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Conformance Evaluation of Lean Integrated Project Delivery (LIPD) For Indian Construction Industry

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Abstract

Integrated project delivery (IPD) can be used to improve project outcomes using a collaborative approach through early involvement of parties and a multiparty agreement. Lean construction refers to the application & adaptation of the Toyota Production System (TPS) concepts and principles in construction projects for the reduction of waste. Over the last 20 years, the construction industry has become less efficient despite having good project delivery systems like Integrated Project Delivery (IPD), Design-Build (DB), Design-Bid-Build (DBB) and Construction Management Risk (CMR). The amount of waste (man, money, material & time) in different construction activities needs to be minimized to the maximum possible extent. An efficient project delivery system is missing for the Indian construction projects. This research work introduces Lean Integrated Project Delivery (LIPD) as a solution which uses a combination of lean management principles & IPD for waste reduction during construction activities. Further, LIPD conformance would be carried out in the Indian construction industry for the successful implementation of new project delivery system by identifying Critical Success Factors (CSF). Till date, there is no research carried showing LIPD conformance in India. Data for this research has been collected using questionnaire survey using Saaty's scale from experts working in several construction industries of India and has been analyzed using Analytical Hierarchy Process (AHP). The sample size for research work is 40, which was collected from 24 different construction & project management companies in India. This paper elaborates conformance of LIPD in India and the reason for poor implementation of the same.

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1. Introduction

The construction industry is a challenging industry consisting of a large number of activities for completion of the project. An efficient project delivery method is required for project completion within the stipulated time and budget with minimum wastage of resources. Different project delivery systems with different characteristics have been discussed in this paper. From the period of the 1940s to 1990s Design-Bid-Build (DBB) and Construction management

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& Risk (CMR) were the most widely used project delivery methods in the United States. As the building construction has become more complex, the construction industry has become more specialized, segregating a process that was formerly directed from one master builder but still some problems are occurring with these project deliveries. So, in 1990s Design-Build (DB) project delivery was introduced as a solution [1]. This project delivery method seeks to improve project outcome through a collaborative approach, but a collaboration of all parties/teams are not done from the initial level. Some parties like contractors are included in the project after 20% completion of design [2]. So, some difficulties still remain unresolved in this project delivery method. Later, IPD (Integrated Project Delivery) was introduced to provide solutions to previously faced problems. In this method, all parties are included from the beginning of the project. However, IPD does not actively focus on reducing the waste generated during the several construction activities. According to [3], the construction industry has long been censure for being wasteful, unsafe, fragmented, inefficient, and ineffective [4]. So, a new project delivery method is required which focus on reducing construction waste along with achieving other conventional goals on any project delivery method. LIPD (Lean Integrated Project Delivery) is the perfect solution for the current challenge of project delivery systems.

Lean Integrated Project Delivery (LIPD) is a “multi-party contract that specifies the use of lean management practices as conceived in the lean project delivery system”. In other words, LIPD means “The efficiency of lean with the collaboration of integrated project delivery”. This contrast is needed because IPD only refers to the multi-party agreement, regardless of what practices are used.

2. Literature review

IPD (Integrated Project Delivery)

According to [5] Integrated project delivery (IPD), is a collaborative alliance of project participants into a process that tacks the Talents and perception of all participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication, and Construction. Specifically, according to [6] IPD consists of a multidisciplinary team of design and construction professionals assembled to complete a project, who are bound together initially by alternative forms of agreement that require team members to share risk and reward, contribute equally, and employ alternative processes and technologies, all in support of achieving reduced cost, time, loss and waste metrics. (El Asmar et al., 2013) has delineated in their research after performing several compression matrices for cost, time, delay, errors and concluded that IPD performs very well with respect to traditional project delivery methods in waste generation, delay and cost overrun.

LEAN Construction & Management

As a term, lean production & management is the collective synonym for the production system that was first developed in the car-manufacturing environment at the Toyota Motor Corporation which is famous as the Toyota production system (TPS) [4] and it consists of 14 principles that can be divided in to 4P's [7]. Koskela is the one who has lots of research on Lean and is known as the father of lean construction. Lean is a production management-based approach to project delivery which highlights on changing the traditional project delivery and work to minimize waste and to achieve maximum value. Lean focus on the reduction of the non-value added activities to decrease the amount of waste [9]. According to [10] Inspired by Koskela's (1992) important study of production theories in construction, industry has embraced lean principles for nearly one and a half decade. Most research and implementation has focused on construction processes, especially addressing the waste inducing effects of poor planning Some work has extended to the design process, and even lean project delivery although, the results have not yet matched those achieved by Toyota manufacturing. Lean Construction is considering several tools like LPS (Last Planner System), Visible Management, Just in time(JIT) Technology, Total Quality Management(TQM), 5S &6S on-site Management ,huddle meetings, first run studies [9] & [11] which are mainly focusing on the reducing amount on waste in construction activity in terms of man, money, material, and time.

3. Methodology

Primarily, this research focuses on identifying Critical success factors (CSF) associated with the implementation of Lean Integrated Project Delivery (LIPD) in India and the objective of this study is to investigate CSF factors of LIPD in detail and more systematically through identifying construction industry perspective towards combined project delivery in India. This research project collected its data using the questionnaire survey method. The specific methodology was based on a literature review, Face-to-Face interview, and a questionnaire survey. The research steps are as follows,

- **Factor identification:** Through literature survey of past 15-20 years and semi-structural interviews with field experts having 15 years plus experience, total 78 different critical success factors were identified for successful implementation of a LIPD in infrastructure projects in India.
- **Formation of questionnaires:** The questionnaire was designed according to Satty's scale (1-3-5-7-9) [12], like 1=Two criteria contribute equally to the objective, 3=Experience and judgement slightly favour one over another, 5=Experience and judgment strongly favour one over another, 7=Criterion is strongly favoured, and its dominance is demonstrated in practice, 9=Importance of one over another affirmed on the highest possible order & 2,4,6,8=Used to represent compromise between the priorities listed above. The entire questionnaire is divided into 5 parts, 1) General introduction of the respondent, 2) Factors related to IPD, 3) Factors Related to waste generation, 4) Factor related to Lean Management, 5) Factor related to conformance.
- **Data Collection:** respondents were given the option of answering the questionnaire in Google docs online that included in E-mail or completing it in hard copy. And based on this data has been collected. The questionnaires were filled by the differ field persons like Project Manager, Contractor, Site Engineer, Planning engineer, site supervisor, PM Consultant, Designer, developers etc.
- **Data analysis and Discussion:** All the collected data is stored in excel sheets. For the interpretation of data collected, we use the Analytical Hierarchy Process (AHP).

4. Data collection & analysis

Data Collection

Major data collection is done with the help of a questionnaire survey. A total of 74 numbers of questionnaires were distributed to respondents ranging from Project Manager, Contractor, Site Engineer, Planning engineer, site supervisor, PM Consultant, Designer, developers having 5-15 year of construction industry experience involved with different project delivery methods. Selection of the respondent was done by stratified random sampling. The reason for using stratified random sampling is that it can represent each preference group proportionately. On the other side, the construction companies were chosen from the top 50 companies that have a wide range of experience in handling big projects.

To ensure better responses, the surveys forms were distributed by hand and follow-up were made via telephone. Such efforts ensured better response and help to explain its objective while obtaining broader inputs from the respondents. Still, out of all questioners, we get only 40 responses back which includes, Project Manager (8), Contractor (5), Site Engineer (7), Planning engineer (6), site supervisor (5), PM Consultant (7), Designer (3). So, by this, we can consider that awareness & seriousness towards research work in the construction field is very less.

Data Analysis

For the data analysis, we choose the Analytical Hierarchy Process (AHP) for differentiating the most critical success factors using the hierarchy process. So, here is some process for calculation. The first step is to prepare the pair-wise comparison matrix as shown in eq.-1 using the values which are obtained in data collection. The 2nd matrix of pairwise comparisons $A = [a_{ij}]$ represents the intensities of the expert's preference between [13]

individual pairs of alternatives (A_i versus A_j , for all $i, j=1, 2, \dots, n$) according to [12] is derived from values of matrix-1 as shown in eq.-2. Our main goal is to compute a vector of weights $\{w_1, w_2, \dots, w_n\}$ associated with an eigenvector method, w is the weight vector.

$$W = (W_i / W_j) = \begin{bmatrix} W_1/W_1 & W_1/W_2 & \dots & W_1/W_n \\ W_2/W_1 & W_2/W_2 & \dots & W_2/W_n \\ \vdots & \vdots & \ddots & \vdots \\ W_n/W_1 & W_n/W_2 & \dots & W_n/W_n \end{bmatrix} \dots \text{Eq} \rightarrow 1$$

$$A = (a_{ij}) = \begin{bmatrix} 1 & a_{12} & \dots & a_{1j} \\ 1/a_{12} & 1 & \dots & a_{2j} \\ \vdots & \vdots & \ddots & \vdots \\ 1/a_{1j} & 1/a_{2j} & \dots & a_{in} \end{bmatrix} \dots \text{Eq} \rightarrow 2$$

In the 3rd step, each matrix is normalized and be found the relative weights. The right eigenvector gives the relative weights (W) corresponding the relative eigenvalue $\lambda_{\max}$, as Eq.-3.

$$Aw = \lambda_{\max} * w \dots \dots \dots \text{Eq.-3}$$

After that Priority of eigenvalue (PV of EV) is calculated.

In the 4th step, the consistency is calculated. it is defined by the relation between the entries of [14] A: $a_{ij} \times a_{jk} = a_{ik}$. The Consistency Index (CI) can be calculated, using the following Eq.-4. Where n=number of responses.

$$CI = \frac{\lambda_{\max} - n}{n - 1} \dots\dots\dots Eq.-4$$

Using the final consistency ratio (CR) can conclude whether the evaluations are sufficiently consistent. The CR is calculated as the ratio of the CI and the random index (RI), as indicated in Eq.-5.

$$CR = \frac{CI}{RI} \dots\dots\dots Eq.-5$$

The CR value ≤ 0.12 then it is accepted upper limit for CR [14]. In bellow table N= numbers of factors.

Table 1: (RI Value tables for calculation)

n	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
RI	0.88	1.10	1.24	1.34	1.40	1.44	1.48	1.51	1.53	1.55	1.57	1.58	1.59	1.60	1.61

5. Result and discussion

After analysis of all the collected data using AHP, we can get the following results which are shown in **Table: 2 to 8**. The table also shows the weighted distribution of the factors according to the PV of EV values. The top 16 Critical factors were according to Values (PV of EV) and arranging the brainstorming session with respected field experts. The CR value is ≤ 0.12 for all 7 tables. Which means the values are according to the accepted upper limit for CR [14] So, we can consider matrix as a consistent one & calculations are satisfactory.

Table-2: Factors which are responsible for successful completion of the project on schedule with design cost

Factors	PV-of-EV	Rank
<i>Trust on team members during the project</i>	0.072	1
<i>Project delivery/implementation speed</i>	0.072	2
<i>Communication between team members</i>	0.071	3
<i>Continuous improvement in work performance project by project</i>	0.071	4
<i>System quality throughout the project</i>	0.070	5
<i>Conflict resolution between teammates</i>	0.069	6
<i>Construction speed</i>	0.068	7
<i>Working in different teams</i>	0.066	8
<i>No blame Culture</i>	0.066	9
<i>lost time injuries</i>	0.065	10
<i>Amount of design change during the project</i>	0.064	11
<i>Gain and pain sharing of work in the project</i>	0.063	12
<i>The requirement of extra labor then schedule</i>	0.062	13
<i>amount of re-work in the project</i>	0.061	14
<i>Waste recycling rate</i>	0.061	15

Table-3: Factor responsible for Delay in Planning

Factors	PV-of-EV	Rank
<i>issue related to funding and another monetary parameter</i>	0.143	1
<i>lack of knowledge for one of kind project</i>	0.143	2
<i>Frequently change in requirement from the client</i>	0.133	3
<i>the issue in land acquisition</i>	0.132	4
<i>Environmental clearance</i>	0.120	5
<i>inappropriate attitude from the client</i>	0.113	6
<i>Site Clearance</i>	0.108	7
<i>Objection from a nearby organization</i>	0.108	8

from the **Table-2** we have selected top 3 factors having maximum values for PV of EV from 0.071 to 0.071 and **Table-3** we have selected top 2 factors having maximum values for PV of EV from 0.133 to 0.143 as a critical factor.

Table-4: Factors responsible for waste caused in the Construction industry (Management Stage)

Factors	PV-of-EV	Rank
<i>Frequently design change</i>	0.060	1
<i>Poor design coordination among project participants</i>	0.060	2
<i>Slow decision making</i>	0.059	3
<i>Waiting for equipment</i>	0.059	4
<i>Poorly scheduled delivery of material to the site</i>	0.059	5
<i>Lack of control</i>	0.058	6
<i>Poor planning</i>	0.057	7
<i>Waiting for skilled labor</i>	0.057	8
<i>Poor layout of the site</i>	0.055	9
<i>Poor Site management</i>	0.055	10
<i>Over Allocation of material</i>	0.054	11
<i>lack of worker training</i>	0.054	12
<i>Lack of trust</i>	0.053	13
<i>Too few supervisor and foreman</i>	0.053	14
<i>Over Allocation of equipment</i>	0.052	15
<i>Over Allocation of workers</i>	0.052	16
<i>Waiting for material</i>	0.051	17
<i>lack of design information</i>	0.051	18

from the **Table-4 & Table-5**, we have also selected top 3 factors having maximum values for PV of EV from 0.059 to 0.060 and 0.082 to 0.084 as a critical factor.

Table-5: Factors responsible for waste caused by "Human Resource/ labors)" in project

Factors	PV-of-EV	Rank
<i>The understanding between engineers and labors</i>	0.084	1
<i>Lack of supervision causing relief in workers</i>	0.084	2
<i>Unnecessary labor movement</i>	0.083	3
<i>Rework and repair required due to defective work</i>	0.081	4
<i>Waiting for labor</i>	0.081	5
<i>Mishandling or error was done by labor</i>	0.079	6
<i>Theft of material / Equipment</i>	0.076	7
<i>Accidents</i>	0.074	8
<i>Unnecessary leave</i>	0.073	9
<i>lack of proper knowledge of work</i>	0.072	10
<i>Unnecessary resting</i>	0.072	11
<i>The health of the workers</i>	0.070	12
<i>Unnecessary chaos</i>	0.070	13

Table-6: Factors responsible for waste caused by "Equipment" in project

Factors	PV-of-EV	Rank
<i>Waiting for equipment</i>	0.138	1
<i>Error in erection of equipment</i>	0.133	2
<i>Use of outdated equipment with problematic parts</i>	0.132	3
<i>Unnecessary movement and transportation within the site</i>	0.125	4
<i>Mishandling or error caused during the work</i>	0.120	5
<i>Time is taken for maintenance</i>	0.119	6
<i>Miscommunication between the driver and signalman</i>	0.117	7
<i>Driver having less knowledge</i>	0.115	8

from the **Table-6** we have also selected top 2 factors having maximum values for PV of EV from 0.133 to 0.138 as a critical factor.

Table-7: Delay in the supply of material

Factors	PV-of-EV	Rank
<i>Late information</i>	0.211	1
<i>The inappropriate attitude of supplier</i>	0.207	2
<i>Higher demand for material in the market</i>	0.200	3
<i>Transportation</i>	0.193	4
<i>Very less required product</i>	0.189	5

from the **Table-7** we have selected top 2 factors having maximum values for PV of EV from 0.207 to 0.211 as a critical factor.

Table-8: Causes of degradation of the material

Factors	PV-of-EV	Rank
<i>Lack of proper storage space</i>	0.184	1
<i>Poor handling</i>	0.183	2
<i>Maintenance of storage area not done</i>	0.164	3
<i>Quality check is not done</i>	0.158	4
<i>Negligence by caretaker</i>	0.157	5

And from the **Table-8** we have selected factor having maximum values for PV of EV is 0.184 as a critical factor. Another major thing which is noticed during data analysis regarding the LEAN Construction and IPD knowledge in the people of construction industries in India. Which is shown in **fig.-1** as a spider web diagram and abbreviation of Figure are in **Table-9**. On the basis of that, we can say that awareness is very less in people. Only 35% of people know LEAN, IPD and Work with this Project delivery.

Table 9: Abbreviations for Fig: 1

A1	Know <i>IPD</i> concept and Work with this concept.
A2	Know <i>IPD</i> concept but Not Work with this concept.
A3	Don't Know <i>IPD</i> concept and Not Work with this concept.
A4	Know <i>LEAN</i> concept and Work with this concept.
A5	Know <i>LEAN</i> concept but Not Work with this concept.
A6	Don't Know <i>LEAN</i> concept and Not Work with this concept.

Figure 1 : (Spider Web Diagram for awareness & work experience in LEAN & IPD)

From the **figure-1** we can say that the awareness regarding the LEAN and IPD in the construction industry of India is very less.

6. Conclusion

This paper proposes an evaluation of Lean Integrated Project Delivery (LIPD) conformance among the construction industry of India. The use of LEAN Construction & IPD by the Indian construction industry is still in its infancy. Although some professionals have worked on either IPD or LEAN or both projects, a majority either does not have direct experience or not familiar with this concept. So, to work with a combination of these concepts is quite difficult. Although according to factors derived from the AHP analysis we can say that Lean Integrated Project Delivery (LIPD) has its conformance among the construction industry of India but the implementation of this requires around 10-15

years. For that, the education of LEAN & IPD in construction studies is required from the earlier stage of engineering studies. These are some of the reason which delays the implementation of LIPD in India. These factors are 1) less awareness regarding the research work in construction, 2) a huge amount of competition in the market, 3) no time to learn new technology, 4) lack of knowledge & skills in labours and 5) lack of training & resist to the change.

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