Turkish Online Journal of Qualitative Inquiry (TOJQI)
Volume 12, Issue 6, July 2021: 6589-6596

A Study on Lean Principle Selection in Construction Projects using Analytical Hierarchy Process

B.S. Adheel [a], S. Shanmugapriya[b]

[a] Student, Department of civil engineering, Coimbatore institute of technology
[b] Associate professor, Department of civil engineering, Coimbatore institute of technology

Abstract

Purpose: This paper aims to achieve a study in which the analytical hierarchy process is used for the selection of the best lean principle that can be implemented in the construction industry.

Design /Methodology: The difficulty in choosing the lean principles faced by the construction companies is to be addressed in this paper. The method includes the conduction of direct interviews with the experts from the construction industry after identification of influential factors, the judgmental scores obtained from the respondents are used in the AHP method to find out the best lean principles from the alternatives.

Findings: The results indicated that AHP is a successful method that helps in avoiding the difficulty in the selection process of the best lean principle in a construction company.

Research limitations: The study targets only the selection of lean principles in the construction industry. A study must be initiated to check whether the selected lean principle will be compatible with that construction firm during the implementation process.

Practical implications: The utilization of the perspective will specify that AHP allows the best lean principle selection in the construction industry

Originality/value: The research provides an ease in the lean selection problems in the construction projects

Keywords: Lean principle selection, lean construction system, Analytical hierarchy process

1. Introduction

The term “lean” was coined in the mid-eighties to describe a set of manufacturing techniques discovered in the Japanese automotive industry, mainly at Toyota, by opposition to mass production (Subhash Dev Hiwase, 2016). It is a methodology that creates value for customers by minimizing waste (Alan Mossman, 2009), Lean includes a wide range of principles and tools to identify and remove waste to increase process velocity (Alex Douglas. et al,2014).

The construction sector uses a high amount of resources which also results in the production of wastes, this is mainly caused due to inefficiently managed construction processes. Hence, to improvise the steps of eliminating these problems, the management process should be integrated properly focusing on a particular Lean system. Lean construction guarantees that an estimated work is completed faster and reduces wastage on material, time, and costs suffered throughout the construction activities and the firms have complications in choosing the right leanprinciple.

The involvement of problems in the selection of lean principles is a typical multi-criteria decision-making problem (Fu-Kwun Wang. et al,2013). For the selection of the best lean principle, there are various methods one of the methods is AHP (S. Vinodh et al,2012). In this study, AHP has been used for selecting the best lean principle.

Multi criterion Decision-Making (MCDM) tools are generally applied in arriving at an optimum decision when face with multiple alternatives having multi conflicting and non- commensurable decision criteria (Fu-Kwun Wang. et al,2013). The technique is a well-known tool for solving complex real-life problems due to its intrinsic ability to judge diverse alternatives concerning various decision criteria to choose the best alternative. one of the popular MCDM technique utilized for solving decision problem is: Analytic Hierarchy Process (AHP) (Thomas Saaty, 1970), Some of the lean principles in the construction industry include streamlining of processes with identification of value, mapping, adoption of workflow, elimination of waste and breakdowns (Vinodh et al,2010a).

AHP is a theoretical measurement through pairwise comparisons and depends on the opinions of experts to obtain the priority scale. These scales count the invisible in relative terms. The comparisons are made using a scale of absolute judgment that shows how one factor dominates another for a given attribute. The most important concern of AHP is regarding the inconsistencies arising with the judgment and in this paper, it has been addressed to ensure that the judgments are stable enough to achieve the research objectives that lead to the selection of the best lean principle alternative through the establishment of hierarchical structure with the identification of the critical enabler, criteria, attribute, and principles with respect to the attributes using AHP analysis.

2. Development of Hierarchical Structure

A hierarchical structure clearly shows the dependency of each lean factor over another. Lean obstacles may vary from one another but still holds a very strong connection between them in anyangle, with number of hurdles that ground the selection and implementation of right lean principle in an industry can overcome their barriers with help of this hierarchical structure of lean in an organization. Although, these lean factors may show slight variations based on the size of the project or organizations.

Since, the lean construction system was developed based on the knowledge gathered through the study of literature review and collection of the opinions from the construction industry experts. A lean construction system with five enablers, ten criteria, and 27 attributes was generated. The five enablers are leadership, compliance and avoidance, people's association, organizing style, and strategy and policy. Moreover, these five enablers is fulfilled with the help of the criterions such as personal involvement, culture of excellence, change management, well organized tasks, resource allotment, and the attributes which supports the action of the enablers to head to their goal of successful selection and implementation of a new lean principle which thereby is the best amongits alternative. The enablers head the lead to obtain the lean system in any organization and play apivotal role in the avoidance of confusion in the selection of the best lean principle by the construction companies.

Table 2. Lean hierarchical influential factors

Enabler	Criteria	Attribute	Description
Leadership (L) (Fayek Aziz,, 2018)	Personal Involvement (PI) (Nicola Bateman ,2018) Culture of excellence (CI)(Zoe Radnor, 2010)	Top management support (TS) Team cooperation (TC) Worker's Involvement (WI) Vision development (VD) Mission motivation (MM) Visual Management (VM)	Process with at most support in this decision making. To inspire the worker, so they will work Frontline engagement is backbone of a successful project. Future oriented declaration of the company's purpose and aspiration of the integration of a new lean principle. Having a purpose and connection to everyone's personal career impacts by being driven
Compliance and Avoidance (CA) (Hayyan Zaheraldeen et al. ,2015)	Change Management (CM)(Z J et al ,2006) Well organized tasks (WT)(Osborne s, 2012)	Smooth approval process (SP) Owner's acceptance to change(OC) Innovative learning (IL) Minimization of non- value - added activities (MA) Measurement of inventory waste(MW) Total waste reduction (TR)	Making the stake holders to understand the change and accept new lean principle Acceptance by the decision makers to change existing principle with other Create learning to elicit the change Elimination of non -value added activities which does not have any value. Identification of inventory waste and controlling Using less materials to minimize waste generation

People's Association (PA) (Fayek Aziz, 2018)	Resource Allotment (RA)(Walley,2006) Staff Participation (SP) (Wendal et al,2014	Lean personal appointment (LP) workforce adoption to newprocess (WP) Staff Collaboration (SC) Effective skill Learning (EL)	Recruiting of lean skilled person with existing laborsadaptation by there lean professional. Acceptance by the labors to change present leanprinciple and implement other alternatives people getting together to achieve a common goal bysharing their ideas and skills Training for acquiring a new ability
Organizing Stylei(OS) (Hager Leite et al. ,2015)	Lean concept connect (LC)(Walley ,2006) Lean Planning (LP) (Wendal et al. ,2014)	Detailed design (DD) Time reduction in fragmentation issue (TI) Task splitting (TS) Controlled materialProcurement (CP) Supplier deduced relationship (SR)	Designing system in the construction with aim ofdecreasing time, effort and waste of materials. The fragmentation process influence design decisionswhich take a plenty of time to solve splitting of task in order to be cautious to reduce waste Limiting the purchasing and storing of materials Better communication with supplier in understanding the lean convenience to deliver materials at right time with right quantity
Strategy and Policy (SP) (Nicola, Bateman ,2019)	Financial Plan (FP) (A.N.A Mukthar et al ,2014) Quality Establishment(QE) (Abdul halim M ,2014)	Costing plan for cutdown unwanted activities (CA) Lean funding proposal plan (LP) Inclusion of training expense (IE) Simplified project design (SD) Sequence method (SM) Total quality management tools(TT)	Budget plan shortened by cutting down unwantedexpense generating activities The cost for implementation of lean and the cost lostin replacing the lean principle Skill training cost for education and self-development Adjust all the phases according to the principle selected Determines if procedure were followed during construction

By using the basic lean influential factors from the Table 2 indicates that main purpose is to assist in the creation of the lean construction system which is used for the selection and implementationprocess of best lean principle in the construction industry.

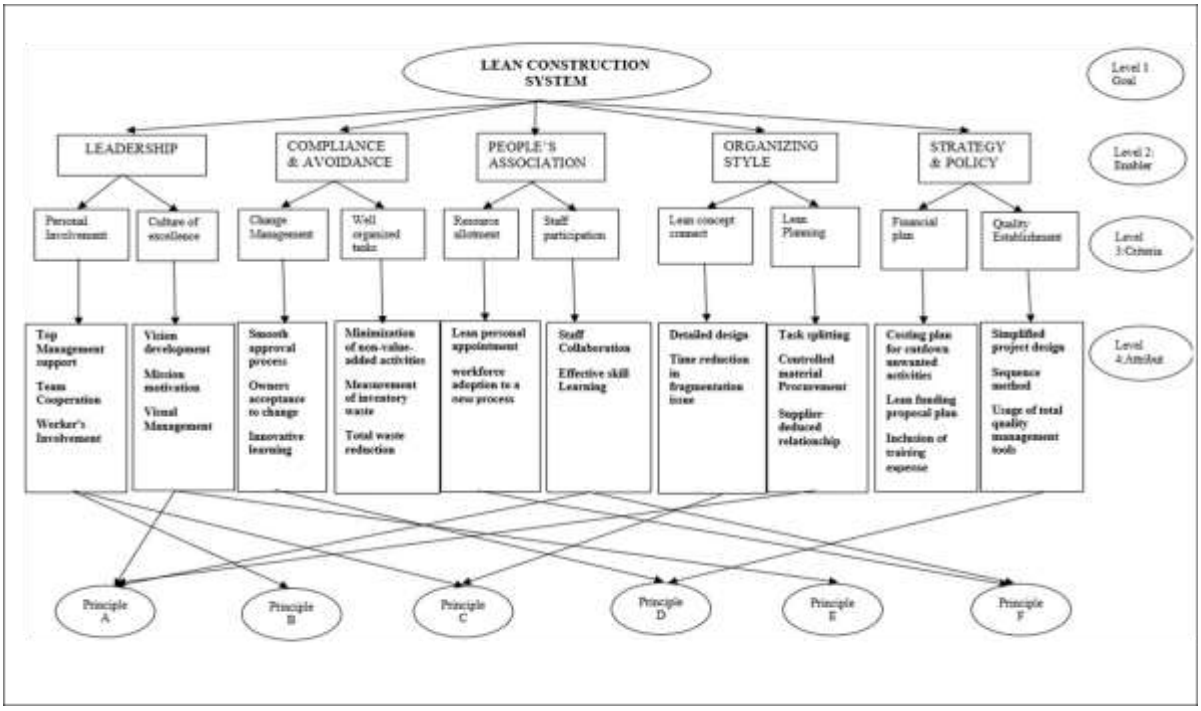

Fig 2. The hierarchical structure of lean construction system

(Ricardo Viana Vargus,2010), these enablers and their criteria along with their attributes were usedto develop

the hierarchy shown in Figure 2.

After creating the hierarchical structure shown in Figure 2, the five lean principles were compared pairwise to each of the 27 attributes. To provide ease of view in Figure 2, the principal alternatives are connected to the attributes with a single comparing line for every alternative. Aftercompleting this foundation work, the case study was conducted to examine the application of AHPusing the hierarchical structure shown in Figure 3 to select the best lean principle.

3. Case Study

The case study has been carried out in 5 construction companies located in Chennai, India. The organizations has implemented lean and other quality management techniques. There existed a need for the organizations to select the best lean construction principle for implementation. The best leanprinciple needed to be selected from the following alternatives:

Principle A - Identify Value from the Customer's Point of View

Principle B - Define the Value Stream

Principle C - Eliminate waste

Principle D - Flow of work process

Principle E - Pull planning and scheduling

Principle F – Continuous improvement

3.1 AHP Methodology

AHP is a technique to solve multi-criteria decision problems (Vinodh et al,2010a) It requires paired comparison judgments to determine the influence of one element over another foreach number of elements for an element on the higher level using 1-9 scale.

The steps followed in the AHP to obtain the best lean principle alternative are structured as follows:

Step 1 -The six lean principles are devised. The objective of the work is the selection of the best principle based on the feedback from the experts and the involved construction firm.

Step 2 -The problem is hierarchically structured into different levels constituting lean enablers, lean criteria, lean attributes, and lean principle alternatives.

Step 3 -The responses are taken from the experts are tailed into the pairwise comparison matrix todetermine the local weight of the enablers, criteria, and attributes so that calculations are executedto find the maximum global weights for each principle alternative, if the consistency of elements is satisfactory then the decision is taken based on the normalized values, else the procedure is repeated till these values form up in the desired count.

3.2 The Comparison Scale

In AHP comparison of elements play a vital role, however, the comparison can be done in variousmethods but here, the relative importance scale between two different elements (SAATY, 2005) is used. Attributing values that vary from 1 to 9, the scale finds the relative importance of an alternative when compared with another alternative as seen in Table 3.2.

Table 3.2- Relative importance scale (SAATY, 2005)

Intensity of Importance	**Explanation**	**Remarks**
1	Two criteria give uniformly to the purpose	Equally Chosen
3	Opinion somewhat commends one factor above the Other	Absolutely Chosen
5	Opinion somewhat commends steadily one factor above the other	Steadily Chosen
7	Factor is steadily prized and its supremacy is revealed in execution	Very Steadily Chosen

9	The proof supporting one factor above other is of the maximum attainable range of authentication	Extremely Chosen
2,4,6,8	Midway choices between two adjoining opinions	Intermediate Choices

4. The Application Of AHP

To choose the best lean principle through AHP calculations, the hierarchical structure has been developed. The scores collected from the experts using the relative importance scale are used to determine the best principle alternative and the response was collected in five construction firms.

4.1 Pairwise Comparison Matrix

After hierarchy has been developed that is seen in the Fig.2, pairwise comparison matrix is performed for the three levels of the hierarchical structure including the enablers, criteria, and attributes. As in the beginning the value obtained from the experts are put in the pairwise matrix for the enablers, to determine the local weights of the enablers for a firm is seen in the Table 4.1.1.

Table 4.1.1 Pairwise Comparison matrix-enabler

ENABLER	LEADERSHIP	COMPLIANCE AND AVOIDANCE	PEOPLE'S ASSOCIATION	ORGANIZING STYLE	STRATEGY AND POLICY
LEADERSHIP	1.00	9.00	7.00	8.00	9.00
COMPLIANCE AND AVOIDANCE	0.11	1.00	9.00	8.00	9.00
PEOPLE'S ASSOCIATION	0.14	0.11	1.00	9.00	6.00
ORGANIZING STYLE	0.13	0.13	0.11	1.00	7.00
STRATEGY AND POLICY	0.11	0.11	0.17	0.14	1.00

An example of pairwise comparisons of enablers is shown in the Table 4.1.1, simultaneously pairwise comparisons is performed for rest of the firms.

Table 4.1.2 Local weight of enablers

FIRM NO.	1	2	3	4	5
LEADERSHIP	0.3897	0.4911	0.3842	0.3208	0.3643
COMPLIANCE AND AVOIDANCE	0.3107	0.2548	0.2897	0.3432	0.3676
PEOPLE'S ASSOCIATION	0.1863	0.1389	0.1958	0.1417	0.1702
ORGANIZING STYLE	0.0958	0.0847	0.1128	0.1614	0.0435
STRATEGY AND POLICY	0.0176	0.0305	0.0175	0.0329	0.0545

(1) The local weights of five different judgmental scores are shown in the Table 4.1.2. The offerings of each enabler to the goal are found out by these calculations made using these local weights. The inconsistencies are checked over to determine whether the respondent's choices have been consistent or not. To verify the consistency, the consistency indices table (SAATY,2005) is looked at with the maximum value. After the determination of the local weight of the enablers, the criteria must be evaluated in pairs to determine the local weight of the criteria. Every criterion is compared with each other according to the grouping under the respective enablers using pairwise comparison matrix similar to that of enablers seen in Table 4.1.1, which leads to the finding of the global weight of the criterion.

Table 4.1.3 Global weight calculation – Criteria

CRITERIA	LOCAL WIEGHT					GLOBAL WIEGHT				
FIRM NO.	1	2	3	4	5	1	2	3	4	5
PERSONAL INVOLVEMENT	0.833	0.833	0.875	0.889	0.500	0.325	0.409	0.281	0.342	0.182
CULTURE OF EXCELLENCE	0.167	0.167	0.125	0.111	0.500	0.065	0.082	0.040	0.043	0.182
WELL ORGANIZED	0.980	0.923	0.800	0.976	0.600	0.305	0.235	0.275	0.283	0.221
RESOURCE ALLOTMENT	0.020	0.077	0.200	0.024	0.400	0.006	0.020	0.006	0.006	0.006
STAFF PARTICIPATION	0.900	0.667	0.500	0.875	0.667	0.168	0.093	0.071	0.171	0.113
LEAN CONCEPT CONNECT	0.100	0.333	0.500	0.125	0.333	0.019	0.046	0.071	0.024	0.057
LEAN PLANNING	0.900	0.714	0.889	0.876	0.876	0.086	0.061	0.143	0.099	0.038
FINANCIAL PLAN	0.100	0.286	0.111	0.124	0.124	0.010	0.024	0.018	0.014	0.005
QUALITY ESTABLISHMENT	0.833	0.833	0.833	0.857	0.800	0.015	0.025	0.027	0.015	0.044

(2) After the determination of the local weight of the criteria through pairwise-matrix, the criteria must be multiplied with the local weight of the enabler obtained in the Table 4.1.2 to determine the global weight of the criteria for five of the companies where the response was collected and is shown for the calculation of global weight seen in the Table 4.1.3.

(3) The influence of each attribute on the goal is determined by calculations to obtain the localweights of the attribute similarly as seen in the Table 4.1.4. Though setting this as an example, this calculation is carried out for the remaining companies.

Table 4.1.4 Global weight - Attribute

ATTRIBUTE	GLOBAL WEIGHTOF ATTRIBUTE				
FIRM NO.	1	2	3	4	5
TS	0.195	0.239	0.218	0.623	0.072
TC	0.116	0.151	0.031	0.319	0.091
WI	0.014	0.019	0.032	0.058	0.019
VD	0.041	0.053	0.016	0.640	0.087
MM	0.021	0.025	0.016	0.305	0.072
V M	0.003	0.004	0.008	0.056	0.023
SA	0.204	0.157	0.151	0.584	0.107
OC	0.085	0.051	0.110	0.353	0.099
IL	0.015	0.027	0.014	0.064	0.014
MA	0.004	0.012	0.004	0.551	0.002
MI	0.002	0.007	0.002	0.252	0.003
TW	0.000	0.001	0.00026	0.19685	0.00139
LA	0.145	0.080	0.064	0.889	0.085
WP	0.023	0.013	0.007	0.111	0.028
SC	0.017	0.040	0.057	0.857	0.045
EL	0.002	0.006	0.014	0.143	0.011
DD	0.075	0.054	0.115	0.889	0.034
TI	0.011	0.007	0.029	0.111	0.004
TS	0.006	0.015	0.010	0.562	0.004
CP	0.003	0.008	0.007	0.368	0.001
SR	0.000460	0.001	0.001013	0.069847	0.000577
CA	0.009	0.015	0.008	0.623	0.034
LP	0.005	0.009	0.016	0.318	0.006
IC	0.001	0.001	0.004	0.059	0.003
SD	0.002	0.003	0.002	0.667	0.006
SM	0.001	0.002	0.003	0.273	0.005
UT	0.000147	0.000	0.000523	0.059718	0.000815

(4) The finding of the global weight of the attributes seen in the Table 4.1.4 are found by the computation of local weights of attribute with global weight of criteria seen in the Table 4.13. Similarly, the principles with

respect to attributes are compared to one another leading to the determination of local and global weights resulting to the final priority table.

Table 4.1.5 Final priority result for lean principle with respect to attribute

PRINCIPLE	FIRM 1	FIRM 2	FIRM 3	FIRM 4	FIRM 5
A	0.1920	0.2220	0.2354	0.2728	0.0687
B	0.2245	0.1317	0.1508	0.1987	0.1929
C	0.19415	0.164	0.2367	0.1159	0.28
D	0.14295	0.1784	0.2121	0.113	0.350
E	0.19245	0.17204	0.246	0.2406	0.1434
F	0.05395	0.1317	0.2206	0.059	0.53

(5) The table 4.1.5 shows the final priority scores for lean principles with respect to attributes for all the five firms, which further drives to the finding of the best lean principle.

5. Results and Disscusion

After the conduction of the analysis for five companies, the results in the Table 4.1.5 shows that the firm 1 presents principle B - value stream mapping with 22.4% score as the best lean principle among other lean principle alternatives, (Sudhir dalal, 2013) denotes that VSM is a map that outlines the current and future state of a system, allowing users to understand where they are and what wasteful acts need to be eliminated. In firm 2 and 4, principle A - identifying values have the maximum scores with 22.2% and 22.7% among the lean principle alternatives, (Muhammad S Khan et al, 2015) states that identifying value is most important lean principle as it addresses customer values practically. It also indicates that principle A- identifying value could help the firms to really know about the requirements of the clients in the construction firms. The firm 3 portrays principle C- eliminate waste with 23.6 % contribution as best lean principle, (Maciej Pieńkowski,2014) notifies that, the most difficult part is not removing waste itself, but identifying and highlighting it, which should precede the process of elimination. Whereas in firm 4, principle F- flow of work process with 53% is shown as the best lean principle, (Reymon Fayez Aziz, 2013) exemplifies the principle D - flow of work process as one of the most effective ways to increase efficiency of construction industry is to improve planning and control process.

By identifying and defining the most critical Enablers, criteria, and attribute, it has lead tothe selection of the right lean principle for implementation in five firms, which shows us that, the most critical attributes in the construction firm are Detailed design and staff collaboration. The acceptance with tracking of allotment avoids the most vulnerable mistakes of lean in work forces (Ruben Cornelissen, 2013). The organizations concluded giving high scores for the enabler leadership seen in Table 4.1.2 as they think this enabler plays a vital role in changing the traditional construction practices as it highly depends on the support and willingness of the top management in order to authorize and initiate the successful introduction and execution of new lean principle in their organization. Also, characteristic and traits of leadership are more conductive for successful implementation of lean principle (Alessandro laureani, 2015).

The Table 4.1.3 stated that the criteria change management and resource allotment topped as the scores from the firms tipped that the management criterion is influencing the enabler leadership, which shows that preparation and support are needed when redefining a process especially during projects that bare working of multiple sub-contractors at a time (Rafael Sacks, 2014).

This paper has studied the main challenges that the organization face today which resides in their ability to choose the most consistent lean principle from the alternatives. Thus, with the determined critical enablers, criteria, and attributes such as leadership, change management and top management helps in overcoming the problems, the organization can now clearly find the best lean principle to start with the implementation process.

5.1 Managerial Implications

The creation of the lean construction system is important and should be discussed with lean experts. Here the major hindrances in the selection of lean principle are to be listed out by splitting of different linked factors which when combined gives the best lean principle. Then the managers should rate them from 1-9 to get scores, followed by interpreting the scores and selecting the highest attaining score between the lean principles. Moreover, the managers could insist on the lean implementation in their company process starting with the

highest scored lean principle.

6. Conclusion and Recommendation

This study has determined 27 attributes that show crucial potentials in the making up of the 10 criteria which are combination gives the linkage to the 5 enablers, thus helping to understand the hurdles, hence providing ample ability of the company to choose the best lean principle to implement in their construction projects. The comparative study results mostly in one lean principle Identifying value, is to begin the Lean approach, there needs to be an understanding ofwhat value means to the target consumers. By identifying value, not only it'll be able to create something customers will pay for, but also a price point that is acceptable to them.

References

[1] Remon Fayek Aziz and Sherif Mohamed Hafe. Applying lean thinking in construction and performance improvement (2013): Alexandria Engineering Journal.

[2] Alessandro Laureani and Jiju Antony Leadership characteristics for Lean Six Sigma(2015): Total Quality Management & Business Excellence Journal.

[3] Bateman, N. and Rich, N. (2003). Companies' perceptions of inhibitors and enablers for process improvement activities. International Journal of Operations, 23(2), 185-199.

[4] S. Vinodh K.R. Shivraman S. Viswesh, (2011),"AHP-based lean concept selection in a manufacturing organization", Journal of Manufacturing Technology Management, Vol. 23.

[5] Ricardo Viana Vargas(2010), "Using the analytical hierarchy process (AHP) to select and prioritize projects in a portfolio", Research gate

[6] Thomas L. Saaty (2008), Relative Measurement and Its Generalization in Decision Making Why Pairwise Comparisons are Central in Mathematics for the Measurement of Intangible Factor