# The Development of Real-Time Integrated Dashboard: An Overview for Road Construction Work Progress Monitoring

**Jawa Anak Gara*, Rozana Binti Zakaria, Eeydzah Aminudin, Jeffryl Azniel Adzar, Omar Sedeeq Yousif**

School of Civil Engineering, Faculty of Engineering, Universiti Teknologi Malaysia, Johor Bahru, Malaysia

**Abstract:** Progress monitoring is an essential factor in successful project delivery and a mark of the excellence of construction project management in Malaysia. Therefore, it is important to know the current progress and detect deviations from the schedule as early as possible. Today's project reporting and progress measurements are still labor extensive, time-consuming, and human error-prone due to reliance on the manual and traditional monitoring process. Project officers are under too much pressure and overloaded with many works that need to be done and submitted promptly. Hence, in a linear construction such as roads where travel distance and safety are the main concern, the development of a dashboard is necessary to improve the efficiency and effectiveness of project progress monitoring. The data acquisition technologies will help speed up the data acquisition and transfer the information to the dashboard, data consolidation, and arranging the data on a single screen for the information to be monitored at a glance. This paper highlights the development of a new Real-Time Integrated dashboard model for road construction progress monitoring. To achieve the research objectives, a survey questionnaire, observation from the standard progress-monitoring method, interview, and case study must be done thoroughly to produce a good dashboard for monitoring road construction. However, this paper only portrayed an overview of construction road monitoring and the relevance of research needs. The proposed research findings will bring a new way of project monitoring and progress measurement into a greater height, reduce project delays, fast interim payment, reduce disputes, effective project reporting, and better decision making. **Keywords:** progress monitoring, project reporting, progress measurement, dashboard.

## 实时集成仪表板的开发：道路建设工作进度监控概述

**摘要：**进度监控是项目成功交付的重要因素，也是马来西亚建筑项目管理卓越的标志。因此，重要的是要了解当前的进度并尽早发现与计划的偏差。由于依赖于手动和传统的监控过程，当今的项目报告和进度测量仍然需要大量劳动力、耗时且容易出现人为错误。项目官员压力太大，有许多需要及时完成和提交的工作。因此，在诸如道路之类的以行驶距离和安全为主要考虑因素的线性建筑中，有必要开发仪表板以提高项目进度监控的效率和有效性。数据采集技术将有助于加快数据采集速度，将信息传输到仪表盘，进行数据整合，将数据整理在一个屏幕上，让监控信息一目了然。本文重点介绍了用于道路施工进度监控的新型实时集成仪表板模型的开发。为实现研究目标，必须通过调查问卷、标准进度监测方法观察、访谈和案例研究，才能制作出一个良好的道路施工监测仪表盘。然而，本文仅描绘了施工道路监测的概述和研究需求的相关性。拟议的研究成果将把项目监控和进度衡量的新方法带到更高的高度，减少项目延误，快速中期付款，减少纠纷，有效的项目报告和更好的决策。

**关键词：** 进度监控、项目报告、进度测量、仪表板。

Received: February 3, 2021 / Revised: March 6, 2021 / Accepted: April 16, 2021 / Published: May 28, 2021

About the authors: Jawa Anak Gara, Rozana Binti Zakaria, Eeydzah Aminudin, Jeffryl Azniel Adzar, Omar Sedeeq Yosif, School of Civil Engineering, Faculty of Engineering, Universiti Teknologi Malaysia, Johor Bahru, Malaysia

# 1. Introduction

Progress monitoring is an essential factor in successful project delivery and a mark of construction projects' excellence [1]. It is important to know the current progress and detect deviations from the schedule as early as possible. Today, project progress measurements are still labour extensive, time-consuming, and human error-prone due to reliance on manual and traditional monitoring processes [2]. Therefore, the accuracy of progress reporting is crucial and among the challenges in the construction industry that needs to be improved for better project delivery. Hence, the current project progress monitoring, measurements, and reporting have to be improved with a new paperless monitoring system that is more reliable and trusted by the team members, top management, and the stakeholders [3]. They need to know the project progress, whether datelines are met, within budgets, and good quality.

## 1.1. The Importance of Project Monitoring and Dashboard

On-site project progress monitoring is important for accurate and timely assessment of work progress. It allows top management to adjust when the project progress deviates from the planned schedule [4]. As it involved a huge amount of reporting and urgent requests by top management for quick data, the need for new ways of data collecting, measuring, and reporting is urgently needed to overcome these issues. Road constructions generate floods of data that keep accumulating during the project life cycle. Most of the time, the managers are overloaded with several projects simultaneously, which may increase the stress level and decrease their productivity. Accurate progress measurement and real-time monitoring are vital in the construction industry to reduce problems during the construction phase. However, a lack of a systematic approach and technique for construction progress monitoring is why some of the projects, issues, and problems are neglected. Therefore, there is a need for an integrated real-time dashboard to monitor construction work progress. Hence, developing an integrated real-time dashboard for construction monitoring work progress is essential for a quick view of the project performance and up-to-date project status.

A dashboard is a paperless project management tool to convey information to the construction teams and stakeholders in the fastest way. The current progress monitoring is practiced manually based on progress measurement methods and needs human presence, which is time-consuming, subjective, error-prone [5], leading to bias. Monitoring for manual road construction work progress has limitations in getting precise data. Therefore, inefficacies using the traditional based progress monitoring methods indicate the need to adopt new tools and technologies for better work progress monitoring [6]. The contact capture technology will assist in automating the measurement and information for effective progress monitoring and tracking. The data acquisition with the capture technology method is possible for volumetric progress in linear infrastructure such as roads where the earthmoving, slope cutting, and backfilling are involved. Additionally, three dimensional (3D) noncontact capture measurements using laser scanners also can be integrated, and with the increasing current IoT technology, it helps in supporting progress monitoring, tracking, and reporting [7].

Despite recent advances in Construction 4.0, progress monitoring is still dominated by traditional approaches, including manual paper-based collection and recording of on-site activities [3]. In traditional reporting, the project team spent too much time updating instead of executing and finishing the works within the stipulated time. Lack of systematic techniques and automated progress evaluation and being dependant on traditional monitoring contributes to inaccurate reporting. Existing new tools and technologies such as dashboard systems with the help of the Internet of Things (IoT) could provide a new dimension to the construction industry and paperless monitoring and reporting. A dashboard is a communication tool for providing data to viewers as graphical displays generated by computers to collect, organize, and present data and information to the users [8]. The real-time data acquisition and integrated dashboard with the help of and contact capture tools and IoT is foreseen having a vast opportunity to be used in the construction industry. Hence, developing a new integrated dashboard is a great intervention tool to uphold the project progress monitoring system in project management.

The development of an integrated real-time integrated dashboard avoids depending too much on traditional and conventional reporting. Traditional and conventional reporting is one factor contributing to the project delay, cost overrun, and many disputes. The proposed real-time integrated dashboard model for progress monitoring may reduce project delay and minimize project disputes during project cycles. Furthermore, with the increasing number of advanced data acquisition technologies for automated measurements and calculation of the work done and site progress, the integrated dashboard offers vast opportunities in project progress monitoring. A dashboard allows web interfaces to adapt to the screen size of their device and collects accurate information from multiple data acquisition sources [9]. Accurate and regular progress monitoring enables a project team to know the status of their project, the decisions to be made, and corrective actions to be taken without disturbing the workflow. Thus, integrated dashboard model development is useful to capture the user's attention for immediate data during construction.

In reviewing and determining the project's status as time-consuming, an integrated dashboard is an essential tool in project progress monitoring. The idea was supported by Hamzeh [10]; a project dashboard is a great tool used to monitor and control project progress and project reporting. There has been an increasing demand for quick data collection and automated construction progress monitoring in the construction industry [11]. Therefore, developing a new integrated dashboard for project progress monitoring with real-time information is vital for the construction industry for precise data. Instant access to the project status, fast, accurate, and reliable information is sought for better project monitoring. The real-time integrated dashboard features real-time data updates, visual charts, and graphs and can be viewed immediately at a glance. The relevant data such as project health, project progress status, tasks, project risks, and payment status can be easily viewed. A dashboard loaded with charts, graphs, symbols, images, words, colours, and project information are useful for teams' meetings, presentations, decision making, and early mitigation of project risks.

## 2. Dashboard Design Model

The design of the proposed dashboard should address how information is captured, modelled, and displayed on the screen. A dashboard is a paperless project monitoring tool that enables the project management team to know its project status and make rapid decisions. The dashboard design shall be user-friendly, easy to understand, and effective progress monitoring with consistent measurements. Hence, it is vital to use a dashboard in the construction industry for better project monitoring. According to Hamzeh et al. [10], due to the continuous advancement of Information and Communication Technologies (ICT) and the fast-paced construction industry, increasing data information, and overwhelming project reporting in the construction environment today, a proper real-time model of integrated dashboard design needs to be proposed. The real-time integrated dashboard is expected to collect, summarize, and present information to determine any project schedule deviation for better monitoring and rapid decision-making.

A dashboard model is an important element in dashboard development and is considered part of communication tools between data and knowledge. In the geospatial dashboard, technologies such as user-oriented, visualisation perception, and visual media are important elements to be considered [9]. The dashboard model shall be in line with user requirements as well as easy and convenient to use. A better model plays an important role in the effective display of information and data. Besides that, the selection and organisation display media such as graphs, charts, tables, and drawings contribute to the best practices in the dashboard design model [10]. A dashboard is a visual display of the most important information inherent to achieve objectives, data consolidation into one dashboard concept and arranged on a single screen to provide quick information and monitoring project status at a glance [12].

The overall purpose of a real-time model of an integrated dashboard as a decision support system tool is a project performance monitoring and to identify possible issues that need to be addressed when implementing a construction project [12]. The development of a dashboard can be divided into several phases, such as the selection metrics, the flow of data and information, the relationship between metrics and decision making. Besides, there is an option for forecasting and developing different scenarios based on data collected, simulation models, and the connection to the project's financial status [10]. Visual systems and dashboards convert raw data and numbers into valuable information in the construction industry and can lead to a direct conclusion from the visual dashboard [10]. Dashboards presentation should fit on a single screen, have a good layout, contain colours for better perception, and indicators for decision making [12].

Table 1 Summary of dashboard types [13]

| Types | Characteristics | Interactivity | Update frequency | Purpose |
|---|---|---|---|---|
| Strategic | Simple display mechanism consists of static snapshots | Low | Moderate | View and decide or question |
| Analytical | Contains various parameters and comparisons | Moderate | Low | View and question, explore what-if scenarios |
| Operational | Simple media to attract user's attention | High | High | View and act |

There are several types of dashboards depending on their role and the variables they are using in the industry. Based on Table 1, the dashboard design model in this research falls somewhere between analytical and operational types. The design characteristics of a dashboard depend on the needs and roles of the dashboard. In the construction industry, dashboards can be used to monitor many types of data, functionality, and information as well as to achieve the project objectives. A dashboard helps superintendent officers and project managers to identify trends and patterns of project progress. The visualization and communication of the project progress and display of the project progress and important information on a single screen to achieve project objectives and the timeline stipulated in the contract. Besides, the integrated dashboard enables consistency in project reporting. It enables day-to-day project monitoring and planning by allowing the 3D models simulation to be a great communication tool between the site, main office, and stakeholders. A dashboard provides a reliable monitoring system to enable a transparent, clear, and precise view of the status of the tasks by collecting and exposing a user-centric set of information [14]. Thus, the dashboards' design model layout should be friendly, concise, and simple to use and allow decision-makers

to focus on relevant and important information provided from the dashboard. A good dashboard can display all relevant information on a single screen without the need for scrolling or switching between multiple screens and the ability to view information.

### 2.1. Integrated Dashboard Application and Processes in Project Monitoring

Monitoring work progress in a linear infrastructure project such as road projects whereby a long-distance and a large amount of data is collected is complex and time-consuming. Thus, the importance of efficient communication, visualisation, and real-time site work progress has encouraged many researchers to introduce several automated technologies as a consistent problem-solving tool for construction work progress monitoring [8]. Therefore, a real-time integrated dashboard is introduced to the construction industry to enhance the project monitoring process, detect any deviation from the schedule as an automated actual site progress measurement tool, and improve project communication. The dashboard can easily be integrated into other data acquisition technologies such as 3D laser scanning, computer vision technology, LiDAR, photogrammetry, and IoT for automated real-time monitoring systems [8]. Superintending officers must monitor the progress activities to prevent delays from working progress, and they are supposed to access real-time integrated dashboards easily to notify the real site progress. However, the dashboard must be updated daily to obtain the latest site progress.

Abduldaem and Gravell [15] argued that the development of a dashboard provides a better understanding of the project, allows site managers to make a fast decision and take corrective actions. In addition, the development dashboard also provides KPIs values according to predefined goals and provides a glance at the current project status [16]. While augmented reality [17], capturing technologies [18], and IoT [19] improve visualisation, reporting, and direct updating from the construction site. It would save time on reviewing the reports and calculating manual data. Thus, it would display real-time information with the development of a dashboard and subsequently reduce manual paperwork. These technologies allow the automation of construction processes and potentiality to improve construction progress monitoring and reporting and reduce human errors [16].

The integrated dashboard is to facilitate the process of project progress monitoring in the construction industry rather than depending on traditional project manually. As manual project progress monitoring relies on paper reports that entail a huge amount of manual data collection, the effort must be made to use imaging technologies to assess the actual work progress rather than depending too much on traditional paperwork assessment [17]. A project monitoring dashboard is a vital tool in helping to keep your projects in order and detecting potential schedule delays during the early stage. It is an important tool for better project communication and project progress monitoring. In addition, the dashboard would help to get real-time data, spot in-site problems, and build a solution for easy decision-making. The integrated dashboard is an easy place to find out at a glance every aspect of the project. A project dashboard model should contain project status, task status updates, visual charts, and graphs. As a result, there is a substantial need for effective tools to monitor construction projects continuously. The real-time integrated dashboard is a perfect choice to provide a reliable monitoring system that enables fast information.

In construction management, an integrated dashboard can be used as a visual interface to report the most important real-time data and information at a glance to meet the predefined objectives of the project. A dashboard is a management tool that helps store the project data for fast and rapid monitoring and enhances communication and coordination by providing automated real-time project information. It reduces manpower and time for manual intensive project monitoring process as normally practiced at the construction site. This system allows users to access the project status and information everywhere, subject to the availability of the internet line. The integrated dashboard system manages the information flows between the site, the main office, and the stakeholders. Timely information about project status is crucial to avoid construction rework and waste of time during construction. The integrated dashboard is developed to allow construction and management teams to access real-time information remotely.

### 2.2. Monitoring of Road Construction Progress

Since road constructions involved a huge volume of earthworks to be moved, cut, and filled following the construction drawings and specifications, it is normal for road constructions' to pass through difficult terrains and many types of soil profiles. Earthwork activities involved operation such as site clearing, stripping vegetation and topsoil, excavations, cut and fill, subbase, subgrade, road base (illustrated in Figure 1), and premix works (Figure 2). A large volume of earthworks is an essential part of road construction project activities. Therefore, planning, scheduling, and supervising earthworks operations are important in obtaining the earthworks' movements and productivity. In road construction monitoring, the earthwork progress activities are determined by the volume and quantity of earth to be cut and filled and slope cutting and hauling [20]. To capture measurements and estimates for roadworks, project teams use digital photography captured from a camera mounted with a UAV to determine the current progress of works. The combination between Global Navigation Satellite

Systems (GNSS) and robotic total station surveying methods are the perfect solution to assess the earthwork volumes, excavations, and placement of materials [20]. The road construction consists of site clearing, sub-grade, sub-base, road base, premix, and earthworks to form the road embankments (Figure 1).

An Unmanned Aerial Vehicle (UAV) with modern remote sensing technology has become more accessible to the construction industry nowadays. Images captured from UAV photogrammetry are used for mapping, taking measurements and quantities, and reconstructing the geometry of a road surface. An unmanned aerial vehicle has been used to map surface deformation, landslide monitoring, open pits monitoring, mines, and stockpiles, and generate a detailed model before and after each construction stage to determine earthwork quantities [20]. The accuracy of UAV photogrammetry depends on factors such as the quality of the photographs, the characteristics of the measured surface, Ground control points (GCPs), and flight height. UAV photogrammetry is a fast and convenient way of measuring and calculating earthworks volumes and enables the realistic assessment of material and labour needs in road construction.

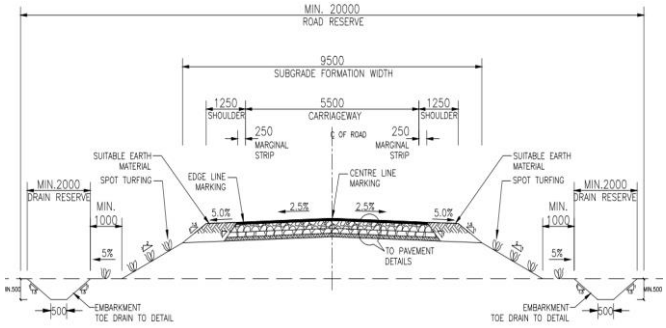


Fig. 1 Typical cross section (Own research)

Kim and Chi [21] mentioned monitoring earthwork processes using visual sensors to extract activity, progress, and productivity through vision-based processing algorithms and track the progress of earthwork processes by combining technologies based on computer vision such as photogrammetry and video analysis. Visual data in the form of photographs of the site environment is obtained. The photogrammetric tests determine earth volume excavated while the video analysis generates statistics regarding the site activities. The combination of photogrammetry and video analysis enables the project manager to measure the productivity of the machinery and determine site performance factors [22]. Normally, the earthworks will commence after site clearing and removal of unsuitable materials. The earthworks involved transporting soil from approved borrow pits to the site and compacted layer by layer to form a formation level.

During the earthwork operation such as excavation, the road reserved boundary and road centerline until the works' limit shall be identified and set by a surveyor. The cut area shall be excavated till the formation level. The accuracy of the surface models and the volumes of earthworks excavation are measured by UAV photogrammetry [20]. Typical pavement construction illustrated in Figure 2 shows that the volumes and areas of the pavement can easily be calculated using construction drawings, schematic drawings, or calculated with UAV photogrammetry.

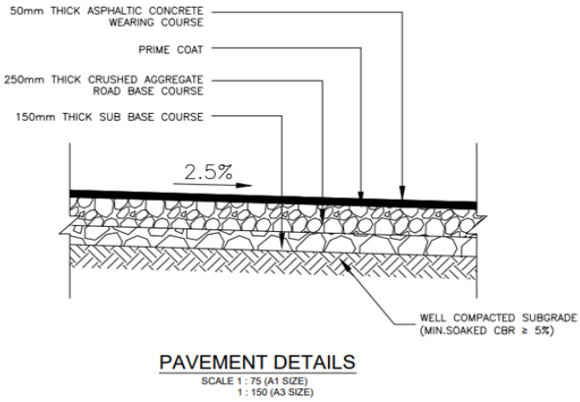


Fig. 2 Pavement details (Own research)

The increasing advancement of new technology recently provides more data acquisition tools and technologies to collect more data and information needed. Data collected from the new technologies are transferred and uploaded to the dashboard via the fast-paced development of information and communication technologies (ICT), Internet of Things (IoT), and big data analytic for automated progress monitoring. Data acquisition technologies to be used in this research, such as automated geospatial technology and imaging technology besides traditional manual construction data collection.

### 2.3. Automated Construction Work Progress

Kim and Chi [21], in their study on construction performance monitoring via still images, time-lapse photos, close range, aerial site images, and laser scanners mentioned, timely and accurate on-site construction operations can bring immediate awareness on project status and issues to be resolved immediately to avoid more problems and schedule deviations. A study by Braun [23] proposed that a more accurate and applicable metric for evaluation of the quality of a point cloud for automated construction monitoring using a scan-vs-BIM method. According to Deng et al. [24], during construction activities, combining computer vision and BIM as tools for automated progress monitoring for accurate, timely, and intuitive information is vital for effective and successful decision-making during progress monitoring at the construction site. Automated construction progress monitoring method proposed by Hadi et al. [5] using Structured-from-Motion (SFM) and Multi-View-Stereo (MVS) algorithms coupled with photogrammetric to generate as-built 3D point clouds to produce an accurate automatic outdoor and indoor progress monitoring throughout the entire project duration.

In a linear infrastructure such as road, repetitive

construction activities involved lengthy site distance, and automated real-time data integrated dashboard measurement systems will reduce construction problems, enhancing visualisation and documentation [12]. In conventional construction, site engineers frequently need to visit construction sites to measure the actual progress and detect any deviation to the schedule baseline for early rectification. These types of reporting take a month to produce a report. The manual reports normally are in the form of a Gantt chart or other reporting formats. The preparation of these progress reports is always difficult, time-consuming, and costly. The manual collection and assessment of actual site progress for road construction are often delayed and subject to inaccuracies. Thus, it is very common for road contractors to submit the monthly work progress reports in a month or more. Hence, with an integrated real-time dashboard development, potential delays in data collection and progress assessment can be minimized drastically.

Although many capturing technologies are used to capture images and automated progress measurement during construction, real-time integrated data is still required for better monitoring and decision making. However, according to [7], the construction industry still suffers from a lack of holistic, automated, and real-time monitoring systems to address construction issues. 3D systems are used to calculate and track the construction progress immediately. Ratajczak et al. [16] developed aerial data capturing and 3D reconstruction methods using AR for construction site monitoring and documentation to access relevant information directly on site. To achieve that, the AR system must be registered to the physical world environment based on remote localization and online tracking to visualize actual progress. Therefore, an integrated dashboard is necessary to assist data acquisition technologies for real-time and automated progress monitoring.

An automated construction progress monitoring increases reporting efficiency and accuracy and eliminates bias elements in reporting, especially projects with a high level of complexity. Inability to accurately capture construction progress leads to project delays, suffer from time and cost overruns. To address these issues, this research requires automated construction monitoring focusing on imaging technology, data processing, and visualisation methods in detecting construction progress integrating directly to the integrated real-time dashboard. Data will be collected and analysed by the dashboard for real-time information and better monitoring. Daily capturing site photographs is one method of recording as-built progress information in a road construction project. Traditionally, site photographs were collected and stored as a visual record during project construction. However, with the advancement of technologies, photographs captured can be analysed directly with other acquisitions' technologies to automate measurements and reports. These new technologies and tools, such as the dashboard, can reduce reporting time and provide proper project controls.

### 2.4. Project Progress Reporting & Tracking

In construction, work progress is the most important element that everybody wanted to see. Failure to report the work progress when required gives a bad impression to the project officers on how to monitor the project during construction. Traditional reporting is usually to be done monthly and weekly, subject to the contract's requirement. Nowadays, the demand for real-time site work progress is increasing, and real-time integrated dashboard development is a perfect tool to resolve the issues. During site meetings or project meetings, the progress of works shall be tabled to make everyone aware of the project's health. To monitor the project closely, all project progress parameters need to be presented during the meeting. All issues presented and agreed upon during the meeting should be reported to the clients, stakeholders, and interested parties involved in the projects. With the development of the dashboard later, the issues of late reporting, disputes on the work progress, and many construction issues can be resolved to complete the projects.

Real-time progress reporting could address many project issues by providing timely information and accurate project progress and site activities [2]. A progress reporting would enable project managers and management teams to mitigate issues that may hinder the project progress. Frequent updating, real-time reporting, and systematic productivity analysis would contribute to project delivery success. However, conventional systems reporting, monitoring, and tracking are labor-intensive, time-consuming, and inaccurate — site issues are recorded in a site diary to show the site's daily activities. The numbers of workers and visitors in and out of the project should be recorded as proof if anything occurred at the construction site and should be kept for certain years before it can be destroyed. A traditional site diary can be replaced by the project integrated dashboard after the completion of this research. All data required needs to be key-in into the integrated dashboard and can be viewed anytime and anywhere. Everyone has a verified, same data and standard measurement and reporting. The integrated dashboard will minimize disputes, reduce errors in reporting, and subsequently contribute to the project's success.

Reporting of the work progress is an essential component in construction project management monitoring. The demand for fast data, accurate and regular progress reporting in the construction industry today needs a great tool to report the work progress and the project status. The development of an integrated dashboard is vital in managing and monitoring the construction project. A dashboard can portray the

trends of the project progress, budgets, the quality required to achieve, the problems encountered, the cost involved, and the decision-making to be made at a glance. Early warnings on project deviations and delays provide a space for the construction team to take corrective actions before it is too late. In project delivery excellence, the project should complete on time as stipulated in the contract documents, within budget, and the required quality and safety measures. It a great reduction in the time spent compared to the current manual reporting.

Therefore, the development of a project dashboard is vital and can reduce the time taken as per current manual reporting. Hence, to review the report, gain a better understanding of the project progress trends, improve quality and safety, good decision making, and corrective actions. The project status dashboard can be viewed daily, weekly or monthly as required. Thus, the basic needs of the project status integrated dashboard, the basic requirement, and the boundaries of the dashboard need to be established to enable a successful automated progress monitoring. The integrated dashboard as an information system tool effectively communicates important project information to the management's attention. It positively addresses the project's issues to get more grasp about the project performance and overall work progress. Hence, it is necessary to develop an integrated dashboard as a tool to support management teams on daily project operations.

Projects behind schedule or deviation from the original schedule are unfavourable events and shall be avoided in any construction project. It leads to time overrun, cost overrun, and leads to disputes among the construction team, with everyone tries pointing and blaming each other [5]. Thus, real-time progress tracking remains a vital component in construction management in achieving the project objectives. An automated progress tracking integrates with the help of data acquisition collection technologies such as (not limited to) geospatial technologies, augmented reality, 3D-imaging, IoT connected to the dashboard are great tools for progress tracking, reporting, and monitoring. In normal practice, project progress tracking depends on supervisors daily or weekly assessment that involves intensive manual data collection and may cause data entry error [17]. Supervisors need to know their roles and responsibilities and coordinate the work effectively according to plans and drawings to ensure tasks are prioritized correctly and executed productively.

## 3. Research Design Proposal

To achieve research objectives (dashboard development), both quantitative and qualitative approaches methodology were used. Questionnaires survey is used in three expected outcomes (i) Identification of the problems faced during road construction monitoring; (ii) Able to ranking the benefits of integrated real-time dashboard development model; and (iii) Able to ranking the progress monitoring parameters for an integrated dashboard. Target respondents shall be construction management participants, including project managers, project directors, managing directors, engineers, consultants, clients, contractors, and academia. Relative Important Index (RII) techniques were used to determine the reliability and merit of the responses. The ranking was carried out through the Likert scale, and top results and parameters were identified. The later, the Dashboard development is designed via programming model and functionalities that include the User Acceptance Testing (UAT) and expected will provide a Dashboard for progress monitoring with verification of real-time integration.

## 4. Overview on Project Monitoring Process of Road Construction: A Case Study in Sarawak, Malaysia

Construction progress monitoring has been perceived as one of the key factors to project success. At the same time, a construction progress assessment is essential to determine the status of the project. Monitoring the work progress to enable the project's adherence to project schedules and budget is the most highly valued performance metric by the project owner [25]. Constantly monitoring and updating project progress and schedules enables project managers and management teams to closely manage the project (as illustrated in Table 2). Any deviations to the schedules can be detected at an early stage to reduce the construction delays. The disputes will be minimised, and time and cost overrun can be avoided. Poor performance management due to lack of frequent monitoring of the project teams' actual progress and site conditions, lacking the most up-to-date construction progress information, contributes to project problems and delays. This paper used an overview of Pan Borneo Highway development in Sarawak Malaysia.

The development and upgrading of the proposed Pan Borneo Highway (WPC08) is an undergoing highway project in Sarawak, Malaysia. The monthly work progress reporting and monitoring, as illustrated in Table 2, are currently implemented the project under the supervision of the Public Works Department Sarawak.

Table 2 Project progress reporting as reported 25th July 2020 for Pan Borneo project WPC08

**Progress as at 25th July 2020**
*Time Lapsed : 1354 days of 1705 days = 79.50 %*
*Days Delay/Days Ahead: 312 days behind schedule*

| OVERALL Progress | Physical (%) | Financial (%) | Total Float (Days) | Realistic Completion Date |
|---|---|---|---|---|
| Schedule | 61.75 | 65.02 | -318 | December 2022 |
| Actual | 51.25 | 53.26 | | |
| Variance (+ / -) | - 10.50 | - 11.76 | | |

| MONTH | April 2020 | May 2020 | June 2020 | July 2020 |
|---|---|---|---|---|
| Achievement per month (%) | 47.46 | 47.96 | 49.85 | 50.05 |

| SELANGAU SECTION PROGRESS | Physical (%) | Financial (%) | Total Float (Days) | Realistic Completion Date |
|---|---|---|---|---|
| Schedule | 74.81 | 75.16 | -318 | December 2021 |
| Actual | 63.70 | 64.55 | | |
| Variance (+ / -) | -11.11 | -10.61 | | |

| BALINGIAN SECTION PROGRESS | Physical (%) | Financial (%) | | |
|---|---|---|---|---|
| Schedule | 50.52 | 56.18 | -318 | December 2022 |
| Actual | 40.53 | 43.40 | | |
| Variance (+ / -) | -9.99 | -12.78 | | |

As traditional construction progress monitoring is time-consuming, costly, and prone to error, manual data collection lacks accuracy. Projects are usually being monitored to determine whether the projects are:

i. Running on schedule
ii. Behind schedule
iii. Critically delays

The main purpose of monitoring the project progress is to determine the project's status, and if there is any deviation to the schedules, immediate actions can be taken. The constructive and immediate corrective action assists project monitoring teams to come out with proper intervention tools and controlling the project management process to achieve successful project delivery. Monitoring project progress performance involves determining whether the project is on schedule, ahead of schedule, behind schedule, and under or over budget (Figure 3).

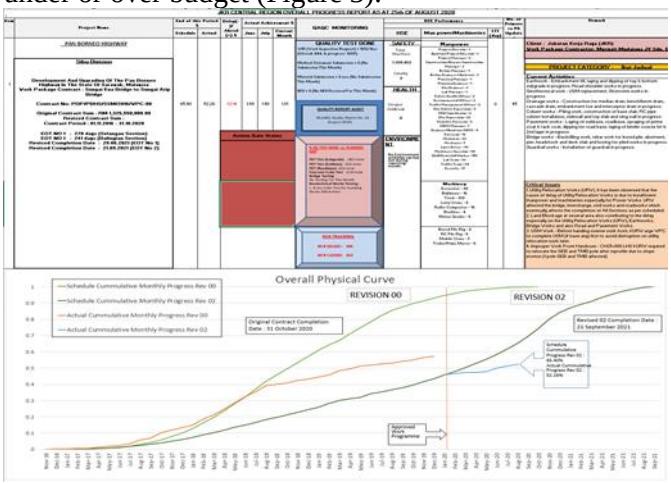


Fig. 3 Progress report as of 25th August 2020 Project Pan Borneo WPC08

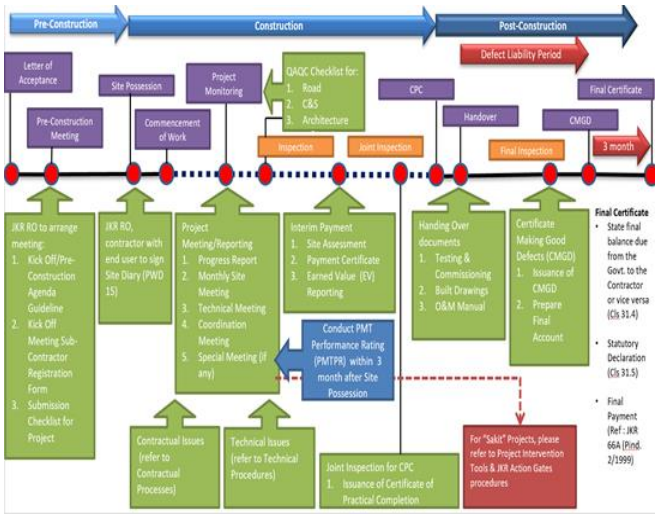


Fig. 4 JKR Sarawak Project monitoring process (JKR Sarawak Manual of Instruction (MOI), 2019)

The current practice of the JKR Sarawak project monitoring process is illustrated in Figure 4. The Construction stage Project monitoring starts after receiving the letter of acceptance until the issuance of the final certificate. Proper project management, monitoring, and reporting during the construction stage would reduce downtime and project delays. All the issues need to be addressed urgently to minimizing disputes, and the project closure needs to be done in the stipulated time according to the contract documents. If a project encountered problems and derails from the original schedule, implementing intervention tools and an action gate is necessary for project monitoring and a way forward to complete the project as the time frame stipulated in the contracts.

Project progress monitoring tools are introduced to manage the project on the ground better. Project management scheduling tools such as Primavera P6 and Microsoft Project were introduced as effective project monitoring and reporting platforms. Still, these tools are stand-alone tools for the project teams to perform site progress assessments. With the addition of the proposed integrated dashboard, all relevant parties such as project teams, top management, and stakeholder could access the project progress easily if given the password to access the proposed dashboard. Sharing the information across project teams, top management, and stakeholders is the main objective of this research.

## 5. Conclusion

Work Progress monitoring is an essential task to ensure the project progresses according to schedule, budget, scope, and quality and safety expectations. To leverage the construction progress monitoring methods and address gaps in knowledge, this research is undertaken, as well as to develop the integrated dashboard for project progress monitoring and more accurate reporting to the higher authority directly from the site. All parties and stakeholders can access it with

the help of advanced computing technology. Automation construction progress monitoring and reporting through an integrated dashboard can significantly impact project management and increase the efficiency and precision of the project management process. The password will be given to the authorised parties and the project teams to access the integrated dashboard. The integrated dashboard monitoring system is a systematic information systems collection and analysis to determine the construction progress and measurement. Therefore, choosing a good and effective dashboard is critical. The study on the overview of the dashboard for the real-time integrated road construction progress monitoring is vital in project work progress monitoring. Aligned with dashboard technology and the Internet of Things (IoT), we sincerely hope that the study will lead to further improvement in the construction industry.

## Acknowledgement

The authors would like to acknowledge the Universiti Teknologi Malaysia and the Department of Public Works for sponsoring the Collaborative Grant. Highly gratitude's to the authors/researchers from Universiti Teknologi Malaysia (UTM) via Research Management Centre for financial support. Extended thanks to the Department of Public Work Sarawak and co-authors and everyone involved directly or indirectly to assist and support this research.

## References

[1] ZHANG C., & PAZHOOHESH M. Automated Construction Progress Monitoring Using Thermal Images and Wireless Sensor Networks. *Building on Our Growth Opportunities*, Regina, Canada, 2015: 1-10. https://www.academia.edu/15605464/AUTOMATED_CONSTRUCTION_PROGRESS_MONITORING_USING_THERMAL_IMAGES_AND_WIRELESS_SENSOR_NETWORKS

[2] MOSELHI O., BARDAREH H., and ZHU Z. Automated Data Acquisition in Construction With Remote Sensing Technologies. *Applied Sciences*, 2020, 10(8): 1-31. https://doi.org/10.3390/app10082846

[3] OMAR H., MANDJOUBI L., and KHEDER G. Towards an Automated Photogrammetry-Based Approach for Monitoring and Controlling Construction Site Activities. *Computers in Industry*, 2018, 98: 172-182. https://doi.org/10.1016/j.compind.2018.03.012

[4] KOPSIDA M., & BRILAKIS I. Real-Time Volume-to-Plane Comparison for Mixed Reality-Based Progress Monitoring. *Journal of Computing in Civil Engineering*, 2020, 34(4). https://doi.org/10.1061/(ASCE)CP.1943-5487.0000896

[5] HADI M., FARNAD N., ALI. H. A., and SAEID. N. Automated Progress Controlling and Monitoring Using Daily Site Images and Building Information Modelling. *Buildings*, 2019, 9(3): 1-20. https://doi.org/10.3390/buildings9030070

[6] PURI N., & TURKAN Y. Bridge Construction Progress Monitoring Using Lidar and 4D Design Models. *Automation in Construction*, 2020, 109. https://doi.org/10.1016/j.autcon.2019.102961

[7] BEHZADAN A. H., SHERAFAT B., CHANGBUM R. A., and REZA A. Automated Methods for Activity Recognition of Construction Workers and Equipment: State-of-the-Art Review. *Journal of Construction Engineering and Management*, 2020, 146(6): 1-19. https://doi.org/10.1061/%28asce%29co.1943-7862.0001843

[8] STEHLE S., KITCHIN R., and STEHLE S. Real-Time and Archival Data Visualisation Techniques in City Dashboards. *International Journal of Geographical Information Science*, 2019, 2: 344-346. https://doi.org/10.1080/13658816.2019.1594823

[9] JING C., DU M., and LI S. Geospatial Dashboards for Monitoring Smart City Performance. *Sustainability*, 2019, 11: 1-23. https://doi.org/10.3390/su11205648

[10] HAMZEH F., EZZEDDINE A., SHEHAB L. and KHALIFE S. Early Warning Dashboard for Advanced Construction Planning Metrics. *Construction Research Congress*, ASCE, Phoenix, Arizona, USA, 2020: 67-75. https://doi.org/10.1061/9780784482889.008

[11] PU Z., & REBOLJ D. Automated Continuous Construction Progress Monitoring Using Multiple Workplace Real Time 3D Scans. *Advanced Engineering Informatics*, 2018, 38: 27-40. https://doi.org/10.1016/j.aei.2018.06.001

[12] VASNIER J.-M., MARANZANA N., MESSAADIA M., and AOUSSAT A. Preliminary Design and Evaluation of Strategic Dashboards Through the Technology Acceptance Model. *Proceedings of the Design Society: DESIGN Conference*, 2020, 1: 777–786. https://doi.org/10.1017/dsd.2020.18

[13] PAPPAS L., & WHITMAN L. Riding the Technology Wave: Effective Dashboard Data Visualization. *Human Interface and the Management of Information*, 2011, 6771: 249-258. https://doi.org/10.1007/978-3-642-21793-7_29

[14] MOHAMMADFARID, A. SALGADO REYES N. E., BORGHEI A. H., CAMINO SOLÓRZANO A. M., GUZMÁN RODRÍGUEZ M. S., and RIVERA VALENZUELA M. A. Web-Based Executive Dashboard Reports for Public Works Clients in Construction Industry. *New Knowledge in Information Systems and Technologie*, 2019, 2: 285-294. https://doi.org/10.1007/978-3-030-16184-2_28

[15] ABDULDAEM A., & GRAVELL A. Principles for the Design and Development of Dashboards: Literature Review. *Proceedings of INTCESS 2019 - 6th International Conference on Education and Social Sciences*. Dubai, U.A.E, 2019: 1307-1316. http://www.ocerints.org/intcess19_e-publication/papers/412.pdf

[16] RATAJCZAK J. MARCHER C., SCHIMANSKI C. P., SCHWEIGKOFLER A., RIEDL M., and MATT D. T. BIM-Based Augmented Reality Tool for the Monitoring of Construction Performance and Progress. *2019 European Conference on Computing in Construction*. Chania, Crete, Greece 2019: 467-476. https://ec-3.org/conf2019/wp-content/uploads/sites/2/2019/08/Contribution_202_final.pdf

[17] D. GREENWOOD, ZAHER M., and MARZOUK. M. Mobile Augmented Reality Applications for Construction Projects. *Construction Innovation*, 2018: 18(2): 152-166. https://doi.org/10.1108/CI-02-2017-0013

[18] NAVED A., FAWAD N., and MUHAMMAD A. I. Construction Monitoring and Reporting Using Drones and

Unmanned Aerial Vehicles (UAVs). *The Tenth International Conference on Construction in the 21st Century*. Colombo, Sri Lanka, 2018: 325-332. https://e7b3ad67-c36a-4cc9-8f96-7f6f62f269de.filesusr.com/ugd/0d72f4_2b8387d5250a441ab17fe08ad626f2c7.pdf
[19] JOHN S. T., ROY B. K., SARKAR P., and DAVIS R. IoT Enabled Real-Time Monitoring System for Early-Age Compressive Strength of Concrete. *Journal of Construction Engineering and Management*, 2020 146(2). https://doi.org/10.1061/%28asce%29co.1943-7862.0001754
[20] JULGE K., ELLMANN A., and KÖÖK R. Unmanned Aerial Vehicle Surveying for Monitoring Road. *Baltic Journal of Road and Bridge Engineering*, 2019, 14(1): 1-17. http://dx.doi.org/10.7250/bjrbe.2019-14.430
[21] KIM J., & CHI S. Multi-Camera Vision-Based Productivity Monitoring of Earthmoving Operations. *Automation in Construction*, 2020, 112: 103-121. https://doi.org/10.1016/j.autcon.2020.103121
[22] ŠOPIĆ M., VUKOMANOVIĆ M., ZAVRŠKI I., and CAR-PUŠIĆ D. Estimation of the Excavator Actual Productivity at the Construction Site Using Video Analysis. *Organization, Technology and Management in Construction*, 2021, 13(1): 2341-2352. https://doi.org/10.2478/otmcj-2021-0003
[23] BRAUN A., TUTTAS S., BORRMANN A., and STILLA U. Improving Progress Monitoring by Fusing Point Clouds, Semantic Data and Computer Vision. *Automation in Construction*, 2020, 116: 1-53. https://doi.org/10.1016/j.autcon.2020.103210.
[24] DENG M., MENASSA C. C., and KAMAT V. R. From BIM to Digital Twins: a Systematic Review of the Evolution of Intelligent Building Representations in the AEC-FM Industry. *Journal of Information Technology in Construction*, 2021, 26(5): 58-83: https://doi.org/10.36680/j.itcon.2021.005
[25] HAN K., DEGOL J., and GOLPARVAR-FARD M. Geometry- and Appearance-Based Reasoning of Construction Progress Monitoring. *Journal of Construction Engineering and Management*, 2018, 144(2): 1-42. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001428

**参考文:**

[1] ZHANG C., 和 PAZHOOHESH M. 使用热图像和无线传感器网络的自动化施工进度监控。以我们的增长机会为基础，加拿大里贾纳, 2015: 1-10. https://www.academia.edu/15605464/AUTOMATED_CONSTRUCTION_PROGRESS_MONITORING_USING_THERMAL_IMAGES_AND_WIRELESS_SENSOR_NETWORKS
[2] MOSELHI O., BARDAREH H., 和 ZHU Z. 使用遥感技术在建筑中自动采集数据。应用科学, 2020, 10(8): 1-31. https://doi.org/10.3390/app10082846
[3] OMAR H., MANDJOUBI L., 和 KHEDER G. 迈向基于自动化摄影测量的方法来监测和控制施工现场活动。工业计算机, 2018, 98: 172-182. https://doi.org/10.1016/j.compind.2018.03.012
[4] KOPSIDA M., 和 BRILAKIS I. 基于混合现实的进度监控的实时体积平面比较。土木工程计算杂志, 2020, 34(4). https://doi.org/10.1061/(ASCE)CP.1943-5487.0000896
[5] HADI M., FARNAD N., ALI. H. A., 和 SAEID. N. 使用每日现场图像和建筑信息模型进行自动化进度控制和监控。建筑物, 2019, 9(3): 1-20. https://doi.org/10.3390/buildings9030070
[6] PURI N., 和 TURKAN Y. 使用激光雷达和四维设计模型的桥梁施工进度监控。建筑自动化, 2020, 109. https://doi.org/10.1016/j.autcon.2019.102961
[7] BEHZADAN A. H., SHERAFAT B., CHANGBUM R. A., 和 REZA A. 建筑工人和设备活动识别的自动化方法：最先进的审查。建设工程与管理学报, 2020, 146(6): 1-19. https://doi.org/10.1061/%28asce%29co.1943-7862.0001843
[8] STEHLE S., KITCHIN R., 和 STEHLE S. 城市仪表板中的实时和档案数据可视化技术。国际地理信息科学杂志, 2019, 2: 344-346. https://doi.org/10.1080/13658816.2019.1594823
[9] JING C., DU M., 和 LI S. 用于监控智能城市绩效的地理空间仪表板。可持续性, 2019, 11: 1-23. https://doi.org/10.3390/su11205648
[10] HAMZEH F., EZZEDDINE A., SHEHAB L. 和 KHALIFE S. 高级施工规划指标的预警仪表板。建筑研究大会，美国土木工程师协会，美国亚利桑那州凤凰城, 2020: 67-75. https://doi.org/10.1061/9780784482889.008
[11] PU Z., 和 REBOLJ D. 使用多个工作场所实时三个维度扫描进行自动化连续施工进度监控。高级工程信息学, 2018, 38: 27-40. https://doi.org/10.1016/j.aei.2018.06.001
[12] VASNIER J.-M., MARANZANA N., MESSAADIA M., 和 AOUSSAT A. 通过技术验收模型初步设计和评估战略仪表板。设计学会会刊：设计会议, 2020, 1: 777–786. https://doi.org/10.1017/dsd.2020.18
[13] PAPPAS L., 和 WHITMAN L. 驾驭技术浪潮：有效的仪表盘数据可视化。人机界面和信息管理, 2011, 6771: 249-258. https://doi.org/10.1007/978-3-642-21793-7_29
[14] MOHAMMADFARID, A. SALGADO REYES N. E., BORGHEI A. H., CAMINO SOLÓRZANO A. M., GUZMÁN RODRÍGUEZ M. S., 和 RIVERA VALENZUELA M. A. 面向建筑行业公共工程客户的基于网络的执行仪表板报告。信息系统和技术新知识, 2019, 2: 285-294. https://doi.org/10.1007/978-3-030-16184-2_28
[15] ABDULDAEM A., 和 GRAVELL A. 仪表板的设计和开发原则：文献综述。第六届教育与社会科学国际会议论文集。阿联酋迪拜, 2019: 1307-1316. http://www.ocerints.org/intcess19_e-publication/papers/412.pdf
[16] RATAJCZAK J. MARCHER C., SCHIMANSKI C. P., SCHWEIGKOFLER A., RIEDL M., 和 MATT D. T. 基于建筑信息建模的增强现实工具，用于监控施工性能和进度。 2019 年欧洲建筑计算会议。干尼亚，克里特岛，希腊2019: 467-476. https://ec-3.org/conf2019/wp-content/uploads/sites/2/2019/08/Contribution_202_final.pdf

[17] D. GREENWOOD, ZAHER M., 和 MARZOUK. M. 建筑项目的移动增强现实应用。建设创新，2018: 18(2): 152-166. https://doi.org/10.1108/CI-02-2017-0013
[18] NAVED A., FAWAD N., 和 MUHAMMAD A. I. 使用无人机和无人驾驶飞行器进行施工监测和报告。第十届21世纪建筑国际会议。斯里兰卡科伦坡，2018: 325-332. https://e7b3ad67-c36a-4cc9-8f96-7f6f62f269de.filesusr.com/ugd/0d72f4_2b8387d5250a441ab17fe08ad626f2c7.pdf
[19] JOHN S. T., ROY B. K., SARKAR P., 和 DAVIS R. 物联网启用混凝土早期抗压强度实时监测系统。建设工程与管理学报，2020 146(2). https://doi.org/10.1061/%28asce%29co.1943-7862.0001754
[20] JULGE K., ELLMANN A., 和 KÖÖK R. 用于监测道路的无人机测量。波罗的海路桥工程杂志，2019 14(1): 1-17. http://dx.doi.org/10.7250/bjrbe.2019-14.430
[21] KIM J., 和 CHI S. 基于多相机视觉的土方作业生产率监测。建筑自动化，2020，112: 103-121. https://doi.org/10.1016/j.autcon.2020.103121
[22] ŠOPIĆ M., VUKOMANOVIĆ M., ZAVRŠKI I., 和 CAR-PUŠIĆ D. 使用视频分析估算施工现场挖掘机的实际生产率。建筑组织、技术和管理，2021，13(1): 2341-2352. https://doi.org/10.2478/otmcj-2021-0003
[23] BRAUN A., TUTTAS S., BORRMANN A., 和 STILLA U. 通过融合点云、语义数据和计算机视觉改进进度监控。建筑自动化，2020，116: 1-53. https://doi.org/10.1016/j.autcon.2020.103210.
[24] DENG M., MENASSA C. C., 和 KAMAT V. R. 从建筑信息建模到数字孪生：建筑/工程/施工和设施管理行业智能建筑表示演变的系统回顾。建筑信息技术学报，2021, 26(5): 58-83: https://doi.org/10.36680/j.itcon.2021.005
[25] HAN K., DEGOL J., 和 GOLPARVAR-FARD M. 基于几何和外观的施工进度监控推理。建设工程与管理学报，2018，144(2): 1-42. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001428