Application of Lean Techniques, Enterprise Resource Planning and Artificial Intelligence in Construction Project Management

Velagapalli Vickranth, Sesha Sai Ratnamala Bommareddy, V.Premalatha

Abstract: ***A construction project is a temporary production system which is designed and delivered within a specified time and budget. The traditional system has approximately 50% of non-value-added efforts and waste. As the traditional ways cannot handle complex and uncertain activities, there is a need for innovative and advanced systems that will help the project teams' deal with the issues in projects. Lean techniques, Enterprise Resource Planning and Artificial Intelligence are such innovative techniques which have a good impact in the construction industry. As each system has the impact only in the implemented stage of construction, there is scope for loss of resources in the other construction phases. This paper proposes a contagious loop system comprising of Lean techniques, Enterprise Resource Planning and Artificial Intelligence as the robust approach for construction project management to improve the productivity, reduce the cost, time, resources and discuss the importance of implementing the contagious loop system. This paper uses exploratory method for evaluating the individual gains of Lean techniques, Enterprise Resource Planning and Artificial Intelligence by exploring and understanding the available literature, case studies and tries to propose an advanced implementation system to the construction industry for achieving minimization of resources, improving the productivity within the built environment.***

Index Terms: ***Artificial Intelligence (AI), Construction Project, Enterprise Resource Planning (ERP), Lean Techniques (LT).***

I. INTRODUCTION

There are numerous projects which failed to be delivered within the specified time, budget and standard quality resulting in additional re-working. Many projects fail even after putting required amount of effort in installing new technologies and adopting new strategies [1]. A significant problem was identified i.e there is no process available which is good enough to manage the work relations between the company and its suppliers during the life cycle of a project [2]. Changes in the supply and demand have effect on project management by increasing the cost, delivery time, waste of resources and can even decrease the project quality and safety. Studies show that, construction wastes reflect to huge quantities of production.

This significant presence of wastes in construction results in reduction of the overall performance and productivity.

Mitigation measures have to be taken to increase the performance, productivity and to remove the wastes in construction industry [3]. There is approximately 57% wastage of productive time in the construction activities [4]. The traditional approaches to construction or the conventional project management systems have a lot of cavities in resolving the problems [5] - [8]. The innovative and advanced systems that are proposed to deal with such issues are the Lean Techniques, Enterprise Resource Planning and Artificial Intelligence in individual construction phases so that there will be maximum usage of all the resources and minimum loses of the resources during each phase of construction thereby improving the productivity.

A. The Conventional Project Management Method

In simple terms, the reason for management of a project is to acquire the goals of projects that are agreed upon before the start of the project. It should utilize and deploy tools, skills, techniques and available resources to facilitate projects to be able to complete projects in time. A good and effective project management will help to meet the customer expectations and exceed them, which will result in use of available resources to their maximum extent; be it time, money, people, space, among others, and strive for a successful completion of project within budget and on time. Such management will instill confidence in their team and that process will be filed for future references [9]. It has been observed that the tools behind construction management and project management like; CPM (critical path method); WBS (work break down structure); and EVM (earned value management); failed to finish the construction projects within provided budget, time and the quality desired for the project [10].

The failures which occurred in the current projects and its administration process help us to design the requirements for a new approach. This was later recalled by [6] who stated that; there was an unsuitable match between the conceptual models to that of the reality observed in project management. This results in presence of poor robust system in the existing management concepts. A new approach must be pillared on the expanded Transformation, Flow and Value generation foundation to optimize performance in projects. A proposal was given by [3], that all the works and resources can be interlinked by schedule and the inadequacies to work as per schedule is the proof of failure

Revised Manuscript Received on April 09, 2019.

Velagapalli Vickranth, Department of Civil Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Guntur, A.P, India.

Sesha Sai Ratnamala Bommareddy, Department of Civil Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Guntur, A.P, India.

V.PremaLatha, Department of Computer Science & Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Guntur, A.P, India.

of responsibility which was supported by [11], who advised that the construction management systems which are currently in use don't consider the effects of important production system variables which can significantly influence the construction cycle. From lean techniques, enterprise resource planning and artificial intelligence point of view, the current process of construction project management rests on an unstable model.

The present project management system pursues to manage activities through scheduling and controls them by utilizing output measures, but they fail even after the effort to manage those activities and completely miss the work process management, the creation and value delivery. In the present dynamic environment with complexities, uncertainties, fast tracked and short duration projects, multiple competing, frequent changing demands from clients, technology and the market, activities are rarely connected together in just a simple consecutive chains; rather the work between and within tasks is connected to work through shared resources and/or relies upon work in progress, and therefore coordinating projects in such dynamic environment cannot be guaranteed even with very detailed critical path method schedules. In such situations, the reliable release of work starting with one group then onto the next is estimated or overlooked. Project managers who completely depend on these schedules face the uncertainties yet rarely see it emerging within the project from their dependence on scheduling of tasks and control of activities [3].

The failures were examined by [12] in using the scheduling for projects and showed that, around 50% of the tasks on week by week work plan are completed before the end of the planned week and the failures which occurred in the planning have been moderated or controlled by contractors using an effective variability management. There are other distinguishing features between lean techniques, enterprise resource planning and artificial intelligence in construction practice and conventional project management, specifically: a) they concentrate on waste reduction in construction processes; b) they seek to minimize irregularity and variability so that there will be flow of material and information in processes without any interruptions; c) they provide continuous monitoring of work progress, productivity and provide immediate work modifications wherever required.

B. Lean, ERP & AI Method

Planning phase

a) lean tools

It is defined as a way to structure a production system to reduce the waste of resources and effort in order to produce the maximum possible amount of value [13]. This can be possibly done only through collaboration of all the project stakeholders i.e. Vendors, Engineers, Owner, Contractors, and Consultants etc at the early period of the project where they can discuss and share their views for a better output of the project and its design [14]. Essentially, lean tools aim to combines the benefits of the Master Builder concept [14]. One can assume lean construction as an image of mesoeconomics. Lean construction is based on the criteria of project-level management and on the concepts that manage production-level management. Lean principles state that for any successful project undertaking, there will be involvement and interaction of the project and the production management [15].

b) lc fuzzy cognitive map

The Fuzzy Cognitive Map explains the degree of causal relationship among the elements. The strength and its impact of the elements can be computed using the map [16]. This output was derived from literature review data, interviews and case studies from construction companies. It is the result of a stable progressive approach finished with its validity. Arrows state the elements influence i.e the "plus" and "minus" signs indicate the positive and negative relationship with the elements and its intensity [17].

c) fundamental principles of lean

- Define the value from customer's point of view
- Understanding value stream of the steps involved in the process and to create the end product
- Reduce waste
- Make a smooth flow of value added activities
- Prefabricate and modularize building systems
- Use a combined pull scheduling to provide all the internal and external customers what they require, when they request it
- Try for perfection by committing to continual improvement in all areas of the process

d) lean construction tools

- Last Planner System
- Pull Planning
- Weekly work plans
- First-Run Studies (Plan, Do, Check, Act)
- 5S's
- Plan percent complete
- Daily Stand up meetings
- BIM
- Percentage Progress Complete
- Just In Time (JIT)

Table 1 explains the main differences between LC and the conventional construction techniques.

Table 1 Difference between Conventional construction and Lean construction systems
***(Source: DOI 10.5592/otmcj.2013.2.2Research paper)*[17]**

Conventional System		Lean System
Production and project management using activity oriented approach	►	Defining standard objectives for delivering the work
Focuses on optimizing the project activity and identifying customer value in design	►	Tries to maximize the performance to customer at project level
Dividing the project into parts, putting them in logical sequence to focus on each activity	►	Parallel designing of product and process

Monitoring each activity against its schedule and budget projections	►	Applies production control throughout the entire project life

Table 2 Time, techniques and tools used to persuade and train the three hierarchical levels
***(Source: DOI** 10.5592/otmcj.2013.2.2Research paper)* **[17]**

Stage	Directions	Involved Teams
Designing	Communication of Top Managing team ↓ Defining of Multiple Project Members ↓ Training ↓ Including the Technical people of Lean ↓ Defining the Aims ↓	Top managing team
		Project team wing
		Project team wing and staff
		Project team wing
Execution	Observing the work and Collection of Data ↓ Improving the activities by continuous meetings ↓ Visual Display to monitor the process and grasp the benefits ↓	Staff
		Project team wing and staff
Repeating the improved system	Analysis of results and Sharing the knowledge	Top managing team and Project team wing and staff

Table 2 summarizes the time, techniques and tools necessary for implementation of Lean Construction in a project.

As there are number of lean tools which can be used during construction project management, requirement for each individual tool requires many stakeholders to be involved which results in inability of using Lean tools in all the phases of construction.

Execution phase

a) enterprise resource planning (erp)

The construction industry is a highly fragmented industry. It needs to communicate on a large scale with other related businesses such as material and equipment suppliers, vendors, subcontractors and clients. ERP systems connect the entire companies operations such as accounts, financial data, labor data, production and distribution, etc. They also link the company to its customers and vendors at different phases of the life cycle. ERP systems are being used by construction companies to increase the relationship with the customers, strengthen the supply chain management, improve the flexibility of the organization, provide better decision making options, to reduce project completion time and reduce the costs. ERP systems are designed to incorporate and automate the company's business procedures such as labor management, accounting, production, sales, building operations and maintenance. The goal of ERP is to provide single time information entry when it is created and to make the information transparent to all the participants within the organization.

b) erp basic concepts

ERP systems are implemented in construction industry for the following purposes:

- Improvement of customer relation responsibilities.
- Supply chain partnership strengthening
- Enhancing the organizational flexibility
- Improving the decision-making capabilities
- Reduction of project completion time and cost

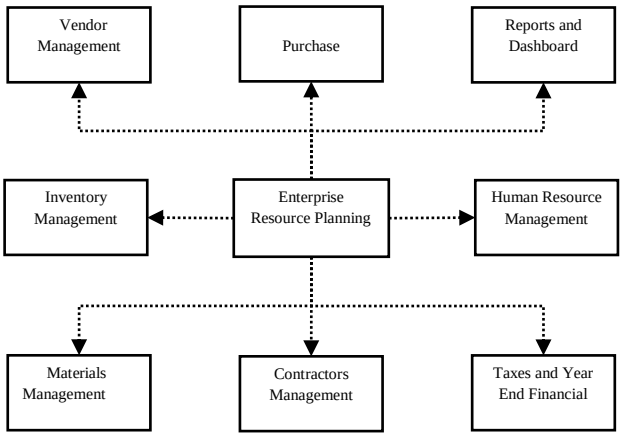

Figure 1 Basic Key modules of ERP

There are very few studies conducted regarding the implementation and use of ERP in the construction firms, however most issues arise from the construction project management and suppliers; and the final affect that these systems will have will be on the delivery process [18].

ERP is a software based system which can help in the data analysis of the daily work progress with respect to all the resources and stake holders involved during the life cycle of the project which will benefit the management of the project in the construction project management by improving the productivity. ERP cannot be used in monitoring phase as this phase requires live review detail analysis of the work process for continuous monitoring of work and spontaneous decision making with respect to the work which is not possible by ERP.

Monitoring phase

a) artificial intelligence in construction

Artificial intelligence gathers collective data available and tries to decode the information for any patterns, models and trends and tries to implement the capabilities of machines to model the basic understanding of humans. For this process to be completed, AI uses the machine learning for finishing the tasks and executes them with faster speed and accuracy. The easy access to cloud-based applications and mobile devices, resulted in easy data gathering (work photos,

materials used, work hours, machinery utilization etc) at jobsite and has grown drastically over the years. Such information is gathered to do deeper analytical study and logical reasoning for the what-if scenarios to make projects and companies more profitable. Artificial intelligence throws light on the hidden insights of data that the basic human understanding cannot interpret to understand. Artificial Intelligence is trying to improve the productivity, quality and the safety of workers where the activities are being hampered during the construction.

b) alerts

Field reporting software allows the workers to enter into the site using voice command or by manual typing. These systems can be designed to send alerts and notifications to the management based on certain keywords. Words like "delay" or "safety" can be stored in the design so that an alert will be sent to the project manager or safety manager to notify them for any potential issues. Such alerts help the important stakeholders notified in real-time even if they are not present at the jobsite.

c) optical character recognition (ocr)

Using OCR technology, users can search the required drawings and can convert them into documents, images and into editable data which can be browsed when required. Many drawing applications depend on OCR to scan the drawings, to name and number the sheets automatically and hyperlink the related drawing sheets together which saves the time of manually processing the drawings for viewing, markups and sharing.

d) safety sensors

With the help of Internet of things, automation at the jobsites has been increasing with the advancements in technology. Using such devices (wearable – Spot-r) in jobsites can make the work place a safer place for the workers. Safety sensors help in locating the workers at jobsite and can send alerts to the management if a worker slips or falls.

e) drones

Drones and drone mapping softwares (Drone Deploy) reduce the time required for collection of accurate survey maps and aerial images of a jobsite. Drone survey is mainly done to study the work progress even when the person is not available at the jobsite. This is additionally used for identifying the issues and conflicts in the jobsite which cannot be identified from ground and can only be found using aerial images of the jobsite.

f) robots

Following the autonomous vehicles, robots have started to conquer the jobsites in construction industry. Robotic machinery like Hadrian X, 3D printers, Demolition robots etc are making a way into the construction sector thereby improving the productivity and quality of work and reducing the waste of resources. Use of robots in construction activities is increasing rapidly as it results in more benefits for the company than any conflicts and safety issues in the jobsite [19].

g) doxel ai

Doxel is a Silicon Valley startup claiming to provide AI-enhanced software which is focused at improving construction productivity. Doxel uses rugged robots and drones equipped with cameras and LiDAR sensors to monitor and scan worksites. The visual data is processed using deep learning algorithms to measure the currently installed quantities and the rate of production by matching against the desired planning and design parameters for the client. The AI platform can also detect errors in the construction by comparing visual data from everyday scans of the jobsite to small scale design models [20], [21].

II. RESEARCH SIGNIFICANCE

The traditional ways are unable to handle the complex and uncertain activities in project, resulting in waste of resources, money, time and poor quality. To reduce the cost, time, resources and to increase the productivity, a new, innovative and advanced system is proposed for construction project management which helps in eradicating the errors in conventional system.

III. DESCRIPTION OF WORK

This paper proposes a contagious loop system in Figure 2 consisting of Lean techniques, ERP and AI as a innovative and robust approach for construction project management to improve the productivity, reduce the cost, time, resources and discuss the importance of implementing the contagious loop system. Firstly the construction life cycle is divided into three phase's i.e Planning, Execution and Monitoring phases.

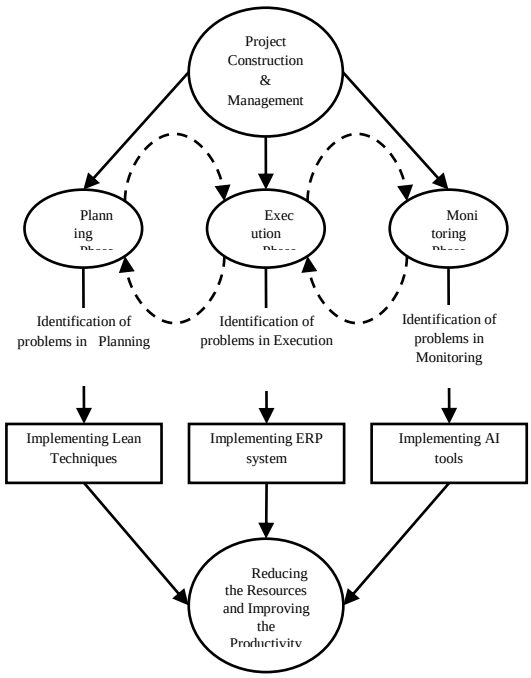

Figure 2 Proposed Contagious Loop System for Construction Project Management

In each phase the commonly occurred errors with respect to the traditional management system are identified and the best innovative and robust tool available is implemented for reducing the errors and increasing the work productivity. This paper uses exploratory method for evaluating the gains of Lean techniques, ERP and AI by exploring and

understanding the available literature, case studies for achieving minimization of resources, improving the productivity within the built environment.

IV. RESULTS AND DISCUSSIONS

Implementation of Lean Tools, Enterprise Resource Planning and Artificial Intelligence in the construction project management system rather than the traditional conventional system will help in reducing the errors in the conventional system and could improve the production system of a project, provides better communication, improves the relationships, reduces the wastage of resources, increases the productivity and quality.

Lean tools like the Last Planner System, Weekly Work Plan, Look-ahead Schedule, Percent of Planned Complete, 5S etc can help solve problems which arise during lifecycle of project. Ms. Francis, planning engineer, Larsen & Toubro, mentioned how the basic principles of Lean – elimination of resource waste, increasing the customer value, doing the work right way - first time, pull mechanism and continuous innovation can be implemented in construction works by using the lean principles in six construction activities in four construction sites and attained good results. They implemented the five S technique and Value Stream Mapping to identify the value adding and waste activities during construction process thereby tracking the inventory levels, lead times and cycle times.

By implementing Lean construction techniques, they have achieved target of 20% energy saving and 10% of water saving. Figure 3 shows the energy conservation target and the achieved percentage of energy conserved. Figure 4 shows the water conservation target and the achieved percentage of water conserved. Lean techniques help to make the construction more structured resulting in reducing the occurrence of variables [22].

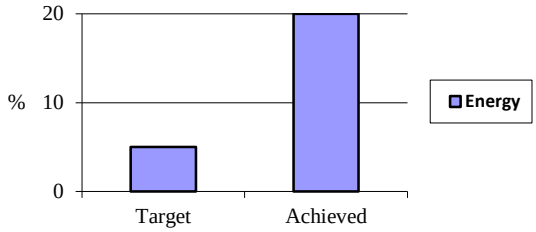

Figure 3 Energy Conservation comparison

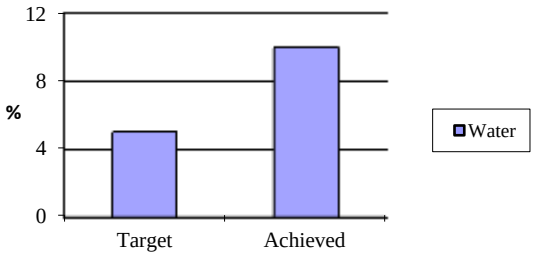

Figure 4 Water Conservation comparison
***(Source: L&T sustainability report 2014)*[22], [23]**

Implementing Last Planner System during construction activities could be appropriate to solve the problems which arise at site like reducing the delays, optimization of resources thereby reducing the project cost. Figure 5 shows the difference between the planned duration of the construction activities and the actual duration after implementing Last Planner System. Figure 6 shows the difference between the estimated cost and the actual cost after implementing LPS. The main advantage of using Last Planner System for the construction activities is to provide assistance to the project planners to understand better the process of construction and accurately predict the forecast. This shows that accurate planning can increase the productivity of construction activities and improves the resources utilization [24].

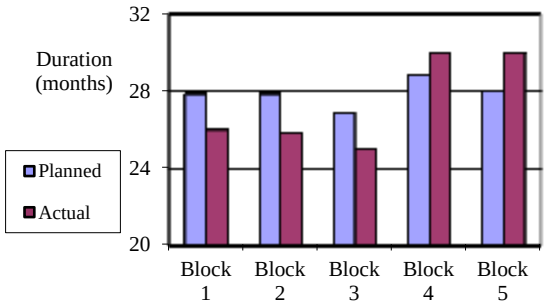

Figure 5 Planned duration Vs Actual duration

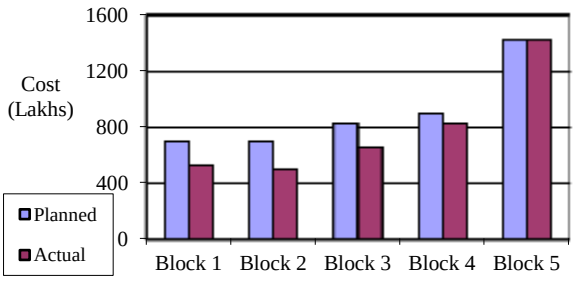

Figure 6 Planned Cost Vs Actual Cost
***(Source: IJERTV3IS051307)* [24]**

ERP will provide solution for managing the entire functioning of construction firm, decision making, growth and development of the organization. ERP systems can benefit the construction companies by providing integrated and structured system resulting in operations which can be modified easily and provide transparency in information and its access [25].

Benefits of ERP systems:

- Presence of inbuilt integrated work environment
- Scope for automation
- Easy access to information for all the employees
- Supply of integrated applications for all departments
- Change adaptability to facilitate a standard process
- Achieve balance in all aspects
- Program management practices and planning throughout the lifecycle of project.

AI implementation has been providing success in many civil engineering areas like prediction, risk analysis, decision-making, resource optimization, classification and selection. It is also playing a major role in constructing, maintaining and managing different aspects in the construction project management system. AI has potential to perform better than the conventional methods and has number of significant benefits that makes it powerful and practical tool for solving the problems in the construction project management.

V. CONCLUSIONS

Implementation of each proposed system in the required construction phase will have lot of benefit to the construction sector resulting in use of resources fully and reducing the wastage of the used materials, reducing the project cost, handing over the project in time and with good quality.

For better and standard performance of the proposed system, Lean tools and Enterprise Resource Planning can be combined together and be implemented for a consistent and improved framed network for the production system and increase the productivity and utilize the resources up to the maximum extent in the built environment.

Functional areas like project and land development, facility, configuration and property management, maintenance period work scheduling, digital services, information regarding real estate can be included in Residential and Commercial firms. ERP systems can help push the detailed project information to homebuyers, marketing agents, and construction firm managers - all from one source.

REFERENCES

1. Ashkena and Matta, "Why good projects fail anyway," *Harvard Business Review*, vol. 81, no. 9, pp. 111-114, 2003.
2. Arbulu and Ballard, "Lean supply system in construction," in Paper presented at the 12th annual conference of the International Group of Lean Construction, Helsinga, Denmark, 2004.
3. Aziz and Hafez, "Applying lean thinking in construction and performance improvement," *Alexandria Engineering Journal*, vol. 52, no. 4, pp. 679-695, 2013.
4. "Lean Construction Institute," [Online]. Available: http://www.leanuk.leanconstruction.org/whatis.htm,.
5. Johnston and Brennan, "Planning or organizing the implications of theories of activity for management of operations," *Omega, International Journal of Management Sciences*, vol. 24, no. 4, pp. 367-384, 1996.
6. Koskela, "An exploration towards a production theory and its application to construction," VTT Publications, 2000.
7. Koskela and Howell, "Reforming project management: the role of planning execution and control," in *9th Annual Conference of the International Group for Lean Construction (IGLC-9), 6-8 August*, Singapore, 2001.
8. Ballard and Howell, "Implementing Lean Construction: Stabilizing Work Flow," in *Proceedings of the 2nd Annual meeting of the International Group for Lean Construction*, Santiago, Chile, 1994.
9. Glenn, 2007. [Online]. Available: http://www.evancarmichael.com/Business-Coach/223/The-Importance-and-AwesomePower-of-Project-Management-in-Todays-Business-Environment.html.
10. Abdelhamid, "The Self-Destruction and Renewal of Lean Construction Theory: A Prediction From Boyd's Theory," in *Proceedings of the 12th Annual Conference of the International Group for Lean Construction*, Helsinger, Denamrk, 2004.
11. Bashford, Walsh and Sawhney, "Production system loading-cycle time relationship in residential construction," *Journal of Construction Engineering and Management*, vol. 131, no. 1, pp. 15-22, 2005.
12. Ballard and Howell, "Competing Construction Management Paradigms," in *Proceedings of the 2003 ASCE Construction Research Congress*, Honolulu, Hawaii, 2003.
13. Koskela, Howell, Ballard and Tommelein, "Foundations of Lean Construction," *Elsevier*, 2002.
14. Abdelhamid, El-Gafy and Salem, "Lean Construction: Fundamentals and Principles," *American Professional Costructor Journal*, vol. 4, pp. 8-19, 2008.
15. Abdelhamid, "Lean Construction Principles," 2007. [Online]. Available: http://www.slideshare.net/tabdelhamid/lean-construction-introduction.
16. Kosko, "Fuzzy Cognitive Maps," *International Journal of Man-Machine Studies*, vol. 24, no. 1, pp. 65-75, 1986.
17. Locatelli, Mancini, Gastaldo and Mazza, "Improving Projects Performance with Lean Construction: State of the Art, Applicability and Impacts," *Organization, Technology and Management in Construction - An International Journal*, vol. 6, no. 2, pp. 775-783, 2013.
18. Connor and Dodd, "Achieving integration on capital projects with Enterprise Resource Planning Systems," *Automation in Construction*, vol. 9, no. 5-6, pp. 5515-5524, 2000.
19. "Esub Construction Software," [Online]. Available: https://esub.com/artificial-intelligence-construction-future-construction/.
20. "Doxel," [Online]. Available: https://www.doxel.ai/.
21. "Medium," [Online]. Available: https://medium.com/@doxel/introducing-artificial-intelligence-for-construction-productivity-38a74bbd6d07.
22. Ingle and Waghmare, "Advances in Construction: Lean Construction for productivity enhancement and waste minimization," *International Journal of Engineering and Applied Sciences*, vol. 2, no. 11, pp. 2394-3661, 2015.
23. "L&T," [Online]. Available: http://www.larsentoubro.com/media/31295/ltsustainabilityreport2014.pdf.
24. Hussain, Sekhar and Fatima, "Analysis of Lean Construction by Using Last Planner System," *International Journal of Engineering Research & Technology*, vol. 3, no. 5, pp. 1059-1065, 2014.
25. Chung, Skibniewski and Kwak, "Developing ERP Systems Success Model for the Construction Industry," *Journal of Construction Engineering and Management*, vol. 135, no. 3, pp. 207-216, 2009.

AUTHORS PROFILE

Velagapalli Vickranth received his B.Tech degree in Civil Engineering from V.R.Siddhartha Engineering College A.P. He is presently pursuing M.Tech degree in Construction Technology & Management from Koneru Lakshmaiah Education Foundation A.P. His area of Interest is in "Project Management, Quality Control in Construction Projects & Applications of Artificial Intelligence in Constructions"

Sesha Sai Ratnamala Bommareddy received her B.Tech degree in Civil Engineering from USHARAMA College of Engineering And Technology A.P. She Completed her Postgraduation M.Tech degree in Construction Technology& Management from Koneru Lakshmaiah Education Foundation A.P. She is working as an Assistant Professor in Dept of C.E,K.L.E.F,Vaddeswaram,Guntur,A.P.She is an author of three research papers in International Journal's. Her area of Interest is in "Construction Engineering and Management"

PremaLatha Velagapalli received her B.Tech degree in Computer Science and Engineering from P.V.P.Siddhartha Institute of Science and Technology (JNTU-H) A.P. She Completed her Postgraduation M.Tech degree in Computer Science and Engineering from Karunya University,Coimbatore,T.N. She is working as an Assistant Professor in Dept of C.S.E,K.L.E.F,Vaddeswaram,Guntur,A.P.She is an author of four research papers in International Journal's. Her area of Interest is in "Software Agent's in Internet of Thing's"