



AREA OF LINKAGE BETWEEN LEAN CONSTRUCTION AND SUSTAINABILITY IN INDIAN CONSTRUCTION INDUSTRY

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ABSTRACT

Purpose- *The purpose of the research paper to study the area of linkage between lean construction (LC) and sustainability in Indian construction industry and rank the identified attributes on the basis of the responses given to their severity to construction projects in India.*

Design/methodology/approach- *The research was conducted by a structured questionnaire that was sent to 180 professional working in Indian construction industry. This questionnaire requested the respondents to give a score to the 26 attributes identified that are 15 lean construction tools for enabling sustainability and 11 attributes as area of linkage between lean construction and sustainability in Indian construction industry through literature review. They were asked to rate the attributes on a Likert scale rating of 1 to 5. The data collect than analysed using relative importance index and reliability analysis.*

Findings- *The research study identifies the top five Significant lean tools for enabling sustainability are: first run studies, six sigma, kanaban, last planner system and visualization tool having relative importance index (Rii) of 0.80, 0.781, 0.779, 0.77 and 0.75 respectively. Most significant area of linkage between sustainability and lean construction are: resource management, waste reduction, energy minimization, elimination of non-value added activities and health and safety improvement as the outcome benefits of linking lean construction and sustainability in Indian construction industry having a relative importance index of 0.83, 0.779, 0.776, 0.77 and 0.76 respectively.*

Research limitations- *The research focused on the responses received through the questionnaire and the number of respondents is 180 with a response rate of 41%. A further more detailed research is required to know the broad effect of lean tools on sustainability in Indian construction industry.*

Key words: Indian Construction Industry, Lean Construction, Sustainability and Waste Reduction.

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1. INTRODUCTION

The contribution of Indian Construction industry to GDP is about 8 % on an average in last 5 years (Planning Commission of India 12th five-year plan, 2015). Indian Construction industry provides employment to approx. 41 million persons and it is ranked second in providing jobs after Agriculture sector in India (Dixit, Pandey, Mandal, & Bansal, 2017). The Construction sector is the 2nd largest producer of jobs in India after agriculture and in spite the employment generation and the economic importance of the sector, it encounters issues such as low productivity, cost overrun, generation of waste, lack of energy efficiency for its operation, requirement of fresh water, delays in completion of projects and lack of professional practices in the industry (Doloi, Sawhney, Iyer, & Rentala, 2012). The Construction industry is an important activity within most economies and the GDP get influenced by Construction Productivity to a large extent (Kolm & Ythier, 2006) (Cox, 1998) (Cox et al., 1998), cited in (Madi, Essential factors affecting accuracy of cost estimation of building contractor's, 2003). Construction sector strongly affects various other sectors and has a direct impact over various economic, educational, transportation, and other sectors. Therefore attention should be paid to identify the major challenges in Construction sector and their solutions (Mahamid, 2013), some of the main challenges are low productivity, waste generation, energy consumption, impact on surrounding environment, water usage, and other social and economic issues (Ballard & Howell, 2004). To overcome these challenges and complete a project within budget and on time, using appropriate project management techniques. Sustainability in Construction (green Construction) and lean Construction has been use in other countries since last over 20 years. In this paper, attempt has been made to identify the area of linkage between sustainability and lean construction (LC) in Indian Construction industry.

The concept of Lean construction and Sustainability were adopted by construction industry to enhance its efficiency and productivity of its operations from top management level to on site construction. In this paper we attempt to identify the area of linkage between sustainability and lean construction in Indian construction industry. LC is a production administration based way to deal with project delivery another approach to plan and manage work flow. Lean production administration has caused an improvement in assembling configuration and supply together. LC stretches out from the targets of a lean production framework: work flow and reduce waste - to particular systems and applies them in a modern project delivery process (Lean Construction Institute, 2012)

2. LITERATURE REVIEW

2.1. Development of Lean Construction Over Time

Many established researchers such as Abdullah et al. (2009), Jorgensen and Emmitt (2008), (Lim V. L., 2008) and (Koskela, 1992)) have confirmed that LC offers many benefits when implemented in the construction projects. The main advantage is construction industry could cut down the construction cost due to the use of correct materials and less waste generation (Suresh et al., 2011) by the proper project planning and proper project planning would shorten the duration of the construction project and promote the quality and sustainability of the project itself (Bertelsen, 2004).

There are many key concepts or tools of LC that can be adopted throughout the project phases by the stakeholders. In an earlier stage of its implementation, (Koskela, 1992) proposed three principles of production philosophy be used at early project phase, which includes tools (i.e. Kanban and quality circles), a manufacturing method and a management philosophy (i.e. Just-In-Time (JIT) and Total Quality Control (TQC)). Some of the examples of the key concepts are JIT, TQC, Total Productive Maintenance (TPM), Employee involvement, Continuous improvement, Benchmarking, Time-based competition, Concurrent Engineering (CE), Value-based strategy (or management), Visual Management, Reengineering and Lean manufacturing (Bae & Kim, 2008). In addition, (Alinaitwe, 2009) has simplified and depicted the key concepts of LC included JIT, Total Quality Management (TQM), Business Process Re-engineering (BPR), CE and Last Planner System (LPS); Teamwork and Value Based Management (VBM) (Harris & McCaffar, 1997). Simonsson & Bjornfot, (2012) showed the financial advantages of enhancing lead times, lessening inventories and bringing down assembling costs on the impacts of work process enhancements with expanded productivity as the resultant yield.

(Salem, Solomon, Geneidy, & Minkarah, 2006) Study evaluated the effectiveness of six LC key concepts to the University of Cincinnati's garage project. The data collection methods included observations on sites, interviews, questionnaires and documentary analysis. The key concepts involved were LPS, increased visualisation, daily hurdles meetings, first run studies, 5s (housekeeping) process and fail safe for quality and safety (Dulaimi & Tanamas, 2001). Based on the findings, the implementation of 5s process and fail safe for quality and safety did not meet the expectations due to increase of the budget. There was a need for behavioural changes and training for effective use of key concepts. The rest of the key concepts selected for the project were either ready to use or were recommended with some modifications (Huovila & Koskela, 1998).

Meanwhile, Suresh et al. (2011) introduced nine primary key concepts of LC that could be implemented in the LC practice. These key concepts were essential to the implementation of LC, which are LPS, productive meetings, increased visualisation, off-site prefabrication, 5s/5C, mistake proofing/ poka-yoke, root cause analysis, five "whys" and first run studies and JIT. The conclusion of the study showed that there is no need to use all of these key concepts in the construction project (Green & May, 2005).

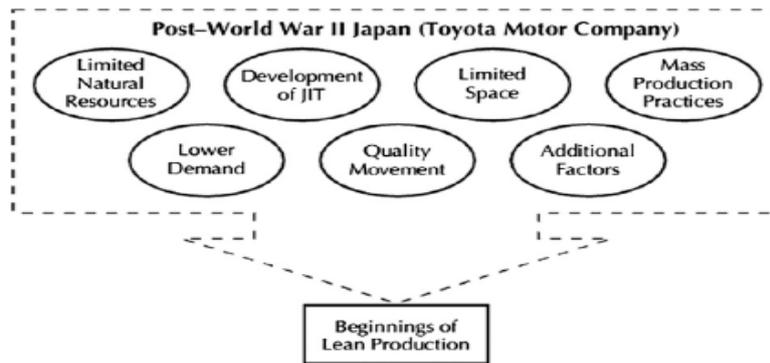


Figure 1

Lean construction supplements traditional construction management approaches with (1) two critical and necessary dimensions for successful capital project delivery by requiring the deliberate consideration of material and information flow and value generation in a production system; and (2) different project and production management (planning-execution-control) paradigms (Abdelhamid 2007). There is a demand for more holistic approaches to be integrated into the existing LC key concepts application with other concepts. (Bashir, Suresh, Proverbs, & Gameson, 2011), introduced health and safety approach in the implementation of lean principles. The OHSAS 18001 could be incorporated with the key concepts of LC. OHSAS 18001 has been tested and internationally recognised to improve health and safety performance of the construction company. As a result, by having a safer and conducive workplace at sites, it would increase the productivity of the project and gave job satisfaction to the client (Brandon, 2005).

Moreover, by using LPS as a basis of LC approach, Abdelhamid (2003) suggested Six Sigma application opportunities in construction projects. Six Sigma is an organized and efficient process for strategic process improvement and new product and service development that relies on statistical methods and the scientific method to make significant reductions in customer defined defect rates (Linderman et al., 2003). The existence of Six Sigma as a continuous improvement technique in a project would provide a combined, coherent and holistic approach to continuous improvement of the project (Pepper and Spedding, 2010).

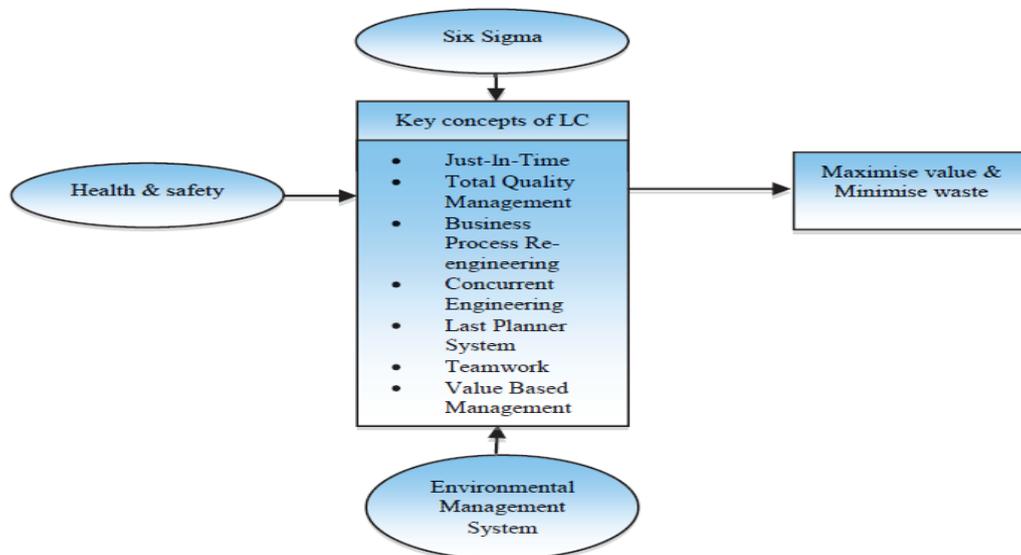


Figure 2

2.2. Sustainability in Construction

In the course of the most recent couple of decades, a typical meaning of sustainable development has been created, the center of standard maintainability believing is to strike a harmony between three measurements: ecological, social and financial manageability (Bansal, 2005). In the development business, attention to reasonable advancement has expanded. The primary green building rule, presented in the UK, is the Building Research Establishment Environmental Assessment Method (BREEAM). From that point forward, a few nations have built up their own particular green or natural cordial building programs (Potbhare et al., 2009). A portion of the projects incorporate the Leadership in Vitality and Environmental Design (LEED) of the USA, the Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) of Japan, Indian Green Building Council (IGBC) and the Green Star of Australia (Zimmerman and Kibert, 2007). Construction industry significantly contributes to improve the quality of life of people. However, development of construction industry and its products lead to environmental problems on a global scale (Ngowi, 2000). It is estimated that the construction industry is responsible for approximately 40 percent of energy consumption, 30 percent of CO₂ emissions and 40 percent of total solid waste generation (Hajek, 2002).

As indicated by the United Nations World Commission on Environment and Development (WCED, 1987) sustainability is characterized as "advancement that addresses the issues of present eras without bargaining the capacity of future eras to address their own particular issues" The construction industry concentrates on three aspects of sustainability; environmental, social and economic, in different ways. Sustainability has been defined as economic growth that meets the current generation's needs without compromising the opportunity and the potential for future generation needs (WCED, 1987) (El-zeny, 2011). Sustainability in the construction industry is also been regarded a way forward for the construction industry to achieve sustainability in development while considering environmental, socio-economic and cultural issues into account. (Shafii, 2006). The construction industry is urged to move from traditional wet construction method towards environmentally friendly, energy efficient and less waste generation methods of construction (Abdullah, 2015). There is in this way an earnest need to apply feasible improvement standards to development industry hones (Zhang, wu, Shen, & Skitmore, 2013) The current worldwide monetary downturn gives an exceptional chance to re-evaluate the manageability of development projects and grow more imaginative practices (Baloi & Price, 2003) (Love, Holta, Shen, & Irani, 2002)

2.3. Integration of Lean Construction and Sustainability

Environmental Management System (EMS) shared the same goal as a lean concept, which is reducing waste. Basically, EMS provides an effective framework on the environment that can assist companies in fulfilling their responsibilities towards protecting the world environment (Gbedemah, 2004). By integrating EMS to LC key concepts in the construction sites, it would maximize the customers satisfaction as well as minimize the waste (Mitsubishi et al, 2008). According to Puvanasvaran et al. (2011), the potentials of both integration remain unexplored since changes within the business environment and innovative technologies can widely impact operational process and procedures. Most of these concepts are interconnected and it is important to understand all the key concepts of LC, which may improve performance while minimising construction waste. The "correct tool at the correct time" is the best phrase describing this concept. Hence, it is important for the stakeholders to responsible and chooses the best approach of the key concepts that right to be implemented in their construction sites.

3. RESEARCH METHODOLOGY

For this research paper consider a poll overview strategy or (questionnaire survey method) has been received to discover the Area of Linkage between Lean construction and Sustainability in Indian construction industry. First the impact of various Lean construction tools and techniques on Sustainability in Indian construction sector has been analyzed through the Relative importance index (RII) and secondly the attributes identified through literature review as the area of linkage between lean construction and sustainability were analyzed using Relative importance index (RII), Factor analysis and other techniques. The method is utilised broadly in various worldwide research papers as talked about above in the literature review. A total of 15 lean construction tools and techniques and 11 area of linkage identified from literature. Respondents were made a request to rate the chose properties/elements influencing construction efficiency utilizing a Likert scale 1 to 5 (Rami Huges, 2014), the respondent was represents the different type of professionals working or consulting in Indian construction sector through a fair and holistic approach to provide equal chance to all the stakeholders involve in the Indian construction industry. Heterogeneity in the example review was kept up by moving toward the gatherings of chose respondents, those were speaking to the imperative parts of the Indian construction industry.

3.1. Data Collection

3.1.1 Conduct of Research

A structured questionnaire is floated with 180 number of respondents working in Indian construction sector and 76 valid responses were received out of 180 with a response rate of 41%.The respondents were asked to rate their responses over the Likert scale rating from 1 to 5 for the factor affecting construction productivity. The questionnaire header part contains useful information about the study and then contains some basic information to the respondent about the study and the questionnaire and space at the last of the questionnaire is provided to write some comments if they have any about the study or the questionnaire. The questions were designed in such a way that they were simple and can easily understand by the respondents.

The questionnaire is divided into two main parts are as follow: Overview of the researcher and the study, Introduction for Lean construction and Sustainability and The questionnaire itself. The received responses by the respondents were summarised in an Excel data sheet and the data analysed using SPSS software and the tests and analysis are performed were discussed below. Relative importance indices (RII) is performed to know the priority of the significant factors and then followed by Reliability analysis is performed to check the consistency of the data received. Factor analysis is performed to reduce the dimension of the data and to identify the grouping of attributes on the basis of the correlation exists in between them.

3.2. Method used to Analyse the Results of the Questionnaire

The respondents were asked to rate their perception towards the adoption of sustainability and lean construction in their organizations and benefits of synchronizing sustainability and lean construction on a Likert scale of 1 to 5 as per their level of severity of impact and influence and the benefits of synchronising sustainability and lean Construction in the Indian context. The value given to the Likert scale rating are as follows:

- No effect (or no opinion)
- Less effect (no or minimal effect)

- Minor effect (minor problem)
- Serious effect (medium problem)
- Very serious effect (major problem)

It was noticed that the numbers (1-5) did not have linear scale intervals, nor did they demonstrate equal intervals (Naoum, 1998).” Research into Construction industry has utilised both quantitative and qualitative methodologies, quantitative methodologies incorporate work based models, figure models (Thomas, Malony, Horner, Smith, Handa, & Sanders, 1990)and measurable pattern investigation of sources of info like work costs, material costs and property costs (Tran & Tookey, 2011) (Naoum, 1998).” A relative importance index (Rii) was applied to prioritise the severity of the factors” (Iyer & Jha, 2005) (Lim & Alam, 1995) (Enshassi, Mohammad, Mustafa, & Mayer, 2010) (Dixit, Pandey, Mandal, & Bansal, 2017).

Research into construction industry has utilised both quantitative and subjective methodologies. Quantitative methodologies incorporate work ponder based models, figure models (Thomas et al., 1990) and measurable pattern investigation of sources of info like work costs, material costs and property costs (Tran and Tookey, 2011).The research utilised for in this paper is Quantitative research philosophy. An aggregate 26 attributes have been distinguished through the accessible writing audit and master feeling and the questionnaire is imparted to all partner and gatherings in Indian construction Industry. The respondents were made a request to rate the huge variables according to their effect calculate over construction efficiency utilising a Likert scale have a rating from 1 to 5 (Makulsawatudom, 2004). The components were then positioned utilising a relative importance indices (Lim and Alum, 1995). From this positioning, 10 elements were identified as the lean tools for enabling sustainability and outcome benefits of linking lean construction and sustainability in Indian construction industry.

$$R_{ii} = \frac{\sum_{r=1}^5 r * n_r}{5 N}$$

r is the rating on a Likert scale (1-5) as for the impact on construction efficiency for a specific element influencing construction profitability, nr is the quantity of respondents giving a specific Likert scale rating r, N is the aggregate number of respondents to a specific inquiry

3.3. Respondents Profile

Table 1 Lean construction tools and techniques for enabling Sustainability in construction (Rii Table I)

Rank	Total Responses	Total Score	RII	Lean tools for enabling sustainability in construction industry
1	75	300	0.80	How would you rate First run studies for enabling sustainability in construction
2	75	293	0.78	How would you rate Six Sigma for enabling sustainability in construction
3	75	292	0.78	How would you rate Kanban for enabling sustainability in construction
4	75	287	0.77	How would you rate Last planner system for enabling sustainability in construction
5	75	282	0.75	How would you rate Visualisation tool for enabling sustainability in construction
6	75	282	0.75	How would you rate 5S tools(Sort, Set in order, Sustain, shine and standardise) for enabling sustainability in construction
7	75	281	0.75	How would you rate Concurrent engineering for enabling sustainability in construction
8	75	277	0.74	How would you rate Daily huddle meetings for enabling sustainability in

				construction
9	75	276	0.74	How would you rate Pull approach for enabling sustainability in construction
10	75	276	0.74	How would you rate Total quality management (TQM) for enabling sustainability in construction
11	75	271	0.72	How would you rate Kaizen for enabling sustainability in construction (Kaizen is the Japanese word for "continual improvement").
12	75	270	0.72	How would you rate Fail-safe for quality studies for enabling sustainability in construction
13	75	270	0.72	How would you rate Value stream mapping for enabling sustainability in construction
14	75	266	0.71	How would you rate Total preventive maintenance for enabling sustainability in construction
15	75	245	0.65	How would you rate Just in Time (JIT) for enabling sustainability in construction

Table 2 Attributes for Area of linkage between Lean construction and Sustainability in Indian construction industry (Rii Table II)

Rank	Total Responses	Total Score	RII	Area of linkage between sustainability and lean construction
1	75	311	0.83	How would you rate Resource management as the outcome benefit of Linking Lean Construction and Sustainability
2	75	292	0.78	How would you rate waste reduction as the outcome benefit of Linking Lean Construction and Sustainability
3	75	291	0.78	How would you rate Energy minimisation as the outcome benefit of Linking Lean Construction and Sustainability
4	75	289	0.77	How would you rate Elimination of non-value process as the outcome benefit of Linking Lean Construction and Sustainability
5	75	285	0.76	How would you rate Health and safety improvement as the outcome benefit of Linking Lean Construction and Sustainability
6	75	283	0.75	How would you rate Value maximisation as the outcome benefit of Linking Lean Construction and Sustainability
7	75	283	0.75	How would you rate Cost reduction as the outcome benefit of Linking Lean Construction and Sustainability
8	75	280	0.75	How would you rate Quality Improvement as the outcome benefit of Linking Lean Construction and Sustainability
9	75	277	0.74	How would you rate Continuous improvement as the outcome benefit of Linking Lean Construction and Sustainability
10	75	268	0.71	How would you rate Design optimisation as the outcome benefit of Linking Lean Construction and Sustainability
11	75	257	0.69	How would you rate Performance maximisation as the outcome benefit of Linking Lean Construction and Sustainability

3.4. Data Analysis

3.4.1. Respondent Demographic Information

Figure one shows the profile of the respondents of the survey, it was ascertained that for the sample of respondents, 30% of the respondents are at the operation level, 38% are at the middle-level management and 32% are at Top management level respondents. The respondent was chosen through a wide range of experience varies from 22% of the respondents having an experience of 0-5 years, 28% having an experience of 5-10 years, 26% having an experience of 10-15 years and 24% of the respondents having an experience of more than 15 years in the industry.

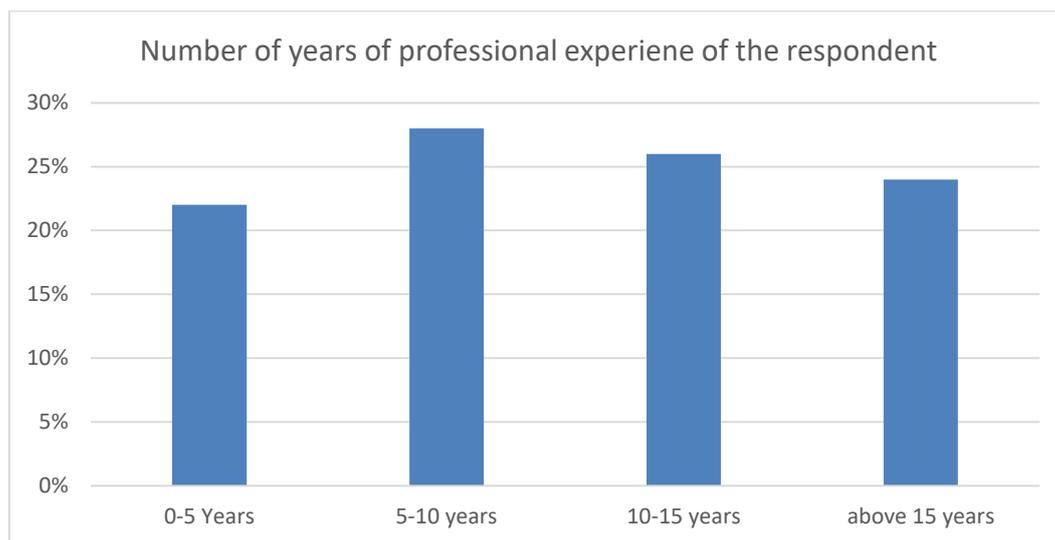


Figure 3 Significant lean tools for enabling sustainability in Indian construction industry (Rii table I)

According to the sample collected and analysed of the respondent from Indian construction sector, the most significant five lean tools for enabling sustainability in Indian construction industry are: First run studies, six sigma, kanban, last planner system and visualization tool these tools having relative importance index (Rii) of 0.80, 0.781, 0.779, 0.77 and 0.75 respectively.

Most significant area of linkage between sustainability and lean construction in Indian construction industry (Rii table II)

The significant outcome benefits of linking sustainability and lean construction in Indian construction industry are: resource management, waste reduction, energy minimization, elimination of non-value added process and health and safety improvement those were the most significant areas of linkage between sustainability and lean having the Rii value of 0.83, 0.779, 0.776, 0.77 and 0.76 respectively.

4. RELIABILITY ANALYSIS

The dependability investigation is required to guarantee the build of the model after some time (i.e. consistency of measured traits and scale), Cronbach's alpha test was performed on whole information. The estimation of $C\alpha$ could be somewhere around 0 to 1, where a higher esteem indicates the more prominent inner consistency and the other way around. The estimation of $C\alpha$ is expanded by a substantial number of factors, so there is no set elucidation with respect to what is a satisfactory breaking point (Zhang X. , 2005). In any case, a general guideline applies to most circumstances with the accompanying extents: $C\alpha > 0.9$ indicates superb, $0.9 > C\alpha > 0.8$ denotes great, $0.8 > C\alpha > 0.7$ denotes satisfactory, $0.7 > C\alpha > 0.6$ denotes sketchy, $0.6 > C\alpha > 0.5$ denotes poor and $0.5 > C\alpha$ means unsatisfactory (Doloi, Sawhney, Iyer, & Rentala, 2012). The estimation of $C\alpha$ for all properties computed is 0.928 which is thought to be superb.

5. DISCUSSION

The most used lean tools for enabling sustainability in Indian construction industry are first run studies, six sigma, Kanban, LPS, visualization tool; while JIT is the least used technique for enabling sustainability in construction. Previous research shows that visualization tool, LPS, six sigma and value analysis are the most used lean tools for enabling sustainability in

construction (Oyedolapo Ogunbiyi, 2014), and environmental advantages, for example, diminishing waste of out dated segments, lessening vehicle discharges, and reusable bundling are credited to JIT (Ross and Associates, 2004). Essentially, JIT has been recognized as a noteworthy part of lean construction idea with the general target of guaranteeing that the right amounts of materials are conveyed to the correct area as at when required (Eriksson, 2010). On the other hand, there is by all accounts low utilization of some lean methods, this could be ascribed to the moderate rate of reception of the idea of lean in Indian construction industry.

The most important areas of linkage between lean and sustainability are resource management, waste reduction, energy minimization, elimination of unnecessary processes and improvement in health and safety; while performance maximization is the minimum positioned range. From the examination, it could be seen that resource management and waste reduction are most grounded range of linkage amongst lean and sustainability. This is likely in light of the fact that construction wastes are non-esteem including and they constitute genuine dangers to sustainability and lean construction. Performance maximization was the slightest positioned linkage. Notwithstanding, the respondents respected all the distinguished regions of connection as significant, since the minimum Rii was 0.69. This recommends there are cooperative energies and linkages between lean construction and sustainability

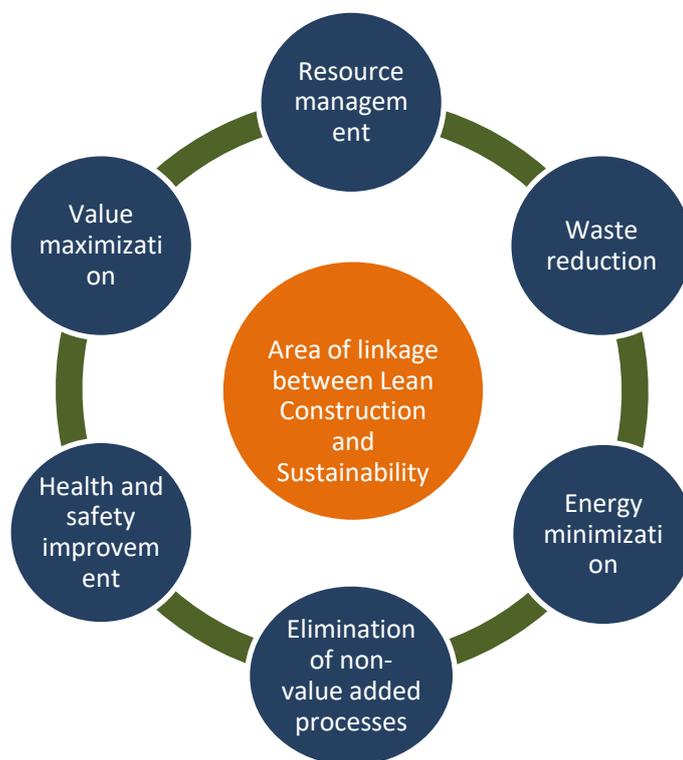


Figure 4

6. CONCLUSIONS

The research paper suggests the area of linkage between lean construction and sustainability in the Indian Construction industry through the questionnaire data collection method. The benefits were identified, analyzed and the outcomes suggest that there is a direct linkage between sustainability and lean Construction. The main lean tools for enabling sustainability in Indian construction industry such as: First run studies, six sigma, Kanban, last planner system (LPS) and visualization tools. And just I time (JIT) is having least impact as per Rii ranking. The main area of linkage between lean construction and sustainability in Indian

construction industry are: resource management, waste reduction, energy minimization, elimination of non-value added processes and health and safety improvement.

7. LIMITATIONS

One of the significant limitation of this research is that the reactions got are perspectives of every respondent speaking to their individual association, and there may be contrasting perspectives among respondents inside a similar association. It ought to likewise be noticed that the outcomes displayed depend on the perception of respondents of associations that have had encounters with lean administration application. In assistance of this investigation, the study ought to be expanded and extended by a more hearty approach using contextual analyses approved by master assessments in the range of lean and sustainability. Future research will examine the obstructions and achievement variables to the execution of lean and sustainability, how the effect of lean Construction can be evaluated in manageable development, and in addition the centre drivers of lean and sustainability. The research focused on the responses received through the questionnaire and the number of respondents is 180 with a response rate of 41%. A further more detailed research is required to know the broad effect of lean tools on sustainability in Indian construction industry.

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