution to this problem is a new form of project delivery which is “designed to accomplish the lean objectives of maximising value and minimising waste”.

Collaboration and integration as key elements of lean project delivery are also identified by Pasquire & Connolly (2002) in their paper on off-site

fabrication where they state that the integration and co-ordination of trades are a “major influence on the success or otherwise of project delivery” (Pasquire & Connolly, 2002). It is therefore clear that a major failure in project delivery is a lack of integration and co-ordination, problems in interface, and conflicts in the relationship between the designers and the contractors. Miles & Ballard (2001) suggest that the best way to resolve these issues would be through the introduction of a “cross functional team” and a move away from the traditional “top-down” management structure. However, the authors acknowledge that this would involve a fundamental change in the mindsets of all parties and that this will be one of the biggest obstacles to the implementation of any new form of project delivery (Miles & Ballard, 2001).

2.8 Drivers for Change:

The main challenge facing the widespread adoption and implementation of lean construction is change i.e. changing the mindsets of the people involved in the industry and making them see and understand the real benefits. Garnett et al (1998) identified that all organisational change is people driven; people are the key to the success or otherwise of any proposed change and therefore people must be the main focus of attention in this process. People are fearful of what they don't understand and therefore training and education must be the first step of the implementation process. This was identified by Ebbs (2011) who argued that lean construction cannot implement itself and that people are the most important factor in this implementation, and that in order to succeed, organisations need to “up-skill their workforce and encourage a regime of continuous improvement” (Ebbs, 2011).

Along with education and training, other factors which are key to the successful implementation of lean construction in any organisation include the visible commitment of senior management to the change process; ensuring that the employees are kept fully informed and have full knowledge of what is happening throughout the change process; and motivating and incentivising employees through rewards schemes, etc.

This is recognised by Ebbs (2011) who states that “senior management must encourage employees to become part of the lean journey and acknowledge the efforts of their staff in the same time”.

However, unless the previously identified benefits are clearly identified as being achievable and the methods for realising them are proven, there is no real driver for change (Pasquire & Connolly, 2002). Any lack of visibility of these benefits will be one of the biggest obstacles to change. The value of solving the existing problems within the construction industry is very difficult to measure, however without tangible measurements and results, there is no real driver to change. As is often the case, it seems that habitually, the biggest driver to change is crisis within the industry. In the absence of crisis, the realisation of tangible benefits must therefore be the driver. Benefits such as improved profits, improved working conditions, reduced risk exposure, empowerment, etc. need to be clearly identified as being achievable. Otherwise, lean construction practices will not be incorporated.

2.9 The Irish Construction Industry:

The construction industry is a key sector in the Irish economy and experienced steady growth from the late 1980's up until the economic crash in 2007 as indicated by the below table which shows the CSO figures for the construction industries contribution to the Irish economy during this time (CSO, 2016).

Construction Contribution to Irish Economic Activity		
Period	% of GDP	% of GNP
1970 - 1979	12.10%	12.10%
1980 - 1989	10.90%	11.80%
1990 - 1999	10.80%	12.20%
2000 - 2009	16.40%	19.30%
2010 - 2015	6.20%	7.40%

Table 1: Construction contribution to Irish economic activity 1970-2015

Construction is particularly important to the area of job creation. This was never more obvious than during the boom years of the Celtic Tiger when the construction industry accounted for 13.4% of total employment, and at its peak in 2007, over 270,000 people were directly employed in the Irish construction industry with another 100,000 people employed indirectly (Bobek & Wickham, 2015).

The global financial crisis of 2007 and the subsequent bursting of the Irish property bubble had a catastrophic impact on the Irish construction industry, and the Irish economy as a whole. In the 4 years that followed, employment levels plummeted to a point where, by 2013, direct employment stood at fewer than 100,000, with 50,000 indirectly employed. Over 200,000 jobs had been lost and construction now accounted for less than 6% of the overall employment in Ireland, down from a high of nearly 14%. The situation was so bad that 36% of all unemployed males and 20% of the live register had previously been working in the Irish construction industry (RICS, 2014).

However, figures from the CSO (2016) and the RICS (2014) indicate that the Irish construction industry is well and truly on the road to recovery and the prospects for the industry are brighter now than they have been in almost 10 years. These figures show that the industry bottomed out in 2012 with an output of €9.1 billion, and steadily increased from there to €11 billion (2013), €12.5 billion (2014) and €15.3 billion (2015). The most recent CSO figures (Q1, 2016) show a 13.6% year-on-year increase in the Irish construction sector output to Q1 2016, including a 4.2% increase on the preceding period.

In terms of employment, figures from the CSO (2016) show that over 116,000 people were directly employed in the construction industry in Q1, 2015 which represents an increase of almost 19,000 from the lowest point reached in early 2013. This is an increase of almost 20%, and when the figure for indirect employment is added in, represents 8.5% of total employment in the Irish economy. These figures are still substantially

lower than the highs reached during the boom but nevertheless indicate a return to significant growth.

One positive of the economic downturn is that it has highlighted significant issues which have prevailed within the Irish construction industry such as the continued use of antiquated project procurement and delivery formats and the acceptance of inefficiencies and waste as by-products of a booming industry. In light of the new return to significant growth, industry players are keen not to repeat the mistakes of old and are now looking to new project procurement and delivery formats to ensure that this does not happen. Lean construction is perhaps the most significant development in this area however, the research previously identified is entirely focused on construction industries outside of Ireland. There appears to be limited information available regarding the awareness of lean construction in Ireland, or into its adoption and implementation.

In very recent years the concept of lean construction has been introduced to the Irish construction industry, primarily through the efforts of the Lean Construction Institute - Ireland, which was founded in 2014. Prior to this however, Ebbs (2011) carried out an investigation into whether or not lean construction can improve the Irish construction industry. This research took the form of a questionnaire which was developed to get the opinions, attitudes, experience and likely behaviours of construction professionals towards lean construction (Ebbs, 2011). The 41 responses received indicated that not only can lean construction principles succeed in the Irish construction industry, but they can also substantially improve it. However, as per the earlier findings in this paper, Ebbs identified that a significant and fundamental cultural change would be required in order to realise these improvements.

At the Lean Construction Institute (Ireland) launch event in 2014, Tolan et al. conducted a survey to gauge the level of understanding and experience of lean construction methods, tools and techniques amongst Irish construction industry stakeholders. The survey sample size was 116 people and the results indicate that “there is a strong interest from an

industry wide perspective in adopting Lean Principles into the Irish Architectural, Engineering & Construction (AEC) Industry” and suggests that “the demand for change is real”. However, the actual number of lean practitioners was much lower than the lean awareness levels which indicate that while the theory of lean principles is understood, there still appears to be some way to go with to increase adoption rates. However, as this survey was carried out at the LCI (Ireland) launch event, its findings are most probably not truly indicative of the Irish construction industry as a whole as it must be assumed that the majority of those surveyed had at least a basic understanding of, or at least an interest in lean construction, so much so that they were sufficiently motivated to attend such an event.

Ebbs et al (2015) conducted a research study aimed at investigating how the theory of lean construction compares with the current practice in the Irish construction industry. The results from this study indicate that lean construction theory is not reflected in practice in the Irish construction industry and that there is limited real knowledge or understanding of the lean construction concept and principles outside of the basic objectives of eliminating waste and adding value. Also, similar to research referenced previously in this paper, there appears to be a need for tangible evidence of the benefits on offer before there can be any commitment to the adoption of lean principles (Ebbs et al, 2015).

Chapter 3 – Research Question:

The literature review has identified studies which have investigated the adoption and implementation of lean principles in construction industries around the world. It has also highlighted the challenges faced by organisations wishing to adopt lean construction methods, and the benefits which are potentially available to organisations should they adopt a lean philosophy. However, the vast majority of information available relates to foreign construction industries and the information identified by the research on the Irish construction industry is limited at best. Based on this, it is clear that a gap exists in the current knowledge and understanding of the adoption and implementation of lean construction in Ireland.

In order to further examine this area and to try to address this knowledge gap, research was carried out **to investigate the current level of dissemination of lean principles in the Irish construction industry.**

Based on the results from studies identified in the literature review the author formulated the following hypotheses pertaining to lean in the Irish construction industry which would be tested as part of this research in order to support the primary objective.

- There is a high adoption rate of lean principles in the Irish construction industry.
- There is a good understanding of the need to adopt lean principles in the Irish construction industry.
- There is a positive attitude towards lean construction in Ireland.

Chapter 4 – Research Methodology

4.1 Background

The research aim is to investigate and identify the level of dissemination of lean construction methods, tools and techniques in the Irish construction industry. It also aims to identify the current understanding of lean construction and to gauge attitudes towards lean construction in the Irish construction industry.

The research for this paper was carried out in two stages. Firstly, secondary research was carried out using primarily journals, research papers and internet searches. The author found that books dedicated to the field of lean construction are quite rare. This secondary research is detailed in the literature review and provided the author with a substantial amount of information and a direction in terms how the primary research needed to be structured in order to achieve the best possible results. Both the IGLC and LCI websites were a great source of guidance, information and referencing in the field of lean construction.

Primary research data was gathered through cross-sectional research in the form of a questionnaire. This questionnaire was developed to obtain data pertaining to the extent of the dissemination of lean construction in the Irish construction industry, the level of understanding of lean construction and the current industry perceptions of LC. The research is of cross-sectional design and due to the nature of the research it was difficult at the outset to predict the direction of the relationships identified; there may be competing theories; there may be contradictory evidence or there may be a lack of evidence available, and as such the research naturally adopted a non-casual non-directional approach.

The author investigated the possibility a qualitative approach to the primary research through interviews with industry representatives to understand their views on lean construction. However, in order to achieve

the desired holistic view of the Irish construction industry, this method was rejected for a number of reasons:

- The author would not be able to collect sufficient research data to test the hypotheses.
- The data collection and analysis process would be too time consuming.
- The results could be difficult to analyse and compare.
- The author could unintentionally bias the interview responses.

4.2 Questionnaire

When considering the format of the questionnaire, the author considered the research which had previously been carried out both in Ireland and abroad, as detailed in the literature review section of this paper. The three Irish studies identified did not specifically address the research aim of this paper i.e. to investigate the adoption and implementation of lean construction in the Irish construction industry, as demonstrated below:

- Ebbs (2011) carried out an investigation into whether or not lean construction can improve the Irish construction industry;
- Tolan et al (2014) conducted a survey to gauge the level of understanding and experience of lean construction methods, tools and techniques amongst Irish construction industry stakeholders. However, this study was conducted at an LCI (Ireland) event and is therefore deemed not to be representative of the Irish construction industry as a whole, and;
- Ebbs et al (2015) conducted a research study aimed at investigating how the theory of lean construction compares with the current practice in the Irish construction industry. However, the surveys conducted as part of this research were based specifically on the adoption of BIM as a tool of lean construction.

The author therefore decided to base this study on the research which has been conducted outside of Ireland, and specifically on the studies

conducted by Common et al (2000) in the UK, Johansen et al (2002) in the Netherlands, and Johansen et al (2007) in Germany. Therefore, the questionnaire builds on that used in the initial survey carried out on the UK construction industry by Common et al. (2000). This same questionnaire was used in the Dutch study (2002), and the German study (2007), albeit updated and developed to reflect changes in the industry in the 7 years since the questionnaire was initially conceived.

The questionnaire is based on a conceptual framework which was conceived as part of the UK study carried out by Common et al (2000), and derived a set of fundamental attributes that are associated with a lean approach, namely Procurement, Planning, Management and Control. This framework was developed further for the German study by Johansen et al (2007) in order to reflect advancements in lean construction to that point. The linkages between the questionnaire and the framework are shown in Appendix 1. This conceptual framework forms the basis for the questions which cover the following 8 areas:

- Procurement
- Management
- Planning / Control
- Collaboration
- Behaviour
- Design
- Supply
- Installation

The research carried out by the author has identified the core questionnaire has now been used in at least 3 previous research papers i.e. Common et al. (2000), Johansen et al. (2002), Johansen et al. (2007), albeit with minor modifications to reflect developments in the industry or regional variations, and the author therefore considers it to be sufficiently tested.

In order to ensure that the questionnaire remained as true as possible to the original, the author of this paper contacted the co-author of the original 2000 (UK) paper, Eric Johansen, to find out as much information as possible about the original questionnaire. Due to the passage of time, Mr. Johansen was unable to provide the author with the required information on the questionnaire from the initial study, but he was able to put the author in contact with the co-author of the German study, Lorenz Walter. Mr. Walter was able to provide the author with information on the questionnaire used in the German study (2007). To enable results to be compared and contrasted with previous research, and in order to maintain continuity in the research to facilitate possible further research development in other countries, the author decided to keep the questionnaire as true as possible to this previous research. However it was understood that modifications may be required to consider more recent developments in lean construction and to make it applicable to the Irish construction industry.

In order to test the applicability of the questionnaire, both in terms of content and context, the author conducted a pilot study with 3 people who have significant experience in the Irish construction industry. Two of these people worked for organisations familiar with lean construction (one organisation was already implementing lean tools and techniques). The third participant had a limited knowledge of the concept of lean construction and worked for an organisation that was not actively engaging in the adoption of lean. As a result of this pilot study, 2 questions were deleted from the original 12 in the questionnaire as they were deemed to be not applicable to the Irish construction industry and 1 question was re-phrased as it was deemed that it may cause some confusion with the recipients. The questionnaire was also reviewed so as to avoid any issues of confidentiality i.e. participants were not asked to divulge information regarding their organisations which may be deemed confidential in nature.

4.3 Sampling

The objective of this study was to achieve a holistic view of the adoption and implementation of lean construction in the Irish context, and in an ideal world this would be carried out using a random sampling method. However, random sampling is very difficult to carry out in practice and therefore a convenience sampling method was adopted. Convenience sampling lends itself to the holistic approach of this survey. The goal was to obtain as large a sample size as possible from a broad spectrum of organisations operating in the Irish construction industry in terms of size (turnover, number of employees, etc.) and discipline (civil, mechanical, electrical, etc.). It was also deemed important to try to include organisations that, on the face of at least, are and are not, currently engaged in lean construction. This method is similar to that which has been used in previous surveys of this nature.

Taking into account the % rate of response from previous similar surveys, and the distribution size for this survey, the authors aim was to gain representation from 20-25 organisations across a wide spectrum to ensure a genuine cross-section was achieved. The author acknowledges that cross-sectional research traditionally involves a larger sample size, and that previous research used sample sizes of between 50 – 100 organisations. However, this previous research was carried out in countries with significantly larger construction industries than Ireland. Also, the aim of this study was to gain representation from as many different organisations as possible, not just representation from as many individuals as possible, which also restricts the achievable sample size. A limitation of the three aforementioned Irish studies is that they specify the number of individual respondents, not the number of organisations represented. It may well be possible that a large % of their respondents represent only a small number of organisations and this will not give a true representation of the Irish industry as a whole. Therefore, based on the size of the Irish construction industry, target representation from 20-25 organisations

would provide a sufficient cross section to give validity to the results and a solid basis for comparing and contrasting with previous research.

The author has 15 years' experience in the Irish construction industry, and during that time has developed a large network of contacts which were leveraged in order to compile the distribution list. Once the details of the questionnaire were finalised, the author was able to distribute the questionnaire and a covering letter via email to 49 recipients, each representing a different organisation. The questionnaire and covering letter are shown in Appendix 2 & 3. Where possible, the author tried to target only senior management or executives in the organisations, as it was deemed that these individuals would be the most well informed regarding the activities in their organisation.

4.4 Data Analysis

In quantitative research, there are 2 types of data which can be obtained from research studies, Categorical and Continuous. The data collected as part of this research is Categorical data and includes Nominal and Ordinal variables. Nominal variables refer to variables that reflect different categories or names of things such as occupation type. Ordinal data refer to the order of the variables, such as an individual's education level. There are also 2 types of statistical analysis which can be used to interpret the data:

- Descriptive statistics form the basis of every quantitative study and are used to describe the basic features of the data in a study and provide simple summaries about the sample and the measures. The author used descriptive statistics for the analysis of this survey.
- Inferential statistics provide ways inferring characteristics from small groups of participants or onto much larger groups. While descriptive statistics just describe the data, inferential statistics enable interpretation of what the data means.

The research data obtained was analysed using quantitative interpretation in order to understand the level of dissemination of lean construction in the Irish construction industry. The research data was also subjected to an interpretive analysis in order to understand the knowledge of lean construction in the industry and also participant's views on lean construction. As the questionnaire is based on the studies carried out in the UK (2000), the Netherlands (2002), and Germany (2007), direct comparisons could be drawn with the results from these surveys which not only facilitated analysis based on location, but also based on changes resulting from the passage of time. The other studies referenced earlier i.e. US (2008), Abu Dhabi (2012), and the US (2013) are independent of this questionnaire and therefore direct comparisons could not be drawn, however their results could be used as reference points for this study.

4.5 Ethical Considerations:

This research poses little or no ethical risk to the participants involved or the organisations they represent. No vulnerable population members were involved and there was no deception of the participants involved. The questionnaire was developed so as to avoid any issues of confidentiality i.e. participants were not asked to divulge information regarding their organisations which may be deemed confidential in nature.

Chapter 5 – Research Results

5.1 Response Rate

The average response rate achieved in the studies covered in the literature review is 34%.

- UK (2000) – 35%
- The Netherlands (2002) – 20%
- German (2007) – 28%
- USA (2008) – 39%
- Abu Dhabi (2012) – 47%

The response rate for this questionnaire was 47% based on a distribution of 49 questionnaires with 23 responses. The author had hoped to achieve a higher response rate, particularly in light of the personal nature of the relationships with a large portion of the distribution list, however a response rate of 47% is significantly above average based on the previous studies identified and is also above average based on the typical response rate of 20-30% for this type of survey as indicated by Kent (2001). Based on this, the survey results are deemed to be acceptable in terms of being used to draw reliable conclusions.

The questionnaire responses are reviewed in line with the structure of the conceptual framework.

5.2 Procurement

Question 1: What share of your annual turnover is made up from design & build contracts, management contracts, general contracts or sub-contracts?

The results from the questionnaire are shown below:

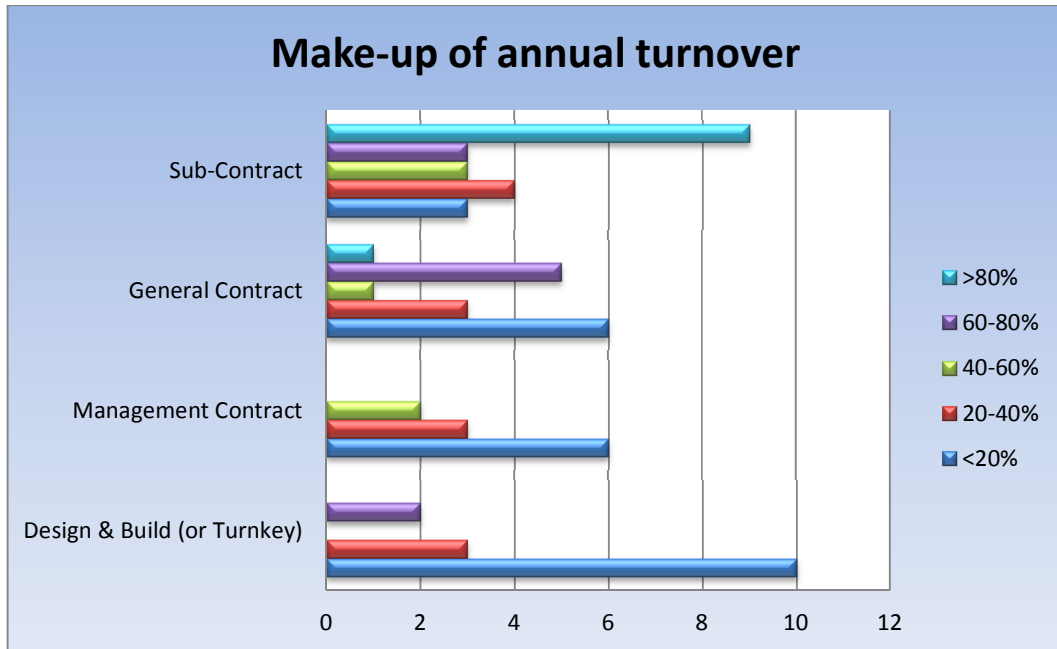


Fig 1: Make-up of annual turnover

What share of your annual turnover is made up from the following types of contract?						
Answer Options	>80%	60-80%	40-60%	20-40%	<20%	Response Count
Design & Build (or Turnkey)	0	2	0	3	10	15
Management Contract	0	0	2	3	6	11
General Contract	1	5	1	3	6	16
Sub-Contract	9	3	3	4	3	22
answered question						23
skipped question						0

Table 2: Make-up of annual turnover

Engaging in design-build or management contracts involves design work and in order to understand the level of integration between design and construction work as carried out by contractors, Question 3 asked the respondents to identify the methods by which this design work was carried out.

Question 3: What route are adopted for any design work taken on by your organisation – all in-house, partial in-house, or all sub-contract?

The results from the questionnaire are shown below:

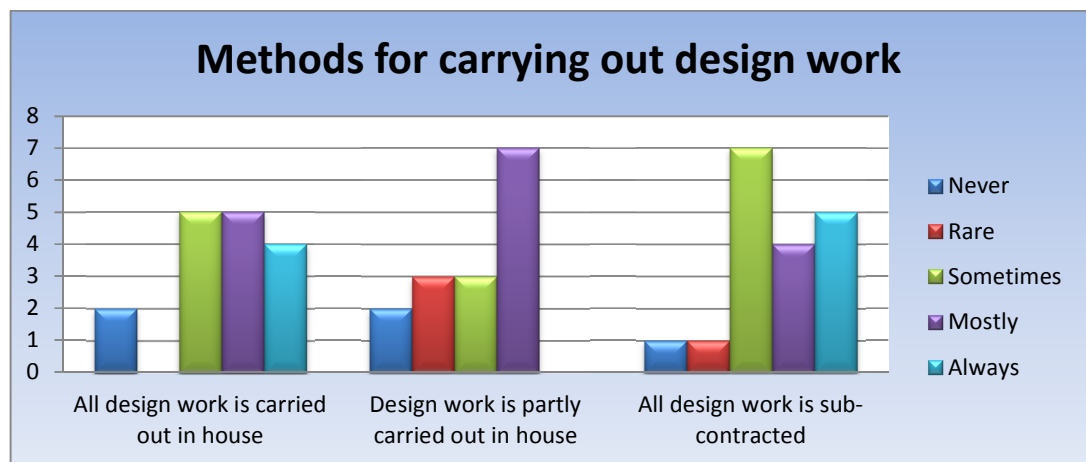


Figure 2: Methods for carrying out design work

If your company take on design work, what routes are adopted for the development of the design?						
Answer Options	Always	Mostly	Sometimes	Rare	Never	Response Count
All design work is carried out in house	4	5	5	0	2	16
Design work is partly carried out in house	0	7	3	3	2	15
All design work is sub-contracted	5	4	7	1	1	18
<i>answered question</i>						22
<i>skipped question</i>						1

Table 3: Methods for carrying out design work

5.3 Management

Question 2: Which of the following principles is your company currently involved in – Concurrent Engineering; Supply Chain Management; Value Streaming; Last Planner; TQM; Benchmarking?

The results from the questionnaire are shown below:

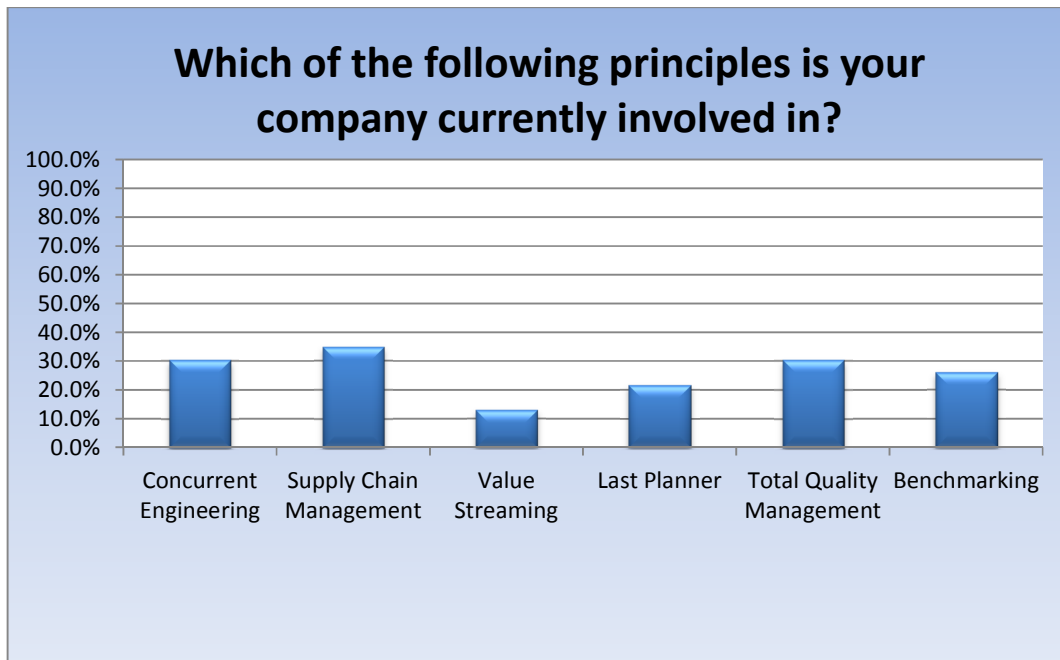


Figure 3: Usage of lean management tools

Which of the following principles is your company currently using?		
Answer Options	Response Percent	Response Count
Concurrent Engineering	30.4%	7
Supply Chain Management	34.8%	8
Value Streaming	13.0%	3
Last Planner	21.7%	5
Total Quality Management	30.4%	7
Benchmarking	26.1%	6
answered question		23
skipped question		0

Table 4: Usage of lean management tools

5.4 Planning

The application of lean planning tools such as Value Streaming and Last Planner are seen as key to the successful implementation of lean construction. Participants were therefore asked to indicate the level of adoption of these tools compared to the traditional planning tool i.e. Critical Path

Question 4: Does your organisation apply any of the following techniques to the design/planning/construction process – Critical Path; Value Streaming; Last Planner; Look ahead Planning?

The results from the questionnaire are shown below:

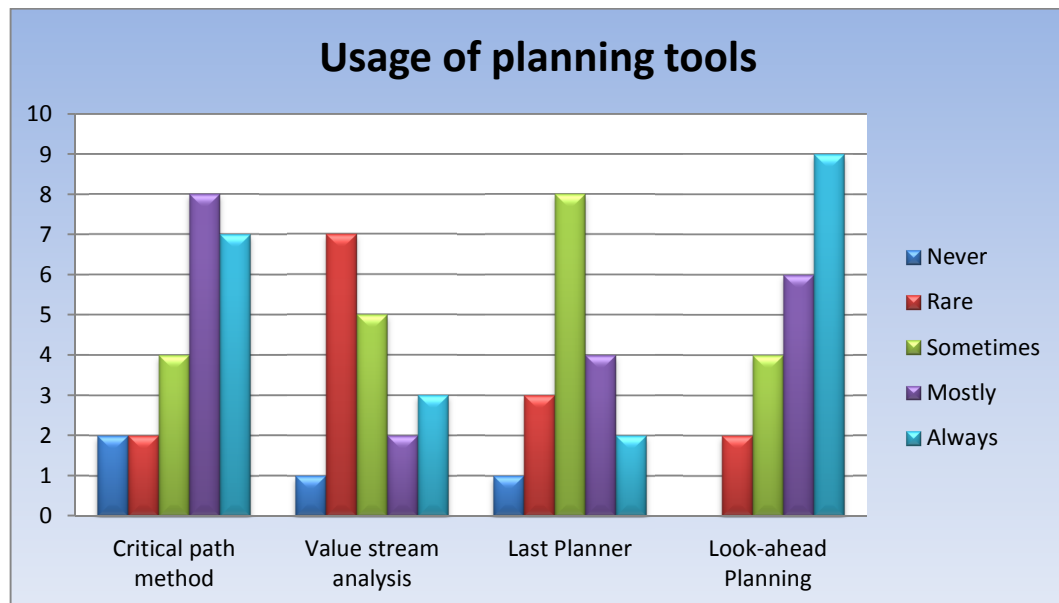


Figure 4: Usage of lean planning tools

Does your company ever apply any of the following techniques to the design / planning / construction process?						
Answer Options	Always	Mostly	Sometimes	Rare	Never	Response Count
Critical path method	7	8	4	2	2	23
Value stream analysis	3	2	5	7	1	18
Last Planner	2	4	8	3	1	18
Look-ahead Planning	9	6	4	2	0	21
<i>answered question</i>						23
<i>skipped question</i>						0

Table 5: Usage of lean planning tools

5.5 Collaboration

Collaboration is identified earlier in this paper as a cornerstone of lean philosophy. The participants were therefore asked to indicate their use of technologies which have been recognised as supporting lean construction by assisting the collaboration process.

Question 5: Does your organisation ever apply any of the following tools to support project collaboration – Doc. Management; Video Conferencing; 3D; 4D; Project Information System?

The questionnaire results are shown below:

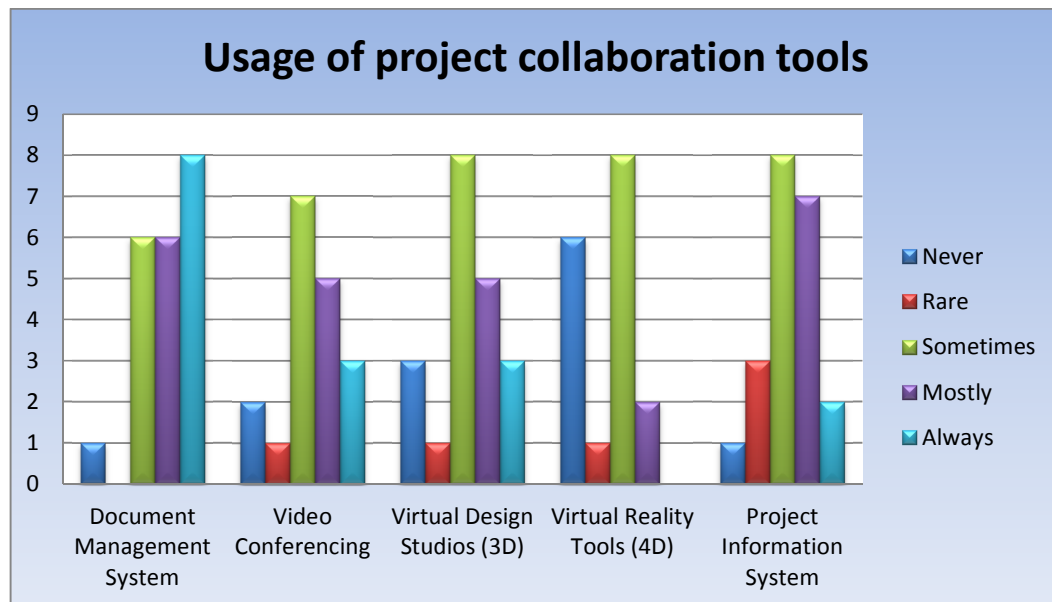


Figure 5: Usage of project collaboration tools

Does your company ever apply any of the following tools to support project collaboration?						
Answer Options	Always	Mostly	Sometimes	Rare	Never	Response Count
Document Management System	8	6	6	0	1	21
Video Conferencing	3	5	7	1	2	18
Virtual Design Studios (3D)	3	5	8	1	3	20
Virtual Reality Tools (4D)	0	2	8	1	6	17
Project Information System	2	7	8	3	1	21
<i>skipped question</i>						0

Table 6: Usage of project collaboration tools

5.6 Behaviour

In order to understand people's attitudes towards lean construction, the participants were asked to give their opinions on the level of knowledge share within their organisations and whether or not they believed there was a sincere commitment to implement and accept change. Both of these questions are crucial to the success or otherwise of the implementation of lean construction.

Question 8: On a scale of 1 to 5, how do you view your organisation with regard to the sharing of ideas/knowledge between employees and a willingness to change?

The questionnaire results are shown below:

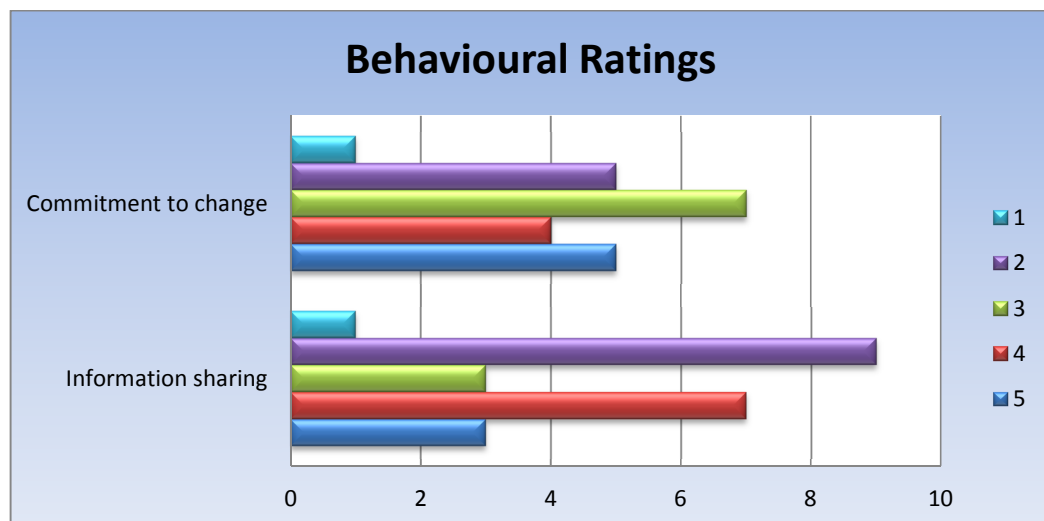


Figure 6: Behavioural Ratings

On a scale of 1 to 5, how do you rate your company with regard to the following? (1 = poor, 5 = excellent)						
Answer Options	1	2	3	4	5	Response Count
Information sharing	1	9	3	7	3	23
Commitment to change	1	5	7	4	5	22
answered question						23
skipped question						0

Table 7: Behavioural Ratings

5.7 Design

As identified earlier in this paper, collaboration and integration are key elements of lean project delivery, and a major failure in project delivery is a lack of integration and conflicts in the relationship between the designers and the contractors. Seeking input from all project stakeholders through lean planning techniques is key to the successful integration of design and construction, as is the use of advanced technologies such as BIM. The following questions were used to gauge the adoption of lean planning tools in the design process.

Question 4: Does your organisation apply Design Structure Matrix to the any of the design process?

The questionnaire results are shown below:

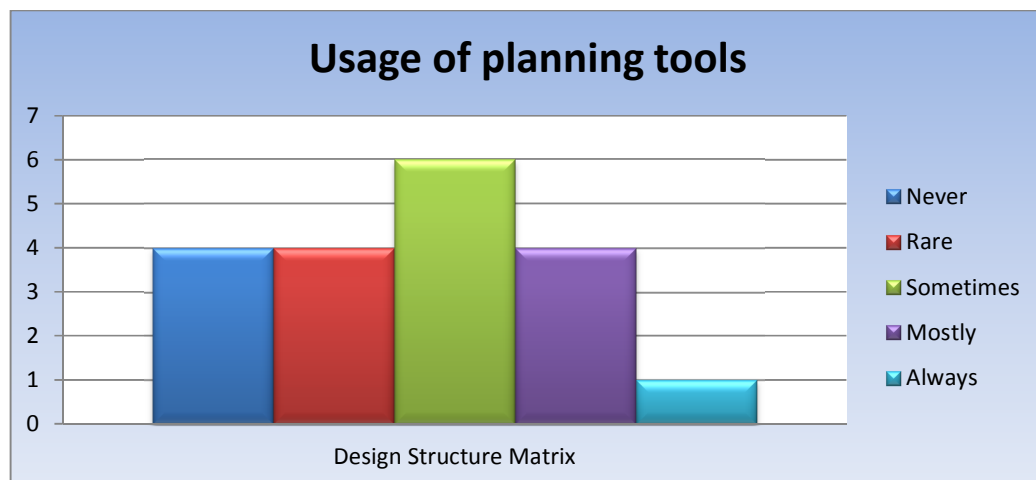


Figure 7: Usage of planning tools

Does your company ever apply the following technique to the design / planning / construction process?						
Answer Options	Always	Mostly	Sometimes	Rare	Never	Response Count
Design Structure Matrix	1	4	6	4	4	19
<i>answered question</i>						23
<i>skipped question</i>						0

Table 8: Usage of planning tools

Question 5: Does your organisation ever apply Virtual Design Studios (3D) or Virtual Reality Tools (4D) to support project collaboration?

The results from the questionnaire are shown below:

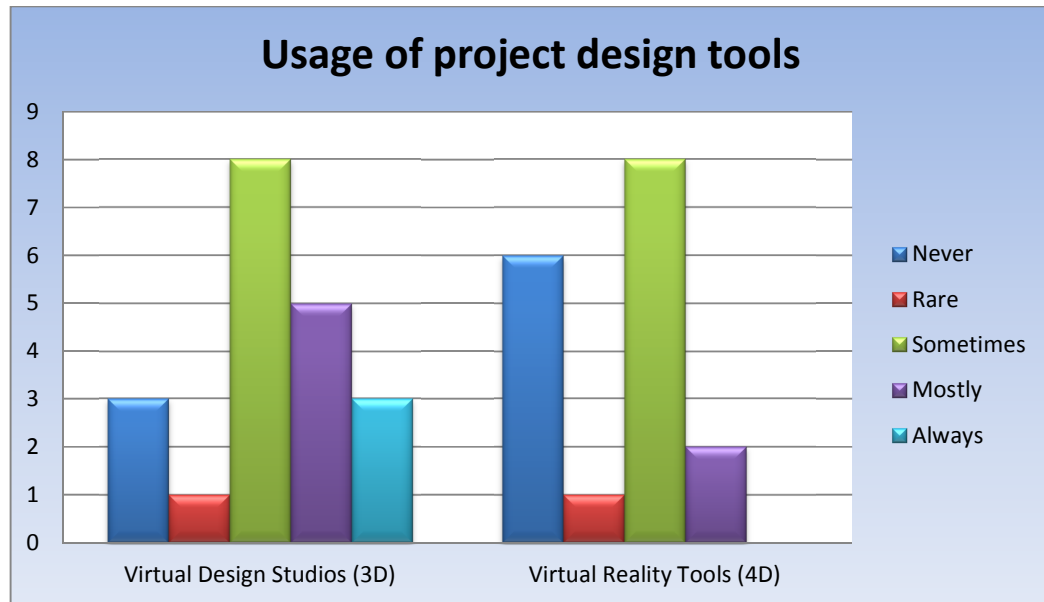


Figure 8: Usage of design tools

Does your company ever apply any of the following tools to support project collaboration?						
Answer Options	Always	Mostly	Sometimes	Rare	Never	Response Count
Virtual Design Studios (3D)	3	5	8	1	3	20
Virtual Reality Tools (4D)	0	2	8	1	6	17
<i>answered question</i>						23
<i>skipped question</i>						0

Table 9: Usage of design tools

5.8 Supply

Lean supply involves facilitating the construction process by ensuring that materials of the correct quantity and quality are delivered to site on time. The participants were asked to indicate what tools their organisations use in order to achieve this.

Question 2: Which of the following principles is your company currently involved in – Supply Chain Management; Value Streaming; Just in Time; Partnering?

The results from the questionnaire are shown below:

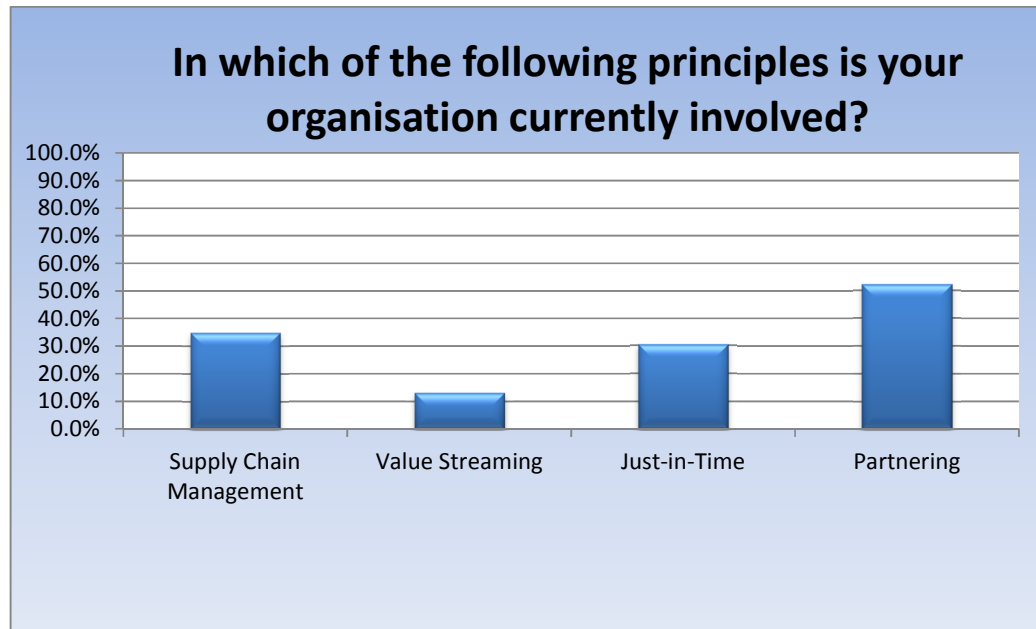


Figure 9: Use of lean supply tools

Which of the following principles is your company currently involved in?		
Answer Options	Response Percent	Response Count
Supply Chain Management	34.8%	8
Value Streaming	13.0%	3
Just-in-Time	30.4%	7
Partnering	52.2%	12
answered question		23
skipped question		0

Table 10: Use of lean supply tools

5.9 Installation

A constant workflow must exist in order to facilitate lean installation. The participants were asked to indicate their organisations adoption rate of some of the tools which can be used to assist the achievement of a constant workflow.

Question 6: Which of the following methods, if any, does your company use during construction – 5S; Co-ordinated Deliveries; Pre-fabrication?

The questionnaire results are shown below:

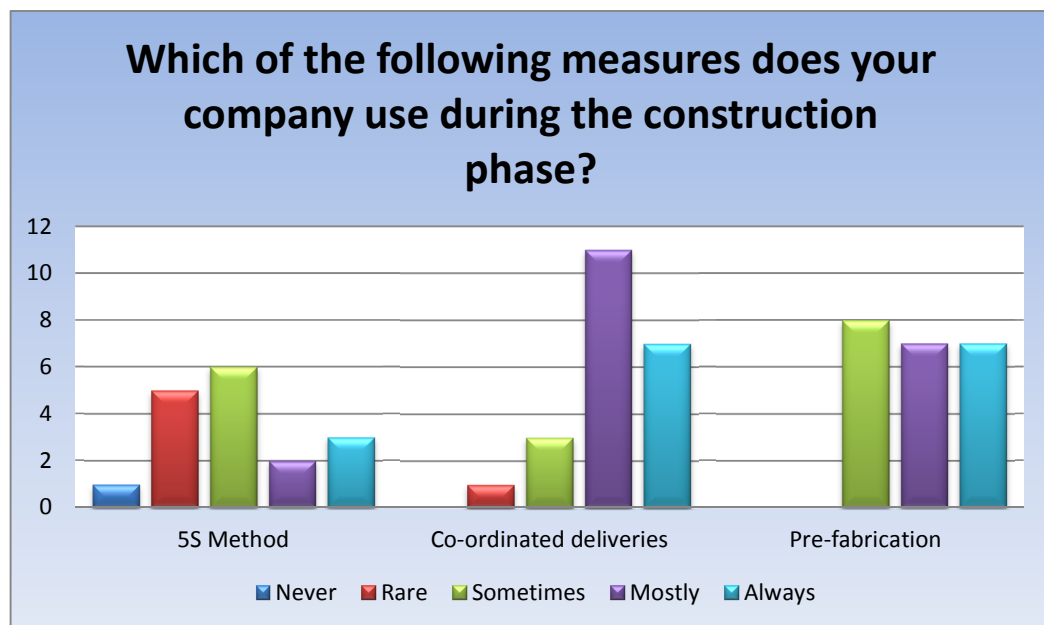


Figure 10: Use of lean installation tools

Which of the following measures does your company use during the construction phase?						
Answer Options	Always	Mostly	Sometimes	Rare	Never	Response Count
5S Method	3	2	6	5	1	17
Co-ordinated deliveries	7	11	3	1	0	22
Pre-fabrication	7	7	8	0	0	22
answered question						23
skipped question						0

Table 11: Use of lean installation tools

5.10 Demand for Change

The construction industry has always been a challenging and demanding industry in which to operate, and anecdotal evidence would suggest that it is only getting worse, not better. In order to put this anecdotal evidence to the test, the participants were asked to answer questions which would indicate their experience of these demands and of their awareness of the need to change their ways in order to meet these demands.

Question 7: How would you describe your client's attitudes to technology, lower costs, faster turnover and client involvement over the past 5 years?

The questionnaire results are shown below:

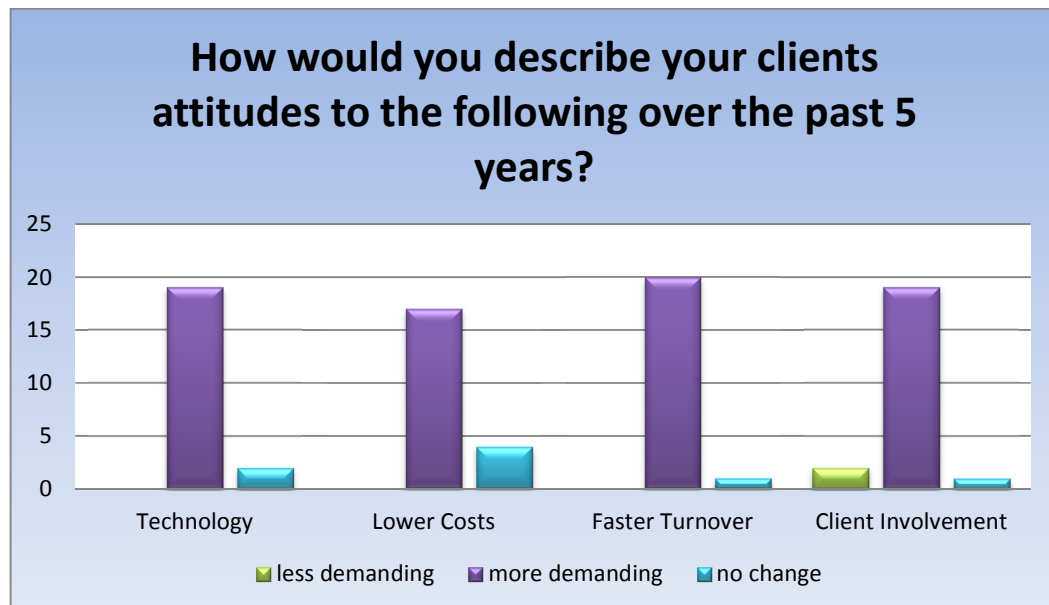


Figure 11: Demand for change

How would you describe your client's attitudes to the following over the past 5 years?				
Answer Options	no change	more demanding	less demanding	Response Count
Technology	2	19	0	21
Lower Costs	4	17	0	21
Faster Turnover	1	20	0	21
Client Involvement	1	19	2	22
Other (please specify)				0
answered question				22
skipped question				1

Table 12: Demand for change

5.11 Perceptions of lean adoption

In order to gain an insight into the extent to which the participants considered themselves as adopting lean principles, they were asked the following question:

Question 9: What is the current position in your organisation regarding the adoption of lean construction?

The questionnaire results are shown below:

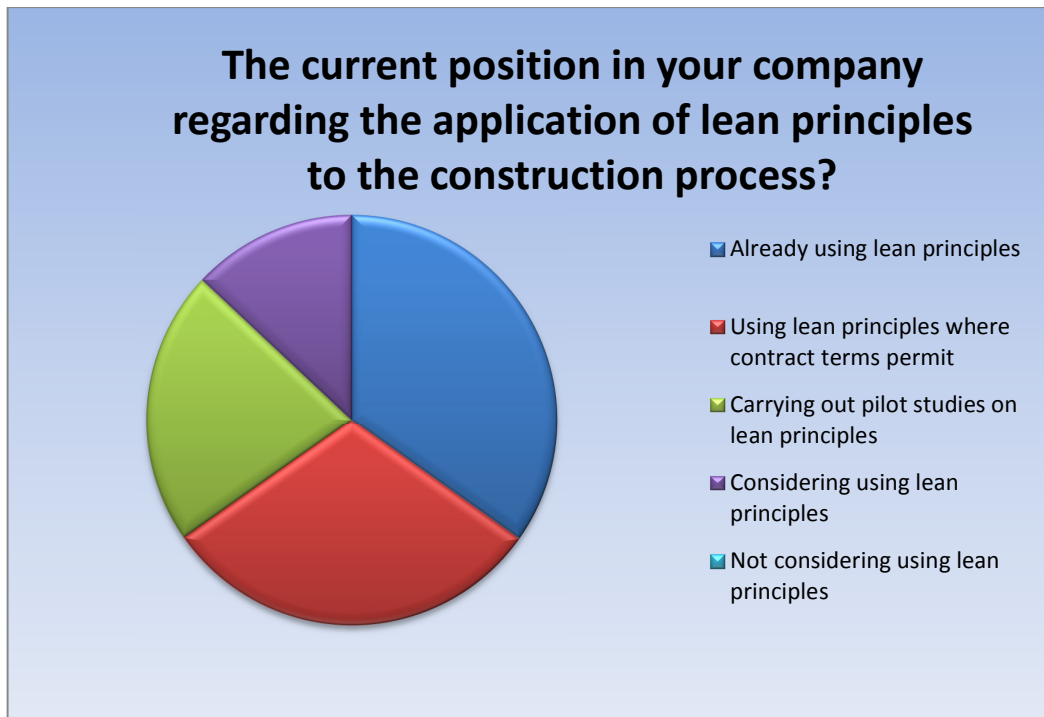


Figure 12: Adoption of lean principles

What is the current position in your company regarding the application of lean principles to the construction process?		
Answer Options	Response Percent	Response Count
Already using lean principles	34.8%	8
Using lean principles where contract terms permit	30.4%	7
Carrying out pilot studies on lean principles	21.7%	5
Considering using lean principles	13.0%	3
Not considering using lean principles	0.0%	0
answered question		23
skipped question		0

Table 13: Adoption of lean principles

5.12 Perceptions of lean transferability to construction

To better understand the participant's views on the whether or not lean principles are transferable to the construction industry, they were asked the following question:

Question 10: How do you view the application of lean principles to the construction industry?The results from the questionnaire are shown below:

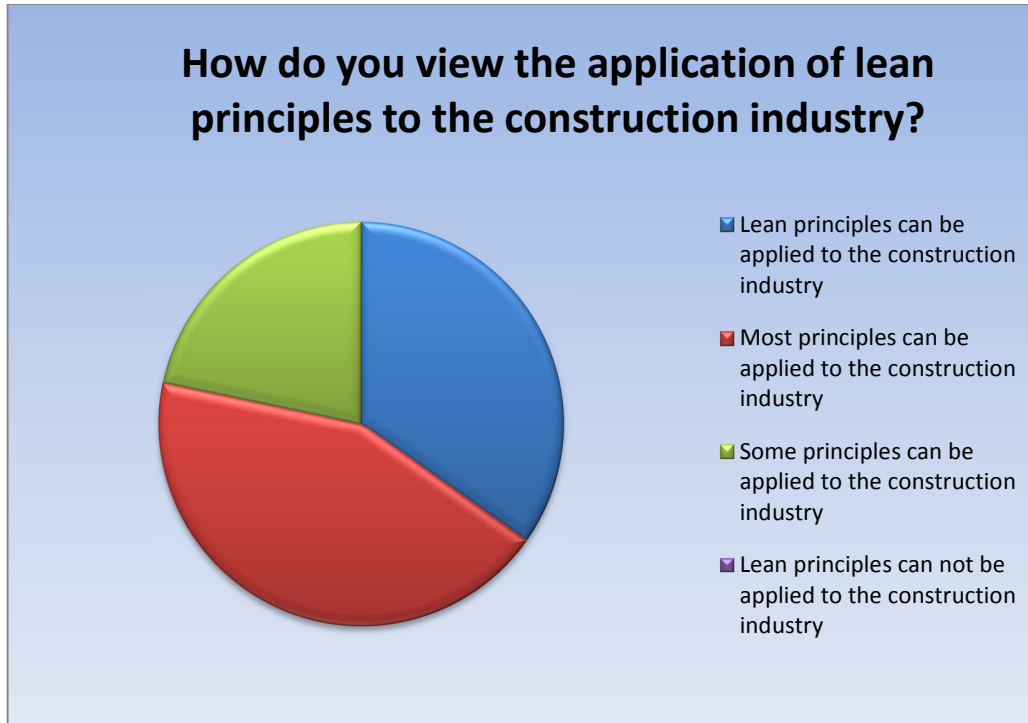


Figure 13: Perceptions of lean construction

How do you view the application of lean principles to the construction industry?		
Answer Options	Response Percent	Response Count
Lean principles can be applied to the construction industry	34.8%	8
Most principles can be applied to the construction industry	43.5%	10
Some principles can be applied to the construction industry	21.7%	5
Lean principles can not be applied to the construction industry	0.0%	0
answered question		23
skipped question		0

Table 14: Perceptions of lean construction

Chapter 6 – Discussion

6.1 Hypotheses Tested

The objective of this research, as identified earlier in this paper, was to investigate the current level of dissemination of lean principles in the Irish construction industry.

The author formulated the following hypotheses pertaining to lean in the Irish construction industry which would be tested as part of this research in order to support the primary objective.

- There is a high adoption rate of lean principles in the Irish construction industry.
- There is a good understanding of the need to adopt lean principles in the Irish construction industry.
- There is a positive attitude towards lean construction in Ireland.

The author first conducted secondary research in the form of an extensive review of the current literature available relating to Lean as a concept in itself, the concept of lean construction, and on the adoption and application of lean in construction industries both in Ireland and abroad. Through this process, the author identified a knowledge gap relating to the adoption and application of lean in the Irish construction industry, and in order to address this, carried out primary research in the form of a survey of Irish construction companies to fulfil the research objective and test the hypotheses identified.

The results of this survey can be summarised in terms of the research hypotheses as follows:

There is a high adoption rate of lean principles in the Irish construction industry:

Questions 1-6 in the questionnaire were used to test this hypothesis and relate to the procurement, planning, management, and execution

(collaboration, integration, supply & installation) methods used on construction projects.

Procurement:

Question 1 asked what share of your organisations annual turnover is made up from design & build contracts, management contracts, general contracts or sub-contracts.

The answers to this question highlighted a number of key points. 95% of the responding organisations are involved in sub-contracts and 41% of these organisations generate >80% of their turnover from sub-contracts. Only 13% of the organisations generate <20% of their turnover from sub-contracts. This compares to 53% from the German study (2007). Only 2 responding organisations indicate >40% of their turnover stemming from the preferred lean contract type i.e. design and build. 65% of the organisations are involved in design-build and 48% are involved in management contracting, to at least some extent. These are the preferred contract forms for lean.

Overall the responses to this question indicate that traditional sub-contracting is still the dominant form of contract with the responding organisations. This is similar to the results obtained in both the German study (2007) and the Dutch study (2002), where traditional contracting i.e. sub-contacts and general contracts were dominant. However, it is clear that there is a shift towards the leaner contract types in Ireland, but they still only account for small percentages of turnover at this stage.

Engaging in design-build or management contracts involves design work and in order to understand the level of integration between design and construction work as carried out by contractors, Question 3 asked the respondents to identify the methods by which this design work was carried out.

The answers to this question indicate that there is a large spread in terms of how design work is carried out. The good news from a lean perspective

is that over 40% of the respondent's state that all design work is either mostly or always carried out in-house, with almost 50% indicating that sometimes or mostly, design work is partly carried out in-house. Less than half of the respondents indicate that design work is either always (23%) or mostly (18%) sub-contracted.

As with the forms of contract, this indicates a shift towards lean methods in the Irish industry and is significantly different to the UK study (2000), the Dutch study (2002), and the German study (2007), all of which indicated that the vast majority of design work was either mostly or always sub-contracted.

Management

Question 2 related to management techniques and asked which of the following principles is your company currently involved in – Concurrent Engineering; Supply Chain Management; Value Streaming; Last Planner; TQM; Benchmarking?

At almost 35%, Supply Chain Management is the most commonly used lean management concept amongst the respondents to this survey, closely followed by Concurrent Engineering at 30%. This compares to 12% for SCM and 20% for CE as indicated in the German study (2007). At 13%, Value Streaming is the least commonly used lean management concept compared to 0% in the German study (2007) and 21% in the US study (2013). Last Planner, which is seen as one of the key lean management concepts, is used by just almost 22% of the respondents in this survey, compared to 30% in the US survey (2013) and just 12% in the German study (2007).

The adoption and implementation of lean management concepts is seen as key to the success or otherwise of lean construction, and despite scoring better in general compared to the other European countries surveyed, this survey indicates that the adoption of lean construction management in the Irish construction industry is average at best, with the most common management concept polling less than a 35% adoption

rate. The one positive is that all respondents indicated that they are actively engaged in at least one lean construction concept.

Planning

The application of lean planning tools such as Value Streaming and Last Planner are seen as key to the successful implementation of lean construction. Question 4 therefore asked participants to indicate the level of adoption of these tools compared to the traditional planning tool i.e. Critical Path.

The results from the questionnaire show that Critical Path is still the preferred method for contractors in Ireland with 100% of respondents indicating that they still use the Critical Path method, and over 65% of these respondents use CP either always or mostly. This is even higher than indicated in the German study (2007), where 62% of respondents still used CP. It is also in line with both the UK study (2000) and the Dutch study (2002), both of which identified CP as the tool of choice. It seems therefore that the Irish industry is no further advanced in this respect than the UK industry was 16 years ago.

None of the lean planning tools were adopted by all respondents; however 90% of respondents indicate that they use Look Ahead planning with over 70% of these stating that they use it either mostly or always. The results also identify that most of the lean planning tools are used some of the time, but the dominant tool is still the traditional CP method. As with the management tools, it appears that while there are significant adoption rates, there is still some distance to go before the lean overtakes the traditional methods as the preferred option.

Collaboration

Collaboration is identified earlier in this paper as a cornerstone of lean philosophy. In Question 5, the participants were asked to indicate their organisations use of technologies which have been recognised as supporting lean construction by assisting the collaboration process.

The results show that there is not one technology that is universally used, but both Document Management Systems and Project Information Systems are used by 90% of the participants. However, almost 40% of those who use Document Management Systems do so always whereas only 9% always use Project Information Systems. Good news for lean construction is that 3D virtual design studios are used by over 86% of the participants with just under 50% using this tool mostly or always. Also, and perhaps rather surprisingly, a very new tool for the construction industry i.e. 4D Virtual Reality, is used to at least some extent by over 73% of participants. Both of these figures indicate a significant increase on the German study (2007) where the uptake was below average at best. This perhaps indicates the development of these tools in the 9 years since the German study was carried out. Overall, these results indicate that there is a very positive attitude towards the adoption of technologies which support collaboration in the Irish construction industry.

Integration

A major failure in project delivery is a lack of integration and conflicts in the relationship between the designers and the contractors. Seeking input from all project stakeholders through lean planning techniques is key to the successful integration of design and construction, as is the use of advanced technologies such as BIM. The questionnaire contains two questions to gauge the adoption of lean planning tools and advanced technologies in the design process.

Question 4 asks if your organisation applies Design Structure Matrix to the design process, and Question 5 asks if your organisation ever apply Virtual Design Studios (3D) or Virtual Reality Tools (4D) to support project collaboration.

As indicated in the Collaboration section above, there is significant adoption of 3D tools, and 4D tools are gaining in popularity. Design Structure Matrix, as a tool for planning the design stage of a project is used to at least some extent by 65% of the participants, however 66% of

these organisations use it only sometimes or rarely, with less than 7% using it all of the time. A high adoption of 3D design tools with a low adoption of Design Structure Matrix begs the question about how these organisations are planning and controlling the use of these tools or the design stage as a whole and points to possible room for significant development of the design stage and this merits further investigation. These results are consistent with both the German study (2007) and the US study (2013), both of which indicated low adoption of Design Structure Matrix despite high use of 3D design tools (not Germany).

Supply

Lean supply involves facilitating the construction process by ensuring that materials of the correct quantity and quality are delivered to site on time. Question 2 asked the participants to indicate what tools their organisations use in order to achieve this.

The results show that partnering is used by over half of the participating organisations (52%) compared to 47% in the German study (2007). At just over 30%, Just-in-Time is equal with the 30% indicated in the US study (2013) and significantly higher than the 24% indicated in the German study (2007). Supply Chain Management is used by 35% of the responding organisations which compare favourably to the German study (2007) which indicated an adoption rate of just 12%. Value Streaming (13%) lags behind the adoption rate of 21% indicated in the 2013 US study, but is higher than the results of the 2007 German study which showed a 0% adoption rate.

Installation

A constant workflow must exist in order to facilitate lean installation. Question 6 asked the participants to indicate their organisations adoption rate of some of the tools which can be used to assist the achievement of a constant workflow.

The results show that the use of co-ordinated deliveries and pre-fabrication is commonplace in the Irish industry with 95% of participants using both methods to some extent during the construction phase with 82% using co-ordinated deliveries either mostly or always, and 64% using pre-fabrication either mostly or always. This high usage rate of co-ordinated deliveries in the Irish industry is consistent with the results from both the US and German industries, and while the high pre-fabrication rate is consistent with the high rate seen the 2013 US study (80%), it is significantly higher than the 62% indicated in the German study (2007).

The usage rate of the 5S method was much more conservative with over 35% of respondents indicating that it is used either rarely or never at all, and almost 40% stating that they only use this method sometimes. Despite these low figures, the results are still significantly better than the German results where 84% of participants admitted to never using the 5S method at all.

Overall, the results are positive and indicate that all participants have adopted lean to at least some extent, and that the uptake compares well to the 2007 German study. However, there is only one tool which has an adoption rate of more than 50% suggesting that there is much room for improvement which is supported by the comparison with the 2013 US study, which shows the Irish industry to be below par in the adoption of lean tools. Based on these results, the hypothesis that there is a high adoption rate of lean principles in the Irish construction industry is rejected.

There is a good understanding of the need to adopt lean principles in the Irish construction industry.

Question 7 was used to test this hypothesis.

The construction industry has always been a challenging and demanding industry in which to operate, and anecdotal evidence would suggest that it is only getting worse, not better. In order to put this anecdotal evidence to the test, the participants were asked to describe their client's attitudes to

technology, lower costs, faster turnover and client involvement over the past 5 years.

The results indicated that the vast majority of respondents found their client to be more demanding in all areas, with only 9% finding their clients to be less demanding with respect to client involvement. These results are consistent with the UK study (2000), the Dutch study (2002) and the German study (2007), all of which indicated more demanding clients. This shows that over the past 16 years, client expectations have steadily increased in all areas and in all regions. The significantly high figures from this study also indicate that not only is this trend continuing but it is also accelerating. The high level of awareness of these increased demands would indicate that there is an opportunity for the increased adoption of lean principles in order to meet these increased demands. These results support this hypothesis.

There is a positive attitude towards lean construction in Ireland.

Questions 8, 9, & 10 were used to test this hypothesis and relate to organisational behaviour, the adoption rates of lean construction and attitudes towards lean construction.

Organisational Behaviour:

Question 8 looks at organisational behaviour and whether it is conducive to lean. Participants were asked how they view their organisation with regard to the sharing of ideas/knowledge between employees and in terms of how they view their management's willingness or commitment to change. Both of these questions are crucial to the success or otherwise of the implementation of lean construction.

All participants answered the question on information sharing but only 13% believed that the level of information sharing in their organisation was excellent (compared to 29% in the German study), with 31% indicating that it was good (compared to 53% in the German study). Also, over 43% believed that information sharing in their organisation was below average

or poor (compared to only 6% in the German study). Even taken in isolation, these figures are quite damning for the Irish construction industry. Information sharing it seems will require significant focus and development in order to improve the lean construction implementation success rate.

Looking at the question on management's willingness to change, only 1 participant did not answer this question, and the results are equally as damning as the previous question, with over 59% of respondents indicating that management commitment to change was average at best with only 23% describing it as excellent. Visible management commitment is crucial to any organisational change process, not just the implementation of lean construction. Based on these results, a significant change in management attitudes will be required to facilitate the successful implementation of lean principles in the industry.

Perceptions of lean adoption

In order to gain an insight into the extent to which the participants considered their organisation to be adopting lean principles, Question 9 asked what the current position is in their organisation regarding the adoption of lean construction.

This question was answered by all participants and indicated that all perceived their organisation to be using lean principles in the construction process to at least some extent. In fact over 65% of the participants indicated that their organisation is actively using lean principles with over 21% stating that they are conducting pilot studies. These results are significantly higher than the results from the US study (2013) which indicate an adoption rate of 43%. It is interesting to note that these results suggest significantly higher adoption rates of lean principles in Ireland than had been indicated in the responses to the preceding 8 questions. The participant's perceptions on the levels of lean adoption are higher than had been previously indicated which suggests that while they want to believe

that they are lean, they are not as lean as they would like to think. Further research would be required to fully understand this disparity.

Perceptions of lean transferability to construction

Question 10 seeks to better understand the participant's views on the whether or not lean principles are transferable to the construction industry.

The vast majority of the respondents believe that lean principles are transferable to the construction industry with almost 80% indicating a belief that all or most principles can be transferred. This is very much in contrast to the results from the German study (2007) where the majority indicated scepticism about the transferability of lean principles to the construction industry. However, the strong views expressed here regarding the transferability of lean principles are again in contrast to the actual adoption rates as indicated in the responses to the first 8 questions in this survey and, like the previous question, would again suggest that while there appears to be a theoretical knowledge of, and appetite for lean construction, the actual adoption rates have a long way to go before the theory becomes a reality.

The results indicate that there is a very positive attitude towards the introduction of lean principle in the Irish construction industry and therefore support this hypothesis.

6.2 The Negatives

Traditional project procurement and delivery methods are still dominant in the industry, as demonstrated by sub-contracting and general contracting being the primary forms of contract amongst the responding organisations. This is also indicated by the fact that 100% of participants in the survey still use the Critical Path method of planning projects in the majority of instances, with over 65% of these respondents use CP either always or mostly. This makes for poor reading when compared to previous research and it seems that the Irish industry is no further advanced in this respect than the UK industry was some 16 years ago.

The adoption and implementation of lean management concepts is seen as key to the success or otherwise of lean construction, however, the Irish construction industry seems to be average at best in this regard with Supply Chain Management being the most commonly used lean management tool, even though it only has a usage rate of 35%, while Last Planner, one of the key lean management concepts is used by just 22% of the respondents.

Respondent's perception of attitudes towards lean principles in the construction industry was another area where the Irish industry fared quite badly. Only 13% of respondents believed that information sharing in their organisation was excellent with over 43% classifying it as below average. Also, over 59% of respondents believed that management commitment to change in their organisation was average at best. Both information sharing and management commitment to change are crucial to the success or otherwise of the implementation of lean construction, and based on these results significant changes will be required to facilitate the successful implementation of lean principles in the industry.

6.3 The Positives

A large portion of organisations carrying out design work indicate that this is either mostly or always carried out in-house, with almost 50% indicating that sometimes or mostly, design work is partly carried out in-house. Design-build is a key lean philosophy and this is therefore a positive result.

Likewise, a very high usage rate of project collaboration tools can also be seen in the survey results with over 90% of respondents using Document Management Systems and Project Information Systems. This is a very positive indication of lean practices in action, however it would be nice to see an increase in the frequency with which these tools are used.

The usage rates for both 3D and 4D technology is another very positive result from the survey with 3D virtual design studios being used by over 86% of the participants and 4D Virtual Reality being used, to at least some extent, by over 73% of participants. These results indicate that there is a

very positive attitude towards the adoption of technologies which support design and collaboration in the Irish construction industry. However, Design Structure Matrix, as a tool for planning the design stage of a project, is only used either sometimes or rarely by 66% of the organisations, with less than 7% using it all of the time. A high adoption of 3D & 4D design tools with such a low adoption of Design Structure Matrix begs the question about how these organisations are planning and controlling the use of these tools and would perhaps indicate the need for further investigation.

From the perspective of lean installation, the use of co-ordinated deliveries and pre-fabrication is commonplace in the Irish industry with 95% of participants using both methods to some extent during the construction phase. This high usage rate of co-ordinated deliveries and pre-fabrication is a very positive result from this survey, however, the other installation method identified in the survey (5S) polled very poorly with over 35% of respondents indicating that it is used either rarely or never at all, and almost 40% stating that they only use this method sometimes.

Another positive from the survey was the respondent's high level of awareness of the increasing nature of client demands, with the vast majority of respondents finding their clients to be more demanding in all areas. Client expectations are shown to be steadily increasing in all areas, but the high level of awareness of these increased demands indicates that organisations will need to look to alternative project procurement and delivery methods and therefore there is an opportunity for the increased adoption of lean principles in order to meet these increased demands.

When asked about the current adoption rates of lean construction, over 65% of the participants indicated that they are actively using lean principles and over 21% stated that they are conducting pilot studies. The adoption rate of lean construction would therefore appear to be quite high in the Irish construction industry. However, this represents a significantly higher adoption rate than had been indicated in the responses given to the

previous questions and further research would be required to fully understand this disparity.

The final positive from the survey was the very high level of belief in lean construction, with almost 80% indicating that all or most lean principles can be transferred to the construction industry. However, as with the answers given to the question on adoption rates, the answers provided for this question are in contrast to what actually seems to be happening in practice, as indicated by the answers provided earlier in the survey. It would appear that while there is a great belief in, and appetite for the introduction of lean principles into the construction industry, the actual adoption rates have a lot of catching up to do before lean construction is as ubiquitous in Ireland as many seem to believe it should be.

6.4 Comparison with other countries

As the questionnaire was based on the studies carried out in the UK (2000), the Netherlands (2002), and Germany (2007), this enabled some other interesting conclusions to be drawn through direct comparisons with the results from these surveys. This facilitated analysis based on location, but also based on changes resulting from the passage of time. The other studies referenced earlier i.e. US (2008), Abu Dhabi (2012), and the US (2013) are independent of this questionnaire and therefore direct comparisons could not be drawn, however their results could be used as reference points for this study.

In general, the Irish construction industry fared favourable against all of the other industries reviewed as part of this research in terms of the adoption of lean construction and the attitudes to and perceptions of lean construction in the Irish industry.

With regard to project procurement, traditional contract types still dominate the industry in Ireland which is similar to what has been found in all of the other regions studied. However, we can see a difference in the few instances where design and build contracts are used, as Ireland is ahead

of the other countries in terms of the amount of design work which actually takes place in-house.

Looking at lean management tools, while Ireland has not seen significant usage of tools such as Supply Chain Management and Concurrent Engineering, it is still far ahead of the other European countries where research has shown very limited usage of these tools. The US study carried out in 2013 did indicate increased usage in that region over continental Europe; however it still lags behind the results from the Irish survey.

Compared to the UK and European studies, there is a high usage of technology to support project collaboration in the Irish construction industry. However the most recent European study was carried out some 9 years ago and these results perhaps reflect the rapid technological developments and the increased use of technology by both people and organisations in general during that time, rather than pointing to the Irish industry being more advanced than the others studied.

In terms of the use of lean supply tools, the results from this survey indicate that the Irish construction industry has a higher usage rate than was found in the UK and European studies, however it is below par when compared with the results from the more recent US study which was carried out in 2013 suggesting that there is much room for improvement in the Irish industry

The high usage rate of lean installation methods such as co-ordinated deliveries in the Irish industry is consistent with the results from both the US and German industries, and while the high pre-fabrication rate is consistent with the high rate seen in the 2013 US study, it is significantly higher than the 62% indicated in the German study (2007).

Looking at attitudes towards, and the adoption of lean construction, this study indicates that Ireland is significantly further ahead in both respects than all other regions studied. However, and as mentioned earlier, in both instances it would seem that there is more of a positive mental disposition

to lean construction than there is action on the ground. Nevertheless, this positivity towards lean construction is more than has been seen in any other region surveyed and surely bodes well for the future of lean construction in Ireland, even if there is still a long way to go.

There are two main areas where Ireland lags behind the other regions studied, the first of which is in the use of lean planning tools. The persistent use of the Critical Path method in Ireland is significantly higher than in continental Europe where lean planning tools are more widely used and is more in line with the usage rates found in the UK study. However, this study was carried out 16 years ago and if accurate, the results from this survey suggest that there has been very little development in the Irish industry in this regard.

Knowledge sharing between employees and management commitment to change is the second area where the Irish construction industry fared quite badly compared to the other countries studied, particularly in light of the time which has passed since the European and UK studies in particular were conducted. The results of this survey indicate that the Irish industry is very poor in this respect and has a lot of catching up to do, not only to catch up with other countries but also to help improve the lean construction implementation success rate.

6.5 Limitations

Although the author had hoped for a higher number of responses, a response rate of 47% is seen to be very good, particularly in view of the lower response rates achieved in similar previous studies. However, the author believes that this response rate could have been significantly higher had it not been for the reluctance of some organisations to divulge what they viewed as confidential information. This was a problem from the outset, particularly as the author is employed by what many organisations see as a competitor in their industry. Therefore, in order to increase the response rate, the survey was made confidential i.e. the author has no idea which organisations are represented in the answers or what their

individual answers are. Despite this guarantee of confidentiality, the survey still only yielded a response rate of 47% which despite being quite good, also means that 53% of those surveyed did not respond. No reasons have been given for the non-responses and this must therefore be viewed as limitation to some extent.

Another limitation caused by the confidentiality clause in this survey is that the author has no information on the responding organisations in terms of their size or discipline speciality. We know from previous research (Johansen et al, 2007), that large organisations (200+ employees) are more likely to engage in lean practices than smaller organisations and that there are also variances in adoption rates depending on whether an organisation is involved in civil construction versus mechanical/electrical, for example. As the author has no information in this regard it is not possible to draw conclusions in this regard for the Irish construction industry.

This confidentiality issue is perhaps a further reflection of the poor results achieved in the survey on the question of knowledge and information sharing in organisations. Not only is knowledge sharing key to the success of lean principles in individual organisations, it is also key to the success of lean construction in the industry as a whole. Mistrust appears to be endemic in the industry and while the author can acknowledge that some information needs to be kept confidential, the nature of the questions in this survey do not compromise corporate confidentiality and there should therefore be no issues in this regard. Also, none of the previous studies identified in the literature review have indicated this type of issue so there is a question as to why it seems this issue prevails only in Ireland.

The comparison of this survey with similar surveys carried out in other countries is limited by the passage of time. Supposing that time was not a factor, the results of this survey would suggest that generally Ireland is much further advanced than any other country in terms of lean construction. However, some 16 years have passed since the first of these studies was conducted and the author must acknowledge that changing

perceptions, technological advances, and in particular the recent global recession will all have played a significant role in the more positive results from this survey. Even the most recent comparative study (US, 2013) was carried out 3 years ago and as such is somewhat outdated. The author does not consider the more recent Irish studies (Tolan et al, 2014 & Ebbs et al, 2015) as comparative for the reasons identified earlier in this paper.

Chapter 7 – Conclusion and Recommendations

7.1 Conclusion

When the Celtic Tiger bubble burst and the boom became a bust, organisations were no longer too busy making money and had time to see the Irish construction industry for what it was - fragmented, conservative, and slow to embrace change. This resulted in inefficiencies and waste which could no longer be tolerated and industry players began to look for ways to improve the situation. The elimination of waste and inefficiencies from the process of designing and constructing buildings through the adoption of Lean Construction offers perhaps the greatest potential for these improvements.

Now more than ever, with a return to significant growth in the Irish construction industry, organisations are looking to new project procurement and delivery methods to ensure that history does not repeat itself. Lean construction is the solution however it is still a relatively new concept to the Irish industry. Therefore, there is limited information available on lean construction in the Irish context which is potentially an issue and may act as a barrier to adoption.

Therefore, in order to try to address this knowledge gap, the objective of this research was identified as an investigation into the current level of dissemination of lean principles in the Irish construction industry. This investigation was carried out in the form of a survey of Irish construction companies to understand the adoption level and to attitudes LC in Ireland. Through the analysis of the survey results and testing of the hypotheses posed, the following conclusion can be reached.

The research findings indicate that there is a broad understanding of lean principles and concepts in the Irish construction industry and the adoption rates of lean tools and techniques are quite high. This is particularly evident with the methods used for carrying out design work, the adoption of new technologies such as 3D & 4D virtual reality tools, and the adoption

and use of lean supply and installation techniques. However, the findings also identify that the Irish construction industry is still dominated by traditional project procurement, planning and management tools and techniques and that the use of newer, leaner methods is the exception rather than the norm.

In general, while the overall findings are positive, evidence exists that lean construction still has a long way to go before being fully adopted and implemented in the Irish construction industry. However, along with the negatives, there are some very positive signs that there is an ever increasing rate of adoption and on average the Irish construction industry has fared better than the other industries previously studied. There appears to be a very good foundation already established for the future development and expansion of lean principles in the Irish construction industry and the participants in this survey certainly seem to believe that lean represents the future of construction in Ireland. However, they may need some help along the way to make this happen and the active participation of groups such as the LCI (Ireland) will have a significant role to play in this respect.

7.2 Recommendations

The results from this study indicate that while the Irish construction industry has performed well against other countries with regard to the adoption of lean principles, there is still a long way to go. The general belief that lean represents the future of the construction industry in Ireland is presently not replicated in the actual adoption of lean principles. Further research should be carried out to understand the disparity between beliefs and practice and examine the reasons as to why the adoption rates are not as high as they perhaps could or should be based on the appetite that exists.

This is also where groups like the Construction Industry Federation (CIF) and the Lean Construction Institute can play a pivotal role in supporting and educating construction companies in the ways of lean. The Irish government too can support this process by perhaps following the lead of the British government who have now made the use of BIM as a design and collaboration tool mandatory on all UK government funded construction projects.

This study achieved representation from 23 construction companies in Ireland, and while the author believes the results to be sufficiently credible for conclusions to be drawn, 23 companies is only a small fraction of the whole number of construction companies operating in Ireland. Therefore, in order to get a more holistic view of the Irish construction industry, the survey should perhaps be repeated in the future, this time with the backing of the CIF and LCI.

This study follows and builds on those previous studies carried out in the UK, the Netherlands, and Germany. It was conceived so as to leave a link to the past but would also provide opportunities for the future. As such this study should be brought forward to gain an insight into other countries where lean construction is established or trying to be established. In doing so, not only will a greater insight be gained into lean construction in that country, but comparisons can be facilitated and knowledge shared.

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Appendices

Appendix 1: Matrix identifying the link between the questionnaire and the conceptual framework

Question Number		Link to the Conceptual Framework								Comments
		Procurement	Management	Planning/Control	Collaboration	Behaviour	Design	Supply	Installation	
1	Design & Build (or Turnkey)	x								
	Management Contracting	x								
	General Contract	x								
	Sub-Contract	x								
2	Concurrent Engineering		x							
	Supply Chain Management		x					x		
	Value Streaming		x					x		
	Last Planner		x							
	Just-in-Time								x	
	Total Quality Management		x							
	Partnering								x	
	Benchmarking		x							
3	Design work carried out in-house	x								
	Design work partly carried out in-house	x								
	Design work sub-contracted	x								
4	Critical Path Method			x						
	Value Stream Analysis			x						
	Last Planner			x						
	Look-ahead Planning			x						
	Design Structure Matrix						x			
5	Document Management System				x					
	Video Conferencing				x					
	Virtual Design Studios (3D)				x	x				
	Virtual Reality Tools (4D)				x	x				
	Project Information Systems				x					
6	5S Method								x	
	Co-ordinated Deliveries								x	
	Pre-Fabrication								x	
7	Technology									This question aims to understand if contractors are aware of the need for change
	Lower Costs									
	Faster Turnover									
	Client Involvement									
8	Information Availability		x							
	Information being up-to-date		x							
	Information sharing between employees					x				
	Management commitment to change					x				
	Measurement of unused materials			x						
	Materials management			x						
9	Implementation of quality plans								x	
	Already using lean principles									The aim of this question is to gauge the adoption level of lean
	Using lean principles where contract permits									
	Carrying out pilot studies on lean									
	Considering using lean principles									
Not considering using lean principles										
10	Lean principles can be applied									The aim of this question is to gauge the perception of lean
	Most lean principles can be applied									
	Some lean principle can be applied									
	Lean principles can not be applied									

Appendix 2: Questionnaire Cover Letter

Dear Sir / Madam,

As part of my MBA studies at the National College of Ireland, my final year dissertation takes the form of a research study aimed at investigating the dissemination of Lean principles in the Irish Construction industry. As you know, the recent economic downturn has exposed the unproductiveness, waste and inefficiencies that were previously buried in the “joie de vivre” attitude which prevailed in the construction industry during boom times. The most recent CSO figures show a 13.6% year-on-year increase in employment in the Irish construction sector, indicating a return to growth, and industry players are keen not to repeat the mistakes of old.

Therefore it stands to reason that now is an opportune time to carry out research into the potential for improvements in outdated project procurement and delivery methods. The concept of Lean Construction offers perhaps the greatest potential for such improvements and my research aims to investigate and identify the adoption, implementation, challenges and benefits of Lean in the Irish construction industry.

I would be extremely grateful if you could take 5 minutes of your time to assist me with this research by clicking on the below link and completing the questionnaire. I can assure you that this is a completely confidential questionnaire, and individual companies will not be identified. A summary report of all findings will be made available to all participants.

Thank you very much in advance for your participation.

<https://www.surveymonkey.com/r/XZWD7G6>

Best Regards,

Kevin O'Brien

Appendix 3: Questionnaire

Lean Construction Dissemination & Understanding

1. What share of your annual turnover is made up from the following types of contract?

	>80%	60-80%	40-60%	20-40%	<20%
Design & Build (or Turnkey)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Management Contract	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
General Contract	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Sub-Contract	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

2. Which of the following principles is your company currently involved in? (Tick multiple boxes if applicable)

- Concurrent Engineering
- Supply Chain Management
- Value Streaming
- Last Planner
- Just-in-Time
- Total Quality Management
- Partnering
- Benchmarking

3. If your company take on design work, what routes are adopted for the development of the design?

	Always	Mostly	Sometimes	Rare	Never
All design work is carried out in house	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Design work is partly carried out in house	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
All design work is sub-contracted	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

4. Does your company ever apply any of the following techniques to the design / planning / construction process?

	Always	Mostly	Sometimes	Rare	Never
Critical path method	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Value stream analysis	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Last Planner	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Look-ahead Planning	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Design Structure Matrix	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

5. Does your company ever apply any of the following tools to support project collaboration?

	Always	Mostly	Sometimes	Rare	Never
Document Management System	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Video Conferencing	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Virtual Design Studios (3D)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Virtual Reality Tools (4D)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Project Information System (Extranet, Online Management Tool)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

6. Which of the following measures does your company use during the construction phase?

	Always	Mostly	Sometimes	Rare	Never
5S Method	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Co-ordinated deliveries	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Pre-fabrication	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

7. How would you describe your clients attitudes to the following over the past 5 years?

	no change	more demanding	less demanding		
Technology	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Lower Costs	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Faster Turnover	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Client Involvement	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

8. On a scale of 1 to 5, how do you rate your company with regard to the following? (1 = poor, 5 = excellent)

	1	2	3	4	5
Availability of information on schedule, quality, safety, productivity	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Information being up-to-date	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Level of information sharing between employees	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Management commitment to improving organisational efficiency	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Measurement and investigation of unused materials	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Use of just-in-time for materials management	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Standard and implementation of project quality plans	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

9. What is the current position in your company regarding the application of lean principles to the construction process?

- Already using lean principles
- Using lean principles where contract terms permit
- Carrying out pilot studies on lean principles
- Considering using lean principles
- Not considering using lean principles

10. How do you view the application of lean principles to the construction industry?

- Lean principles can be applied to the construction industry
- Most principles can be applied to the construction industry
- Some principles can be applied to the construction industry
- Lean principles can not be applied to the construction industry

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