# Lean Construction as a Strategic Option: Testing its Suitability and Acceptability in Sri Lanka

**Sepani Senaratne[1] and Duleesha Wijesiri[2]**

## Abstract

Lean Construction is a concept still new to many construction industries in the world. According to Ballard and Howell (2003) countries such as UK, Australia, USA and Brazil have gained significant benefits by adoption of Lean Construction concepts. However, this concept is still new to the Sri Lankan construction industry. Lean Construction can be argued as a strategic option when implementing in a new setting, where certain tests such as its suitability and acceptability needs to be done prior to its implementation. Hence, this study aimed to explore the suitability and acceptability of Lean Construction in Sri Lanka. The study adopted an opinion survey using Delphi Method to collect empirical data. The findings reveal frequent flow activities that generate waste and their causes in the Sri Lankan construction industry. The research further finds that the domestic construction industry workforce is ignorant of these flow activities that create waste and their causes. When tested majority accept the core principles of Lean Construction and are having a Kaizen mentality, which is central to lean thinking. Thus, the study concludes that Lean Construction is suitable and acceptable in the Sri Lankan context. Overall, the study offers an approach to test Lean Construction in a new construction industry using an opinion survey.

Keywords: Flow wastes, Opinion Survey, Suitability, Acceptability, Lean Construction, Kaizen mentality

## Introduction

Construction industry, according to researchers, is a slow progressing industry with frequent problems such as low productivity, insufficient quality, time over-runs, and poor safety which hinder customer delivered value (for example, see Latham, 1994; Egan, 1998). Lauri Koskela (1992; 1993) is a pioneer in introducing lean construction as an approach to address these problems. According to him, all activities can be divided into conversions and flows. Conversion activities produce tangible outputs whilst flow activities bind such conversion activities during the delivery process of the outputs. Although all activities expend cost and consume time, Lean Construction argues that only conversion activities add value and these should be made more efficient, whereas, non-value adding flow activities need to be reduced or eliminated (Koskela, 1993).

[1]PhD., Senior Lecturer, Department of Building Economics, Faculty of Architecture, University of Moratuwa, Sri Lanka.
[2] Research student, Department of Building Economics, Faculty of Architecture, University of Moratuwa, Sri Lanka.


2008: pp. 34-48

Traditional thinking of construction focuses on conversion activities and ignores flow and value considerations. In particular, waste is generally associated with waste of materials in the construction processes while activities such as inspection, delays, transportation of materials and others are not recognised as non value-adding flow activities that may lead to waste (Alarcon, 1995). Womack and Jones (2003) describe waste (muda) as any human activity which absorbs resources, but creates no value. Thus, by eliminating waste, activities can become 'lean'; which provides more with less resources (Womack and Jones, 2003). Researches in United States and Europe have revealed that considerable amount of waste lies in flow processes of construction (Serpell et al., 1995). According to findings by Koskela (1992), these wastes in flow processes of construction such as 'non-conformance quality costs' consume 12% of total project cost; 'poor materials management' causes 10-12% of total labour cost; 'time used for non value-adding activities' amounts to 2/3 of total project time; and 'lack of safety' amounts to 6% of total project cost. Thus, the value hindrance by wastes in flow processes of construction is quite evident – which, then, triggers the necessity to implement a concept such as Lean Construction.

Lean Construction in this study is viewed as a strategic option when implementing in a new setting, where certain tests such as its suitability and acceptability needs to be done prior to its implementation. Next section discusses this aspect of Lean Construction as a strategic option.

# Lean Construction as a Strategic Option

A company, which successfully implements the concept of Lean Construction, would be able to gain significant cost advantage by eliminating cost-consuming flow activities and become a cost leader, a differentiator and a cost-focus. Thus, Lean Construction can be viewed as a strategic option considering its cost leadership, differentiation and focus strategies (for example, see Porter, 1980).

This strategic option should be evaluated before implementing in a new context. Johnson and Scholes (1999) have put forward three 'Strategic Option Evaluation Tests', which are helpful in evaluating a strategic option of this nature before applying to a particular environment (Botten and Sims, 2005). These are Suitability Test, Acceptability Test and Feasibility Test. Suitability Test considers whether the option is the right one in given circumstances. The Acceptability Test considers whether the strategic option will gain crucial support from the people it needs to or whether it will lead to opposition or criticism. The Feasibility Test considers whether a company has the capacity to carry out the strategic option successfully.

While arguing Lean Construction as a strategic option, this study adopts these evaluation tests to examine the applicability of Lean Construction in the Sri Lankan context. The next section attempts to synthesise previous research findings around these evaluation tests in order to develop research questions for this study.

## Suitability Test for Lean Construction

According to the Suitability Test, if a strategic option helps a firm or an industry to overcome a weakness such an option would be suitable for application. 'Waste' is a significant weakness in the construction industry (Skoyles and Skoyles, 1987). Koskela (1992) declares that there has not been a systematic attempt to identify wastes in flow

activities (flow wastes) by the construction industry practitioners until Lean Construction concept was introduced. Thus, if flow waste is identified as a major weakness in a particular industry Lean Construction can be regarded as a suitable option for consideration. Previous research studies on Lean concepts have revealed different types of flow waste.

For example, Shingo (1984) as one of the pioneers of Lean Thinking proposes the following seven types of wastes; namely, waste due to overproduction; waste due to wait periods; waste due to transport; waste due to the system itself; waste due to stock; waste due to operations; and, waste due to defects. On the other hand, Koskela (1992) has identified wastes in construction processes such as number of defects; rework; number of design errors; omissions; number of change orders; safety costs; and, excess consumption of materials. Further, Alarcon (1995) has recognised a variety of wastes relating to work methods, materials, time, labour, operational planning and equipments. Serpell et al. (1995) further identified that productive time is wasted by work inactivity and ineffective work. This study synthesised these different classifications of wastes that were identified by various researchers, under three groups; namely, 'commonly mentioned', 'occasionally mentioned' and 'unmentioned' wastes (see Table 1).

**Table 1: A synthesis of identified wastes**

| **Commonly Mentioned Wastes** | **Occasionally Mentioned Wastes** | **Unmentioned Wastes** |
|---|---|---|
| Waste due to wait periods | Over production | Pilferage |
| Defects | Safety costs | Management time spent on fire-fighting |
| Excess materials | Equipment wear and tear | |
| Waste due to design errors | Resting time | |
| Transport/handling time | Inventing work | |
| Activity delays | Clarification needs | |
| Waste due to operations | | |
| Excessive space/stock | | |
| Rework | | |

Most of these wastes possess a considerable amount of 'temporal wastes' and seem to be intangible and invisible. Thus, this may be a reasonable reason for construction practitioners not realising the existence of these wastes.

In order to eliminate these non value-adding flow activities it is essential to identify the causes/sources of such wastes. Previous research on Lean Construction reveals that flow wastes are caused due to many reasons. For example, Serpell et al. (1995) have categorised these causes as follows (see Figure 1):

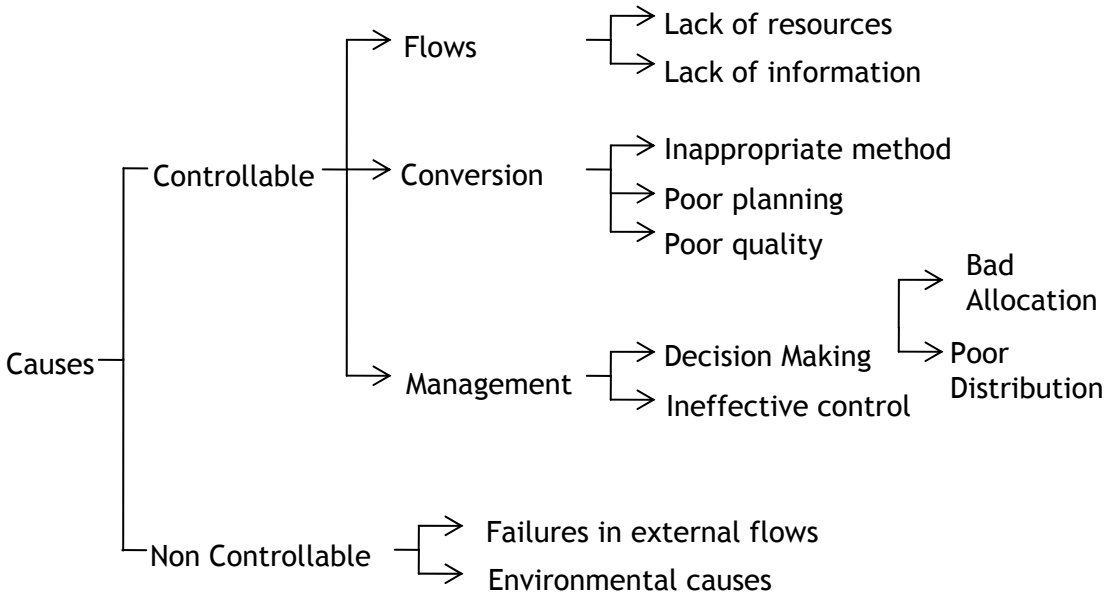


**Figure 1: Causes of wastes**
**Source: Serpell *et al*. (1995)**

According to Serpell *et al*.s' (1995) categorisation, apart from external factors, all other prevalent causes are controllable. Koskela and Leikas (1994) have identified more causes such as hierarchical organisation; uncontrolled and rigid processes; unrecognised or unmeasured wastes; and, long and complicated information and material flows. Further, Alarcon (1995) has identified causes of waste in three sources: management, resources and information (see Waste-Cause matrix in Appendix-A). On the whole, flow waste can incur in various circumstances, from the decision-making activities at a strategic level to the work methods at operational level.

The prevalence of above-identified flow waste and their causes is unknown in the Sri Lankan construction industry. Therefore, the following research question emerged:

- *What are the types of flow waste and their causes existing in the domestic construction industry in order to test the suitability of Lean Construction to the Sri Lankan context?*

## Acceptability Test for Lean Construction

The Test of Acceptability considers whether the strategic option will gain crucial support from the people it needs to or whether it will lead to opposition or criticism. The general management theorists (for example, see Carnall, 1990) argue that people will accept new philosophies if they accept its principles and believe that they are true. Therefore,

principles of Lean Construction and methodologies to attain the concept will be explored in this section.

The core principles of Lean Construction are elimination of non value-adding flow activities and making conversion activities more efficient. In addition, Koskela (1992) has presented several other principles such as

- Increase output value through systematic consideration of customer requirements;
- Build continuous improvement into the process;
- Reduce variability;
- Reduce cycle times;
- Simplify by minimizing the number of steps, parts and linkages;
- Increase output flexibility;
- Increase process transparency;
- Focus control on the complete process;
- Balance flow improvement with conversion improvement; and
- Benchmark

Thus, if the construction workforce is to accept Lean Construction, they should believe in these principles together with the core principles. Still critics of Lean Construction (for example, see Green, 2000) argue that, emphasis of lean thinking on eliminating waste and improving efficiency would be yet another burden on the workforce to improve profits of the company. Thus, if the workforce perceives that Lean Construction would cause further inconvenience to them, they may not accept this philosophy, especially in the long term. Thus, in order to test the acceptability of Lean Construction phenomenon, whether the construction workforce will accept the core principles or not should be investigated.

Furthermore, a number of methods and techniques such as Just In Time, Total Quality Management, Multifunctional Task Groups, Simultaneous Engineering Value-Based Management, Co-makership and Kaizen – which help in attaining 'Lean' – are parts of Lean Construction (Koskela, 1993; Melles, 1994; Alarcon, 1994). However, it can be argued that one particular instrument stimulates all others and, thus, is at the heart of 'Lean' Philosophy: 'Kaizen' (Imai, 1986; Eaton, 1994; Melles, 1994). Kaizen means continuous improvement involving everyone in the organisation including both managers and workers. Therefore, the principle of building continuous improvement in a Lean Construction environment is materialised through Kaizen. Thus, in addition to examining the acceptance of previously mentioned principles of Lean Construction, the reception towards Kaizen (Or Continuous Improvement) should also be checked since it is at the heart of Lean Philosophy.

Therefore, in terms of acceptability the following research question emerged:

- *To what extent the construction workforce in Sri Lanka accepts the core principles of Lean Construction and Kaizen as a central instrument?*

The final evaluation test, Feasibility Test, considers whether a company has the capacity to carry out the strategic option successfully. Thus, Feasibility is difficult to test for the generic industry as a whole. Rather, this test should be carried out more at a company

level following positive results of tests of suitability and acceptability. Therefore, this test was excluded from the scope of the study and could be a further research.

## Research Method

An opinion survey was undertaken based on an adapted Delphi Technique in order to explore the suitability and acceptability of Lean Construction to the Sri Lankan context.

Judgemental Sampling was selected as this sampling technique is inline with the requirement of Delphi techniques which demands the selection of an expert panel to carryout the research. Since the M1 contractors carry out the major construction work in Sri Lanka, it was decided to select the expert panel from the workforce of M1 contractors on the assumption that wastes are predominant in major construction work than in small scale work. Accordingly, construction professionals in the capacities of Project Managers, Site Engineers, Quantity Surveyors, Technical Officers and Foremen, who are supposed to be well experienced with the construction wastes in the industry, were selected from five (05) M1 contracting firms to form the 25-member expert panel as the survey sample for the opinion survey.

The opinion survey was carried out in three steps.

STEP 1: The Delphi Round One Questionnaires were distributed amongst the participants, with the aim of identifying the types of wastes and their sources prevalent in the construction industry. This questionnaire included a list of flow waste and causes identified through previous studies and also were open to mention any unidentified wastes and causes. In order to aid further analysis, a 'Waste-Cause Matrix' was also provided in the same questionnaire.

STEP 2: As the second step, the Delphi Round Two Questionnaires were distributed to the survey sample, presenting the identified crucial wastes and their causes from the First Round. The participants were asked to provide their opinion on whether, these identified wastes and causes from the First Round are frequent in the Sri Lankan construction industry, or not. Further, the participants' opinions were taken through the questionnaire, on whether they believe those wastes can be minimised, should be minimised and so on. Here, the opinion was inquired on whether the construction workforce would accept the core principles of Lean Construction.

STEP 3: As the final step of the study, participants' further opinion on the acceptance of principles of Lean Construction (providing more emphasis to the principle of Kaizen or Continuous Improvement) were obtained through Round Three Questionnaires. This step further refined the acceptability of Lean Construction to the Sri Lankan Context.

The collected data from the first round were analysed based on the statistical measure of Frequency and the data collected from next two rounds were analysed based on Mean and Standard Deviation values. A Mean value exceeding 3.00 would imply that the participants as a whole are in agreement with the given statement and a Mean value less than 3.00 would suggest otherwise. Likewise, the Standard Deviation values for each statement reflect how far that opinion may vary. The validity of the data was examined through a 'Factor Analysis' and the reliability was inspected through a 'Reliability Analysis,' using SPSS 10.0 software.

## Research Findings

From Delphi Round One results, ten (10) types of flow waste frequently prevalent in the domestic construction industry were found (see Table 2). It is interesting to note that the wastes, which obtained the highest frequency responses, for example, 'Defects,' 'Damaged Material' and 'Unnecessary Material Movement,' are mainly related to material. These ten (10) types of wastes were then taken to the Delphi Round Two in order to confirm on the consensus regarding the frequency of existence of these flow wastes in Sri Lanka. The participants were asked to mark their opinions on a scale of 1 to 5, which reflected how far they 'agreed' that the particular waste type was frequent in the Sri Lankan construction industry. The mean and standard deviation values of this survey are shown in Table 2.

**Table 2: Flow Wastes and Opinions**

| Type of Waste | Frequency Percentage | Mean | Standard Deviation |
|---|---|---|---|
| Defects | 96% | 4.28 | 0.46 |
| Damaged Material | 96% | 4.20 | 0.50 |
| Unnecessary Material Movement | 92% | 4.12 | 0.44 |
| Unnecessary Labour Movement | 88% | 4.08 | 0.40 |
| Rework | 88% | 4.04 | 0.68 |
| Design errors | 88% | 3.84 | 0.55 |
| Activity delays | 84% | 4.28 | 0.74 |
| Waste due to wait periods | 80% | 4.04 | 0.45 |
| Pilferage | 80% | 3.80 | 0.41 |
| Clarification needs | 76% | 3.84 | 0.80 |

According to the results, the wastes have obtained mean weighting around 4.00. This suggests that all participants have a common understanding that these wastes are frequent in the Sri Lankan construction industry.

The number of wastes mentioned by each participant in the Delphi Round One differed. This reflected that the varying awareness amongst different professionals regarding flow wastes (see Figure 2). The significant observation from these results is that Project Managers who were more experienced in the panel had mentioned highest number of wastes. Further, Technical Officers and Foremen who had more on-site experience mentioned a higher number of wastes compared to others.

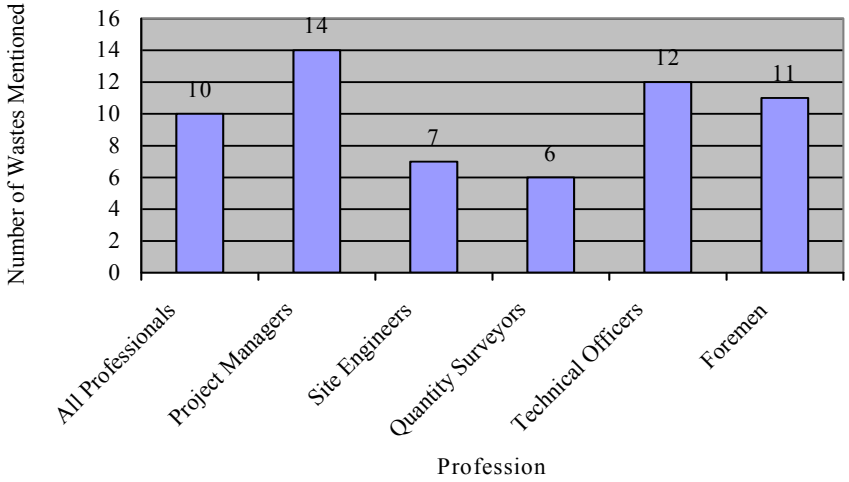


**Figure 2: Number of wastes mentioned by different professionals**

Moreover, based on Delphi First Round results, eight (8) frequent causes of above identified flow wastes were obtained (see Table 3). These eight (08) types of wastes were then taken to the Delphi Round Two Questionnaire in order to confirm on the consensus regarding the prevalence of these causes of flow wastes in Sri Lanka. The mean and standard deviation values of this are also given in Table 3.

**Table 3: Causes of Flow Wastes and Opinions**

| Cause of Waste | Frequency Percentage | Mean | Standard Deviation |
|---|---|---|---|
| Late Information | 92% | 4.09 | 0.51 |
| Environmental Causes | 92% | 3.78 | 0.52 |
| Poor Management Control | 88% | 4.09 | 0.79 |
| Poor Planning | 88% | 4.13 | 0.69 |
| Poor Quality of Resources | 88% | 4.00 | 0.30 |
| Shortage of Resources | 84% | 4.00 | 0.52 |
| Defective Information | 76% | 3.91 | 0.42 |
| Unclear Information | 76% | 3.91 | 0.79 |

The above results suggest that the experts participated in the study have a common consensus that above eight (08) causes of wastes are present in the Sri Lankan construction industry.

A 'Waste-Cause Matrix' (see Appendix A) was also provided to participants in the Delphi Round One to find out, which causes lead to which flow wastes. When closely scrutinising these results, few causes such as Poor Management Control, Poor Planning and Late Information seem to be key sources for a majority of identified wastes (see Figure 3).

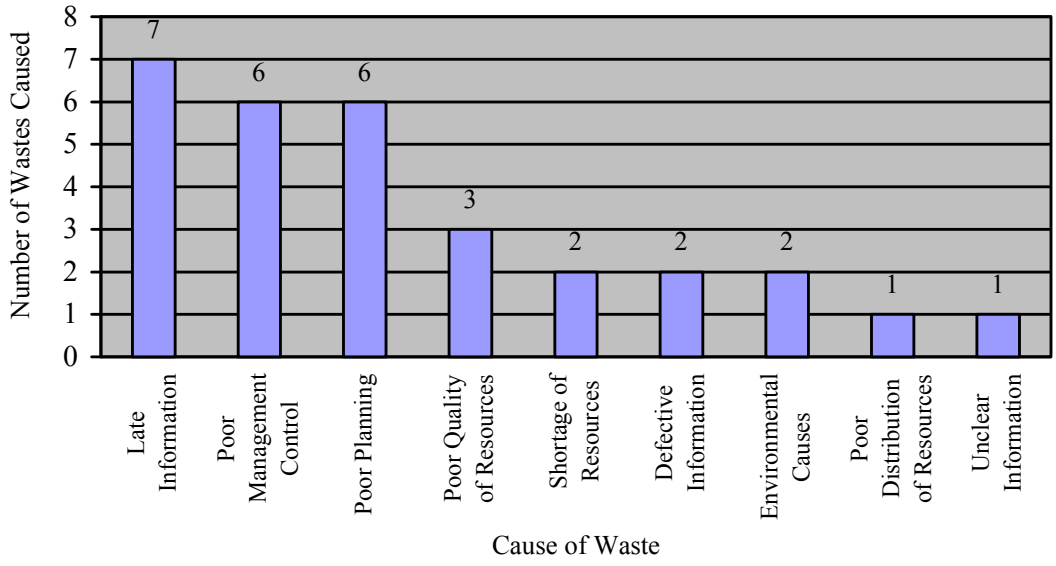


**Figure 3: Causes of Flow Wastes**

Above information regarding the Sri Lankan construction industry can be graphically represented as follows based on the cumulative number of causes and cumulative number of waste types (see Figure 4).

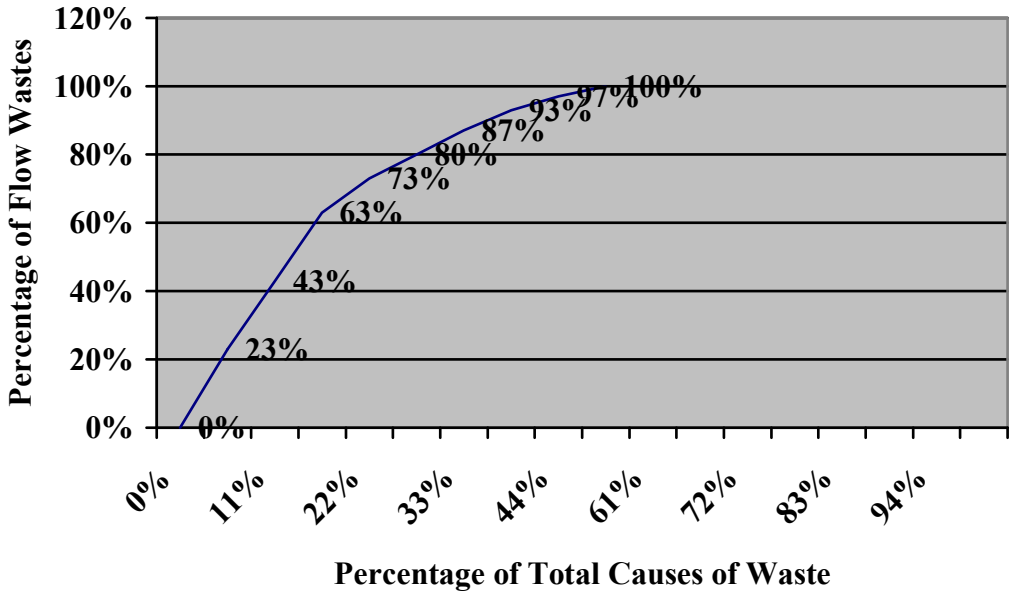


**Figure 4: Relationship between the Cumulative Flow Waste and Causes %**

This graph further confirms that out of all the probable causes of wastes in the Sri Lankan industry, only a very limited number of causes are giving rise to more number of non value-adding flow wastes. This suggests that there is a Pareto Relationship between the causes of flow wastes and types of flow wastes. Accordingly, in the Sri Lankan construction industry approximately seventy percent (70%) of flow wastes are caused by twenty percent (20%) of causes and vice versa.

The opinion regarding the controllability of causes of wastes was also tested in Delphi Round Two Questionnaire. Accordingly, the experts participated in the survey seem to reflect comparatively lesser agreement regarding the controllability of these wastes and their causes (see Table 4). However, according to literature (for example, see Serpell *et al.*, 1995) almost all the causes of flow wastes identified in the Sri Lankan construction industry are controllable. Therefore, it can be argued that the practitioners in the Sri Lankan construction industry are not fully aware regarding these causes of wastes and resulting flow wastes.

After exploring flow wastes and their causes in Sri Lankan construction industry, next the study looked into the 'acceptability' of Lean Construction in the Sri Lankan context. For this, the participants were asked to mark their opinion regarding twenty (20) statements (see Table 4) that relate to core principles of lean thinking following Koskela (1992). The Factor Analysis disclosed that Statements 1, 2, 3, 4, 5, 7, 8, 12, 14, 15 and 18 represented the idea of 'Flow wastes, which are non value-adding, should be eliminated', the Statements 11, 13, 16 and 19 represented the opinion regarding company-wide acceptance for the idea of 'flow wastes should be eliminated' and the Statements 6, 9, 10, 17 and 20 represented the idea of 'To increase output value (through elimination of flow wastes), systematic consideration of customer requirements is essential.'

The results indicated in Table 4 suggest that the Mean values for the three factors are approximately 4.00 without much significant Standard Deviation. This implies that there is consensus amongst the participants that they 'Agree' to these principles; and, also, that they believe that the other practitioners too would accept the ideology of Lean Construction.

In order to further examine the issue of 'acceptability,' the concept of 'Continuous Improvement' or 'Kaizen' was examined in Delphi Round Three Questionnaire. There were fifteen (15) statements, which tested the 'Mentality of Continuous Improvement amongst Sri Lankan workforce' and 'Company-wide acceptance for Continuous Improvement (Kaizen)' (see Table 5).

**Table 4: Results of opinion survey on acceptability to Lean principles**

| Statement No. | Statement | Mean | Standard Deviation |
|---|---|---|---|
| **Factor 1** | **Flow wastes, which are non value-adding, should be eliminated** | | |
| 01 | A majority of earlier mentioned wastes consume significant cost | 4.00 | 0.45 |
| 02 | A majority of earlier mentioned wastes consume a considerable amount of time | 4.04 | 0.50 |
| 03 | Almost all of the earlier mentioned wastes can be eliminated | 3.68 | 0.75 |
| 04 | All the above wastes should be eliminated | 4.20 | 0.50 |
| 05 | The earlier mentioned wastes add no value to the final product | 4.12 | 0.53 |
| 07 | Most of the above mentioned causes of wastes are controllable | 3.64 | 0.81 |
| 08 | Even though a company eliminates above wastes, it will not increase output value | 4.04 | 0.45 |
| 12 | The earlier mentioned causes will give rise to more types of wastes in future | 4.00 | 0.50 |
| 14 | The earlier mentioned causes will give rise to more types of wastes in future | 3.60 | 0.87 |
| 15 | Trying to find the causes of these wastes and eliminating them is of no value | 4.16 | 0.55 |
| 18 | I have many ideas which can contribute to eliminate these wastes and causes | 3.92 | 0.57 |
| **Factor 2** | **Company-wide acceptance for 'elimination of flow wastes'** | | |
| 11 | I can help the company to eliminate these wastes | 4.00 | 0.50 |
| 13 | I think my subordinates will support the company to reduce these wastes | 4.04 | 0.61 |
| 16 | My peers (who are working in the same level of the organisation) will help to reduce these wastes | 4.04 | 0.61 |
| 19 | Trying to eliminate these wastes will not harm my position in the company | 3.96 | 0.61 |
| **Factor 3** | **To increase output value (through elimination of flow wastes), systematic consideration of customer requirements is essential** | | |
| 06 | Adding value to the customer is the prime intention of every activity in the construction process | 4.12 | 0.60 |
| 09 | Giving more attention to customer requirements will minimise the above-mentioned wastes. | 4.16 | 0.38 |
| 10 | Systematic consideration of customer requirements will increase output value | 3.80 | 0.58 |
| 17 | These wastes reduce company profits considerably | 4.12 | 0.60 |
| 20 | Even though these wastes are eliminated, I will not be benefited | 4.12 | 0.44 |

**Table 5: Results of opinion survey on Kaizen mentality**

| Statement No. | Statement | Mean | Standard Deviation |
|---|---|---|---|
| **Factor 1** | **Mentality of Continuous Improvement** | | |
| 01 | Each person in an organisation can contribute to improving the activities of his/her workplace | 4.52 | 0.93 |
| 02 | All activities of the organisation/site can be continuously improved | 4.42 | 0.51 |
| 03 | All activities of the organisation/site should be continuously improved | 4.48 | 0.51 |
| 04 | Not a single day should go by without some kind of improvement being made somewhere in the organisation/site | 4.24 | 0.70 |
| 05 | Continuous improvement will reduce/eliminate non-value-adding activities of an organisation/site | 4.38 | 0.59 |
| 07 | I am not willing to search in ways of continuously improving the work I do | 4.52 | 0.51 |
| 10 | Trying to improve every work activity continuously is not of great importance | 4.33 | 0.48 |
| 12 | I like to seek ideas and learn from many people in order to improve myself | 4.05 | 0.73 |
| 14 | There is no end to improvement | 4.67 | 0.48 |
| 15 | I do not have anything new to learn or improve | 4.62 | 0.50 |
| **Factor 2** | **Company-wide acceptance for Kaizen (Continuous Improvement)** | | |
| 06 | A company's corporate culture should be one that where everyone can freely admit 'problems' and suggest improvements | 4.05 | 0.74 |
| 08 | 'Quality' should be first priority, not 'profit' | 3.04 | 0.59 |
| 09 | I believe my peers are willing to continuously improve the work they carry out | 3.42 | 0.81 |
| 11 | I believe my subordinates are willing to continuously improve the work they carry out | 3.33 | 0.73 |
| 13 | From my experience, I believe that a majority of the workforce in the Sri Lankan construction industry are willing to continuously improve the work they do | 3.05 | 0.74 |

From the above table, all the statements under Factor 1 obtained Mean values more than 4.00. This suggests that there is Continuous Improvement mentality amongst the

practitioners. However, the statements under Factor 2 have obtained comparatively low Mean values with comparatively high Standard Deviations. Therefore, the results reflect that the experts, as a whole, are quite uncertain whether there would be company-wide acceptance for Kaizen or not. A main reason for this contradiction could be that even though the participants believe in Continuous Improvement, they are not practically putting it into practice. In particular, the results of Statement 08 reveal that the participants have a dilemma as to whether quality precedes profit or not. Thus, the lack of process-oriented thinking together with profit motive might be obstructing the Sri Lankan construction workforce to continuously improving themselves. This finding suggests that it is important to make a workforce knowledgeable about profit gains in Lean Construction implementations materialised through Kaizen thinking.

# Conclusions

This research has viewed Lean Construction as a strategic option when considering to implement in a new setting. Accordingly, the research tests the suitability and acceptability of Lean construction in Sri Lanka as a strategic option.

The research findings identified ten (10) types of flow wastes and eight (08) types of causes of flow wastes, frequently prevalent in the Sri Lankan construction industry. A majority of flow wastes and their causes identified were controllable. The research revealed a Pareto relationship of approximately 20: 70 between these flow wastes and their causes . These flow wastes were recognised as a major weakness, which hinders performance and efficiency in the Sri Lankan construction industry. Thus, the study proved that Lean Construction is suitable in Sri Lanka as an option to eliminate this major weakness.

Further, the findings revealed that the Sri Lankan construction workforce accepts the core principles of Lean Construction and has Continuous Improvement or Kaizen mentality. Thus, Lean Construction would be acceptable in the Sri Lankan context. Hence, it is recommended that this concept be implemented in Sri Lanka, provided that each company checks its feasibility within the particular firm.

On the whole, this study offers an approach to test applicability of Lean Construction in a new context. The types of flow wastes and causes together with waste-cause matrix; and, the statements used in the Delphi rounds questionnaires offered in this paper can guide a new study that attempts to implement Lean Construction in a new setting.

# References

Alarcon, L.F. (1994). “Tools for the identification and reduction of waste in construction projects”. *In:* L.F. Alarcon, ed. *Lean Construction*. Rotterdam: A.A. Balkema, 365-377.

Alarcon, L.F. (1995). “Training field personnel to identify waste and improvement opportunities in construction”. *In:* L.F. Alarcon, ed. *Lean Construction*. Rotterdam: A.A. Balkema, 391-401.

Ballard, G., and Howell, G. (2003). “Lean Project Management”. *Building Research and Information*, 31(2), 119-133.

Botten, N., and Sims, A. (2005). *Management Accounting – Business Strategy*. Burlington: CIMA Publishing.

Carnall, C.A. (1990). *Managing Change in Organisations*. London: Prentice Hall International (UK) Ltd.

Egan, J. (1998). *Rethinking Construction: Report of the Construction Industry Task Force*. London.

Eaton, D. (1994). "Lean production productivity improvements for construction professionals". *In:* L.F. Alarcon, ed. *Lean Construction*. Rotterdam: A.A. Balkema, 279-289.

Fowles, J. (1978). *Handbook of future research*. Connecticut: Greenwood Press.

Green, S.D. (2000). "The future of lean construction: a brave new world", in *Proc. of the 8th Conference of the International Group for Lean Construction* (IGLC-8), (ed. J. Barlow) SPRU, University of Sussex, UK.

Imai, M. (1986). *Kaizen*. New York: McGraw-Hill Publishing Company.

Johnson, G. and Scholes, K. (1999). *Exploring corporate strategy* (5th ed.). USA: Prentice Hall.

Koskela, L. (1992). *Application of the New Production Philosophy to Construction*. Technical Report No.72. Centre for Integrated Facility Engineering. Department of Civil Engineering. Stanford University.

Koskela, L. (1993). "Lean production in construction". *In:* L.F. Alarcon, ed. *Lean Construction*. Rotterdam: A.A. Balkema, 1-9.

Koskela, L. and Leikas, J. (1994). "Lean manufacturing of construction components". *In:* L.F. Alarcon, ed. *Lean Construction*. Rotterdam: A.A. Balkema, 263-271

Latham, M. (1994). *Constructing the team: Final Report of the Government/Industry review of procurement and contractual arrangements in the UK construction industry*. London: HMSO.

Melles, B. (1994). "What do we mean by lean production in construction?". *In:* L.F. Alarcon, ed. *Lean Construction*. Rotterdam: A.A. Balkema, 11-16.

Porter, M.E. (1980). *Competitive Strategy: Techniques for analysing industries and competitors*. New York: The Free Press.

Serpell, A., Venturi, A. and Contreras, J. (1995). "Characterization of waste in building construction projects". *In:* L.F. Alarcon, ed. *Lean Construction*. Rotterdam: A.A. Balkema, 67-77.

Shingo, S. (1984). *Study of 'TOYOTA' Production System*. Tokyo: Japan Management Association.

Skoyles, E.R., and Skoyles, J.R. (1987). *Waste prevention on site*. London: Mitchell Publishing Co. Ltd.

Womack, J.P. and Jones, D.T. (2003). *Lean thinking*. New York: Simon and Schuster.

# Appendix-A :Waste-Cause Matrix

E. Please tick the appropriate cause(s) of waste, according to the relevant waste category

| Waste / Cause | MANAGEMENT | Unnecessary Requirements | Excessive Management Control | Poor Management Control | Poor Planning | Bureaucracy, Paperwork | Bad Allocation | RESOURCES | Excessive Amount | Shortages | Misuse | Poor Distribution | Poor Quality | Availability | INFORMATION | Unnecessary | Defective | Late | Unclear | EXTERNAL | Failures in External Flows | Environmental Causes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Waste due to wait periods | ■ | | | | | | | ■ | | | | | | | ■ | | | | | ■ | | |
| 2. Defects | ■ | | | | | | | ■ | | | | | | | ■ | | | | | ■ | | |
| 3. Excess materials | ■ | | | | | | | ■ | | | | | | | ■ | | | | | ■ | | |
| 4. Waste due to design errors | ■ | | | | | | | ■ | | | | | | | ■ | | | | | ■ | | |
| 5. High Transport Time | ■ | | | | | | | ■ | | | | | | | ■ | | | | | ■ | | |
| 6. Activity delays | ■ | | | | | | | ■ | | | | | | | ■ | | | | | ■ | | |
| 7. Rework | ■ | | | | | | | ■ | | | | | | | ■ | | | | | ■ | | |
| 8. Ineffective work | ■ | | | | | | | ■ | | | | | | | ■ | | | | | ■ | | |
| 9. Damaged Material | ■ | | | | | | | ■ | | | | | | | ■ | | | | | ■ | | |
| 10. Unnecessary Labour Movement | ■ | | | | | | | ■ | | | | | | | ■ | | | | | ■ | | |
| 11. Unnecessary Material Handling | ■ | | | | | | | ■ | | | | | | | ■ | | | | | ■ | | |
| 12. Excessive Supervision | ■ | | | | | | | ■ | | | | | | | ■ | | | | | ■ | | |
| 13. Excessive Space | ■ | | | | | | | ■ | | | | | | | ■ | | | | | ■ | | |
| 14. Interruptions | ■ | | | | | | | ■ | | | | | | | ■ | | | | | ■ | | |
| 15. Uncompleted Work | ■ | | | | | | | ■ | | | | | | | ■ | | | | | ■ | | |
| 16. Clarification Needs | ■ | | | | | | | ■ | | | | | | | ■ | | | | | ■ | | |
| 17. Safety costs | ■ | | | | | | | ■ | | | | | | | ■ | | | | | ■ | | |
| 18. Pilferage | ■ | | | | | | | ■ | | | | | | | ■ | | | | | ■ | | |
| 19. Unnecessary Fire-fighting Time | ■ | | | | | | | ■ | | | | | | | ■ | | | | | ■ | | |
| 20. Abnormal Equipment Wearing | ■ | | | | | | | ■ | | | | | | | ■ | | | | | ■ | | |