

# Internet of Things Platform to Monitoring & Controlling Project Remotely: A Qualitative Analysis

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**Abstract**— The study objective is to evaluate schedule performance with the Internet of Thing platform in monitoring & controlling construction project. IoT is connecting physicals on the site with virtual things on the screen which enable the stakeholders to collaborate anywhere in real time. It used a qualitative method for coding, data visualization and finding a pattern to draw a conclusion with NVivo software. Data sources for the literature review consist of 26 journal articles about the Internet of Things in constructions project. They were published after the 4th industrial revolution in 2011. A structured interview was used as instrument data collection from four experts. Findings of the study show that the IoT platform can reduce rework, increased productivity, shorten project organization process, improve stakeholder collaboration, and use valid project document & information of the project case study. These show how IoT Platform can increase the schedule performance. This study embraces us to use the 4th industrial revolution technologies in the construction industry.

**Keywords**— internet of things, 4<sup>th</sup> industrial revolution, monitoring & controlling project, schedule performance.

## I. INTRODUCTION

The use of advanced technologies in 4th industrial is not only the internet of things but also big data and artificial intelligence. These technologies are already there but we don't optimize it. Especially in the developing country in this case study, the constraint of the new technology adoption is their reservation about its application and short-term investment. Traditional management systems and means have been far from enough to meet the needs of the requirements of the project's management [1].

The internet of things (IoT) is a global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies [2]. IoT allows connected devices to be monitored and controlled remotely through an internet network infrastructure. Connected devices can be sensors, actuators, smartphones, computers, buildings and home/work appliances, cars and road infrastructure elements, and any other device or object that can be connected, monitored or actuated [3]. The independent devices of the past are now being connected to the Internet including machine-to-machine (M2M), person-to-machine (P2M), and

person-to-person (P2P) systems [4]. The use of IoT can integrate data and reduce human intervention resulting in transparency, accuracy, efficiency, economic value, and other additional values [5]. Granted, to date most of IoT deployments have been incremental and evolutionary, streamlining an existing process here, cutting some costs or improving productivity there [6].

The application of IoT in virtual project management takes a case study on an industrial building project of PT. X. By takes the case study, the author will evaluate schedule performance with the IoT platform using the qualitative method. This industrial project uses an organizational type of matrix-balanced. This can be seen from the job role of the Project Manager like a coordinator [7] and not including the decision of the project budget/commercial and material specification approval. This is done to avoid conflict of interest, by separating technical matters in the field and commercial decisions at the head office. The decisions must go through the approval of the Project Owner on the Project Manager's recommendation.

In addition, this project uses the compression schedule of fast-tracking technique where activities are carried out in parallel [7]. Accelerating the schedule may increase the number of critical activities [8]. The compression schedule of this project increases the risk of work and may produce rework. Reducing the risk that occurs due to fast-tracking can be done by increasing project monitoring and controlling. The visit of other consultant teams to the field is carried out as needed. This makes monitoring and controlling of the project are inefficient on schedule performance.

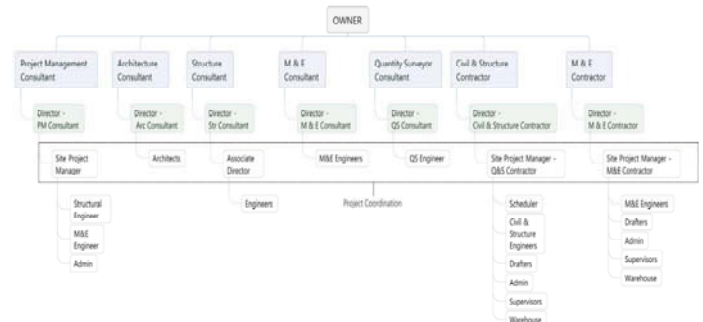


Fig. 1. The matrix-balanced organizational structure of PT. X Project

This research aims to evaluate schedule performance in the project monitoring & controlling system using the IoT platform. The application of IoT technology is a solution for virtual project management without being limited by distance and collaborating all stakeholders involved in real time. The optimum IoT communication system in project monitoring and control can launch organizational processes virtually. The optimal monitoring and controlling of the project can directly improve project schedule performance.

## II. LITERATURE REVIEW

The scope of this study is schedule control on monitoring & controlling process group. The suit IoT technology is cloud base digital collaboration & mobility, and real-time Sense Platform. Where changes that occur in the process of monitoring & controlling need to be updated quickly, transparently, accurately and efficiently to each stakeholder.

Authors collected 26 journal articles about the Internet of Things applications in the construction industry. It used as references and comparisons with this study as shown on the meta-analysis table. The novelties are as follows:

- The case study of PT. X Industrial Project in Indonesia that uses the matrix-balanced organizational and uses the fast-tracking as compression schedule technique.
- The construction phase studied is during Monitoring & Controlling using the schedule management knowledge area.
- The IoT platform variables used is Cloud-Based Digital Collaboration & Mobility using Dropbox, TeamGantt & Basecamp platforms, and the Real Time Sense Platform using web-based CCTV.
- This research method uses value engineering method and qualitative analysis through interviews with experts. It used NVivo 12 software to code & categorize the data, to display the data and to draw off its conclusion.
- The objective of this research is to evaluate the effects of the IoT platform on schedule performance.

TABLE I

A META-ANALYSIS OF IoT APPLICATIONS IN THE CONSTRUCTION INDUSTRY

No	Author	Year	Location	Internet of Things Variables			Methods		
				Building Information Modelling (BIM)	Cloud Based Digital Collaboration & Mobility	Real Time Sense Platform	Quantitative	Qualitative	Value Engineering
1	Tang et al.	2012	Taiwan		V		V	V	
2	Lee and Yu	2012	South Korea		V		V	V	
3	Kang et al.	2013	United States	V	V		V		
4	Kim et al.	2013	South Korea		V	V		V	
5	Tjell and Sijtsma	2015	Sweden	V	V			V	
6	Gustafsson et al.	2015	Sweden	V	V		V		
7	Shibeika and Harty	2015	United Kingdom	V	V			V	
8	Dave et al.	2016	Finland	V	V	V		V	
9	Khan et al.	2016	United Kingdom		V			V	
10	Li et al.	2016	Hong Kong	V	V	V		V	
11	Jaurainen et al.	2016	Finland	V				V	
12	Han and Farid	2017	United States	V		V		V	
13	Bhat et al.	2017	India		V		V		
14	Zhong et al.	2017	Hong Kong	V	V	V	V	V	
15	Junior et al.	2017	Brazil		V	V		V	
16	Svidt et al.	2017	Denmark	V	V	V		V	
17	Teizer et al.	2017	Germany	V	V	V		V	
18	Montoya et al.	2017	Spain		V	V		V	
19	Petri et al.	2017	United Kingdom	V	V			V	
20	Li et al.	2017	Hong Kong	V	V	V	V	V	
21	Li et al.	2018	Hong Kong	V	V	V		V	
22	Xu et al.	2018	Hong Kong	V	V	V		V	
23	Woodhead et al.	2018	United Kingdom	V	V	V		V	
24	Hattab and Hamech	2018	Lebanon	V	V		V		
25	Ma and Liu	2018	China	V				V	
26	Sankaran et al.	2018	United States	V	V		V		
27	Berawi et al.	2019	Indonesia		V	V		V	V
Total				10	23	14	6	23	1

NVivo showed many major themes from the collected journal articles, such as information, data, process, and system. It means IoT application in the construction industry changes how information, data, process, and system working. Every staff survey that is produced in companies around the world has a major theme in the results, 'Nobody keeps us informed, we are not consulted' [9]. We're spending 80 percent of our time collecting data and 20 percent of our time analyzing it. With technology enhancements, we're trying to flip those percentages [10].

This research aims to evaluate schedule performance improvement in the project monitoring & controlling system using the IoT platform. The application of IoT technology is a solution for virtual project management without being limited by distance and collaborating all stakeholders involved in real time. The optimum IoT communication system in project monitoring and control can launch organizational processes virtually. The optimal monitoring and controlling of the project can directly improve project schedule performance.

### A. Cloud Base Digital Collaboration & Mobility

One reason for the industry's poor productivity record is that it still relies on paper to manage its processes and deliverables such as blueprints, design drawings, procurement, and supply-chain orders, equipment logs, daily progress reports, and punch lists [11]. The digitization process means the hardcopy of paper becomes an online soft copy, sharing information in real time to help project collaboration, periodic progress tracking, risk assessment, and quality control. This is anticipated better, and the results are more reliable.

The readiness of internet infrastructure in Indonesia is far from enough. Refer to the Global Competitiveness Report 2018, the weakness of the adaptation of information and communication technology to cable internet customers is only 2.3% of the population. This made Indonesia ranked 104. In addition, the number of internet users in Indonesia is still small, namely 25.5% of the population and with a ranking of 110 compared to the others [12].

The decision in determining the platform to be used depends on the total project budget, the greater the project budget, the more complete and detailed platform packages are needed. Dropbox Business, Teamgantt, and Basecamp are the platform used in this case study of PT. X project.

### B. Real-Time Sense Platform

Projects in the site process a lot of data that occurs, but only a few are recorded that can be measured and processed. IoT sensors and wireless technology can enable equipment and assets to be intelligent by connecting them with others. In the site of construction projects, IoT will enable construction machinery, equipment, materials, structures, and even formwork to "communicate" to the central IoT platform. The IoT platform shows critical performance parameters in real-time. Sensors, near-field-communication devices, and other technologies can help to monitor productivity and reliability. Potential uses are monitoring and repair, inventory management, quality assessment, energy efficiency and safety [11].

Understanding the current status of the project and knowing what is going on the site, is very important for

construction experts to monitor and control construction projects. In the past, project information and regular photos were obtained by visiting the project site. Now, using IoT can access project information and site photos through devices connected to the data server. In this case study, several CCTV HD units were installed at the project site. Modern CCTV system is the most practical value belongs to the objects tracking in real time [13].

### III. METHODOLOGY

This study does a depth qualitative analysis from the previous study [5] used value engineering method. Value Engineering (VE) is an effort with systematic and organized system function, production, and service to reach the essential function of life cycle cost [14]. The targeted objective in this study is achieved with a qualitative method using NVivo software on the information phase and the evaluation phase. There are generally three steps in qualitative data analysis: data reduction (the process of selecting, coding and categorizing the data), data display, and the drawing of conclusions [15].

There are two qualitative data in this research. Secondary data are using 26 journal articles as shown in Table I. And the primary data were collected through interview with the experts. Authors interviewed 4 experts as follow, operational manager from the owner, construction manager from the consultant, civil & structure coordinator from the owner, and MEP Coordinator from the owner. We use judgment sampling technique which involves the choice of subjects who are most advantageously placed or in the best position to provide the information required [15].

The objective is to evaluate the effects of IoT communication to schedule performance with qualitative method. The qualitative data is 26 journal articles and 4 interview transcripts. Authors found function analysis system technique (FAST) through a value methodology standard from the previous study [5].

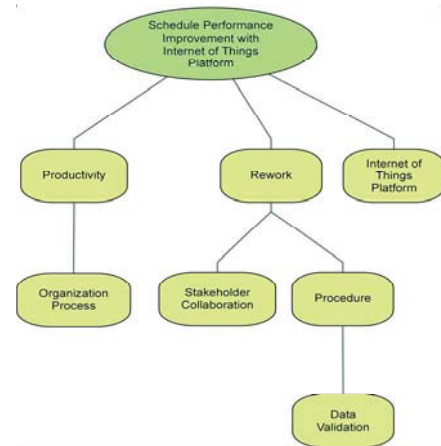


Fig. 3. Structure theme from the FAST Diagram

### IV. RESULT & DISCUSSION

To codify is to arrange things in a systematic order, to make something part of a system or classification, to categorize [16]. The theme structure in NVivo 12 from the interviews is to explain the increase in project schedule performance using the IoT platform. Based on the results of the FAST Analysis The following diagram of the theme structure in Fig. 3. This structure will be used as a coding reference for the journal articles and the transcripts interview in NVivo 12.

Fig. 4. below shown percentage agreement of schedule performance improvement using IoT platform from the article journal as a literature review. The title of the 1<sup>st</sup> rank article is [17]. In relation to BIM research and practice, this study contributes to the knowledge of BIM-design implications. Results highlight the need for implementing a BIM-based design “process” rather than only a BIM-based design “tool” so that collaboration and shared understanding can be an integral part of the design process [17]. This study explained that IoT platform can increase stakeholder collaboration through the process. Refer to the FAST

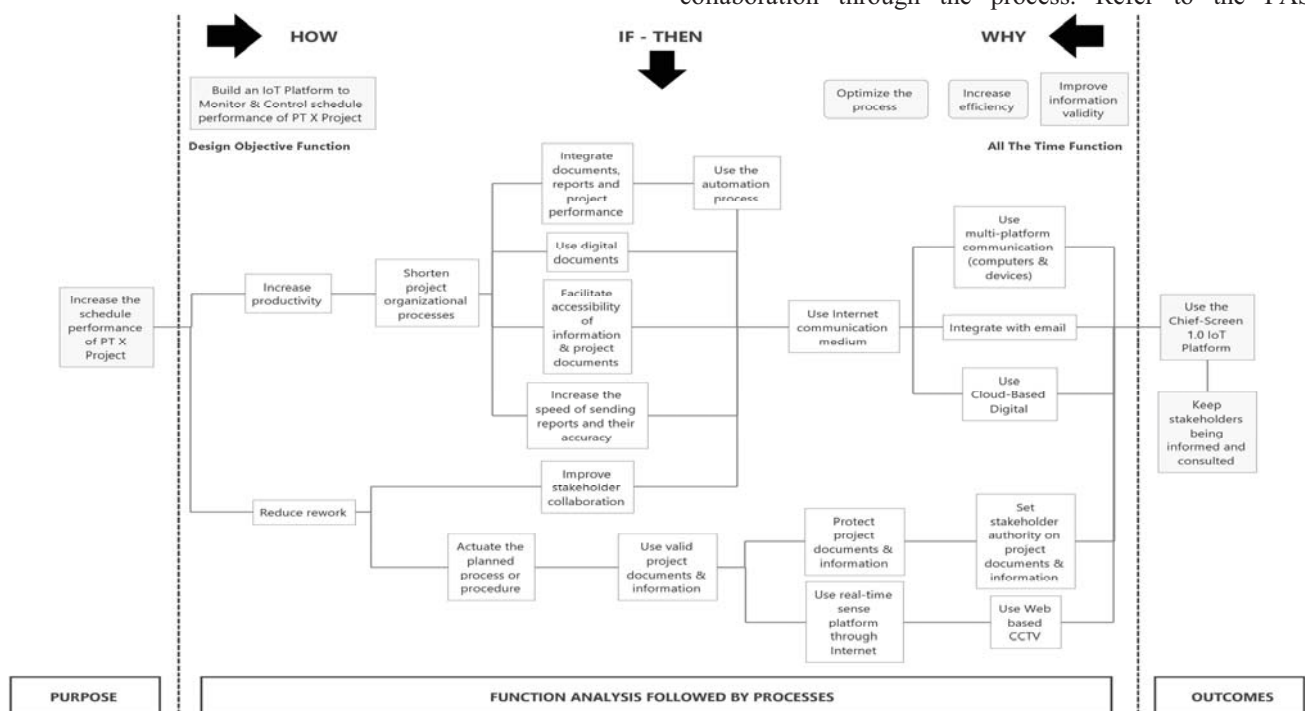


Fig. 2. FAST diagram of the IoT platform with the schedule performance improvement



diagram in Fig. 2. These things can affect of rework reduction then improve schedule performance.

The IoT platform can improve schedule performance by improving workflow to reduce rework, defect, and errors which are detrimental to the project [17,18,19,20,21,22,23]. According to [18,24,25,26,27,28,29,30] the high percentage of defects detected in buildings that have the root cause in the construction phase could be avoidable with a more accurate and efficient control of the process. The present work proposes a novel integration model based on the information and communications technologies for the automation of both construction work and its management at the execution phase.

The IoT platform help to collect data from the site and collaborate effectively all stakeholders in real-time [1,23,26,31,32,33,34]. Accurate and timely understanding of on-site information about work tasks and construction resources facilitates management decisions toward improving construction productivity [21,35,36,37,38]. The IoT platform will accelerate organization processes to finish the project [17,19,20,29,39,40,41,42]

Authors categorized the interview transcripts as follow the themes in fig. 3. with an average of percentage coverage is 97.63%. Seeing the results of coding the primary data there is no new category that appears, which shows that a series of structure categories of functions analyzed to form an adequate representation of schedule performance improvement events on the IoT platform. The most dominant themes are; rework, productivity, procedure, organization process, stakeholder collaboration and data validation by the number of coding as shown in fig.5.

Using NVivo, the interjudge-reliability can be calculated in the form of percentage agreement and kappa coefficient. The reliability test results on the percentage agreement obtained an average value of 94.03% and a minimum value of 87.89%. While the kappa coefficient obtained an average value of 0.86 and a minimum value of 0.76.

Operational Manager quote about IoT platform is “For me, the main purpose of IoT is basically to collect data. If we know the data, then we can do something from it. For example, I don't know what is happening in the site, so with IoT, I can get detailed things through the internet at the real-time or after and analyze the data. This is the beauty of IoT.”

Coordinator MEP quote about the procedure is “in the case study of this project happened where the contractor requested approval directly from the owner and it violated the procedure. PM Consultants and other Consultants do not know what has been approved, so it is very risky at the time of implementation. With digitalization, it can guarantee that the procedures we plan can run according to the stages.”

Construction Manager quote about organization process is “Using IoT platform, all stakeholders such as consultants do not need to be in the field, reducing paper use, and making decision-making time faster as in this project only takes 1-2 days. So, the construction time can also be started faster.”

Coordinator civil & structure quote about data validation is “Dropbox, teamgantt, and basecamp can save project documents and reports on the cloud storage. It can be accessed easily for monitoring and analysis with any devices, anywhere and anytime.”

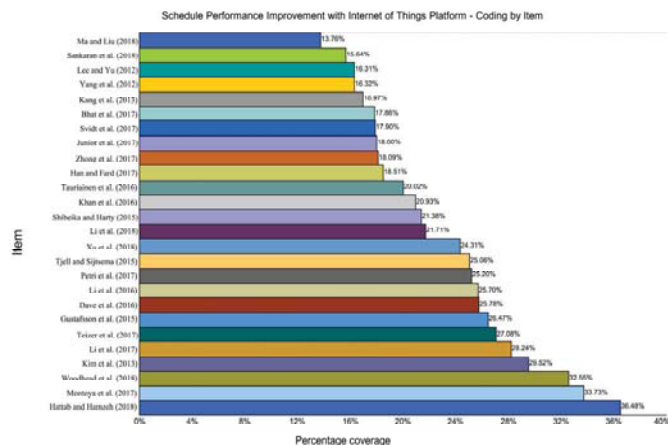


Fig. 4. Percentage coverage of schedule performance improvement with the internet of things platform from 26 journal articles using NVivo

No	Codes	26 Article References		4 Transcript Interviews	
		Number of coding	Aggregate number of coding	Number of coding	Aggregate number of coding
1	Nodes\Internet of Things Platform	856	856	52	52
2	Nodes\Productivity	874	1660	0	60
2.1	Nodes\Productivity\Organization Process	786	786	60	60
3	Nodes\Rework	166	1786	12	109
3.1	Nodes\Rework\Procedure	396	973	18	55
3.1.1	Nodes\Rework\Procedure\Data Validation	577	577	37	37
3.2	Nodes\Rework\Stakeholder Collaboration	647	647	42	42

Fig. 5. Compared by number of 26 coding references article and 4 transcript interviews using NVivo

## V. CONCLUSION

The study objective is to evaluate the effect of schedule performance using IoT platforms. FAST diagrams in fig. 2. are generated by a value methodology standard in the previous study [5] as a reference to the theme structure in fig. 3. The qualitative data were 26 journal articles and 4 interview transcripts that were analyzed using NVivo.

After conducting the qualitative analysis with NVivo, we found that there are 6 most important factors are; reduce rework, increased productivity, shorten project organization process, improve stakeholder collaboration, and use valid project document & information. The 6 factors are increasing the schedule performance of the project case study using the IoT platform.

We learn from history that the 4th industrial revolution has happened in the exponential curve. After IoT, others coming wave are big data and artificial intelligence in the near future. We suggest doing more studies for the implementation of the 4th industrial revolution technologies in the construction industry.

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