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A NOVEL FRAMEWORK FOR DEVELOPING A DYNAMIC SURVEY DASHBOARD: CASE STUDY OF A SELF-ASSESSMENT AND PLANNING SURVEY FOR OFF-SITE CONSTRUCTION FACILITIES

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ABSTRACT: Surveys have been recognized as a valuable tool for obtaining a current picture of a particular topic, with specific best-practice guidelines established to ensure the survey's effectiveness. These guidelines include designing surveys that are well-structured, visually engaging, dynamic via a continuous responses collection process, and timely in terms of the generation of the analysis report. Surveys have been used in construction as a source of information for many applications (e.g., customer satisfaction, conflict and dispute, success factors, waste, risk, time, cost). This paper proposes a generic framework for the development of a dynamic survey-based dashboard that is in line with the survey design's best practices. It is composed of three phases: (1) survey development, (2) cloud data pipeline, and (3) dashboard development. To demonstrate the use of the proposed framework, it is applied and tested on a case survey for wall-framing estimation practices in the off-site construction industry. At the foundation of the case study is the construction industry's shift towards off-site construction approaches to improve the performance and predictability of projects through developing proper planning systems. Given that existing studies often focus on the planning of case-specific production lines, the industry can benefit from a generic tool that allows companies to assess their planning performance and compare it to other companies in the field. This application allows off-site construction companies to continuously reflect on their performance and serves as a planning tool by identifying opportunities for improvement when planning their operations by learning from other companies.

1. INTRODUCTION

Survey research has been recognized as a suitable methodology since the 1950s (Malhotra and Grover 1998) to obtain a current picture of a group such as a community, an organization or a professional association (Janes 1999). Surveys provide the ability to tap into complex and multifaceted phenomena while maintaining a certain degree of standardization, which is necessary for quantitative analysis and hypothesis testing. Surveys rely on self-reported answers obtained from a sample of respondents that represents the parent population (Speklé and Widener 2018). These samples can be citizens of a given country, employees of a company, customers of a certain service or any other group (Synodinos 2003). Depending on the objective of the study, the target group, their geographic distribution and the available resources, the survey can either be self-administered or conducted through a personal interview. Self-administered surveys are characterized by the ease of administration and the necessity for clear questions

(Synodinos 2003). The way each question is constructed has a significant implication on the resulting answers (Janes 1999). Personal interviews, on the other hand, can be less burdensome to the respondents since the presence of the interviewer provides flexibility and the opportunity to engage with another person (Synodinos 2003).

Several best practices have been established for the design of effective surveys. The developed questions should be well-structured with proper use of words to ensure clarity of the question, along with the accuracy and reliability of the respondent's answers. (Heckman and Smith 1995). Synodinos (2003) suggested the use of graphical presentations or visuals to enhance clarity and provide consistent understanding among the respondents. Heckman and Smith (1995) demonstrated that in addition to the wording of questions, other elements such as response format, context and non-verbal aspects, including physical layout and visual presentation, can noticeably influence answers. Visuals include graphical, numerical and symbolic languages that convey meaning (Christian and Dillman 2004). Hence, adding suitable visuals such as pictures increases engagement in the survey (Toepoel 2018). As such, developing a questionnaire with a professional appearance, appropriate formatting, and graphical content can help engage the respondents and allow them to complete the questionnaire easily. (Synodinos 2003). Surveys often represent a snapshot at a certain period of the current state of the problem understudy (Janes 1999). However, this can be a limiting feature of the survey over time if the state is continuously changing. This stresses the need to design surveys that are dynamic, as opposed to static, by continuously collecting survey responses at different points in time from the group of interest and dynamically integrating the corresponding output in the analysis. Moreover, survey-based studies can take several months, or even years in certain cases, to complete the whole administration process (i.e., data collection, cleaning, analysis and report generation). For instance, a study by Galloway (2006) that aims to assess stakeholders' views on the critical path method scheduling practice in the US used an online survey that was open for six months to collect responses. The research team took another six months to analyze the results and write the report. This can create a gap between the date the data was collected and the date the output is generated (i.e., the report), thus introducing a delay between the current state (time of response collection) and the time of decision-making. As such, generating the survey output in a timely manner, as defined by the need and the scope of the study, is essential for timely decision-making. Based on the above, designing surveys that are well-structured, engaging, dynamic and timely are among the best practices for ensuring accurate and reliable responses for timely decision-making.

In the construction industry, surveys have long been used as a valuable source of information to identify academic and practical problems to assess the current state of practice and propose the necessary solutions (Radziszewska – Zielina 2020). This indicates that the role of surveys in construction is primarily informative and are mainly used for processing and transferring information to facilitate decision-making. A wide variety of research problems in the construction domain have leveraged the use of surveys, including building condition assessments, customer/stakeholder satisfaction, the social aspects of construction, conflict and dispute, success factors, construction waste, risk, time and cost management (Radziszewska – Zielina 2021). The industry has also shown an increasing trend to adopt an approach that transforms the building construction process from the job site into a controlled factory environment known as offsite construction (OSC) to improve the performance and predictability of the construction projects (Hong et al. 2018; Jin et al. 2018). A proper planning system for the production process is necessary to maximize the benefits of OSC (Altaf et al. 2018). In this case, planning entails the estimation of the production time, defined as the time needed to produce a certain building component (e.g., walls, floors) in the factory, as an input for creating production schedules (Alsakka et al. 2023a). The total production time is dependent on the cycle times of each workstation in the production line, which are estimated based on its influencing factors, such as workers, machines, material, automation, errors, etc. (Alsakka et al. 2023a). Altaf et al. (2018) and Alsakka et al. (2023a) mention several studies in the OSC industry that have leveraged different tools (e.g., simulation, optimization, digital twins, machine learning and sensing technologies) to estimate cycle time at the workstation level in OSC. Although these studies have been successfully developed and can be transferable to different OSC factories, their main limitation is that they are custom-tailored for the case factory understudy, restricting their immediate use by other OSC companies. As such, the industry can benefit from a generic tool that allows companies to assess their planning performance and compare it to other companies in the field. This can be beneficial for companies that need to upgrade their operations (e.g., a company that produced wall panels manually can learn from a company that produced them using

a semi-automated machine) and for companies that are newly joining the OSC industry and have no historical data of their own (by learning from the practices of existing companies, for example). Moreover, benchmarking enables OSC companies to continuously evaluate their performance and plan improvement actions to cope with the dynamic business environment (Goncharuk et al. 2015). The method involves selecting companies for comparison, collecting data about their process (production) and the process of the companies to be compared, estimating their performance and the performance of comparable companies from the industry, identifying performance gaps and analyzing their causes, and planning the improvement mechanism.

The conducted literature review showed the benefits and the importance of developing surveys that are well-structured, engaging, dynamic and that provide results in a timely manner for timely decision-making. Although surveys have been successfully used to gather information and obtain insights in the construction industry, they can be further enhanced to meet these best practices. Moreover, the industry can benefit from a tool that allows companies to assess their planning performance and compare it to other companies in the field. Therefore, this paper proposes a generic framework for the development of a dynamic survey-based dashboard that is in line with the survey design's best practices. The framework is demonstrated in a case study in the OSC industry for self-assessment and planning. This provides OSC companies with two main benefits: (1) a self-assessment tool by which to continuously reflect on their performance as compared to other companies and (2) a planning tool to identify opportunities for improvement and better plan their operations by learning from other companies.

2. METHODOLOGY

This study adopts the Design Science Research (DSR) methodology to develop and evaluate the survey-based self-assessment and planning framework in OSC. DSR provides a standardized and structured approach to design and validate artifacts, i.e., solutions to solve the identified problems upon gaining the necessary knowledge on the topic of interest (Hevner et al. 2004). Typically, DSR is comprised of four steps: (1) problem identification, (2) objective definition, (3) framework design and (4) framework demonstration (Peffers et al. 2007). During the first step, "problem identification", this study conducted a thorough literature review to gather knowledge on the benefits and best practices of designing and conducting surveys as well as the current state of their applications in the construction industry. While the review revealed the wide use and effectiveness of surveys in construction, the survey administration stage, as well as the data analysis and report publishing stage, can take a long period of time, impacting timely decision-making. As such, these were generally not aligned with the best practices of survey-based studies: dynamic, visually engaging and timely. As such, the objective of the proposed framework, as part of the "objective definition" step, is to develop a dynamic survey-based dashboard driven by industry-wide data. The designed framework aims to solicit information from the respondents on the topic of interest in an engaging and dynamic manner while presenting the results in an interactive dashboard for timely decision-making. The third step, "framework design," included the design of the proposed framework. The framework design is composed of three phases: (1) survey development, (2) cloud data pipeline and (3) dashboard development. Several tools were employed in the development of the framework, including Microsoft (MS) Forms, MS Power Automate, MS Excel, OneDrive and PowerBI. MS Forms was used to collect information from the respondents on the topic of interest, while MS Power Automate was used to develop automated data flows between MS Forms and MS Excel on OneDrive cloud storage. Meanwhile, PowerBI was used to develop the dynamic and interactive dashboard on the topic of interest. To assess the usefulness of the proposed framework as part of the "framework demonstration" step, a hypothetical case study in the OSC industry was considered. The conducted review showed the potential benefits of a self-assessment tool in the OSC industry that allows a company to benchmark its performance against its peers. This would help the company better plan its operations, identify opportunities for improvement and remain competitive in the market. Specifically, the case study included developing a case survey on framing operation practices, soliciting data from hypothetical industry practitioners, automatically collecting and cleaning the data, and presenting the results in a dynamic and interactive dashboard. Ultimately, a company of interest can better plan its framing operations once it benchmarks its performance against its peers and identifies opportunities for improvement.

3. PROPOSED FRAMEWORK

The proposed framework for a dynamic survey-based dashboard is composed of three phases: (1) survey development, (2) cloud data pipeline, and (3) dashboard development. Figure 1 showcases the developed framework. The following sub-sections illustrate each of the three phases.
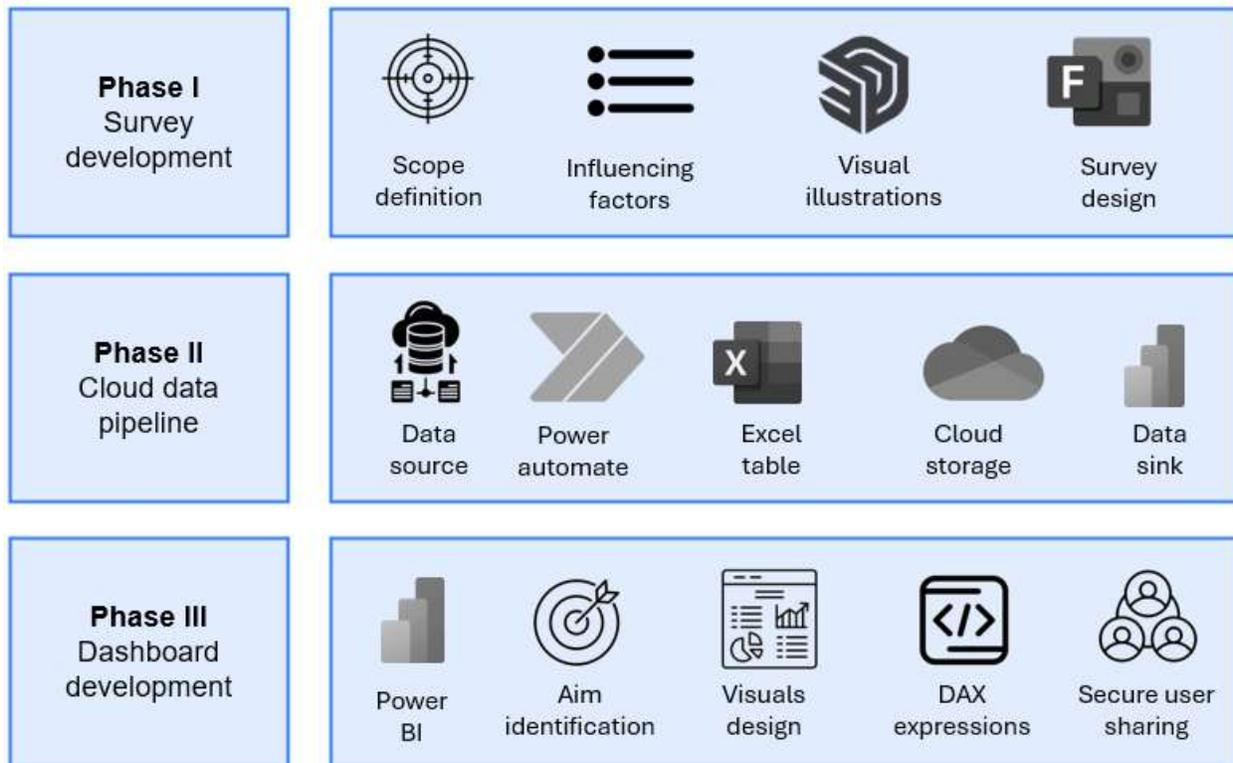

Figure 1: Proposed framework

3.1 Phase I: survey development

The first phase of the proposed framework aims to design and conduct an engaging survey questionnaire on the topic of interest to solicit information from the respondents. This phase starts with identifying the scope and purpose of conducting the survey and the expected outcomes. For example, the scope might be related to walls, flooring or roofing operations. The next step is to develop the survey questionnaire, which is achieved by developing the questions upon conducting the proper review of the literature. Accordingly, an MS Form is designed to collect data from the respondents of interest. The questions are developed in a way that permits a structured collection of the data. As such, the use of multiple-choice questions, dichotomous questions (e.g., Yes and No questions), and open-ended quantitative questions is recommended. In an effort to enhance the engagement of the respondents and to improve the reliability of the survey output, the MS forms questions are supported by high-quality illustrations as a visual tool to make the questions more intuitive and easier to understand. It shall be noted that the survey is kept anonymous, and no information related to the respondents is recorded. The respondents are also required to provide their consent to share the collected information anonymously. In case they do not agree to share their information, they can leave the survey at any time.

3.2 Phase II: cloud data pipeline

Once the MS Forms survey questionnaire is developed, a cloud data pipeline is established to design the data flow across the framework. A data pipeline typically involves a set of interrelated activities starting with a data source and ending in a data sink. Data pipelines can support data-driven decision-making given their ability to streamline and process data in different formats from several sources with minimal human interventions (Munappy et al. 2020).

In this study, a cloud data pipeline is developed to streamline the flow of the data throughout the developed framework to allow for the timely and dynamic update of the survey responses and results. It is divided into three components: (1) data source, (2) automated data integration and (3) data sink. In this case, the data source component consists of the MS Forms responses filled by the respondents. The automated data integration component is further divided into three sub-components: data workflows, data storage and data processing. Automated cloud data flows are developed using the MS Power Automate feature, which allows for the automation of repetitive tasks based on a defined trigger – an event that initiates the flow. In this case, a workflow (WF1) was designed to automatically populate data in an Excel table upon receiving a new MS Forms response (i.e., the trigger). The Excel table is stored on the cloud using OneDrive and is formed from a template that maps the questions included in the MS Forms. This means that for every question of interest, a column is included in the Excel table to store the data collected from the responses. Regarding data processing, automated data cleaning and processing steps can be embedded within Excel using the available features, depending on the selected case application. Data processing can include standardizing data, handling incomplete records, removing duplicates, data formatting and data transformation. Another data workflow (WF2) is developed whereby the Excel table storing the response data on the cloud is connected to PowerBI. This connection is achieved by using PowerBI's ability to load the Excel File on the Web as a data source. This is further supported by PowerBI's "refresh" and "incremental refresh" features that allow the software to continuously load data from the Excel file. The purpose of WF2 is to create an indirect link between the responses obtained in MS Forms and the dashboard that will be developed in PowerBI. Through this link, the dashboard will automatically update as soon as a new response is submitted, reflecting the timely and dynamic features of the developed framework. Finally, the last component of the developed data pipeline is the data sink. PowerBI is considered the data sink in this case since it is the final destination of the data. When the data reaches PowerBI, it can be transformed into actionable insights by creating interactive and dynamic visualizations that can be further used in the decision-making process.

3.3   Phase III: dashboard development

The third phase of the proposed framework aims to develop a dynamic and interactive dashboard as per the identified scope and objective of the survey. Upon filling in the MS Form and developing the automated data flows that link the responses' output to PowerBI, the dashboard will be updated accordingly. Therefore, any new response submitted will be reflected in PowerBI within a few minutes. Upon continuously updating the dashboard, practitioners can access the latest data and industry trends and utilize these trends to reflect on their practices and improve their performance.

The first step in developing the dashboard is to define its goal as per the selected case application. The second step is to design the dashboard, which includes the selection of the visuals, the specific data input for each visual and the visual's formatting. Moreover, the dashboard should permit data filtering based on a selected respondent through the use of the filtering features and slicers in PowerBI. The use of DAX (Data Analysis Expressions) in PowerBI is recommended to custom-tailor the visuals for the intended use. DAX is a formula language that allows the creation of custom calculations and measures to be used in the generation of visuals. Finally, the last step in developing the dashboard is to publish it on the web and share it with the relevant stakeholders. Access permissions will be assigned as necessary (e.g., viewer, editor). This step also includes setting up manual or scheduled data refreshing to ensure that the dashboard is in alignment with the most recent MS Forms responses.

4. FRAMEWORK DEMONSTRATION

Once the framework has been developed, it can be used for several applications related to the self-assessment and planning upon tailoring each of the three phases to the case application. In this study, the framework is demonstrated using a hypothetical case study of wall-framing estimation practices at the workstation level in panelized construction facilities.

As part of the "survey development" phase, factors influencing framing operations in the OSC industry were first identified. Then, the survey questionnaire on MS forms was developed accordingly. A study conducted

by Alsakka et al. (2023) explored the factors that affect framing operations in OSC facilities. These covered different categories related to the product being fabricated (e.g., panel dimensions, number and type of studs, quality and availability of shop drawings), the workers (e.g., their number, work shifts, the day of the week), the machines (e.g., machine breakdowns and errors) and the material (e.g., material type, material availability). As such, Table 1 shows the list of framing influencing factors that are included in this study, the corresponding type of question that was included in the survey questionnaire and whether or not the question was accompanied by an illustration.

Table 1: Framing operations influencing factors included in the MS Forms survey questionnaire

| Framing influencing factor	Type of question in MS Forms	Includes visual illustration?
F1. Number of workers allocated to framing operations	A text type restricting the answer to a number	No
F2. Automation level of framing operations	Multiple choice question with four options: (1) manual (on the floor), (2) manual (on a table), (3) semi-automated or (4) fully automated	Yes
F3. Number of openings in the wall panel (e.g., windows and doors)	Multiple choice question with three options: (1) no openings, (2) one opening or (3) two openings	Yes
F4. Type of wall	Multiple choice question with two options: (1) interior wall or (2) exterior wall	Yes
F5. Length of the wall panel	Multiple choice question with 3 options: (1) Less than 20' long, (2) 20' to 40' long, or (3) More than 40' long	No
F6. Type of structural material of the wall panel	Multiple choice question with three options: (1) engineered wood, (2) dimensional lumber or (3) finger-jointed dimensional lumber	Yes

Figure 2 exemplifies how visual illustrations were included in the MS form survey questionnaires to keep the respondents engaged and ensure a smooth understanding of the questions. Based on the six identified factors, six corresponding questions were included in the questionnaire. Additionally, the survey included a seventh question regarding the duration of the wall framing operations based on the specific scenario of the company. The seventh question presents as a five-option multiple-choice question. The options include: (1) 15 minutes or less, (2) 16 to 30 minutes (3) 31 to 45 minutes, (4) 45 to 60 minutes, or (5) more than 60 minutes. Once the wall framing influencing factors and the expected output (i.e. framing duration) have been identified, a company can complete the same survey questionnaire again for different types of wall panels. For example, if a company fabricates walls with openings and walls without openings of different lengths, they can submit two responses: one for each type of wall opening for a certain wall length. Since the framework is being evaluated on a hypothetical case study as the actual data collection is still in progress, a total of seven responses were filled by a research team in the OSC industry. Each response is a representation of an OSC company.
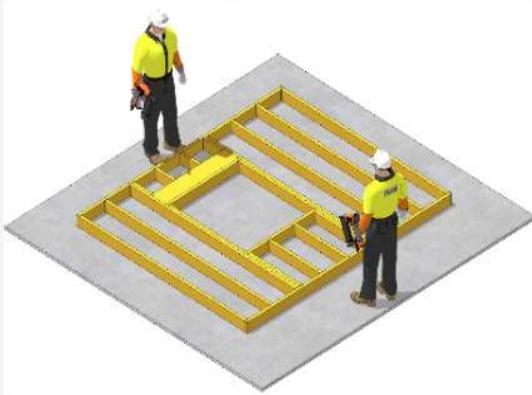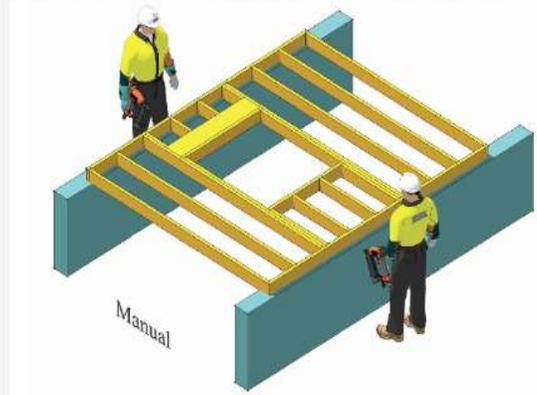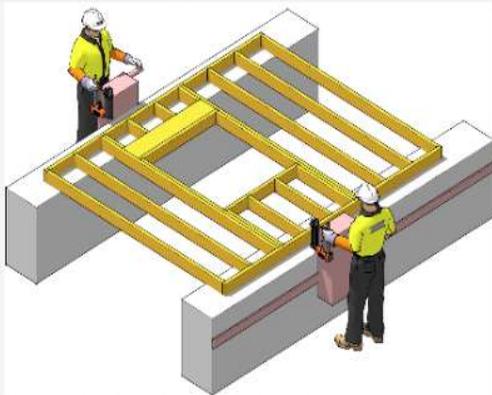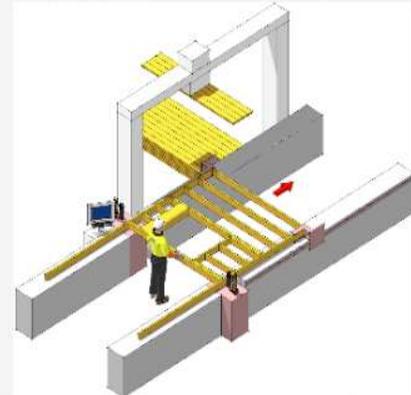
Figure 2: Illustrations used in MS Forms for the automation level of framing operations

In the second phase of the framework "cloud data pipeline", the data pipeline is developed following the "cloud data pipeline" phase, as follows: 1) Responses filled through MS Forms act as the data source of the pipeline; 2) WF1 is implemented to automatically populate the data obtained from the MS for responses in an Excel table stored on OneDrive with nine columns. The first column is a unique identifier for the company, while the next six columns represent each of the six factors identified in Table 1. The eighth column represents the selected wall framing duration, and the last column represents a numerical value for the framing duration taken as the average of the selected range. Additionally, WF2 was implemented whereby the Excel table in OneDrive was selected and loaded as the data source in PowerBI; 3) PowerBI acts as the data sink in the implemented pipeline as the final destination of the data.

In order to implement the third phase of the proposed framework "dashboard development", the aim of the dashboard was defined to provide a visual representation of the wall framing estimation influencing factors and the corresponding duration for each company. The dashboard should also support the self-assessment and planning of the wall framing operations in the OSC industry. The developed dashboard for all seven responses is presented in Figure 3, with the five main items labeled for easier explanation. The slicer (T1 in Figure 3) shows a drop-down list of the companies in the dataset, enabling the user to select a company

of interest. Because the slicer is linked to all the other visuals in the dashboard, these visuals will be updated based on the company selected from the drop-down list. The table (T2) showcases the values of the wall framing practices of the selected company of interest as identified in Table 1. The figure (T3) that reflects the automation level at the company is also updated based on the company's level of automation. The bar chart (T4) represents the wall framing duration of all the companies in the dataset. The gauge chart (T5) shows the average wall framing duration of the companies (30 minutes in this case), as well as the average wall framing durations of the selected company of interest (e.g., 37.5 minutes for company C4). Finally, the generated dashboard is published on PowerBI Web, granting individuals of interest access to the dashboard. The data can also be refreshed manually when the stakeholders are interested in viewing the most recent data. It should be noted that every time a new response is filled in MS Forms, the company that responded will appear in the drop-down list of the slicer. The company will also automatically be added to the bar chart, and the average duration in the gauge chart will be updated accordingly.

The developed dashboard can be used for two purposes 1) self assessment and 2) planning. For example, with regards to self-assessment, company C4 (as selected in the slicer) can assess where it stands in terms of wall framing duration as compared to its peers based on the bar chart and the gauge chart. The company can also see its wall framing station characteristics as shown in the table (T2). In case C4 wants to better plan its wall framing operations to reduce the duration, it can learn from other companies (such as C3, C6, C2 and C7) as they have lower framing durations. As such, C4 can view the wall framing station characteristics of these companies by selecting each one at a time from the companies' drop-down list in the slicer. For example, C4 might consider upgrading the automation level at the station from being done manually on a table to semi-automated. As such, the dashboard can assist OSC companies in reflecting on their performance in wall framing practices as compared to their peers and identify opportunities for improvement.

Wall Framing Estimation Practices in Off-site Construction

Company Name   C4   ▾   T1

Workers	Automation level	Openings	Type of wall	Length of wall	Type of material
3	Manual (on a table)	One opening	Exterior wall	20' to 40' long	Dimensional lumber

T2

T3

Wall Framing Duration

Duration (minutes)

C1 · C5 · **C4** · C3 · C6 · C2 · C7

Company

T4

Company specific wall framing duration
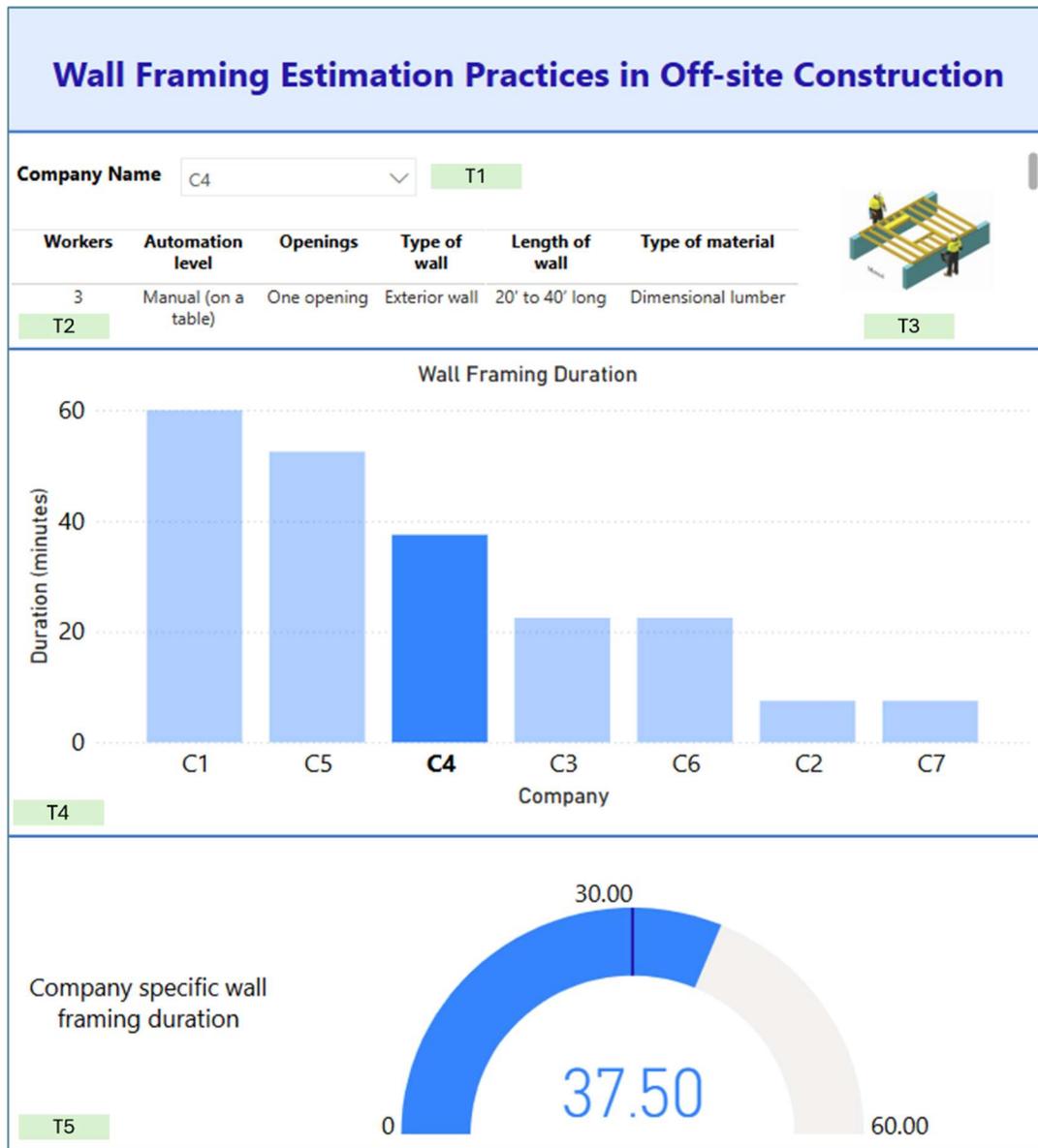
30.00

37.50

0   60.00

T5

Figure 3: Developed dashboard

5. CONCLUSIONS

This paper presented a generic framework for the development of a dynamic survey-based dashboard for timely decision-making that is in line with the survey design's best practices: engaging, dynamic and timely. The framework was developed based on the DSR methodology and is comprised of three phases: (1) survey development, (2) cloud data pipeline and (3) dashboard development. A hypothetical case study related to wall-framing operations in panelized construction was presented to demonstrate the use of the proposed framework. Ultimately, the framework introduces a new perspective to conducting survey questionnaires by ensuring that surveys are engaging, dynamic and timely. This can help a company better plan its operations once it benchmarks its performance against its peers and identifies opportunities for improvement. A potential limitation of this study is the voluntary participation of practitioners in collecting industry-wide data. This can be mitigated by gathering practitioners in a workshop session to discuss and complete the survey. Another limitation of the framework is the use of MS tools, including forms, Power Automate, PowerBI, etc. While these are accessible at no cost when subscribed to Microsoft Office, certain

advanced features might require a paid subscription. However, the proposed framework was designed with no additional purchases required beyond the free versions. Moreover, data privacy might be a concern for certain companies since data is stored online. While this cannot be fully mitigated, it can be alleviated by identifying the access restrictions by the data owner. More advanced data privacy solutions can include the use of blockchain technologies for enhanced security and traceability across the platforms used. Also, as part of future works, the framework will be tested on actual data collected from OSC industry practitioners.

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