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Artificial Intelligence HSE Monitoring & Digital Value Stream Mapping for Prefabrication Yard

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Abstract

In the oil and gas (O&G) construction project, the most critical part is monitoring and tracking the overall productivity of prefabrication. Productivity measurement was previously done using a manual method, where the process and workers' productivity were recorded and analyzed. With the rapid rise of the Industrial Revolution 4.0 (IR 4.0), applying digital technology will improve overall productivity and provide continuous process improvement. There is a lot of digital technology available in the era of IR 4.0; among the technologies potentially adopted in O&G prefabrication work is digitalization through the Internet of Things (IoT). With the various digital solutions in the market, the research study aims to understand and investigate the adoption and application of Digital Value Stream Mapping (DVSM) for monitoring and tracking overall prefabrication productivity through a questionnaire survey method. After the investigation, the Digital Value Stream Map (VSM) framework was developed for productivity monitoring and tracking for prefabrication work in the O&G industry. Then, validate the developed DVSM framework model through interviews with subject matter experts (SMEs) and pilot deployment of the DVSM framework model at a selected onshore prefabrication yard. The pilot deployment of the DVSM framework provided the outcome of the analysis of the existing process flow, then an enabler to predict the future state of the onshore prefabrication process flow by eliminating the waste produced from labor and material. Finally, the pilot deployment of the conceptual DVSM framework model has proven that the model has improved the overall onshore prefabrication productivity; the study recommends further expand the DVSM framework model in the offshore environment where to track and improve overall construction productivity during the hook-up and commissioning phase either for Brownfield projects or Greenfield projects.

1. Introduction

In project management for the brownfield project, among the challenges faced by the project team was monitoring and tracking the construction's productivity during the execution phase. The challenges in the brownfield project face the multiple activities performed simultaneously with the live platform operation [1],[2]. Therefore, it is essential to understand the root causes of the productivity issues in performing the construction work for O&G projects. It was forecasted that the outlook for Man-Hours (millions) spent on Hook-Up and Commissioning (HUC) work for the next three years from 2022, 2023, and 2024 is shown in Fig. 1. It was forecasted that in 2023 and 2024, the highest man-hours for HUC would be 5.4 million man-hours and 4.1 million man-hours [3].

VSM as one of the tools in lean management is to improve the overall process and productivity by eliminating the wastes from the process line [4],[5]. Value Stream Mapping visualizing and comprehending the flow of information and material is made possible, and this definition concurred [6],[7]. The wastes identified in the VSM are from the production routine. Using VSM will provide a systematic process for eliminating wastes from labor, material, design, and workflow [8],[9].

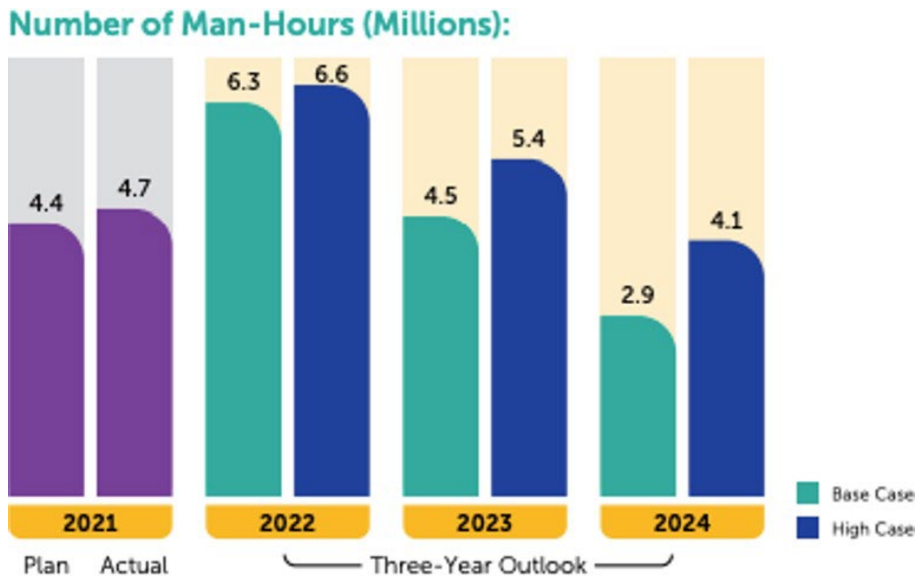

Fig. 1 *Three-year outlook of several Man-Hours (Millions) for Hook-up and commissioning activities [3]*

For the current practice in the O&G company, the monitoring and tracking of the overall productivity during the construction phase work through manual observation and tracking either execution at onshore or at offshore work site. The activity's supervisors or team leader will supervise the construction workers' activity during the prefabrication work. The overall output of the completed prefabrication items achieved by the end of the tasks will be recorded, such as the duration to complete welding and cutting tasks for piping and structural products. Before starting the offshore construction, preparation must be completed onshore, where the prefabrication spools and structural items will be constructed at the prefabrication yard. The offshore execution phases for the brownfield project are divided into three parts: the pre-shutdown phase (Pre-SD), the shutdown phase (SD), and the post-shutdown phase (Post-SD).

On the other hand, the brownfield project's challenges to execute the Hook-up and Commissioning (HUC) tasks during the offshore execution phase. Since HUC phase is conducted offshore, the cost of the HUC phase is high, and project completion within the intended timeline is critical to minimize cost escalation to the overall project cost. Non-productive time (NPT) will cause the project delay, and the Project Management Team (PMT) will incur additional costs to complete the project. However, the delay of the onshore prefabrication work will subsequently impact the start work of the offshore execution phase and the critical milestones of a brownfield project.

The non-productivity man-hours data collected from the execution of the actual project from Malaysian Water was divided into three regions in Malaysia: Peninsular Area (PMA), Sarawak Area (SKA), and Sabah Area (SBA). From the data recorded, the Non- Productive Time (NPT) is categorized into 5 categories in the company definition, which are:

(a) NPT 1- Waiting on Weather (WOW)
(b) NPT 2- Operation Constraints
(c) NPT 3- Simultaneous Operations (SIMOPS)
(d) NPT 4- Resources Constraints/Failure
(e) NPT 5- Reworks/Site Modifications

The recorded NPT from the described regions calculated that the total NPT value in 2018 was RM 81 million, in 2019 was RM 92.2 million, and in 2020 RM 93.6 million, as shown in Fig. 2.

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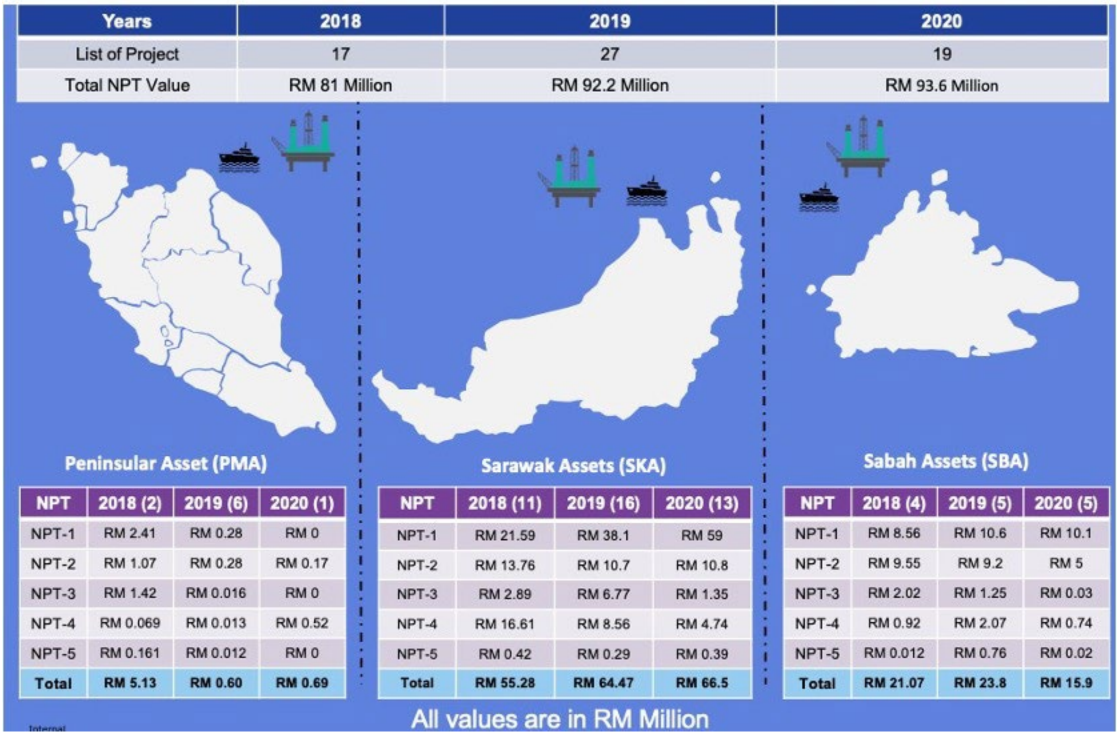

Fig. 2 *Malaysia regional Non-Productive Time (NPT) cost analysis*

2. Project Objective

This paper presented the adoption of the Digital Value Stream Mapping (VSM) framework in applying the Internet of Things (IoT) and Artificial Intelligence (AI) in onshore prefabrication yard. With the implementation of the VSM in digitalization with IoT and live streaming monitoring is available. The main objectives of the usage of digital technology with the integration of the Internet of Things (IoT) are as follow:

(a) Monitor and track the productivity of the workers at the prefabrication hall. This enables the project team (PMT) to identify any non-productivity time (NPT) and areas for improvement.

(b) Safety live streaming monitoring and detecting on the PPE non-compliance, that will be notified to the safety team, and immediate intervention can be taken. The digital system identifies PPE non-compliance of the construction personnel at the prefabrication site.

3. Problem Statement

For the brownfield project, the offshore execution depends on the readiness of the prefabricated items that will be hook-up and installed offshore. The prefabricated items are fabricated at an onshore yard and will be shipped out to offshore based on the offshore hook-up execution strategy. Therefore, it is essential to ensure the prefabricated items are delivered to the offshore site based on the planned schedule to ensure the smooth execution of an offshore campaign. There are 3 major phases for Brownfield projects are Pre-Shutdown Phase, Shutdown Phase and Post Shutdown Phase.

The prefabricated items' priority during the onshore fabrication will be based on the brownfield offshore phases. The fabrication and delivery of the prefabricated items will be based on the plan phases. The onshore fabrication work must complete the prefabricated items on time and deliver the material as planned. Any delay in the pre-fabrication work will subsequently delay sending out the pre-fabrication material to offshore, then will subsequently impact the progress execution at offshore.

To avoid the slippage of the offshore schedule for the Brownfield Project, the project team must ensure the delivery of the prefabricated items as planned. However, to achieve the delivery as planned, the onshore team must ensure the fabrication work as scheduled progress. To achieve the target's progress, it is crucial to ensure the daily onshore prefabrication target's productivity is achieved. This is among the project team's challenges in monitoring and tracking the onshore prefabrication productivity at the fabrication yard. Therefore, it is essential to understand the root causes of the productivity issues in performing the onshore prefabrication work for the O&G brownfield project.

4. Method and Theory

The method uses Artificial Intelligent (AI) technology with IoT, where the monitoring of the hall site uses CCTV connecting to the internet. Then, the prefabrication hall environment translates to the digital twin environment. All the action and activity in the hall will be streaming through the internet, and online live monitoring is in place. The digital system will set several Artificial Intelligence (AI) parameters in the algorithm for monitoring and tracking productivity and HSE PPE compliance. From time to time, the AI parameter algorithm for monitoring and tracking will be improved to ensure the accuracy of identifying activities performed through the developed digital application.

The construction workers' productivity and overall HSE PPE compliance within the prefabrication hall will be monitored and tracked. The outcome of the digital system monitoring through video captured from the CCTV will then feed into the digital system for data processing. Finally, the developed digital system will analyze the live streaming video to come out with the productivity analysis. From the data processing, the AI algorithm is used to identify the activity characteristics to determine the non-active activity and active activity for productivity monitoring.

Another AI algorithm identifies HSE PPE compliance, such as wearing a safety helmet and coverall while working at the prefabrication hall. The flow of the digital system monitoring and tracking for productivity and HSE PPE compliance is shown in Fig. 3 where the capturing activity through the feed input from the CCTV. Then, the captured activity within the prefabrication hall will be processed and to classify the activity based on the construction workers' idle time and active time throughout the day.

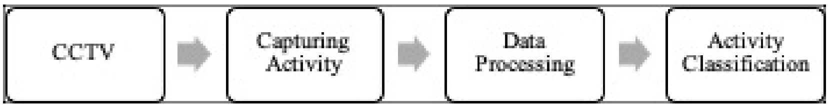

Fig. 3 *Flow process of the digital system for the productivity and HSE compliance monitoring*

5. Productivity in Fabrication Hall

All In construction, the productivity ratio in assessing manual labor productivity shows whether employees are "productive/unproductive" or "working/non-working" [10]. A productivity and safety score for the construction industry with the Construction Safety Audit Scoring System (ConSASS) [11]. Through the evolution of the productivity safety track in the construction industry, labor safety issues have excellent possibilities because of technology applications and labor safety statistics [12].

However, Critical Success Factors (CSFs) will affect the productivity performance at construction sites in Malaysia [13]. A productivity prediction system for the construction of aircraft final assembly, in which the main challenges to having an accurate prediction system are that different labor combinations and production methods significantly impact productivity [14].

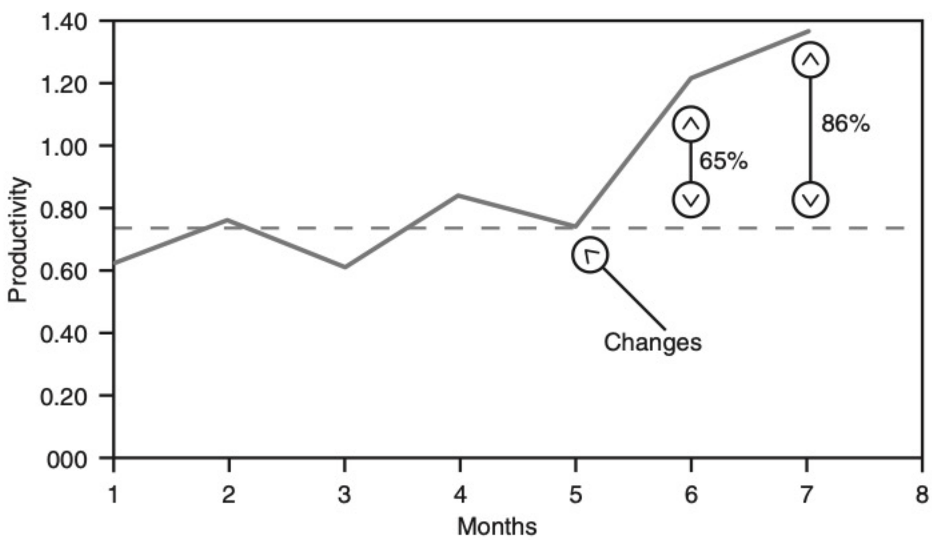

Fig. 4 *The implementation of lean construction and its improvement after a few months [18]*

However, productivity can also be defined as human health, welfare, and productivity [15]. For a construction project, each project will face challenges to achieving good productivity performance, which a study develops a model of the factors that will affect construction labor productivity [13], [16]. Among the productivity challenges are execution at the production management stage and the uniqueness of the multiple workers [10], [17]. However, with the rise of IR 4.0 technology, the application of tracking wearables provides some fear within the labor force, even though the objective is to improve the overall productivity at the construction site [12]. Implementing the lean construction has shown overall productivity improvement, as shown in Fig. 4.

6. Results and Discussion

Through the pilot deployment of this Artificial Intelligent (AI) algorithm application with the Digital Value Stream Mapping (DVSM) in monitoring and tracking productivity and HSE PPE compliance at the onshore prefabrication work site, the project has successfully captured the overall productivity rate in the prefabrication hall. Identifying the active and non-active work within the hall has provided a comprehensive view of productivity during working hours. Also, with the AI algorithm trained to identify activity in the prefabrication work site, the AI agents can identify the idle time and active work that impacts the overall productivity within the prefabrication hall. Improve the overall productivity at the fabrication hall, identify improvement areas, and reduce the completion timing for each fabrication work.

Simplify the process by removing waste or non-productivity steps, improving the workers' overall productivity. Improve the safety at the site, including non-compliance with the safety guidelines, and require live streaming with the operator or management. Non-compliances such as not wearing PPE, safety helmet, coverall, and safety glasses will be immediately notified to the operator. This will avoid any incidents contributing to the lost time injury (LTI).

Fig. 5 shows the HSE PPE violation of not wearing the correct PPE while working at the prefabrication hall. The AI digital system detected this non-compliance. While working at the fabrication area during the night shift, the person did not wear a full coverall and safety helmet. Using the cumulative data collected on the HSE PPE non-compliance in Hall A at the prefabrication yard, PMT can take necessary action to improve overall HSE PPE compliance at the fabrication hall.

Fig. 5 *HSE Violation by the worker at the fabrication hall*

The second objective of digitalization monitoring and tracking is identifying the active and idle time in the prefabrication hall. By trained the AI agents to identify human activity recognition (HAR) in the fabrication hall, as shown in Fig. 6, the construction personnel is identified by their coverall colour.

The data was collected from the site monitoring and tracking at the prefabrication hall for 50 days to identify the root cause of activities that contributed to the causes of low productivity at prefabrication Hall A. The Human Activity Recognition (HAR) detection sample was grouped into active time and idle time in Prefabrication Hall A, as shown in Fig. 7. The daily summary captured 2% of idle time, whereas the active time was 98 % during the day. With these data, the fabrication yard management can identify the potential root causes of the idle time throughout the day. Also, they can pinpoint non-productive time (NPT) activity from the idle time captured video.

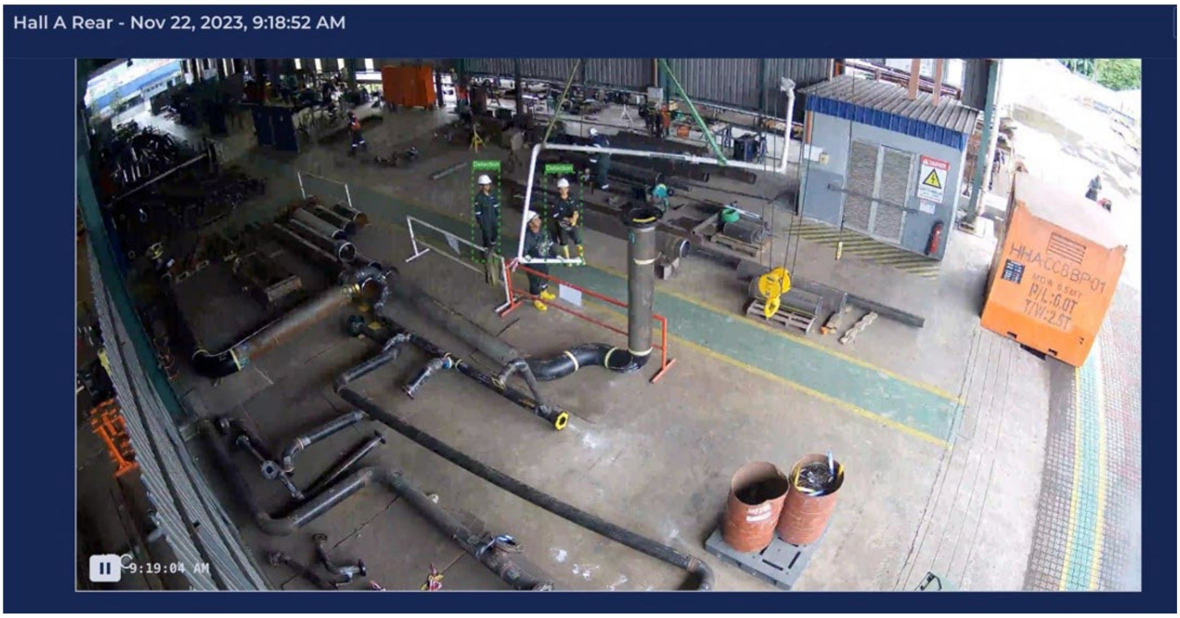

Fig. 6 *Human activity recognition (HAR) at Hall A Prefabrication yard*

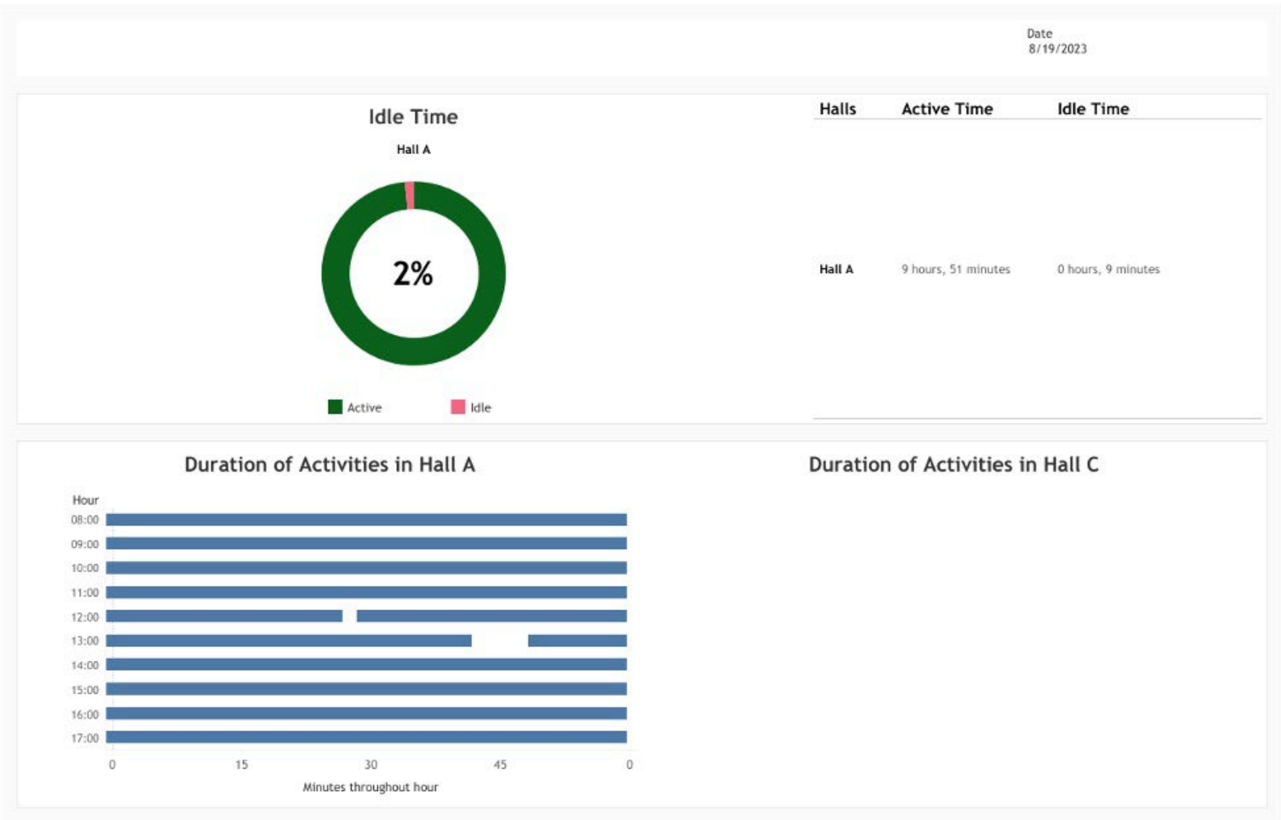

Fig. 7 *The daily summary of the active and idle time detection at Hall A from 8 am to 5 pm*

The Digital Value Stream Mapping (DVSM) framework ran for 50 days, capturing the idle and active time data within Hall A at the prefabrication yard. The collected idle time and active time data were used to calculate the actual productivity achieved within the day based on the actual product output. The equations of Productivity Rate are as follows [19]:

$$\text{Productivity} = \text{Total Output} / \text{Total Input} \quad (1)$$

$$\text{Hall A Productivity} = \text{Total dia-inch Per Day} / \text{Total Active Labour Hours Per day} \quad (2)$$

Example data collected from the Digital System and manual input from the prefabrication Hall A dated 26 July 2023 using Eq. (2) is shown in Table 1:

Table 1 *The compilation data captured from the manual log and digital system to calculate the overall productivity rate*

Manual Data		Digital System		Productivity Rate (Output/Input)
Dia-inch (Weld + Cutting)	Labor Hours	Idle Time	Active Time	Total Dia-inch/Total Active Time
36 dia-inch	64 hrs	35% (22.4 hrs)	65% (41.6 hrs)	0.86 dia-inch/hrs During the day, 0.86 dia-inch can be produced per hour over 41.6 active hours.

The equation above calculates Hall A's daily overall productivity rate in the prefabrication yard. Any day with a productivity rate below 1.0 dia-inch/hrs will be further analyzed to determine the potential root causes contributing to this low productivity. The digital system captured the video during the day, including idle time and active time within Hall A. It will be analyzed to identify the activities potentially contributing to low productivity. From the 50-days data analysis, the top activity that causing low productivity are listed in Table 2 below.

Table 2 *Summarizes the top 5 events contributing to low productivity idle time*

Event	Reasoning	Priority
(1) Work Stoppages due to inspection works	(1) Flag for urgent recognition activity	1
(2) Maintenance activities scheduling during core working hours	(2) Defer the maintenance outside of core hours	1
(3) Objects blocking natural workflow	(3) Safe obstruction impedes workflow	1
(4) Unscheduled workforce meetings during core hours	(4) Schedule for pre 8 am, lunch hour or post 6 pm	2
(5) Missed opportunities to conduct non-essential activities during lunch hour or evenings	(5) Replenishment of inventory, consumables and Supplies	2

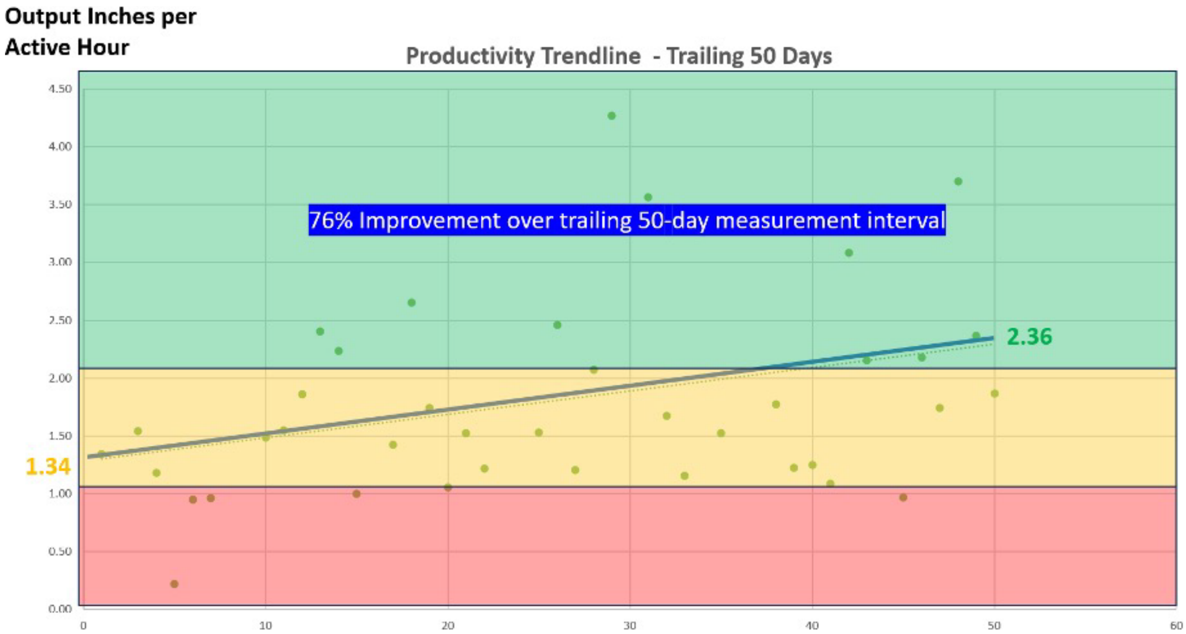

Fig. 8 *The 50-days graph of the productivity rate of output inches per active hour at Hall A fabrication yard*

Finally, the 50-days monitoring and improvement initiative that has taken place at Hall A has shown some improvement. By identifying the non-productive work at Hall A, the management has conducted several discussions, sharing, and RCFA to improve the process. After the root cause stated in Table 2 was identified, the fabrication team at Hall A started to improve their process flow to avoid similar re-occurrence of the above top 5 risks. The results of the improvement action that has been taken are shown in Fig. 8.

7. Conclusion

Through the pilot deployment of the Artificial Intelligent (A) technology for the monitoring and improvement at the onshore fabrication works at Teluk Kalong, Kemaman, it has shown significant productivity improvement for the 50 days period deployment. This pilot implementation is combined with digital and manual data input to determine the Non-Productivity Time (NPT) during the fabrication activity.

The AI system is enabled to provide summary the daily active and idle time at the fabrication yard, and from there the yard operator to identify the potential waste in the fabrication process flow. After the waste identified, the operator will discuss with all parties on the potential process flow improvement can be enhanced and the agreed solution to be implemented at the fabrication floor. Then, after the new Standard Operating Procedure (SOP) established for the fabrication process flow, it will be cascaded to all workers at the fabrication flow. Finally, the new improved process flow will be monitored using the AI digital system, to evaluate the improvement in the active and idle time.

Hence, the new summarize of the idle time and active time in the fabrication floor will be analysed. In overall, through the improvement of the process floor, the collected data has shown the improvement of the daily performance on the fabrication output for welding dia-inch per hours. In the 50 days monitoring, the productivity rate start with 1.36 dia-inch/hour, has significant improved by 76% to 2.36 dia-inch/hour. The improvement process will be continuously monitor as Plan, Do, Act, and Check (PDCA) cycle, to get the best productivity and to achieve great efficiency.

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Thanks to the Integrated Bekok Oil (IBO) Project team for providing excellent support during the fabrication work at Hall A, HHASB Yard Telok Kalong. The collaboration of the project and fabrication teams has significantly improved the yard's productivity rate. Apart from that, the data shown through the initiative taken by the project team has increased the process flow efficiency and eliminated unnecessary waste from the prefabrication activity.

Conflict of Interest

Authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

*The authors confirm contribution to the paper as follows: **study conception and design:** M Sahir Ahmad Shatiry, Zulhasni Abd Rahim, Ikhranizam M. Ros; **data collection:** M Sahir Ahmad Shatiry, Navaneethan Chelliah; **analysis and interpretation of results:** M Sahir Ahmad Shatiry, M. Norman Matlan; **draft manuscript preparation:** M Sahir Ahmad Shatiry, Farah Shafiqah, Navaneethan Chelliah. All authors reviewed the results and approved the final version of the manuscript.*

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