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Journal of Construction Research
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ARTICLE

A Study of Challenges and Benefits of Lean Construction (LC) Principles in Omani Construction Industry

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ARTICLE INFO

Article history
Received: 30 December 2020
Accepted: 2 March 2021
Published Online: 30 March 2021

Keywords:
Barriers
Benefits
Challenges
Lean construction
Lean principles
Implementation
Industry
Oman

ABSTRACT

There are frequent failures in the project delivery in time and increasing the waste in Oman construction industry. Lean Construction (LC) principles which are lean thinking in design and construction process may be a possible solution. Hence, the paper is aimed on exploring the status of the LC practices and its impact on Omani Construction Industry (OCI). The paper presents barriers, potential benefits, and the measures of suitability and acceptability of LC principles. A quantitative research approach was adopted and research data was collected using an online questionnaire survey in Oman. The data were analysed and results are presented in tables and charts followed by critical discussions. The survey found that one-third of the construction professionals have a good awareness and half of them having a higher level awareness about LC practices. More than one third of the construction organisations are adopting LC principles with a high consensus on the suitability and acceptability, and they recognised that time commitment is necessary for the successful implementation and achieve benefits. The study concludes that the reduction in project delivery time and construction at site waste is the key advantage of implementing LC priciples in design and construction stages in the omani construction industry.

1. Introduction

The construction industry is one of the most important economic pillars in all countries around the world. It represents an average 11% of GDP in global markets and it is likely to reach 13% by 2020 (World Bank, 2015) [37]. The Omani Construction Industry (OCI) currently contributes more than 5% to the GDP and this rate is expected to increase up to 11% in 2030 and it is expected that the employment rate will increase to 35% of Omani workers in both public and private sectors by 2030 (World Bank, 2015) [37]. Furthermore, the Central Omani Bank reported that the value of the construction industry in Oman will reach 1.8 billion R.O. (£3.24 billion), representing a real growth of 1.8 % in 2016 (CBO, 2016) [16]. The main concern within the OCI, especially with this predicted increase in workload, is the current high levels of project failures in terms of expected time and agreed budgeted cost of many projects. Academics and practitioners need to seek for new philosophies and approaches to replace

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DOI: https://doi.org/10.30564/jcr.v2i2.2760

the traditional practises of construction management to improve the sector and mitigate the issues of time and cost. Adoption of lean construction principles is becoming popular to overcome these issues and many developed countries have already been adopted.

There are many research studies conducted in the area of LC, which reflects a great interest from academics and also established a subject amongst the construction field. Lean construction extends from the objectives of a Lean production system i.e. maximize value and minimize waste - to specific techniques, and applies them in a new project delivery process" (LCI, 2016) [26]. Similarly, Ballard (1994, 2000 and 2006) [6] [7] [8]; Ballard and Howell (1997) [9] and Al Sehaimi et al. (2007) [4] believe that LC is a combination of tools and techniques where these can be combined and utilised to increase the productivity and decrease the waste of projects. For instance, the impacts of implementing the Last Planner System (LPS) technique in construction projects and value stream mapping technique highlighted by Arbulu et al. (2003)[5] and Lima et al. (2010) [27] are a few examples of LC tools. Building Information Modelling (BIM) and 5S tools are also considered such LC tools (Salem et al., 2004) [32].

The majority of authors like Koskela et al. (2002) [25]; Emmitt et al. (2004) [15]; Björnfot and Stehn (2007) [11] and Mossman (2009) [28] agreed that LC is more concerned about minimizing waste and maximizing value. But, Mossman (2009) [28] claims that the only way to reduce waste and create wealth is by focusing on the customer value, whereas, Björnfot and Stehn (2007) [11] argue that the basic aim of Lean is to help in the delivery of external value by the internal value generating process. Implementing Lean in construction is more difficult than implementing it in manufacturing for many reasons such as: design in construction is rarely used more than once whereas manufacturing is repetition. In addition, manufacturing processes can be designed and optimised where in contrast, construction processes are determined by crews in the field which means a potential for much variability. Therefore, the paper aims to investigate the barriers, and impacts via analysing the current position of LC in Oman in terms of the level of awareness, existence, suitability, acceptability. The rest of the paper is organised into literature reviews, research methodology, data collection and analysing and results discussion followed by conclusions and recommendations.

2. Literature Review

2.1 Introduction of Lean Construction

Numerous researches in the past have focused on investigating the barriers that might be involved in Lean philosophy and hinder its implementation in the construction industry. For instance, some researchers such as Forbes et al. (2002) [16]; Abduh and Roza (2006) [1]; Senaratne and Wijesiri (2008) [35] believe that the lack of a continuous improvement mind set in quality and productivity improvement initiatives is the main obstacle to the implementation of Lean. However, most authors such as Dulaimi et al. (2001) [14]; Al Sehaimi et al. (2007) [4]; Olatunji (2008) [31]; Alinaitwe (2009) [3]; Jadhav et al. (2012) [21]; Shang and Pheng (2014) [36]; Cano et al. (2015) [12] have a consensus that the most important and influential barrier is related to cultural problems. Whereas, Salem et al. (2005) [34] argue that commitment of the top management for implementation of LC concept is the most important factor in its successful implementation.

Furthermore, Shang and Pheng (2014)[36] conceded that the most crucial barriers to implementation of Lean practices, as realised by Chinese building professionals, included their lack of long-term philosophy and the absence of a Lean culture in their organisation. Cano et al. (2015) [12] reviewed 83 academic articles published between 1998 and 2014 and identified 110 barriers based on experiences in applying LC in the construction industry around the world. Moreover, they grouped these barriers into six master categories; people, organisational structure, supply chain, internal value chain, external management and value chain, and externalities.

Also Cano et al. (2015) [12] revealed 10 most critical barriers based on the cause-effect matrix score: (1) cultural problems, (2) lack of participation and integration of all stakeholders, (3) lack of knowledge and awareness of LC, (4) resistance to change by managers, (5) dichotomy design – construction, (6) resistance to change by workers, (7) LC insufficient training, (8) poor and inadequate planning, (9) lack of proper attitude, (10) lack of commitment to continuous work. Research by Al Sehaimi et al. (2007) [4] highlighted the impacts and challenges of implementing Last Planner System (LPS) in the construction industry in Saudi Arabia and found that most of the identified barriers are common. However, the most critical barriers include the lengthy approval process by the client due to the immense amount of paperwork routinely between employees, culture issues, commitment and attitude to time. But, AlSehaimi et al. (2007) [4] also found these barriers may result from some reasons such as difficulties in weekly program coordination between many subcontractors, lack of commitment and attitude to time from some subcontractors, suppliers and consultants which may, unfortunately, be related to Arab culture where delay by one or two hours or even a day is usual.

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In light of the above discussion, many studies have been conducted to examine the potential barriers which hinder implementing Lean concepts in the construction industry. Although these studies found many common barriers, it is believed that these barriers are significantly different between countries where each country often has a unique construction environment. Thus, the paper is focused to identify unique barriers for implementing LC and measure the suitability and acceptability of LC methodology in the Omani construction industry.

2.2 Impacts of Implementing Lean Construction

Despite the existing and potential barriers in its implementation, there are also numerous cases that evidence the benefits of implementing lean philosophy in the construction industry. Some of the research discusses the impacts of LC on sustainability like Huovila and Koskela (1998) [19]; Koskela (2000) [23]; Bidarianzadeh and Fortune (2002) [10]; Koranda et al. (2012) [22]; Nahmens and Ikuma (2009) [30]; Salem et al. (2014) [33]. For instance, Koranda et al. (2012) [22] claim that incorporation of sustainability and Lean results in reduction in process and material waste, reduction in cost and lead time, reduction in water usage, reduction in energy consumption, and improvement in environmental quality. Moreover, environmental issues caused by construction may be minimised and construction technology could be utilised to mitigate the environmental problems (Huovila and Koskela, 1998) [19]. Additionally, Lean could be used as a control system to be applied for sustainable projects. Such a control system would be based on advanced accomplishment and would reduce the environmental impact (Bidarianzadeh and Fortune, 2002) [10]. Moreover, a study was conducted by Nahmens and Ikuma (2012) [30] aimed to examine the effects of Lean on sustainability. It found that LC caused substantial environmental effects by reducing material waste by 64%, significant social effects by eliminating key safety hazards of excessive force, and significant economic effects by reducing production hours by 31%. Furthermore, the same authors discussed the potential impacts on safety throughout applying Lean concepts.

In addition, implementing LC tools such as LPS and increasing visualisation could reduce environmental, social, and economic impacts. For instance, LPS reduces waste and emissions throughout accelerating the work process. Increased visualisation could improve safety and reduce cost issues. 5S tool may reduce waste and minimise cost (Salem et al., 2014) [33]. Other authors like Gaio and Cachadinha (2011) [17] and Salem et al. (2014) [33] investigate the impacts of LC implementation on road works. They revealed that applying LC reduced the existing waste by relative little change in the activity process. For example, in pavement work, production increased by 10% increasing from 40 ton/hour to 44 ton/ hour and consequently, the profit increased by approximately 5.4 % (Gaio and Cachadinha, 2011) [17].

Moreover, Issa (2013)[20] highlighted the impacts of LC techniques in reducing the risk of time overrun in Egyptian construction projects. The study shows that LC tools and principles have a potential to be used in minimising the impacts of risk factors on time objectives for construction projects in developing countries. The results illustrate that project time was reduced by more than 15 %. Therefore, the study recommends to apply Lean thinking in construction projects due to its simplicity and high efficiency (Issa, 2013) [20].

In addition, a case study carried out in the USA in 1998 revealed remarkable benefits of implementing LC such as: office construction time was reduced by 25 % within 18 months, schematic design was reduced from 11 weeks to 2 weeks, and turnover increased to 20 % (Garnett et al., 1998) [18]. Al Sehaimi et al. (2007) [4] claimed that LC improves construction planning and site management. In particular, LPS technique enables supervisors to plan their workload, improve learning process, improving planning and controlling practice, reducing uncertainty, and improving productivity. Past studies highlighted the valuable benefits of applying LC principles have forced to investigate the challenges and benefits of implementing LC. Hence this paper focuses on analysing the current status and impacts of applying lean theory in Oman construction industry.

3. Research Methods

The study adopted a quantitative approach that will help to examine the awareness and understanding about view of LC concepts within Omani construction professionals. This also helps to explore the suitability and acceptability of lean construction practices and its impacts within construction industry. A comprehensive review of literature about the concept of lean construction, its impact and benefits was carried out in those countries having implemented the LC principles in the construction industry. A questionnaire was designed using the findings from literature and to explore the benefits of implementing LC in Omani construction industry. Moreover, the study used the online questionnaire survey method to collect the quantitative data from the professional associated with construction industry in Oman. The probability sampling approach was adopted while selecting the participants to the survey. The data collected from the survey were analysed using SPSS software and the summary of the survey

DOI: https://doi.org/10.30564/jcr.v2i2.2760

findings is presented with tables and charts/histograms followed by result discussions.

4. Data Analysis and Result Discussions

4.1 Background of the Survey Respondents

The total number of responses to the questionnaire was 65 with the majority of respondents representing client organisations, 37 out of 65 respondents representing more than 55% of the whole total of responses. Furthermore, the majority of the clients belong to the public sector which is believed as quite a logical result as most of the client representatives in Oman. In contrast, the majority of the contractor representatives belong to the private sector where, 10 out of 14 contractor representatives are in the private sector organisations.

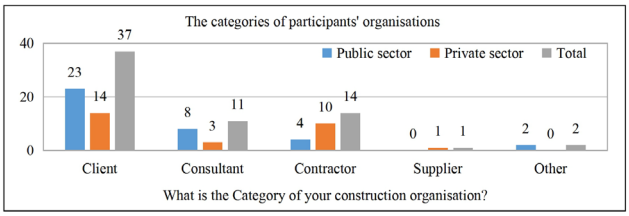

Figure 1. Categories of participants' organisations

Moreover, the majority of participants' organisations are operating in general construction activities such as houses, hospitals, schools, and other kinds of general construction as shown in Figure 2. This type of organisation represents more than 50% of the total participants' organisations. In the same context, the organisations which work on infrastructure projects are the second highest and more than 30% of participants belong to this type of organisation. The results provide the indication on relevancy of the selected sample.

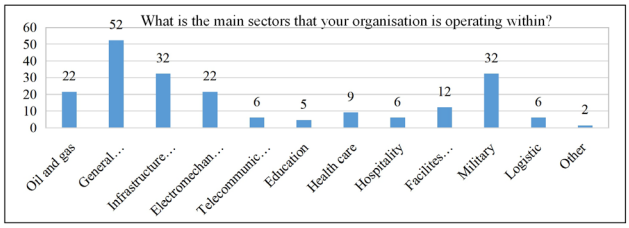

Figure 2. Category of respondents' organisations in terms of their operation activity

The results illustrated in Figure 4 correlate with the previous findings where 35% of the respondents have experienced in the construction industry ranging from 11 to 15 years. Furthermore, 15% of the respondents have more than 20 years' experience in the construction industry. Supporting the management role of the participants as shown in Figure 3.

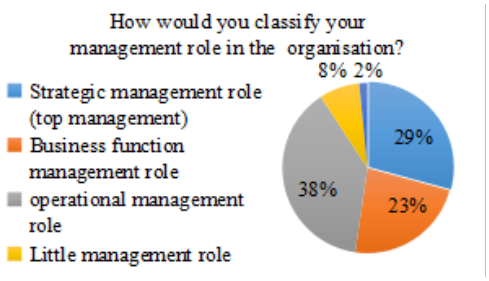

Figure 3. Classification of respondents' management role within their organisation

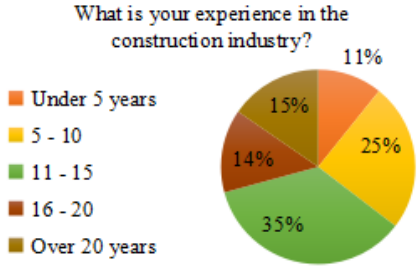

Figure 4. Respondents' experience in construction

Figure 5 represents the roles of respondents hold within the organisation with the majority 64% being engineers and project managers. Engineers in different disciplines represent 39.1% and project managers represent 25%.

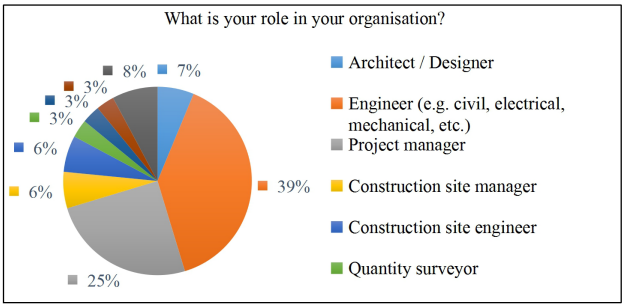

Figure 5. Category of respondents' position

In addition, construction site managers, construction site engineers, and commercial construction managers represent more than 15% (6%, 6%, and 3% respectively). Practically, this result confirms that the majority of the participants are closely involved in the construction field and hence, they are ideal for this research. Table 1 elaborates the working experience of the participants in their current position. For instance, it was found that 19 out of 25 engineers have an experience ranging from 6 to 15 years. Similarly, 9 out of 16 project managers have a working experience of 6 to 15 years in their current positions. Therefore, it is obvious that the majority of en-

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Table 1. Working experience of respondents in their current positions

	What is your experience in this current role?					Total
	Under 5 years	6 - 10	11 - 15	16 - 20	Over 20 years	
Site Engineer	5	9	10	0	1	25
Project manager	3	5	4	2	2	16
Architect / Designer	1	2	1	0	0	4
Construction manager	2	1	1	0	0	4
Construction engineer	0	4	0	0	0	4
Quantity surveyor	1	1	0	0	0	2
Commercial manager	0	1	1	0	0	2
Technician	2	0	0	0	0	2
Other	3	1	0	1	0	5
	17	24	17	3	3	64

gineers and project managers have an adequate working experience in their current designations.

The research also tried to investigate the participants' awareness and attitude towards Lean by examining their membership in LC professional bodies such as Lean Construction Institute (LCI) and/or International Group of Lean Construction (IGLC). Figure 6 indicates that the majority of participants do not have any membership in both LCI and IGLC, also with other recognised construction and engineering professional bodies such as the RICS (Royal Institution of Chartered Surveyors), OSE (Omani Society of Engineers), and the CIOB (The Chartered Institute of Building). In particular, it was found that 42 out of 65 participants, representing more than 58% of the total, do not have membership of any of the listed professional bodies. Also only 6 out of 65 participants have membership of the ICL and IGLC, representing less than 10% of the whole total of respondents. Although this rate is statically considered very low, it gives a positive indication for a promising future of LC in Oman.

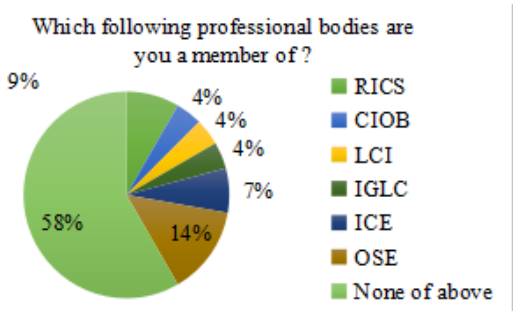

Figure 6. Evaluation of respondents' membership in Lean associations

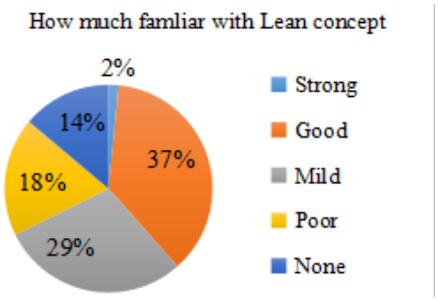

Figure 7. Awareness level of respondents about Lean

4.2 Evaluating the Awareness about Lean Construction

This section of the questionnaire focuses on evaluat-

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ing the awareness of professionals in the OCI about the terminology of Lean and its concepts. Moreover, it endeavours to examine the availability of those concepts and their utilisation within the Omani organisations and one of the most important questions in this survey asked the respondents to rank their familiarity with the term 'Lean'. The ranking of familiarity ranges from strong knowledge to no knowledge. Figure 7 shows a total of 24 out of 65 respondents (more than one-third of the total) have a good awareness. In addition, the result shows that approximately 30% of respondents have a mild knowledge about Lean. However, it was observed that the remaining one-third of participants have a very limited knowledge about Lean (18%) and respondents with no knowledge at all represents 14% of the total. Due to the importance of this particular question, further evaluation through cross tabulating was carried out, in order to determine the awareness of the Omani construction professionals in terms of their categories and organisations.

Table 2 elaborates the categories of respondents (i.e. client, consultant, contractor, etc.) in terms of their awareness about Lean. Consequently, it was found that the majority of the respondents (i.e. 25 out of 65) who have a good and mild knowledge of Lean represent the client organisations. Similarly, the majority of respondents who have a little or no knowledge about LC also represents the client organisations. Therefore, this comparison cannot be asserted due to the high number of client respondents in this survey compared to other categories. Nevertheless, the relation between respondent's organisations sectors (i.e. public and private) and their awareness about Lean can be evaluated where the difference between participants in both public and private sectors are not extremely significant. Table 3 demonstrates that 25 out 65 respon-

Table 2. The relation between respondents' awareness of Lean and organisations category

Client		What is the Category of your construction organisation?					Total
		Consultant	Contractor	Supplier	Other		
How much are you familiar with the term "Lean"?	Strong	0	1	0	0	0	1
	Good	13	4	7	0	0	24
	Mild	12	4	3	0	0	19
	Poor	9	1	0	1	1	12
	None	3	1	4	0	1	9
Total		37	11	14	1	2	65

Table 3. The relation between respondents' awareness about Lean and organisations sector

Public sector		Which sector are you working for?	Total
		Private sector	
How much are you familiar with the term "Lean"?	Strong	0	1	1
	Good	13	11	24
	Mild	12	7	19
	Poor	9	3	12
	None	3	6	9
Total		37	28	65

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dents in the public sector have good and mild awareness of Lean compared with 18 out of 65 respondents who have poor and no knowledge about Lean. Hence, it can be concluded that the awareness levels in both sectors are not significantly different from one another.

Also the Chi-square test was carried out to give an indication of the relationship between the respondent's organisation sectors and their awareness about Lean. The results shown in Table 4 indicate that the Asymptotic Significance is 0.254, which is not less than 0.05 and therefore it can be stated that the relationship between these two variables are not statically significant.

Table 4. Chi-Square test for the results of table 3 using SPSS23

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	5.339a	4	0.254
Likelihood Ratio	5.793	4	0.215
Linear-by-Linear Association	0.004	1	0.949
N of Valid Cases	65		

The result identifying a good level of awareness about Lean within the Omani construction professionals was unexpected compared to the literature and, additional questions were designed in the survey to investigate further the level of awareness of the respondents towards LC. For instance, questions number 11 and 12 requested the respondents to express their level of agreement on some statements that define the concept of LC. Table 5 shows the results to the question that "lean construction is a philosophy that is used to minimise waste in construction processes". 37% of the participants strongly agreed with the statement and a further thirty-five per cent also agreed with statement. Therefore, it can be concluded that more than 70% of respondents agree that LC is used to minimise waste in different processes of construction and this rate is considered significantly high. On the other hand, only five per cent of the respondents disagree and strongly disagree with this statement which is significantly considered as a low rate.

Table 5. Respondents' viewpoints on LC definition (1)

In your opinion, Lean construction is a philosophy that is used to minimise waste in construction processes?					
	(1) Strongly agree	(2) Agree	(3) Not sure	(4) Disagree	(5) Strongly disagree
Frequency	24	23	15	2	1
Percentage %	37	35	23	3	2

Table 6 identifies a similar result to the question LC as "a management methodology focusing on creating value to the customer" with 69% of the participants either responding agree or strongly agree with this statement and only eight per cent of the participants responding disagree or strongly disagree with this statement.

Table 6. Respondents' viewpoints on LC definition (2)

In your opinion, Lean construction is a management methodology focusing on creating value to the customer?					
	Strongly agree	Agree	Not sure	Disagree	Strongly disagree
Frequency	17	28	15	4	1
Percentage %	26	43	23	6	2

It is obvious that the aforementioned results support the previous finding which shows a good and mild level of awareness and familiarity towards Lean within the professionals in the OCI. However, more evaluation was needed to identify the extent of the respondents' awareness about LC components. Question No. 12 was designed to assess the knowledge of the respondents about lean components such as its principles. It was expected that this question would provide a clear indication of the level of awareness about LC in the OCI. Therefore, the participants were asked to specify the principles that are not related to LC. The results are shown in Figure 8, the listed principles are; value, value stream, cost-benefit analysis, pull, and perfection. It is obvious that the only right answer is

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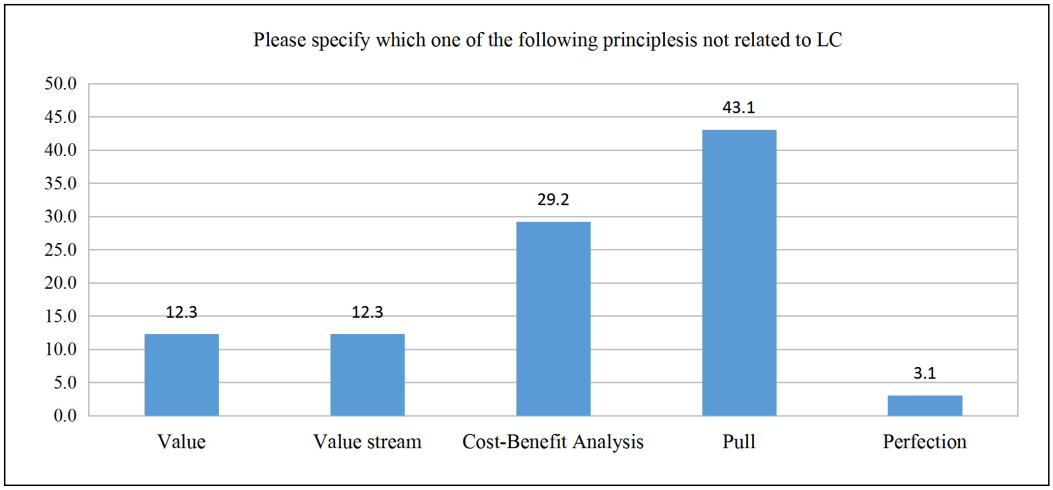

Figure 8. Evaluating the extent of respondents' awareness about LC

Table 7. Evaluation of participants who have a good awareness about LC principles

Value		Please specify which one of the following principles, in your opinion, is NOT related to lean construction					Total
		Value stream	Cost-Benefit Analysis	Pull	Perfection		
How much are you familiar with the term "Lean"?	Strong	0	0	1	0	0	1
	Good	3	1	11	8	1	24
	Mild	3	3	3	10	0	19
	Poor	2	3	1	5	1	12
	None	0	1	3	5	0	9
Total		8	8	19	28	2	65

'cost-benefit analysis' but the data showed that only 29.2 % of the respondents agreed that less than one-third of the respondents have a good level of awareness about LC principles.

Cross tabulation of the results on awareness and understanding of LC, Table 7, identified that those participants who had a strong and good awareness about Lean had also chosen the right answer (cost-benefit analysis). Therefore approximately 50 % of respondents who stated that they have a good awareness of Lean are well knowledgeable about Lean principles.

4.3 Evaluating the Existence of Lean Construction in Oman

When researching into a new methodology and its implementation, it is important to consider how available this methodology is within the country. Therefore, this survey involved some questions which attempted to determine the level of existence and level of implementation of LC in the OCI. Moreover, it attempted to evaluate the different viewpoints of the participants about existence of LC in Omani organisations. Therefore, in question 13, the respondents were asked if they are practising LC principles and techniques in their organisations accordingly. The result in Figure 9 clarifies that LC in not practised in sixty-two per cent of participants' organisations. On the other hand, 25 out of 65 respondents stated that LC is practised in their organisations which represents the other 38 % of the total participants.

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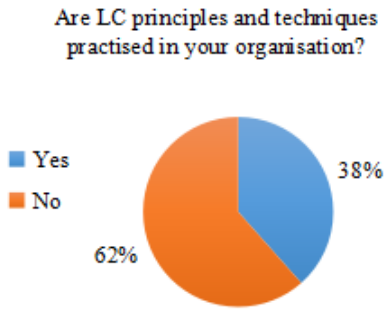

Figure 9. Percentage of respondents' organisation that practice LC methodology

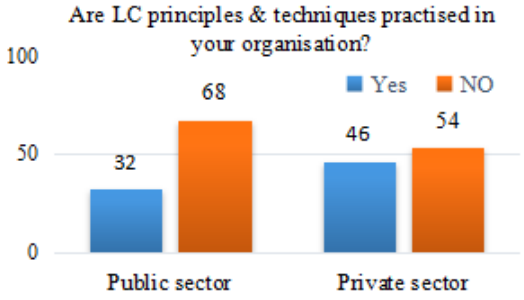

Figure 10. categories of participants' organisations that practicing LC

Moreover, 38 % was considered significantly to be a high rate and was unexpected. A further measurement was needed to clarify this result and the relation between this result and the previous result where the respondents were asked to classify their organisations sector in terms of private and public sector was evaluated. The chi-square test was conducted to evaluate the stoical relation between these two variables. Table 8 illustrates that asymptotic significance was 0.251 which is more than 0.05. Hence, the test indicates that there is no static relation between these two variables.

Table 8. Chi-Square test for the results shown in table 3 using SPSS23

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	1.319a	1	0.251
Continuity Correction	0.794	1	0.373
Likelihood Ratio	1.317	1	0.251
Fisher's Exact Test			
Linear-by-Linear Association	1.299	1	0.254
N of Valid Cases	65		

Regardless of the chi-square test, a cross tabulation between these two variables were created in order to reveal the relation between them. Figure10 shows a total of 68 % of the participants in the public sectors do not practise LC in their organisations compared with 32% who are utilising LC which is almost double the previous percentage. On the other hand, in the private sector the rate for both participants who are practising LC in their organisation and who do not are almost equal.

In light of above, it can be concluded that LC is less practised in the public sector than private sector. This may be interpreted as a logical result due to the interests of private companies to increase their efficiency and reduce their expenses and increase their profits accordingly. In addition, this finding was supported by the result of question 16, where the participants were asked to choose the sector that they believe LC is implemented the most. Figure 11 shows the results that 85 % of the participants believe that the organisations in the private sector mostly adopted LC in their construction project. Moreover, the respondents were asked to express their opinion if they think that LC as a methodology is being implemented into some Omani construction projects. Figure 12 identifies that the majority of respondents, 46 % are not sure about this statement.

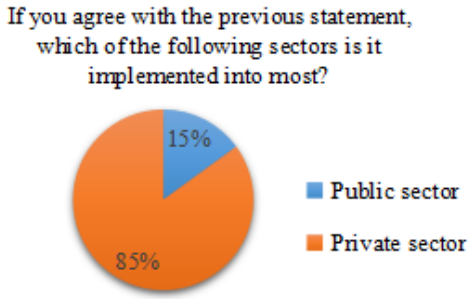

Figure 11. Participants' viewpoint on level of existence of LC in public and private sectors

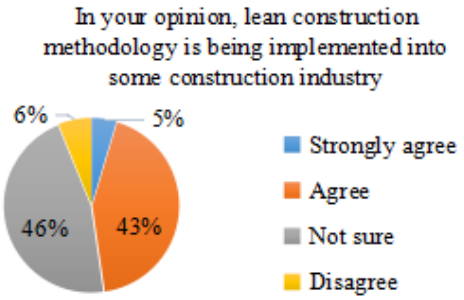

Figure 12. Respondents' opinion on the existence of LC methodology in Oman

Therefore, this could be an interpretation for the high

DOI: https://doi.org/10.30564/jcr.v2i2.2760

rate of the result which was illustrated in Figure 9. 38 % of the participants believe that their organisation practices LC. This result indicates that the majority of the construction professionals in the OCI believe that LC exists and is being currently adopted in the Omani construction projects.

4.4 Evaluation of Suitability and Acceptability of LC Concepts

As it is known and discussed in the literature review that one of the most primary objectives of LC is minimising waste and maximising the customer's value. Therefore, the participants were asked to express their viewpoint about the most common challenges in the Omani construction projects in terms of time, cost and customer value. In addition, they were asked to express their opinion of LC methodology if it can offer a crucial solution for these challenges. Respondents were asked to express their point of view about the statement that "Time and cost overruns are the most common challenges in the Omani construction industry". Results shown in Figure13 reveal that a total of 54% respondents strongly agreed and a further 40% agreed. These two groups of participants represent more than 93% of the total respondents.

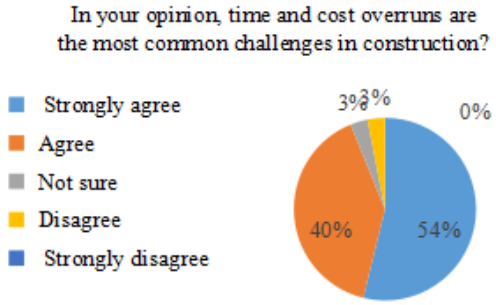

Figure 13. Participants' viewpoints on a statement No. (1)

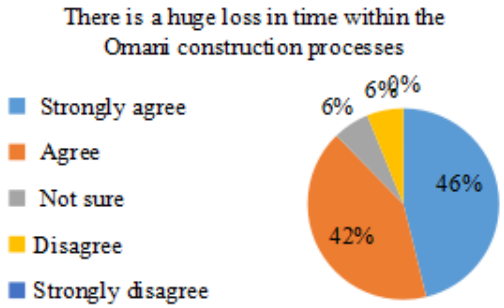

Figure 14. Participants' viewpoints on a statement No. (2)

The respondents were then asked to consider if there are time delays within the construction processes. The result as shown in Figure 14 indicates that 46 % of respondents strongly agree with the statement and a further 42 % also agree with it. It was expected that there would be a high consensus within the participants with regards to the existence of time and cost waste in the construction projects as the literature review clearly identified the majority of delays within construction projects to be linked to failures in terms of time, cost, and quality. Also the participants were asked to share their viewpoints on the statement that there is a wide focus on customer value within Omani Construction Projects. The results in Figure 15 show that only 22 out of 65 respondents agree on this statement. Whereas, the high majority of participants are either not sure or do not agree with the statement which further supports the previous finding that the respondents' have limited awareness about LC in general and about customer value in specific.

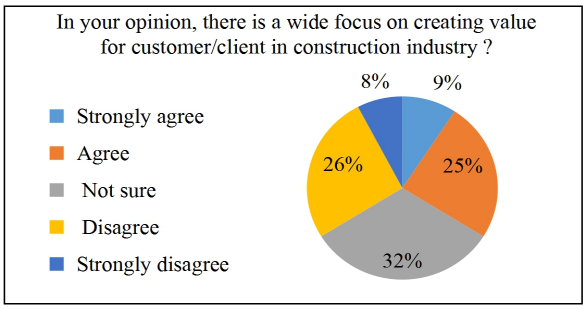

Figure 15. Participants' viewpoints on a statement No. (3)

Respondents were asked if they think LC can offer some crucial solutions for the aforementioned issues in Omani construction projects. Table 9 presents the results that show the positive answer with 91% agreeing that LC concepts could offer some crucial solutions.

Table 9. Participants' viewpoint on suitability of LC solutions

Do you think lean construction concepts could offer crucial solutions for minimising waste and maximising values for the construction industry?		
	Yes	No
Respondents	59	6
Respondents %	91	9

Furthermore, participants were asked to express their viewpoint on the acceptance of LC methodology in OCI. Figure 16 shows a total of 88% respondents believe that LC will be accepted in the OCI.

DOI: https://doi.org/10.30564/jcr.v2i2.2760

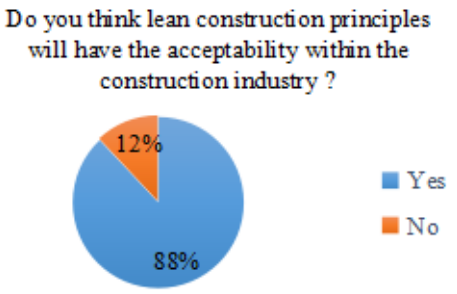

Figure 16. Participants' viewpoint on acceptability of LC methodology in Oman

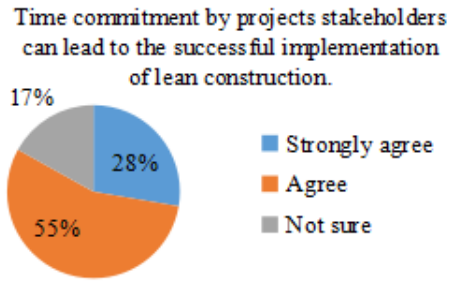

Figure 17. Participants' viewpoints on a statement No. (4)

4.5 Challenge in implementing Lean Construction in Oman

This part of the questionnaire is not attempting to list the barriers and challenges that may oppose implementation of LC in the OCI, rather it attempts to highlight one of the many expected challenges in the implementation process of LC in Oman. Therefore, the survey focused on the challenges that relates to the commitment of project's stakeholders to time. Research by Al Nuaimi et al. (2013) [2] found that one of the major causes of delay in the Omani construction projects is due to the lack of commitment to the time within the project stakeholders. Furthermore, Al Sehaimi et al. (2007) [4] found that lack of commitment and attitude to time from some subcontractors, suppliers, and consultant is one of the biggest barriers in Lean implementation in Saudia Arabia. The participants were asked to consider the statement that "full commitment by project stakeholders and/or participants to the time aspect of projects can lead to the successful implementation of LC in Oman".

Moreover, Figure 17 shows the results and identifies that none of the participants disagree with this statement and more than 83 % agree with it. Therefore, it is obvious that the majority of respondents are aware of the importance of time commitments and they believe that the success of LC implementation in Oman requires a full commitment of all projects' stakeholders. Consequently, this finding correlates with participant's viewpoint on the time importance which was discussed and illustrated in Figures 13 and 14.

4.6 Potential impacts of implementing Lean Construction

This part of the questionnaire attempts to measure the different viewpoints of population about the potential impacts of adopting LC philosophy into the OCI. The question includes five factors as a suggested impact namely; reduction in project time, improving productivity, improving environmental sustainability, improving planning and controlling practice and reduction in project cost. The participants were required to rank these factors according to their importance from 1 to 5 where "1" refers to most important and "5" least important. The relative importance index (*RII*) was utilised in this study as a ranking technique to determine the importance of factors according to survey responses. Thus, *RII* was calculated using the following equation.

$$RII = \frac{\sum W}{HS} * 100$$

Where W = weighting of each factor by respondents ranging from 1 to 5 (i.e. respondent's rating on factor X with the number of respondents identical rating on that factor); H = highest weight; and S = sample size. Table 10 presents the *RII* and ranks of each impact based on participant's viewpoints. It is obvious that the majority of the participants agreed that the most important impact of implementing LC in the Omani construction projects is the reduction of project time. Likewise, most of the participants believe that the improvement of the environmental sustainability of projects is the least important impact resulting from implementing LC methodology in construction projects.

The results clearly show that most of the respondents are aware of the positive impacts with LC adoption. According to previous research as discussed in the literature review, adopting LC in construction projects contributes in reducing the construction processes. For example, the study which was conducted in the Egyptian construction projects by Issa (2013) [20] reveals that the project time was reduced by more than 15 %. The results of this research are therefore compatible with previous studies when considering the impact of LC in increasing productivity and reducing project or operation costs. The study carried out by Gaio and Cachadinha (2011) [17] in different countries such as Portugal, Central Europe, Eastern Europe, developing African countries and in South America found that adopting LC in pavement work increased production by

DOI: https://doi.org/10.30564/jcr.v2i2.2760

Table 10. Ranking of importance of LC adopting impacts in the Omani construction projects

	Most Importance				Least Importance		
Factor/Impact	1	2	3	4	5	RII	Rank
Reduction in project time	25	15	13	5	3	39.69	1
Improving productivity	9	21	10	11	6	47.69	2
Improving environmental sustainability	2	3	9	14	25	66.46	5
Improving planning and controlling practice	9	11	12	15	7	49.85	**3**
Reduction in project cost	11	10	13	8	13	51.38	**4**

10 %., where cost and expenses were reduced, profit increased by approximately 5.4 %.

Regardless of the ranking of importance of LC impacts, it is believed that all the potential impacts are important where they all contribute in improving the construction industry and this ranking was aimed only to examine the expectation of the participants from adopting LC into their construction projects. However, this ranking does not mean in any case that the lowest ranked impact is not an important impact. In contrast, some of those low ranked impacts have a high importance impact such as improvement of environmental sustainability. For instance, many researchers have studied the impact of LC in improving the environmental sustainability such as; Huovila and Koskela (1998) [19], Bidarianzadeh and Fortune (2002) [10], and Nahmens and Ikuma (2012) [30]. Huovila and Koskela (1998) [19] argued that adopting LC into construction projects can reduce the environmental issues and Nahmens and Ikuma (2012) [30] found in their study that LC caused substantial environmental effects by reducing material waste by 64%.

5. Conclusions and Recommendations

5.1 Conclusions

The literature review revealed that one-third of the Omani professionals in the construction industry have a good awareness of the general concept of LC. Furthermore, one-third of the professionals have a high level of knowledge where they are familiar with LC components such as principles and tools. The study discovered that the level of awareness about LC is similar in both public and private sectors within the Omani construction industry which is similar to the findings that showed a global lack of awareness about LC within the construction industry. The survey results revealed that 38% of construction organisations in Oman are adopting LC methodology in their projects with the public sector practising it less than the private sector. A high majority of professionals believe LC is implemented most in the private sector. In contrast, the private sector which is called "profit institutions" are seeking innovative principles and tools that help to increase their efficiency and profits by reducing their cost.

Moreover, the survey results also discovered that the majority of professionals have similar consensus on the most common challenges or issues in the Omani construction projects, which is the huge waste in construction delivery time and overrun of project cost. The literature review showed that applicability tests help to determine if the new philosophies will gain crucial support from people or whether it will lead to opposition or criticism (Senaratne and Wijesiri, 2008) [35]. It is found from the survey that more than 90% of construction professionals in Oman believe that LC methodology will have the acceptability within the construction industry and can also offer a crucial solution for the aforementioned issue in the Omani construction projects.

The literature review highlights that implementing Lean in construction is more difficult than implementing it in manufacturing. It also found that various types of barriers that could hinder the implementation of LC are culture issues, organisational structure and lack of commitment from top management. Also the survey reveales that 83% of professionals in Oman are aware about the importance of time commitments and they believe that the success of LC implementation requires a full commitment of all

 DOI: https://doi.org/10.30564/jcr.v2i2.2760

the project stakeholders. Moreover, interview findings confirm that the most important barriers and challenges that currently hinder implementing LC effectively in the Omani construction projects are lack of commitment of the top management, resistance to change by managers and workers, cultural problems and lack of participation and integration of all stakeholders.

Considering the benefits of implementing Lean philosophy in the construction industry, the study found that the majority of the Omani construction professionals trust in LC methodology and they believe that implementing it into construction projects involves many positive impacts such as reduction in project time, improving productivity, improving planning and controlling practice, reduction in project cost and improving environmental sustainability. Moreover, the interviews confirm that the advantages obtained from implementing LC methodology in the Omani construction projects are reduction of wasted time, enhancing sustainability, simplifying the process, and reduction of cost. These impacts correlating with previous research identified in the literature review. This study concluded that there are no specific studies that have been conducted to investigate the awareness, existence, suitability, acceptability, barriers, and implementation impact of LC. A clear perception was found that LC could be implemented in Oman successfully and potential benefits could be realised in the Omani construction industry. This study can be conceived as a fundamental base for a future study in LC in Oman.

5.2 Limitations Relevant to This Study

Respondents of the questionnaire are not equal in terms of organisations' category (i.e. client, contractor, consultant, and supplier).

The questionnaire was distributed within the selected sample. However, the number of responses of each organisation's category varies. For example, the responses of the client are three times the responses of the contractor. This in turn forms an obstacle to determine the level of awareness about LC in these different construction categories.

Lack of construction organisations adopting LC methodology in their projects. This limitation affected the data collected from the interview in terms of quantity and quality.

5.3 Recommendations and Further Work

Adequate level of commitment, knowledge and skill within organisations is required at strategic management level to get benefits from LC.

Organisations should understand that LC needs to be incorporated into their business strategies, so as to reap the benefits of implementing LC.

A further qualitative study is required to investigate the level of this knowledge in terms of LC principles and techniques.

Structured suitability and acceptability tests are suggested to be carried out.

A framework is suggested to be developed as a guidance for implementing LC in the Omani construction industry.

References

[1] Abduh, M., and Roza, H. (2006). Indonesian Contractors' Readiness towards Lean Construction. Santiago, Chile: 14th Annual Conference of the International Group for Lean Construction.

[2] Al Nuaimi, A., and Al Muohsin, M. (2013). Causes of delay in completion of construction projects in Oman. Bankok, Thailand: International conference on innovation in engineering and technology ICIET 2013.

[3] Alinaitwe, H. (2009). Prioritising Lean Construction Barriers in Uganda's Construction Industry. Journal of Construction in Developing Countries, 14(1), 15-30.

[4] Al Sehaimi, A., Tzortzopoulos, P., and Koskela, L. (2007). Last Planner System: Esperiences from pilot implementation in the Middle East. Taipei, Taiwan: IGLC.

[5] Arbulu, R., Tommelein, I., Walsh, K., and Hershauer, J. (2003). Value stream analysis of a re-engineered construction supply chain. Building Research and Information, 31 (2), pp161-171.

[6] Ballard, G. (1994). The Last Planner. Retrieved 5 25, 2016, Available [online] at http://www.leanconstruction.org/.

[7] Ballard, G. (2000). The Last Planner System of Production Control. Birmingham: School of Civil Engineering, Faculty of Engineering, the University of Birmingham.

[8] Ballard, G. (2006). Rethinking project definition in terms of target costing. Santiago, Chile: 14th Annual Conference on Lean Construction, IGLC.

[9] Ballard, G., and Howell, G. (1997). Toward Construction JIT. In L. Alarcon (Ed.), Lean Construction (pp. 304 - 312). Rotterdam: A. A. Balkima.

[10] Bidarianzadeh, G., and Fortune, C. (2002). Lean Thinking and the Delivery of Sustainable Construction Projects. University of Northumbria: Association of Researchers in Construction Management (ARCOM).

DOI: https://doi.org/10.30564/jcr.v2i2.2760

[11] Björnfot, A., and Stehn, L. (2007). Value Delivery through Product Offers: A Lean Leap in Multi-Storey Timber Housing Construction. Lean Construction Journal, 3(1), Pp33-45.

[12] Cano, S., Delgado, J., Botero, L., and Rubiano, O. (2015). Barriers and success factors in Lean Construction's implementation. Perth, Australia: 23rd Ann. Conf. of the Int'l. Group for Lean Construction.

[13] CBO: Central Bank of Oman (2016). Publication and Statistics. [Online] at http://www.cbo-oman.org.

[14] Dulaimi, M., and Tanamas, C. (2001). The Principles and Applications of Lean construction in Singapore. Singapore, Singapore: 9th Annual Conference of the International Group for Lean Construction.

[15] Emmitt, S., Sander, D., and Christofferse, A. (2004). Implementing value through lean design management. Sydney, Australia: IGLC - 13.

[16] Forbes, L., Ahmed, S., and Barcala, M. (2002). Adapting lean construction theory for practical application in developing countries. Stellenbosch: First CIB W107 International Conference: Creating a Sustainable Construction Industry in Developing Countries.

[17] Gaio, J., and Cachadinha, N. (2011). 'Suitability and Benefits of Implementing Lean Production on Road Works. Lima, Peru: 19th Annual Conference of the International Group for Lean Construction.

[18] Garnett, N., Jones, D., and Murray, S. (1998). Strategic Application of Lean Thinking. Guaruja, Brazil: IGLC-6.

[19] Huovila, P. and Koskela, L. (1998). Contribution of the Principles of Lean Construction to Meet the Challenges of Sustainable Development. International Group of Lean Construction (IGLC).

[20] Issa, U. (2013). Implementation of lean construction techniques for minimizing the risks effect on project construction time. Alexandria Engineering Journal, 52, 697-704.

[21] Jadhav, J., Mantha, S, and Rane, S. (2014). Exploring barriers in lean implementation. International Journal of Lean Six Sigma, 5(2), 122-148.

[22] Koranda, C., Chong, W., Kim, C., Chou, J., and Kim, C. (2012). An Investigation of the Applicability of Sustainability and Lean Concepts to Small Construction Projects. Journal of Civil Engineering, 16(5), 699-707.

[23] Koskela, L. (2000). An exploration towards a production theory and its application to construction, PhD thesis. Helsinki: Technical Research Centre of Finland-VTT.

[24] Koskela, L., and Ballard, G. (2012). Is production outside management? Building Research and Information, 40(6), 724-737.

[25] Koskela, L., Howell, G., Ballard, G., and Tommelein, I. (2002). The foundations of lean construction. In R. and. Best (Ed.), Design and Construction: Building in Value, (pp. 211-226). Sydney, AU.

[26] LCI (2016). What is Lean Design and Construction? Retrieved 5 10, 2016, from http://www.leanconstruction.org/about-us/what-is-lean-construction/.

[27] Lima, M., Rolim, L., and Alves, T. (2010). Value stream mapping of the architectural executive design in a governmental organization. Haifa, Israel: IGLC.

[28] Mossman, A. (2009). Creating value: a sufficient way to eliminate waste in lean design and lean production. Waste in lean design and lean production, pp13-23.

[29] Nahmens, I., and Ikuma, L. (2009). An Empirical Examination of the Relationship between Lean Construction and Safety in the Industrialized Housing Industry. Lean Construction Journal, pp1-12.

[30] Nahmens, I., and Ikuma, L. (2012). Effects of Lean Construction on Sustainability of Modular Homebuilding. American Society of Civil Engineers.

[31] Olatunji, J. (2008). Lean-in- Nigerian Construction: State, Barriers, Strategies and "Go-Togemba" Approach. Manchester, UK: 16th Annual Conference of the International Group for Lean Construction.

[32] Salem, O., Genaid, A., Luegring, M., Paez, O., and Solomon, J. (2004). The Path from Lean Manufacturing to Lean Construction: Implementation and Evaluation of Lean Assembly. Helsingør, Denmark: International Group of Lean Construction (IGLC).

[33] Salem, O., Pirzadeh, S., Ghorai, S., and Abdelrahim, A. (2014). Reducing Environmental, Economic, and Social Impacts of Work-zones by Implementing Lean Construction Techniques. Oslo, Norway: 22nd Annual Conference of the International Group for Lean Construction.

[34] Salem, O., Solomon, J., Genaidy, G., and Luegring, M. (2005). Site Implementation and Assessment of Lean Construction Techniques. Lean Construction Journal, 2(2), pp1-21.

[35] Senaratne, S., and Wijesiri, D. (2008). Lean Construction as a Strategic Option: Testing its Suitability and Acceptability in Sri Lanka. Lean Construction Journal, Pp34-48.

[36] Shang, G., and Pheng, L. (2014). Barriers to lean implementation in the construction industry in China. Journal of Technology Management in China, 9(2), 155-173.

[37] The World Bank. (2015). Retrieved 2 08 2016, Available [online] at http://data.worldbank.org/indicator/NY.GDP.MKTP.CD.

 DOI: https://doi.org/10.30564/jcr.v2i2.2760