New Techniques For Monitoring And Controlling Productivity Of Labour And Plants

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Abstract- *India contributes to almost 10 % of gross national product through construction industry but the construction industry lacks in real time monitoring system for project performance control. Construction project is a combination of varied activities needed to complete the project objectives i.e. time, cost and quality, and delay caused in the project incur extra time and money. The timely completion of various activities requires the labours and Plants to be equally productive and monitoring of the productivity plays a vital role for preserving their productivity. Previous research indicates that there is a lack of appropriate monitoring techniques which could capture real time data precisely for measuring the variation in productivity which affected the decision making for the construction personnel. In this research efforts have been made to identify the innovative ideas which can monitor the productivity of labour and Plant on site in real time, which would help in completing the project in stipulated time and cost and meet the objectives of the project. The objective of the research is to identify factors and rank them which acts as a constraint to the labour and Plants productivity. The methodology used in this paper is to collect the data with the help of questionnaire survey from construction personnels to identify the constraint factors and rank them. After the analysis is done we can identify the gap in the current monitoring techniques in Indian construction industry and provide innovative techniques for onsite monitoring of productivity. The implication of which would be real time decision making and improved productivity.*

Keywords- New Techniques, Productivity Improvement, Labour, Plants, Project performance control.

I. INTRODUCTION

India contributes to almost 10 % of gross national product through construction industry. Construction project is a combination of varied activities which needs to be completed within the constraints of the project i.e. time, cost and quality. If the activities are not completed on time it may delay the succeeding activity and simultaneously entire project. The delay of the project directly increases the time and cost of the project and may indirectly affect the quality of the project while trying to reduce the duration of performing the activity. There are various reasons for the delay of these activities such as unavailability of material, force majeure, dispute between client and contractor etc and these are the reasons which could be identified by every major stakeholder. But there is another dimension called productivity which may delay the duration of the activity indirectly and most of the project personnel fails to see this dimension. Productivity is a measure of efforts put into for performing the activity. It is defined as output / input. Productivity not necessary reduces the duration of the activity in fact if the productivity is more or equal to desired, than the duration of the activity will not be delayed and if the productivity for performing the activity is less than desired than it may delay the activity. For performing the activity there are many resources that are required such as man, money, material, machinery etc. out of the following resources man i.e. labour and machinery i.e. plants are majorly used for performing the activity on site and helps in creating a value. The construction labour comprises of approximately 30% - 50% of the overall project cost so delay will not only affect the duration of the project but will also increase the project cost and on the other hand if the work is performed earlier than its desired duration than it could be a potential saving for the industry. If we do not check and there are certain constraint which are stopping the labour and plants from performing as per their actual rate than it would definitely act in a negative way for the project. The checking of the project activities is termed as monitoring which helps in project performance control. Talking about the monitoring of the productivity of labours and plants in current scenario in the construction industry, there are no standard techniques available which can be adopted by project personnel on the site. There are multiple factors which may affect the productivity of plants such as temperature, breakdown of the equipment, driver skills operating the equipment, site layout etc affecting the productivity of various equipment's such as tower crane, batching plant, concrete pump, transit mixer, passenger hoist and monitoring the plants for reducing these constraints to minimum is necessary. Some of the site monitor the labour and plants with the help of the supervisor while some of the projects are not even monitored. These labour and plants are monitored using time lapse video, photographs and

stopwatch to measures the amount of work done in a particular time but these data is available in a discrete form and not much reliable to calculate the actual productivity. Many researches has been conducted over the past two decades on the same area that discuss on productivity improvement by monitoring. Manual monitoring of productivity of labour and plants has faced many challenges in the construction industry and due to these actions cannot be taken just in time to address the productivity problems. The construction industry does not realize the importance of progressive monitoring tool required for the continuous monitoring of productivity because they do not realize the importance of real time data collection. So, from the above scenario there is a clear indication for the need of new techniques for monitoring the productivity of labour and plants which can provide real time data for real time decision making for the project. The current research paper tries to put light on the innovative ideas and techniques that can provide continuous monitoring of the labour and plants on the site and provide real time data for real time decision making.

II. LITERATURE REVIEW

In 1766 in an article by Quesnay the word productivity was mentioned for the first time. In 1833 Littre said that it is the desire to produce[1]. In late 20th century productivity was defined as "the relationship between output and the means employed to produce that output"[1]. The productivity was also defined as "a quotient obtained by dividing output by one of the production factors" by organization for European economic cooperation[1]. The American association of cost engineers defined productivity as "relative measure of labour efficiency[1]. By summing up all the definitions of productivity from existence till date, various researches gives general consensus to productivity as the ratio of output to input. Reference [2] in their paper suggested 2 factors i.e. technological influential factors which include plants and organizational influential factors which include labours and these two influence the construction productivity As per the study of reference [1] there are two measures of construction productivity (a) total factor productivity (TFP) and (b) partial factor productivity (PFP). Labour and plants productivity falls under PFP where labour productivity is defined as output quantity/labour hours and plants productivity is defined as output quantity/Plant hours. The above equation calculated the productivity but for finding out the effective labour and plants hours its measurement is necessary. The measurement of this effective hours is done by monitoring on site. Monitoring is important because it helps us to identify various factors affecting the productivity of labour and plants. These monitoring of labour and plants is termed as productivity monitoring. Improving labour productivity is of major concern for construction industry where its dependency is on identifying the constraints through monitoring of the productivity[3]. The monitoring helps the managers to decide the strategies for improving the productivity at site but this monitoring is done manually and with a very low frequency due to which there is no continuous assessment of productivity which made the data less reliable. The quality of data collected manually is low which involves human error and thus makes data less reliable [4]. The current monitoring methods are not real time to monitor the productivity and it requires the involvement of human to determine effective working hours which cause human error [5]. Previously Gantt charts were used as a planning and monitoring tool by supervisors but using these kind of tool nowadays is difficult in construction project because it is a manual tool and managing labour and plants at such level manually becomes difficult [6]. At project level we require a continuous monitoring rather than one time effort to measure productivity [6]. These facts helps us to guide in the direction of change in the need of monitoring productivity. Unless and until certain measures are not taken to improve the techniques for monitoring the same error will occur because monitoring each and every labour and plant on site is very time consuming and tedious process. If we do the things in the same manner as we did before than we are going the get the same result as we got before but if we want to see the change in the result we need to do something new and innovative. There is need to develop certain innovative technologies which would provide continuous productivity monitoring and help project managers to take immediate actions to improve the decision making ability for the project. Innovative ideas in the field of monitoring reflects to many areas with one of its area in automation which uses automated data collection technologies for productivity monitoring of labour and plants. The recent analysis of craft time indicated that only 45.5% of craft time is devoted to value added activities and there is no improvement in this percentage in last 40 years [7]. The automated system was suggested by reference [7] where a prototype system is developed which integrate the video analysis with computed vision algorithm which would help to interpret productivity information such as cycle time and delays from the videos without on site manual observation. Reference [4] in their paper discussed about the tracking system which would detect the labour location and movements on the site. The method of automated data collection by using on board microprocessor based sensor on plants such as scrappers can collect data automatically and provide statistical analysis for skilful decision making in real time [8]. Algorithm based techniques which extracts the pixels from an image and identify the moving objects can be used for classification of various labour and plants [9]. Reference [4] In their paper suggested colour coded hardhat tracking system which would identify the difference between the workers and

identify their motion in a given work area which would collect the worker tool time and helps in performance measurement on site. Reference [10] discussed in their paper about the 4-dimensional augmented reality model which is an image based monitoring technique where a difference between the planned construction and as-built drawing would be measured by imposing 4 dimensional planned model over site photographs with the help of different visualization technique such as traffic light metaphor. The combination of a system where a plant, a communication system and central processing system would collect the real time data about the equipment [11]. Another paper on new techniques includes an automated monitoring system for a portable monitoring unit which means plants that includes sensors which is location determining device which would monitor the location and productivity of plants [12]. Reference [6] In their paper discussed about Automated project performance control (APPC) monitoring techniques which includes techniques such as global positioning system (GPS) , radio frequency identification (RFID), 3D camera and laser scanners which effectively tracks the labour and equipment in real time. Another paper by [13] explains about a **w**ireless **r**eal t**i**me produc**t**ivity m**e**asurement (WRITE) system which involves use for digital camera, data processor, computer and wireless modems that statistically identifies the productivity and these data can be shared in project to anyone with the help of internet. A black box monitor and electronic building information model provides real time information of labour [14]. Reference [15] In his paper suggested a technique for the improvement of tower crane productivity by the use of advanced tower crane (ATC) which is provided with wireless radio control and RFID. For better transparency in progress monitoring [16] suggested application of visual data such as videos, photographs with the help of unmanned aerial vehicles as a tool for monitoring and control. Reference [17] discussed about a survey about project management information where the need for data entry at project level created obstacle for project success and suggested use of Automated data collection in construction (ADCIC) which involved computer integrated construction (CIC) as project model for data collection. The framework for automated data collection technology in construction industry was also introduced by[18] which discussed about the perception of automated technologies in construction industries. A 4D model based subsystem which includes component such activity tracking based on image recognition and a mobile computing supported communication environment can be used for more reliable information [19]. The above discussed papers provides techniques which can be implemented in Indian construction scenario. In this paper the study focuses on identifying the factors which affects the productivity of labour and plant and suggesting techniques which will reduces the effect of those factors on labour and plants which will enhance their productivity.

III. STUDY OBJECTIVES AND METHODOLOGY

A. Objectives.

The primary goal of the study is to identify the constraints in productivity monitoring and suggest new techniques which can be used in construction project for better monitoring for productivity improvement.

- To identify the project monitoring gap in construction from literature review.
- To identify the critical factors that affects the productivity of labour and plants.
- To identify new techniques for productivity monitoring in construction projects for project performance control.

The study objectives were accomplished with the help of adopted methodology explained below.

B. Methodology.

The methodology adopted for the study was a literature and questionnaire survey approach. Through literature survey the factors were identified that affects the productivity of labour and plants. The questionnaire survey was prepared and floated to identify the most critical factors affecting the productivity. After identifying the critical factors, a feedback survey was prepared to cater to the solution. The survey was floated to experienced construction personnel to rate the most significant solution as per their experience which would suit the construction industry. The adopted solution from the feedback survey would meet the objective of the study to suggest the new innovative techniques for productivity monitoring on the construction site. The methodology for the study is shown in the Fig. 1 below:

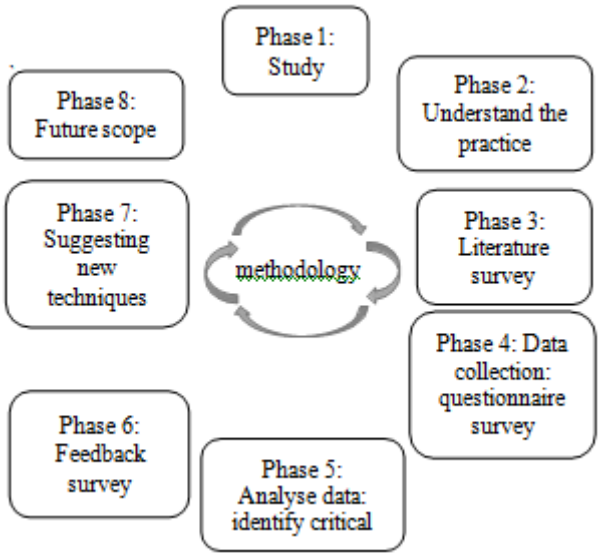

Fig. 1. Methodology of the study

The first and second phase of the methodology involves the identification of the labours and plants for which the factors would be identified which effects their productivity. After understanding the practice following labours and plants are finalized for data collection and improvement process.

The labours identified are as follows:

- Carpenter
- Fitter
- Mason

The factors that effect the labour productivity were considered technical factors, human factors and management factors for the scope of the research paper.

The plants identified were as follows:

- Tower crane
- Batching plant
- Transit mixer
- Concrete pump
- Passenger hoist

The third phase of methodology include the literature survey where after deciding the scope of survey the papers which covered the scope were studied and the previously done research were understood. The factors studied from the literature survey were used in the questionnaire survey for further data collection and analysis was done for ranking the same factors.

IV. DATA COLLECTION AND ANALYSIS

The fourth phase of the methodology includes data collection from questionnaire survey. The questionnaire survey was prepared after understanding the scenario in industry and identifying their need. The survey was floated to 55 construction personnel i.e. project manager, project engineer, supervisor, contractor and others and 30 responses were received with a response rate of 54.54 % for both labour and plants. The questionnaire survey included the questions which capture the current practice adopted in the construction industry for monitoring the productivity and the factors affecting their productivity. The questions asked for factors were rated as shown in table I below:

TABLE I.
QUESTIONNAIRE SURVEY RANKING METHOD.

1	2	3	4
Not applicable	Does not affect it	Somewhat affect it	Directly affect it

The fifth phase of the survey includes analysis of the data collected. The analysis would convert the qualitative data into quantitative data. The analysis of the survey was done to identify the most critical factors from the above mentioned critical factors in the data collection. Although all the above factors affect the labour and plant but as per the response from the experienced construction personnel factors which were in the category of directly affecting it more than 50 % to the labour and plant were taken into consideration for the further study. All the other factors were not considered because it would affect the quality of the study. These identified critical factors will be the main component in suggesting new techniques for productivity monitoring. The factors directly affecting the labour productivity are shown from Fig. 2 to Fig. 4.

A. Technical factors - Labours

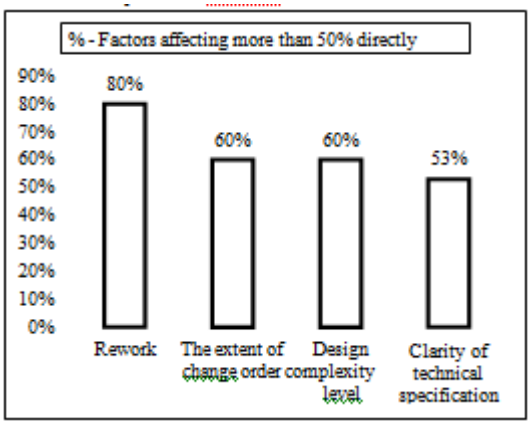

Fig. 2. Critical technical factors affecting labour productivity

B. Human / labour factors - Labours

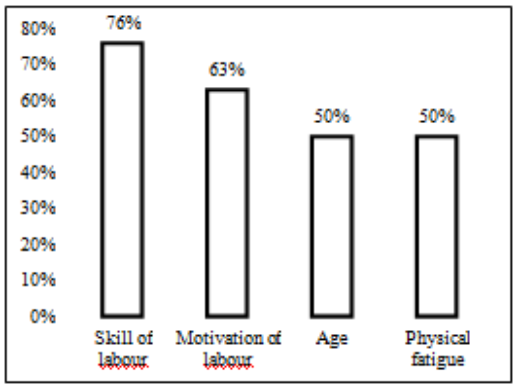

Fig. 3. Critical human factor affecting labour productivity

C. Management factors - Labours

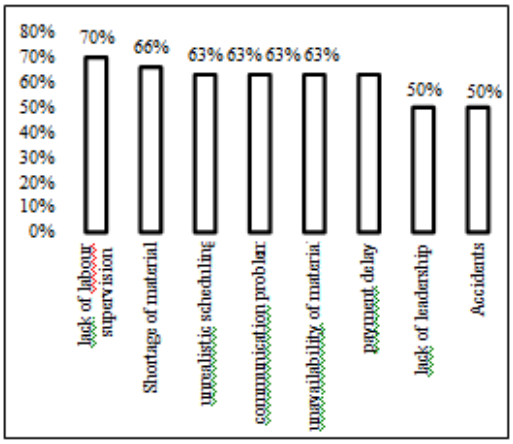

Fig. 4. Critical management factors affecting labour productivity.

After analysis, the critical factors affecting the plants productivity are shown from Fig. 5 to Fig. 9.

A. Tower crane factors – Plants

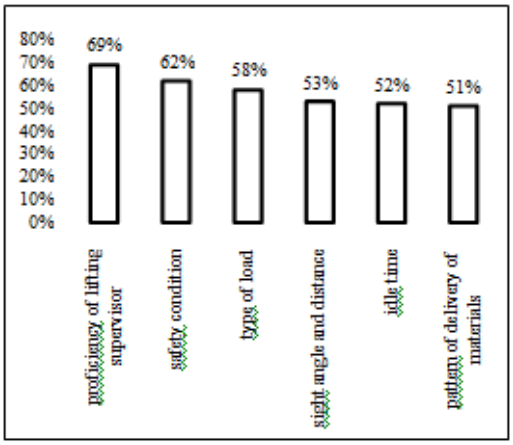

Fig. 5. Critical factors affecting tower crane productivity

B. Transit mixer – Plants.

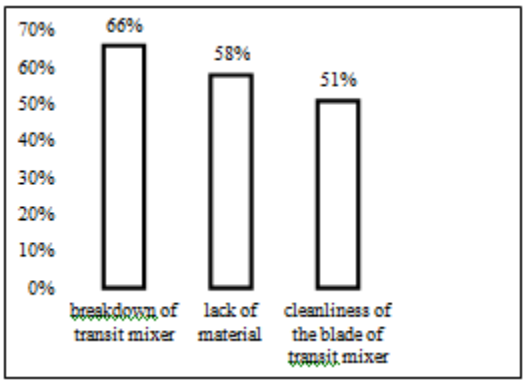

Fig. 6. Critical factors affecting transit mixer productivity

C. Concrete pump – Plants.

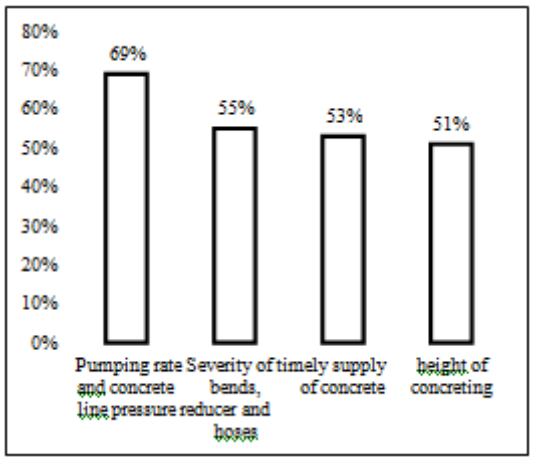

Fig. 7. Critical factors affecting concrete pump productivity

D. Batching plant – Plants.

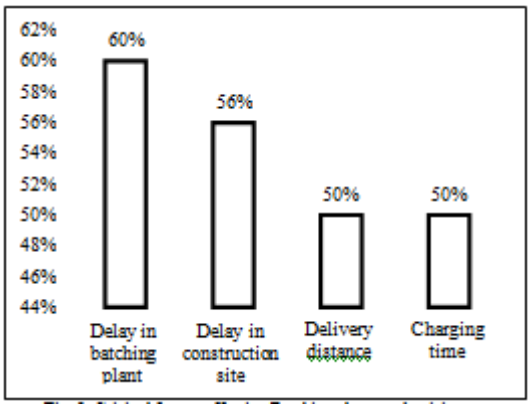

Fig. 8. Critical factors affecting Batching plant productivity.

E. Passenger hoist – Plants.

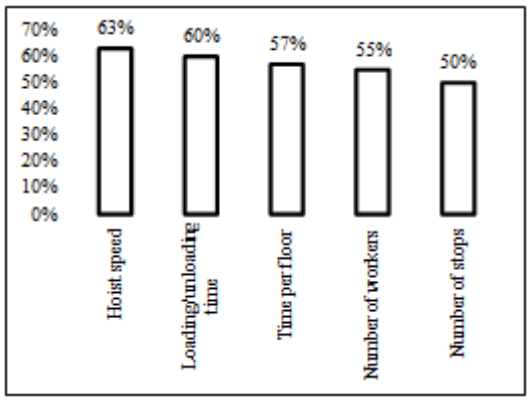

Fig. 9. Critical factors affecting passenger hoist productivity

The above factors are ranked as per the amount of percentage it has impact on the productivity of labour and plants and are shown graphically in the above graphs.

V. FEEDBACK SURVEY

The sixth phase of the methodology is the feedback survey. In this survey after analysing these factors the questionnaire was prepared which included the solution to tackle the factors. The questionnaires consist of 15 questions send to the same construction personnel who answered the previous questionnaire survey to maintain the quality of the study. The questions asked were converted from qualitative to quantitative by Likert scale in the following manner showed below in table II

TABLE II. FEEDBACK SURVEY RANKING METHOD

1	2	3	4	5
Strongly disagree	Disagree	Neutral	Agree	Strongly agree

The feedback survey was floated to 30 construction personnel and response received were 21 with a response rate of 70% which included questions for both labour and plants.

SOLUTION FROM FEEDBACK SURVEY

The seventh phase of the methodology include suggesting new techniques for productivity monitoring of labour and plants. The survey responded by the respondents was analysed using rating scale from 0 to 1. Later the weighted average sum was calculated to identify the solution with more than 80% confidence. The technique used for ranking the solution is shown in the table III below:

TABLE III. RANKING METHOD FOR FINDING SOLUTION

0	*0.25*	*0.5*	*0.75*	*1*	*Weighted sum*
Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Number of responses x 0.80

The solution suggested by the construction personnel from the questionnaire survey are shown in table IV below.

TABLE IV. SOLUTIONS FROM FEEDBACK SURVEY.

Sr.no	Solution
1	Factors such as skills of labour, motivation of labour, communication problem between site management & labour, physical fatigue effects the productivity of labour. Therefore automated real time image processing techniques which recognize 3D position of human body would help in identifying the factors at early stage to improve productivity.
2	Factors such as shortage of material, unavailability of suitable material affects the labour and equipment productivity. These factors can be reduced by using automated activity tracking subsystem based on image processing.
3	Factors such clarity of technical specification, extent of change orders during construction and design complexity level reduces the productivity of labour and equipments. Automated 4 dimensional augmented realty model for monitoring productivity should be implemented instead of manual monitoring techniques
4	Factors such as idle time, proficiency of lifting supervisor, safety condition at site effect the tower crane productivity. Advanced tower crane with radio frequency identification technology improve information flow and drivers efficiency to reduce the factors effecting its productivity.
5	Automated data collection technique such as UAV/ UAS (unmanned aerial vehicle / unmanned aerial system) can increase productivity of tower crane, transit mixer, passenger hoist by identifying factors such as breakdown of transit mixer, time per floor for passenger hoist and pattern of delivery of materials for tower crane
6	Automated RFID technology can be used in batching plant to identify the delay in batching plant and factors such as timely supply of concrete in concrete pump to improve their productivity.
7	Factors such as cycle time, accidents, lack of labour supervision and rework reduces the labour productivity. Algorithm based computational intelligent construction video interpretation would help in reducing the impact of these factors.

VII. RESULT AND CONCLUSION

The feedback survey suggested various automated monitoring techniques which were innovative and could be implemented on the construction site practically. In the current scenario manual techniques such as visualization, parametric estimation, on site supervision and time motion study are used to monitor productivity on site but this are not real time techniques and actual productivity cannot be judged from these techniques. This is what the objective of the study was to identify the gap in monitoring in construction scenario. Secondly the techniques used currently requires human factor to monitor which caused error. The study focused on the objective of suggesting the new innovative techniques such as real time image processing which recognize human position to tackle factor like skill of labour and fatigue of labour. Automated tracking subsystem which reduces the affect of factors such as shortage of material and unavailability of suitable material which affected labour and plant productivity. An automated 4D augmented model for reducing change order, design complexity level and increasing the clarity of technical specification which would increase the productivity of labour and plants. For tower crane an advanced tower crane could be used which may reduce the idle time and lifting efficiency of the supervisor. Automated data collection techniques such as unmanned aerial vehicle can be used to identify working time of labour automatically and can be used to check the breakdown of the passenger lift, breakdown of transit mixer, time per floor for passenger lift to measure their productivity. Radio frequency identification techniques can be used monitor working of batching plant, timely supply of concrete to the concrete pump which shall increase the productivity of batching plant and concrete pump. Another technique called algorithm based computational video interpretation technique was also suggested to reduce the factors such as cycle time, accidents, lack of labour supervision and rework. By adopting these new techniques, the data would be captured in real time, the decision would be made in real time based on real time data. As time is the major factor in the completion of project these techniques would reduce factors that increase the duration of labour and equipment, thereby increasing the productivity and reducing the delay in the project. Therefore, these new techniques have a long term hidden advantage for the entire project lifecycle.

VIII. FUTURE SCOPE

The study had a limitation of implementing the suggested techniques on the case study for its validation on the life cycle of the project. The study can be further undertaken by using the factors affecting the productivity on the site and implementing those techniques on the site to check the reduction in affect of the factors on the labour and equipment. The study also included only few labour and plants for the study therefore this study can also be taken forward by including more number of labours and plants and also the staff member of the site office to validate these new techniques and its performance improvement on every member and plants of the construction project.

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