

TOWARDS AN OPERATIONAL DEFINITION OF LEAN CONSTRUCTION ONSITE

Michelle Sjögren Leong¹, Steve Ward², and Lauri Koskela³

ABSTRACT

Through literature review and drawing from a combined professional experience of over 20 years of lean construction implementation, this paper investigates the key success factor for the automotive industry's uptake of lean production to see what the construction industry can derive from it.

The paper concludes that there exist a variety of definitions of lean, but no existing definition is yet satisfactory to describe lean construction in a rigorously testable method. This is a major obstacle to the successful deployment of lean construction especially when the industry does not have a standard benchmark of "what a lean site looks like". It recommends a small-scale replication of the International Motor Vehicle Programme (IMVP) led International Automotive Plant Study (IAPS) in construction. This will be in aid of developing an operational definition of lean construction, in line with Deming's understanding, in the form of a lean site assessment tool contributing to a Lean Index. A statistical study is also suggested to establish correlation between the degrees of lean application (Lean Index) and project performance.

KEYWORDS

Lean construction, waste, continuous improvement, operational definition, lean construction assessment

INTRODUCTION

This paper is based on UK discussions but with relevance to the global lean construction stage. There is a lack of clarity within the construction sector surrounding the concept of lean construction. Despite repeated calls to employ lean thinking from government via various reports, the majority of the industry has failed to respond. It may be the case that this is due to failure to properly articulate what lean construction means at a practical level.

Furthermore, whilst there are many isolated examples of success with lean construction, the correlation between the extent to which lean is applied and project success has not been properly established. Against this backdrop, the need to improve

1 Director, 6ix Consulting Ltd., Bristol, United Kingdom, +44 7935 312214, michelle@6ixconsulting.co.uk

2 Managing Director, 6ix Consulting Ltd., Bristol, United Kingdom, +44 7917 104399, steve@6ixconsulting.co.uk

3 Professor, University of Huddersfield, School of Art, Design and Architecture, Huddersfield, United Kingdom, +44 (0) 1484 472892, l.koskela@hud.ac.uk

productivity has been identified as a significant opportunity within industry. If national targets are to be realised, it is imperative that efficiencies are found.

Rethinking Construction (Egan, 1998) first recommended the application of lean construction, in the UK, and set specific targets to include an annual reduction of 10% a year in time and cost and 20% reduction in defects. In his speech, on the 10th year anniversary of this report, Egan (2008) gave the construction industry a poor four out of 10 score for its effort. This demonstrates the UK industry's lack lustre drive towards continuous improvement. This can be seen as equivalent to the denial met by leading researchers of the International Motor Vehicle Program⁴ (IMVP), when communicating Japan's competitiveness derived from superior performance to the Western counterparts (Holweg, 2007).

It was until irrevocable proof of under performance was produced and the obvious threat of further market encroachment by this superior performance that the voluntary adoption of lean production practices in Western car manufacturing was witnessed. This led to the revolutionary changes to work practices and attitudes.

Can we do the same for construction? This paper investigates the key success factor for the automotive industry's uptake of lean production to see what the construction industry can derive from it.

BACKGROUND

In order to start the investigation into what lean construction looks like, there is need to revisit lean journeys embarked upon by early adopters in order to give us an insight into what the construction industry's journey may look like and investigate any useful lessons to take onboard.

The Machine that Changed the World (Womack, Jones and Roos, 1990) revolutionised the way manufacturing industry operated and the accelerated adoption of lean by demonstrating the performance difference between lean production and mass production. The International Motor Vehicle Program (IMVP) was set up in the upshot of the second oil crisis in 1979 to investigate problems facing the world of motor vehicles. The "Futures of the Automobile" book, resulting from the IMVP research programme, was presented in 1985 alluding to the new ideas pioneered by the Japanese in gaining market share. This spurred the follow on Phase 2 research programme contributing to contents in the "*Machine*". The IMVP study set out to investigate the different way of working i.e. Toyota Production System (TPS) by the Japanese in order to compare it with the then current Western mass production techniques. The term lean production was coined by Krafcik, a research member of the IMVP team in his Masters thesis, and popularised by the "*Machine*". It was used in differentiating TPS practices to the "buffered" mass production way of working. (Krafcik, 1988a)

WHAT DOES LEAN MANUFACTURING LOOK LIKE?

The International Assembly Plant Study (IAPS) results presented in the "*Machine*" are from the sample of data gathered in 38 assembly plants in 13 countries between 1989-1990 (Krafcik, 1988b). The IAPS had a narrow but deep focus from the point of

⁴ IMPV is the research programme behind The Machine that Changed the World book

the assembly plant but it collects data to enable comparison between “apples and apples”. They also collected data from correlating aspects including measures of plant operations, technology use, product complexity, manufacturing policies and human resource practices. In the second round of data collection from 88 plants and 20 companies between 1993 – 1994, further areas were included e.g. supplier relations, design factors and accounting systems. The IAPS focussed mainly on the productivity measure using labour hours required per car, but used other measures like defects per car to eliminate biases resulting from using one measure. (MacDuffie and Pil, 1995)

Results from the IAPS showed lean production to be twice as productive, to produce three times fewer defects and to achieve this using 40% less space with little inventories (Womack, Jones and Roos, 1990). And importantly, the second round results demonstrated great improvements. It showed European plants made circa 30% improvement in productivity, dropping their hours per vehicle from 37 to 25. European plants showed greatest improvement in quality, reducing defects per vehicle from 90 to 60 (MacDuffie and Pil, 1995).

Management Index

As interesting as the above section is, it still does not show or tell us how lean the production processes are. To do this, the IAPS adopted the 4M approach, namely Man, Machinery, Method and Material. Besides the assessed plant performance results using direct measures of productivity (hours per vehicle) and quality (defects/100 units) showing the existence of large performance spread throughout and within countries, the study also took into consideration that management policies (e.g. training, supportive non-adversarial environment) have huge impact on operations success. Multiple regression analysis showed that characteristics of management affect the relative “leanness” of the production management policies in place. It became obvious in the study that lean production management policies revolved around establishment of processes and safety nets in place to keep the system running while the traditional production management policies were designed to absorb problems cause by low skilled and poorly motivated workforce.

In view of this, to anticipate plant performance, a Management Index comprising four components⁵ (teamwork, visual control, level of unscheduled absenteeism and percentage of floor space dedicated to repair facilities) was designed to capture the leanness of the plants’ production management policy. This proved to be an excellent predictor of plant performance, with productivity and quality improving as plants moved towards leaner operating policies. The relationship was found to be significant to productivity at a 99% level and at a 95% level for quality.

Results of this Management Index showed averages in Japan at 4.8 (very lean), US at 9.1 and Europe at 9.5 in a range of between 2 and 12. As importantly, the index demonstrated that the adoption of lean production method and management policies increased capability of high performance levels regardless of location or corporate parentage. (Krafcik, 1998a; Krafcik, 1988b)

⁵ Each component scored against a number of criteria, e.g. visual control has 4 criteria including broadcasting of performance, degree of statistical process control usage, level of housekeeping, workplace organisation of stock area

WHAT CAN LEAN CONSTRUCTION LOOK LIKE?

As discussed in the introduction section, the automotive industry was in denial of its average performance. Now, the IAPS's robust methodology and dataset allowed for a like for like comparison. This may not have given new insights into the disparity in performance, but provided irrevocable evidence of it and invoked fear and survival in the lesser performers to react.

Unlike the automotive industry, most construction industries are national with local and regional labour market. However, similar drive for continuous improvement can be achieved if organisations with superior performance start capturing market shares within that market.

Arguably, the IAPS led to the successful adoption of lean by the aero industry. The Lean Aerospace Industry (LAI) was setup in 1993 in support of the industry lean programme. According to Wouter, et al. (2008), the aerospace industry is seen to be ten to fifteen years behind the automotive industry in adoption of lean and but that the industry is in grip of a revolution called lean. Their paper tested and supported the hypotheses that the aero industry is following the footsteps in pace with the automotive industry in transformation of the industry, albeit lagging behind in leanness due to the time lag in adoption. Like the IAPS, LAI has developed the Lean Enterprise Self-Assessment Tool (LESAT) to aid in supply chain management with the purpose of testing how lean a supply chain is.

As the construction industry is nowhere near the progression of the automotive or aerospace industry, in order to be able to depict what lean construction looks like, we may be wise to start small but nevertheless pick up on the need for assessing leanness as demonstrated by early adopters.

THE NEED FOR AN OPERATIONAL DEFINITION OF LEAN CONSTRUCTION

WHAT IS AN OPERATIONAL DEFINITION?

In *Out of The Crisis*, Deming (1986) states: "There is nothing more important for transaction in business than use of operational definitions". He goes on to say: "The only communicable meaning of any word, prescription, instruction, specification, measure, attribute, regulation, law, system, edict is the record of what happened on application of a specified operation or test." And: "Adjectives like good, reliable, uniform, round, tired, safe, unsafe, unemployed, have no communicable meaning until they are expressed in operational terms of sampling, test, and criterion".

An operational definition puts communicable meaning into a concept. It is certainly the case that lean thinking and lean construction are concepts and there is a great deal of confusion in industry regarding these concepts.

According to Deming, the formation of an operational definition is a three stage process where:

1. A specific test of a piece of material or an assembly
2. A criterion (or criteria) for judgment
3. Decision: yes or no, the object or the material (or concept) did or did not meet the criteria.

The Management Index used in the IAPS, described in a previous section, acts as an operational definition of lean production and produces a score that tells us how lean a plant is. It is 1) a test of four components with 2) a set of criteria within each component, where 3) a yes/no or scored decision can be made, deriving a single metric of leanness.

The Construction Predicament

Shah and Ward's (2007) paper on defining and developing measures of lean production provide some very salient points for consideration, even for construction. These are:

- They found that early Japanese books contributed to more explicit definitions of TPS and its fundamental components as opposed to the picking and choosing of relevant/perceived fundamental single components in latter literatures.
- The ambiguity of lean production demonstrated in varied descriptions and terminologies is partly due to the evolution of it over a long period as well as to the mixture of other approaches utilised.
- There are two perspectives when discussing lean, a philosophical guiding principle view (conceptual) and a practical set of practices view.
- They found only two studies specifically related to measuring lean production.

The points picked up in Shah and Ward's (2007) paper above reflects, in accordance, to the predicament of the construction industry. Even though not as progressed as the manufacturing industry, the application of lean thinking has been instrumental in transforming construction organisations, according to many papers of the International Group for Lean Construction (IGLC) and in the Lean Construction Journal from Lean Construction Institute (LCI). However the application of it to construction remains sporadic and fragmented with limited evidence of sustainability (Ward, 2015). Koskela (2000) is clear in his view that properly defined production theory is necessary to better enable success in the construction industry, and is critical of Womack, Jones and Roos (1990) five lean principles in that the terms they use are "*imprecise and unsystematic*".

Various parties within construction will have different explanations of what lean construction means. There are inconsistent definitions and little agreement among practitioners. This lack of an identifiable methodology and measure is one of the greater obstacles to lean construction adoption by contractors (Gao and Low, 2013; Stevens, 2014). The multitude of interpretations of lean construction contributes to making evaluating its application and its effectiveness difficult. Rybkowski, Abdelhamid and Forbes (2013) produced a graphic definition of lean from discussions at three occasions of IGLC and LCI meetings. This is due to their acknowledgment that there has been resistance from the lean construction community to commit to a collective definition of lean, even though lean construction has received increasing attention from academics and practitioners over the last two decades (Pekuri, Herrala and Haapasalo, 2012). According to Green (2011), lean construction, partnering and collaborative working rarely live up to the claims made on their behalf due to "definitional vagueness" inducing interpretation by stakeholders in line with individual needs.

This is very much in line with the first author's experience as a lean construction consultant for the past decade. There are huge differences between "lean-ness" amongst different practicing organisations and the level of lean even between projects of one organisation. Chase (1999), McGraw Hill Construction (2013) and Stevens (2014) highlight the fact that organisations and individuals claim to be lean when just implementing one or two elements and aspects of a lean tool or technique. As brilliant a tool as the Last Planner System (LPS) is, unfortunately, many in construction use LPS synonymously to lean construction. And even when claiming to be implementing LPS, one usually finds that it may only be an element of the system being applied e.g. look-ahead, weekly planning etc.

Rybkowski, Abdelhamid and Forbes (2013) detailed the various attempts to define lean over 20 years. Accordingly, they mentioned Oscar Wilde's quote that "to define is to limit". Rightly so, but there is need to highlight the objectives of defining lean. In this case it is to assess lean performance. If so, there may be need to, as suggested by Gao and Low (2014), to separate lean into "conceptual" and "implementation". There may not be need to define lean conceptually, but to have an operational definition of lean is a must if one is to test the application and evaluate its efficacy as strongly demonstrated by the automotive industry's progress in the field. According to Shewhart (1931) this means a clear state where "If you do so and so, then such and such will happen".

As suggested by Stevens (2014), the clarification and realignment of lean's definition and methodology and a meaningful way to measure the value of lean may motivate the construction industry to adopt lean. If how lean a site is can give indication to the expected performance of the project, the mainstream of the industry may be more likely to adopt the lean methodology and its tools and techniques. Stevens (2014) also pointed out that the middle management that controls and influences costs within construction are under time and cost pressure. They will not have the time to understand complex lean models. With no operational definition, heads of organisations cannot know if their sites are correctly applying lean or eliminating waste in line with the lean methodology. How can we induce industry uptake of lean construction if we do not know what the application of lean looks like? This is further corroborated by the McGraw Hill Construction (2013) market report, where potential lean practitioners stated that the lack of industry support and understanding of lean have a high degree of influence on their decision to adopt the lean approach.

A CLEAR BUSINESS CASE FOR THE ADOPTION OF LEAN CONSTRUCTION

Key drivers were identified on the uptake of lean construction in the report produced by McGraw Hill Construction (2013). These include client influence, greater profitability/costs reductions, competitiveness in the market, and programme reductions. There is also a distinct difference in drivers for existing lean practitioners and potential practitioners, with greater profitability/costs reductions being a commonality.

All **existing** lean practitioners agreed and ranked a) client influence, b) being leaders in the lean construction arena and c) the need to keep up/ahead with

competition as top drivers with d) greater profitability/cost reduction and programme reduction to follow, whereas **potential** practitioners are highly influenced by greater profitability/cost reduction and greater productivity.

Understanding the different mind-set of the two groups and the different drivers will help in developing business cases and identifying enablers required to increase and accelerate the uptake of lean construction. In order to establish a clear business case with key drivers in mind, there will first and foremost be the need for an operational definition and defined methodology (components) as stated in the earlier section, very much like the IAPS Management Index.

According to McGraw Hill Construction (2013) only 14% of non-lean practising contractors find the industry inefficient/highly inefficient. This alludes to the argument that, like the automotive industry, there may first be the need to provide an assessment of the performance of the industry to show companies that they are not as efficient as they believe themselves to be, before the introduction of any “solutions”.

Before a decision can be made to want to do something about a problem, there is first the need to acknowledge that the problem is there. This is the case for Volkswagen, when presented with an early notice of the results of the IAPS in Italy 1988. They were convinced that the benchmark figures were the evidence required to motivate and drive changes required within Volkswagen. Renault felt the same after presentation of the full results in Mexico 1989 and used the same methodology to benchmark their assembly plant efficiency. (Holweg, 2007)

Unlike the manufacturing industry, there are currently very few organisations in construction that can demonstrate consistent performance excellence. Hence the difficulty in addressing the point of what a lean project onsite looks like. But visible successes from the pockets of “excellent” applications by demonstration projects and existing practitioners can be found in construction for use to the same effect. These can be utilised to identify characteristics of lean performance and benchmarked against.

The round 2 results from the IAPS results showed that Japanese companies improved least in percentage improvements, as expected due to diminishing returns, but they led and continue to lead and triumph in all aspects of performance. For existing practitioners in construction, this indicates the importance and opportunity for capitalising on a “head start” and continuous improvement.

SUGGESTED APPLICATION OF LEAN INDEX IN CONSTRUCTION

The manufacturing industry, in their successful and sustained uptake of lean, demonstrated that a single metric, Management Index (assessment of management policies, e.g. training, supportive non-adversarial environment), showed strong correlation to operation performance (defects/100 vehicles and hrs/vehicle) and acted as a predictor of project performance. It is suggested that a similar approach be trialled encouraging further and more successful uptake of lean in construction.

LEAN SITE ASSESSMENT TOOL AND LEAN INDEX FOR CONSTRUCTION

A similar study as the IAPS but in construction is proposed here. This will require a site assessment tool, in line with Deming’s understanding of operational definition and will, in turn, produce a lean index. A site assessment may be deemed most

appropriate as it is farthest downstream, where the wastes caused by upstream processes surface and can be captured and ideally rectified at source in future projects. To address concerns that there is currently no comprehensive all round measure of lean performance on site (Forsberg and Saukkoriipi, 2007; Koskela, Bolviken and Rooke, 2013), the site assessment will need to take into consideration pre-construction processes, identifying root causes of poor/average processes and performance on site. The assessment tool should also be able to assess processes and management of processes regardless of circumstances i.e. quality of pre-construction handover to site, quality of clients, procurement, weather etc.

It is recommended that the site assessment be a tool that assesses the performance of construction projects against the 8 wastes associated with lean construction as recommended by Koskela (1992; 2004). This will be required to differentiate the assessment from assessments based on other schools of approaches (Shah and Ward, 2007; Koskenvesa and Koskela, 2011). It needs to evaluate performance against identified functional areas of how a site/project is managed that directly relate to improving the ratio of value to waste. Within the identified areas, there can be criteria of existing, good to great, practices derived from pockets of excellence within the industry. Performance evidence needs to be sought and the meeting of criteria can be assessed, scored and tallied contributing to a lean index. A maturity matrix approach is recommended, to gauge progression from average to excellent against each area, as a lean assessment should not only evaluate performance (Smyth, 2010) but also provide a gap analysis on performance to include recommendations for continuous improvement.

With a robust lean site assessment tool and a strong suite of data collected behind the lean index, a business case may be made for the uptake of lean by industry for both potential and existing lean construction practitioners. The results of the site assessments and lean index can potentially have great benefits. These include:

- Indication of current project performance on individual sites with a route map for specific and immediate improvements
- Initial benchmark of organisational performance based on projects assessed with a route map for specific organisational improvements along the whole value stream
- Identification of management skills gaps
- Rigorous analysis and credible statements of current performance and improvement plans for increased chance of winning work
- Ability to influence client procurement giving advantage to a supply chain that strives for performance improvement with the ability to provide concrete evidence of lean application
- Ability to assist clients in enabling them in better risk management of their supply chain

A statistical study will need to be conducted to investigate correlation between the lean index i.e. degree of application of lean, and project performance.

CONCLUSIONS

Following in the evolution of the lean production journey, there is a need to test the leanness of construction projects onsite to show current performance benchmarked against potential “excellence”, in this case, derived from the existing pockets of excellence. The results may jolt our own industry to an accelerated uptake of lean construction and a change in attitude like the IAPS results did to the automotive industry.

In order to do the above, we must first have a robust and defined methodology and operational measures of what lean construction is, i.e. a standard measure of lean application (leanness).

It is recommended that a similar study to the IAPS be conducted in construction, producing a Lean Index to demonstrate the leanness of projects and organisations. This single metric can contribute to increased competitiveness in a wider industry context and also serve as a continuous improvement benchmark in the individual organisations’ own improvement journey.

REFERENCES

- Chase, N., 1999. Lose the waste – get lean, *Quality*, 38, pp.34-38.
- Deming, W., 1986. *Out of the Crisis*. Cambridge, MA: MIT Centre for Advanced Engineering Study.
- Egan, J., 1998. *Rethinking Construction: The Report of the Construction Task Force*. London: The Stationery Office.
- Egan, J., 2008. *I'd give construction about four out of 10*. [online] Available at: <<http://www.building.co.uk/egan-i'd-give-construction-about-four-out-of-10/3114129.article>> [Accessed 21 February 2015].
- Forsberg, A. and Saukkoriipi, L., 2007. Measurement of waste and productivity in relation to lean thinking. In: *Proc.15th Ann. Conf. of the Int'l Group for Lean Construction*, East Lansing, MI, July 18-20.
- Gao, S. and Low, S. P., 2014. The toyota way model: An alternative framework for lean construction. *Total Quality Management and Business Excellence*, 25(5-6), pp.664-682.
- Green, S. D., 2011. *Making Sense of Construction Improvement*. Chichester, UK: John Wiley and Sons.
- Holweg, M., 2007. The genealogy of lean production. *Journal of Operations Management*, 25(2), pp.420-437.
- Koskela, L., 1992. *Application of the New Production Philosophy to the Construction Industry*. Stanford, CA: Stanford University, CIFE, Dept. of Civil Engineering. Available at: <<http://www.ce.berkeley.edu/~tommelein/Koskela-TR72.pdf>> [Accessed 21 February 2015].
- Koskela, L., 2000. *An Exploration towards a Production Theory and Its Application to Construction*. Ph.D. VTT Technical Research Centre of Finland.
- Koskela, L., 2004. Making do – The eighth category of waste. In: *Proc.12th Ann. Conf. of the Int'l Group for Lean Construction*, Helsingør, Denmark, August 3-5.
- Koskela, L., Bølviken, T. and Rooke, J., 2013. Which are the wastes of construction? In: *Proc. 21st Ann. Conf. of the Int'l Group for Lean Construction*, Fortaleza, Brazil, July 31-August 3.

- Koskenvesa, A. and Koskela, L., 2011. Evaluating site performance through the TFV-theory. In: *Proc. 19th Ann. Conf. of the Int'l Group for Lean Construction*, Lima, Peru, July 13-15.
- Krafcik, J. F. 1988a. *Triumph of the lean production system*. MIT International Motor Vehicle Program. [online] Available at: <<http://www.lean.org/downloads/MITSloan.pdf>> [Accessed 21 February 2015].
- Krafcik, J. F., 1988b. *Comparative Analysis of Performance Indicators at World Auto Assembly Plants*. Masters. Massachusetts Institute of Technology.
- MacDuffie, J. P. and Pil, F. K., 1995. The international assembly plant study: philosophical and methodological issues. In: S. Babson, ed. 1995. *Lean Work: Empowerment and Exploitation in the Global Auto Industry*. Michigan: Wayne State University Press. pp. 181-196.
- McGraw Hill Construction, 2013. *Lean Construction - Leveraging Collaboration And Advanced Practices to Increase Project Efficiency (Smart Market Report)*. Massachusetts: McGraw Hill Construction Research and Analytics.
- Pekuri, A., Herrala, M., Aapaoja, A. and Haapasalo, H., 2012. Applying lean in construction – cornerstones for implementation. In: *Proc. 20th Ann. Conf. of the Int'l Group for Lean Construction*, San Diego, California, July 17-22.
- Rybkowski, Z. K., Abdelhamid, T. S. and Forbes, L. H., 2013. On the back of a cocktail napkin: An exploration of graphic definitions of lean construction. In: *Proc. 21st Ann. Conf. of the Int'l Group for Lean Construction*, Fortaleza, Brazil, July 31-August 2.
- Shah, R. and Ward, P. T., 2007. Defining and developing measures of lean production. *Journal of Operations Management*, 25(4), pp.785-805.
- Shewhart, W., 1931. *Economic Control of Quality of Manufactured Product*. New York: D. Van Nostrand Company.
- Smyth, H., 2010. Construction industry performance improvement programmes: The UK case of demonstration projects in the 'continuous improvement' programme. *Construction Management and Economics*, 28(3), pp. 255-270.
- Stevens, M., 2014. Increasing adoption of lean construction by contractors. In: *Proc. 22nd Ann. Conf. of the Int'l Group for Lean Construction*, Oslo, Norway, June 25-27.
- Ward, S., 2015. *Some Critical Success Factors for Lean Construction*. Dundee, UK: Dundee University.
- Womack, J. P., Jones, D. T. and Roos, D., 1990. *The Machine that Changed the World*. New York: Rawson Associates.
- Wouter W. A., van Blokland, B., Bulato, F., Elferink, N. H. and Santema, S. C., 2008. Using lean performance metrics; Benchmarking the aerospace industry with the automotive Industry. In: *Proc. 20th Annual Conf. POMS.*, Orlando, Florida, May1-4.