DESIGNING AND BUILDING TO MINIMIZE CONSTRUCTION WASTE

Benedict D. Ilozor[1], Charles O. Egbu[2] and Tariq S. Abdelhamid [3]

ABSTRACT

Lean Construction strives for reliable workflow on the construction site by using work-structuring and the Last Planner System. In the construction industry, many factors contribute to unreliable workflow such as late delivery of material and equipment, blue-print errors, change orders, equipment breakdowns, tool malfunctions, improper resources utilization, labor strikes, and environmental (weather) effects. Another important source of variability, which is often overlooked is construction waste, as in by-products of the construction process. This source of reliable workflow impedance create cluttered, congested, and dangerous work conditions. In Lean Construction, 5s or 6s is deployed in order to mitigate the effects of construction waste. Another tact to use, which follows from the continuous process improvement spirit that underlies lean, is to minimize and ideally eliminate this waste. If dealt with appropriately, there can be many benefits, including lower overall cost, faster production, a higher quality, and more sustainable buildings. The purpose of this investigation is to ascertain key sources of construction waste, and whether generation varies with the type and size of the constructions. A sample of 30 general contractors was studied, and several null hypotheses on waste generation and minimization differences were tested using the Kruskal-Wallis H test. Although subtle shifts were observed in the aspects of waste behavior that seemed predicated on construction sectors and capital base, to some extent the proposition that construction type and size can influence waste generation and minimization was validated. Based on this study, some solutions are provided as viable avenues to managing and minimizing construction waste.

KEY WORDS

lean construction, construction waste, workflow problems, waste minimization

INTRODUCTION AND BACKGROUND

The total U.S. construction was projected to be 1.18 trillion dollars in 2007 according to the forecasters at the FMI Corp. (Grogan 2006). A tremendous amount of resources continues to be invested into construction despite progressive growths in this sector since the 1950s. Construction consumes up to 60% of raw materials used in the U.S. economy, and about 136 million tons of building related construction and

[1] Associate Professor and Graduate Assistant & Research Coordinator, Construction Management Programs, School of Engineering Technology, College of Technology, Eastern Michigan University, USA.

[2] Professor, School of the Built Environment, University of Salford, Salford, M5 4WT, England, UK.

3 Associate Professor, 116 Human Ecology, School of Planning, Design and Construction, Michigan State University, East Lansing, MI, USA

A LEAN STRATEGY TO PERFORMANCE MEASUREMENT – REDUCING WASTE BY MEASURING 'NEXT' CUSTOMER NEEDS

Michelle S. Leong[1] and Paul Tilley[2]

ABSTRACT

Despite the odd victory here and there, the construction industry is continuing to be seen by many as a poor performer – especially considering the advances being made in other industries. It is the authors' belief that this is due (to a large extent) from a gateway waste of not measuring and/or using wrong, inappropriate or insufficient measures for performance appraisal. By identifying and using appropriate measures for benchmarking performance, both quick wins and long-term process improvements can be achieved, as better knowledge helps to identify the right direction and focus areas for investing in improvement efforts.

The aim of this paper is to briefly discuss current performance measurement (or lack there of) within the construction industry and through the use of a simple case study example, identify some of the waste and repercussions of either not measuring or using inadequate/inappropriate measures or targets. The paper also aims to explore the notion of measuring NEXT customer needs – as part of a lean performance measurement strategy – in order to try to achieve end user customer satisfaction. A case study example involving the RFI process is then used to illustrate the authors' belief that tailoring measures according to NEXT customer needs will assist in driving behaviour towards end user value, improving performance, reducing waste and contributing directly to the bottom line.

KEY WORDS

data collection, construction, lean, measures, NEXT customer, systems thinking, value, value demand, failure demand

INTRODUCTION

"It is not necessary to change.
Survival is not mandatory."

(W. Edwards Deming)

It has been 10 years since Sir John Egan published his landmark report "Rethinking Construction" (Egan, 1998), however despite clearly identifying the need for improvement and providing numerous recommendations for industry change, the performance improvement targets he set for industry just haven't been realised. Unfortunately – and to a large extent – the industry still continues to under-perform, generally due to a continued lack of design and construction process integration, a lack of focus on quality and customer value, poor contractual relationships and a general lack of understanding as to why poor performance continues, or

[1] Director, Lean Practitioners Ltd. Leckford, Crookes Lane, Kewstoke, W-S-M BS22 9XB, UK Phone +44 845 8673788, Mobile +44 7935 312214, michelle@leanpractitioners.co.uk

[2] Teaching Fellow, School of Engineering, Physics & Mathematics, University of Dundee; UK. Phone +44 1382 385103; p.tilley@dundee.ac.uk

how improvements might be achieved. For his continuous improvement targets to be met, Egan (1998) rightly identified that companies needed to start investing in appropriate benchmarking and performance measurement. Despite such recommendations, this an area in which the construction industry in general is still sadly lacking and what measures are in place, are generally financial in nature and rarely support process improvement decision making (Lantelme & Formoso, 2000; Costa, et.al., 2004).

By not measuring system performance, the industry has no idea of what is affecting current performance levels. By not understanding the factors that impact current performance, the industry will not know what improvement efforts need to be made, where these efforts need to be focused or which efforts will likely reap the best results. Hence, the waste of haphazard initiatives and improvement efforts e.g. concentrating on improving things that do not make much of a difference, implementing changes that actually have a negative impact on the process along the way, or worse, making wasteful activities more efficient.

One of the fundamental principles of 'Lean Thinking' and therefore 'Lean Construction', is that of continuous improvement through the elimination of waste, however to achieve this, benchmarking and performance measurement are necessary components of the process (Ballard, 2000; Liker, 2004). It is only by doing this and ensuring transparency at all levels that the changes needed to improve quality and productivity can be identified. However, to achieve maximum value, it is essential that care be taken in identifying the type of data we collect and the method by which we analyse it.

Through the use of some simple case-study examples, this paper aims to initially show how the waste generated by continued poor industry performance is occurring due to a failure to implement adequate and appropriate benchmarking and performance measurement. The paper will then investigate the concept of the NEXT customer, as a 'lean' approach to identifying the right type data to collect and analyse. Case study examples involving an analysis of the RFI process are used to illustrate the authors' belief that tailoring measures according to NEXT customer needs will assist in driving behaviour towards end user value, improving performance, reducing waste and directly contributing to the bottom line through overall improvements in Quality, Delivery, Cost and Customer Satisfaction.

DEFINING THE PROBLEM

"*... the only way we can be sure that performance is getting better is to measure the improvement. If performance isn't measured, it can't be controlled.*" (Horner & Duff, 2001)

Despite their seeming reluctance to do so, construction companies (particularly in the UK) are being encouraged to benchmark projects using nationally identified Key Performance Indicators (KPIs) – such as those promoted by Constructing Excellence (CE) and the Scottish Construction Centre (SCC) – to supposedly enable them to not only measure their own performance but also compare themselves against their sector of the industry. However, by

only capturing project specific data, they are only measuring their performance against a range of fairly general criteria that may or may not be wholly applicable to their, or other organisations and may have no real bearing on the performance of those businesses as a whole (Costa, et. al., 2004). Comparing themselves to an overall industry average, might not provide much real advantage and may actually send the wrong message if their performance is indicated as being higher than the average, by possibly reducing their incentive to invest in process improvement… succumbing to the "if it ain't broke, don't fix it" syndrome!!!

Another main issue with such KPIs is that as they are based on completed project results, there is too long a time lapse for any immediate impact from improvement strategies: i.e. the plan, do, check and act cycle is too big (Beatham, et. al., 2004). Another vital flaw includes the fact that they do not include details as to why certain levels of performance occurred, or reflect the overall performance of the specific organisations, as they only compare project to project. For those companies using this type of data, there is a fairly high likelihood that it could really be like comparing apples with pears. Instead, companies need to compare themselves against their own overall and specific performance, rather than against poorly defined and possibly inappropriate, external measures. It is also important to note that traditional performance parameters measured in projects, namely costs and schedule, are not appropriate for continuous improvement because they are not effective in identifying causes of productivity and quality losses. (Lantelme & Formoso, 2000; Alarcon et. al., 2001)

Not Measuring Or Using The Wrong Measures

Although there is no shortage of data available within the construction industry, the authors' personal experience has shown that only a very small proportion of it is ever used to create useful information and even less to actually measure system or process performance. What measurement is carried out is often driven by requirements for financial reporting and generally focuses on costs (including the cost impact of actual programme results), profits and overall company turnover. Financial measures alone rarely provide and accurate guide to an individual's performance or a project/company's success as it often neglects issues relating to product quality or customer satisfaction. Instead, it only encourages short term thinking, where the financial results – but not how the results are achieved – become the priority. For example, just because a company's annual turnover is continuing to increase year on year, doesn't necessarily mean that the company is actually performing better and could actually hid some underlying problem.

The construction industry has many examples of how performance is measured using inappropriate criteria, from the site staff whose bonuses are dependent on whether or not their project's profit margins are achieved to the sub-contractors whose performance and therefore payments are based on volume of work done, as opposed to areas of fully completed, defect-free work that enables following trades to commence. As Deming (1986) identifies, an individual's performance

capacity is often limited by the constraints imposed by the system under which they have to operate and as such, whether a project's quality, cost and delivery figures are achieved, is similarly not always due to the capability of the site staff. Unfortunately there are still many who lack this basic understanding of system variation.

Case Study 1 – Failure to View the System as a Whole

This first case study provides an example of how concentrating on only one aspect of a business' overall goals and objectives, can have a negative impact on the business as a whole. In this example, a fairly progressive, medium size UK housing development company had set some rather challenging annual company turnover and profit growth targets – with turnover projections growing from an initial projection of around 20% annual growth in 2003, to nearly 70% year on year from 2004 to 2007). Obviously to achieve these targets required a significant increase in the number of properties to be both produced and sold annually, whilst at the same time overall production costs needed to be reduced.

During 2005, the company was also started attempting to implement 'lean' construction approaches, including the use of "Last Planner" in both design and construction, as well as the use of 3/5D modelling to the design process. As a result of the organisational changes occurring due to a combination of company turnover growth and lean process implementation, internal and external resources became stretched and business performance was adversely affected. By focusing on short term turnover targets and cost cutting exercises, projects were delayed, product quality suffered and purchasers ended up moving into their new properties before they had been properly completed and checked.

The end result of this focus on turnover growth, has meant that there was a disproportionate increase in revisits and aftercare works, resulting in additional business costs and reduced profits. Figure 1 below provides details of the growth of "Customer Care" maintenance issues over a three year period.

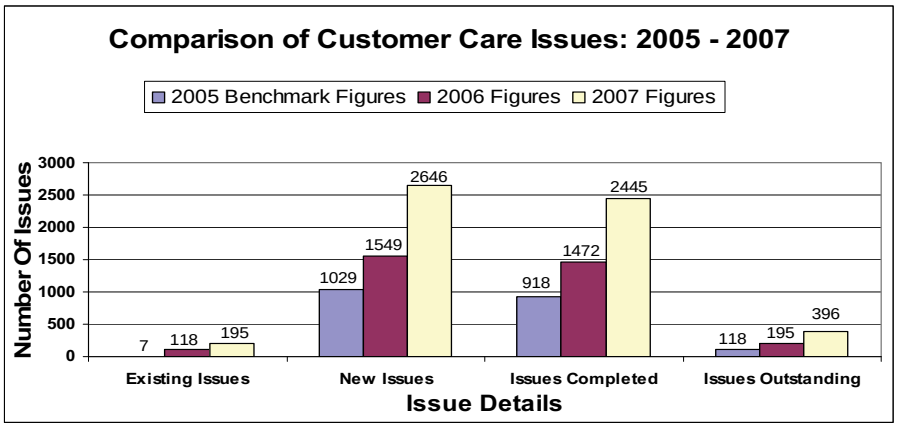

Figure 1: Three Year Comparison of Customer Care Issues

As can be seen, there has been a dramatic increase (157% increase in just 2 years) in new "Customer Care" issues being raised by clients – far in excess of the company's growth over the same period. Not only is this continuing problem (a further increase of 28% over the 2007 figures, up to 30/04/2008) affecting the company's bottom line, but it is also having a negative impact on the company's strong reputation in the market place. In addition, the poorer than expected profit levels have meant that company bonuses could not be paid (despite the hard work of the staff), which has led to increased employee dissatisfaction, resulting in increased staff turnover and a further stretching of the already overstretched staff. This shows that there is a need for a range of measures to be put in place and analysed in order to provide a better understanding of cause and effect relationships, that impact on whole business performance. It is interesting to note that despite the data being available, even this simple analysis is not being carried out by the company. In addition, recommendations to classify these issues have not been addressed and so there is no quantified understanding as to the main causes of the quality failures.

HOW AND WHAT TO MEASURE?

DEFINING AND MEASURING CUSTOMER SATISFACTION

In line with Deming's 'Systems Thinking' approach to achieving the system's aim (Deming, 1994), or similarly the ultimate lean goal of achieving end user customer satisfaction, then we need to satisfy our NEXT customer first. Figure 2 below highlights that if we focus on satisfying ***every*** NEXT customer along the process, then we should ultimately achieve end user satisfaction and contribute to enhanced flow and reduced waste – hence money in everyone's bank quicker – a common business goal. (Ward & McAlwee 2007)

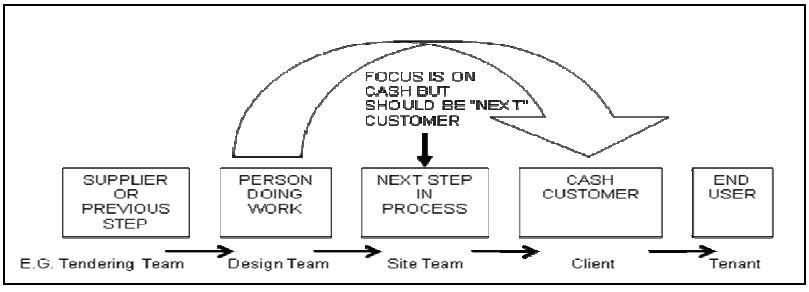

Figure 2: The "NEXT" Customer (Adapted from Ward & McAlwee 2007)

If this is agreeable, then it would be logical to identify what is important to the NEXT customer and then measure how well their requirements have been met. Obviously this is dependent on the process and although Figure. 2 shows a high level process, a more operational example might be:

Stud wall >1st Fix
Electrics>Plasterboard>Tape Joint>2nd Fix
Electrics>2nd Fix Carpentry>Painter

Whilst it is not really important which party carries out the actual measurement, it is important that the results be communicated and that changes necessary to improve performance, be investigated and implemented. In this example, it could be the painter who measures the joiner, who measures the electrician who measures the tape jointer, and so on, with the results achieved, potentially triggering the release of progress payments. If each NEXT customer's requirements are clearly stipulated, agreed and then upheld by the trade before, this would help to reduce the large amounts of interface and quality wastes currently occurring on construction sites. Feedback of such information would also help the preceding company to measure their own performance in relation to meeting NEXT customer requirements. The same would also apply the process indicated in Figure 2.

Case Study – Next Customer Measures

There is evidence of great inefficiencies in the design and documentation process (Tilley et al, 1997; Tilley, 2005) and it is not uncommon to hear ranting comments, from site, as to how wrong, delayed, insufficient or irrelevant design information is delaying progress and creating rework on site. These rantings, are generally from either the principal or the trade contractors – the NEXT customers of the design team.

The following case study and analysis of the project's Request for Information (RFI) records, has been chosen in this context to demonstrate the principles relating to NEXT customer measures and how some of these measures actually already exist, but are not being optimally used. Consisting of both a new build component and the refurbishment of existing residential and commercial retail units, the project – which started in March 2007 and (at time of writing) is currently due to complete in March 2009 – was originally valued at approximately £7 million. Being a fairly complex project, the decision was made to introduce a lean production philosophy as early into the project as possible, gathering the client, design and site team for collaborative planning workshops. All stakeholders seemed to be in consensus with the aims of the system i.e. deliver on time, to required quality and within budget, however the planned activities achieved only hovered around 55%.

Due to some major unforeseen issues in relation to the refurbishment part of the project and the ground works on the new build element, relationships were tense. It is the authors' view that if appropriate data had been collected, collated and analysed from the outset, there may have been far fewer surprises for the experienced companies involved. To exacerbate matters, the usual issues of diminishing design fees and insufficient design time (Tilley, 2005) surfaced, further contributing to the hostile and accusing behaviour. With design issues plaguing the project, planned sessions to improve sub-contractor efficiency were postponed again and again.

In November 2007, the main contractor became impatient and approached the client directly to complain about the design team. Due to the blaming scenario that ensued, the 'Lean' consultant allocated to the project enquired as to what proof there was to confirm the design team's

inefficiencies and how much were they likely to be costing the client. To try to determine designer performance and its impact on the project, an analysis of the RFIs issued, was considered. RFI details were recorded and kept in a register showing the number of each request, to whom and when it was issued, when a response was expected back and when a response was actually received. A data analysis session was then conducted to determine the cause and cost of information flow waste. Figure 3 below shows that of the 383 RFIs issued up to that time, 63% were received later than the allocated timeframes.

Further analysis of the data showed that out of the 63% (238) late responses, 66.4% came from the architects, 16.8% from the civil/structural engineers and 16.8% from the M&E engineers. However, what was of greater interest was the fact that when considered individually, 67.2% of architect's responses, 66.6% of M&E responses and 48.2% of civil/structural engineers' responses, were late.

As contractors are usually criticised for allowing insufficient time to respond to their information requests, the number of days/notice given by the main contractor for the design team to respond, was also assessed. (Anomalies were removed to prevent skewing of the data.)

- The average number of days given to the design team for response, was 10.5 days (sample size of 304 RFIs)
- The average number of days late in response, was 7.5 days/RFI
- The average number of days taken to respond to an RFI, was 18 days.

Based on previous research (Tilley et.al.,1997 and Tilley, 1998), the number of days allowed for a response was considered to be quite reasonable. However, based on the number of RFIs issued up to this point in time and the average time for responses, the design team performance would be considered 'very poor' in relation to both the extent and severity of design problems identified. Having determined that delays to information flow were a problem, an investigation into the root cause of the original RFIs was needed, with the following cause classifications considered to be appropriate: Lack of detail; Design change; Buildability; Lack of site investigations; and Lack of pre-tender info. Using these classifications, Figure 3 below, provides an analysis of the root causes of RFIs on this project.

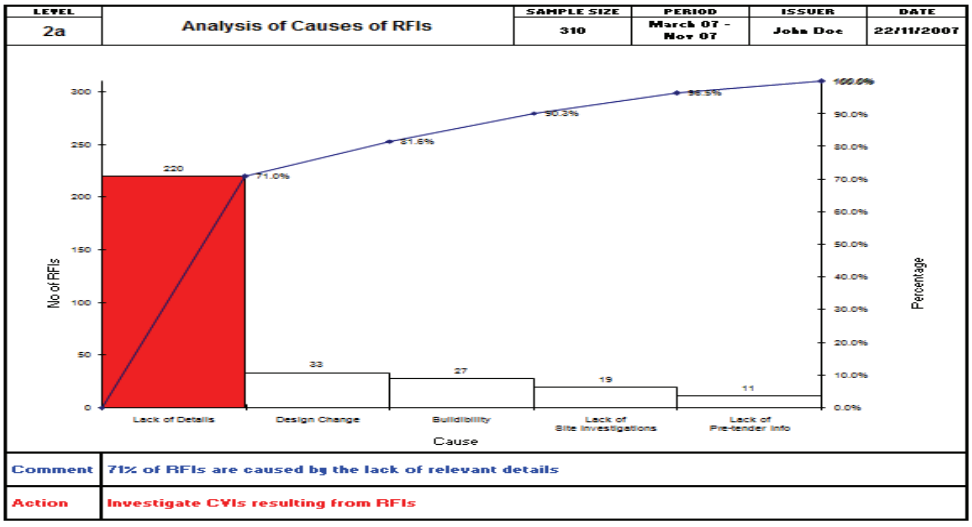

Figure 3: Analysis of Cause of RFIs

As can be seen, 71% of RFIs were due to a lack of detail in the original documents. To assess the issues further, the team decided to investigate the Confirmation of Verbal Instructions (CVI), as they were the results of RFIs. At the time this analysis was carried out, there were a total of 178 CVIs. Figure 4 below, shows that approximately 71% of the CVIs were due to the lack of a proper site investigation. Note that the classifications were reduced as it was team consensus to drill down to the root cause.

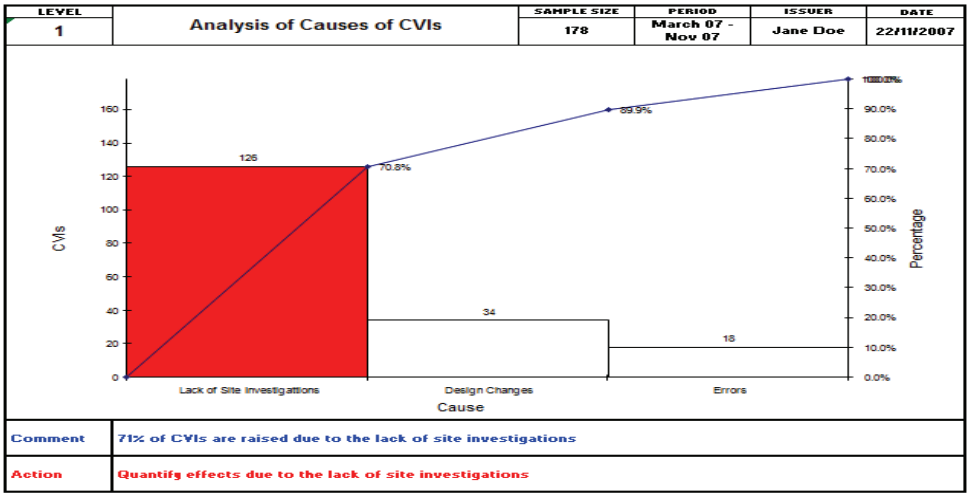

Fig.4: Analysis of Causes of CVIs considering root causes

Table 1 below, provides a summary of the costs relating to these CVIs and clearly shows that the lack of site investigation was responsible for an increase in project direct cost, of approximately £560K.

Table 1: Summary of costs against CVIs

Causes of Variations	Cost (£1,000)	Percentage
Lack of Site Investigations	£560	71%
Design Change	£110	19%
Errors	£95	10%
TOTAL	**£765**	**100%**

At time of writing (April, 2008) there are 395 RFIs and 283 CVIs – currently valued at approximately £2M – and the project is currently approximately 6 months behind programme. However, for the objectives of this paper, the case study clearly shows that it is possible to measure an organisation's performance based on their ability to meet NEXT customer requirements, that the data required may already be available and that there are benefits for those who possesses such data and information. In this case, had the necessary measures been in place, deficiencies with the original site investigation may have been brought to the surface earlier, allowing the design and construction teams to resolve the issues sooner and reduce the amount of delay and rework waste created. Such data, if collated and analysed from a number of projects, would also enable both the design firms and the main contractor to determine trends, thereby helping to make confident business decisions to improve performance.

CONCLUSIONS

The failure to implement appropriate measures is common within the industry and can lead to not only wrong conclusions or behaviour, but also poor decision making due to inadequate information. In order to drive behaviour towards value through the elimination of waste, the industry needs to understand the principles of systems thinking and variation and implement appropriate measures to identify where system improvements can be made.

In line with lean's definition of value and waste (Womack & Jones 1996) when it comes to producing a product, lean services have their definition adaptation for services namely, value demand and failure demand (Seddon, 1992). Value demand is equivalent to lean's definition of value i.e. requests generating what the customer wants, while failure demand are requests generated as a reminder or due to not having done it right first time.

The construction industry deals with both products and services. In terms of product, we need to measure our performance in quality, cost, delivery and health and safety. In "NEXT" and end user customer satisfaction, there is a need to measure percentage value and failure demand. Understanding the type and cause of value and failure demand can give more reliable focus areas for improvement than subjective customer feedback. Value and failure demand can potentially let us know our customers better than they know themselves. It is management's duty to set strategic goals and help staff create fit for purpose "NEXT" customer measures. If the NEXT customers were to be identified right

from the start and appropriate measures put in place (potentially triggering payment), the chances of delivering a project on time, on budget and to the customers requirement will be greater.

FURTHER RESEARCH

One known case of triggering payments based on next customer satisfaction was implemented by a shoe maker Thomas Bata (1876–1932) (Tribus 2004). The next steps for the construction industry is to research how feasible and practical it is to measure and pay according to NEXT customer satisfaction (develop a NEXT customer type contract). The aim of this is to trigger the correct behavior towards end user satisfaction. If as discussed earlier, subcontractors were paid by the room/unit instead of per m^2, it would incentivise them to finish the bits necessary to allow the NEXT customer (next subcontractor in the process) to immediately start value adding work, in line with what the end user wants.

The first author is embarking on a project to introduce systems thinking to a national construction company, investigating inter-departmental ways of assessing NEXT customer relations and measures. This may sound too challenging an idea to embark upon or implement immediately but all it takes is a few strategically positioned lean souls to challenge fixed ideas. We need to start investigating this opportunity one step at a time as recommended in continual improvement, NOT kaikaku, a huge leap, which gets mistaken for continual improvement. To measure for the sake of measuring or measuring using recognised measures because every one does that, that is indeed the question. Considering current industry performance and the current economic situation, do we have time to spend on wasted effort? Sink or swim –a dilemma? But as Deming proclaimed - Survival is optional!

REFERENCES

Alarcon, L., Grillo, A., Freire, J., & Diethelm, S. (2001), Learning from Collaborative Benchmarking in the Construction Industry. *Proceedings of 9th International Conference of the International Group for Lean Construction*. Singapore.

Ballard, G. (2000). "The Last planner System of Production Control". Ph.D. Thesis, School of Civil Engineering, University of Birmingham, Birmingham, UK.

Beatham s., Anumba, C., Thorpe, T., Hedges, I. (2004) "KPIs: a critical appraisal of their use in construction" Benchmarking: An International Journal, v.11, n.1.

Costa, D., Formoso, C., Kagioglou, M & Alarcon, L. (2004), Performance Measurement Systems for Benchmarking in the Construction Industry. *Proceedings of 12th International Conference of the International Group for Lean Construction*. Copenhagen, Denmark.

Covey, S. (1989). The Seven Habits of Highly Effective People. ISBN 0-7432-6951-9

Deming, W. E. (1986) Out of the Crisis, Cambridge University Press, Massachusetts.

Deming, W. E. (1994), *The New Economics*, MIT Press, Massachusetts.

Egan, J. (1998) *Rethinking Construction*. DETR, London.

Horner, M. & Duff, R. (2001) More For Less - A Contractor's Guide to Improving Productivity in Construction, CIRIA, ISBN: 9780860175667

Lantelme, E. M. V. and Formoso, C. T. (2000), Improving Performance through Measurement: The Application of Lean Production and Organisational Learning

Principles, *Proceedings of 8th Annual Conference of the International Group of Lean Construction*, University of Sussex, Brighton, UK.

Liker, J. (2004), *The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer*, McGraw-Hill Professional.

Seddon, J. (1992), *I Want You to Cheat!: The Unreasonable Guide to Service and Quality in Organisations*, Vanguard Consulting.

Tilley, P.A., Wyatt, A.D. & Mohamed, S. (1997), Indicators of design and documentation deficiency, *Proceedings of 5th Annual Conference of the International Group of Lean Construction,* Gold Coast, Australia, 16–17 July 1997, ed. S.N. Tucker, pp. 137–148

Tilley, Paul A. (1998), *Causes, Effects and Indicators of Design and Documentation Deficiency*, Masters Thesis, Queensland University of Technology.

Tilley, P.A. (2005), Lean Design Management – A New Paradigm for Managing the Design and Documentation Process to Improve Quality? *Proceedings of 13th Annual Conference of the International Group of Lean Construction*, Sydney, Australia, 18-21 July, pp. 283-295.

Tribus, M. (2004) Section II p.5. *"Quality Management according to the Teachings of W. Edwards Deming"* NAE Pensacola Florida

Womack, J., Jones, D.T. (1996), Lean Thinking: Banish Waste and Create Wealth in Your Corporation, Simon and Schuster, London,

Ward, S. & McElwee, A. Application of the Principle of Batch Size Reduction in Construction, *Proceedings of 15th International Conference of the International Group for Lean Construction*. Michigan, USA.