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Current Practices of Collecting and Utilizing Daily Work Report Data and Areas for Improvements

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Abstract: ***A significant amount of data including ongoing construction activities, work quantities, resources utilized by contractors, and site conditions is collected in highway construction sites on a daily basis by resident engineers. This data is commonly known as daily work reports (DWRs) in the U.S. Although a lot of time and effort is invested in collecting the DWR data, its utilization has been very limited. This paper discusses current practices of collecting and utilizing DWR data among various Departments of Transportation in the U.S., and discusses the challenges and opportunities for better collection and utilization of the data. An extensive literature review and two nationwide surveys in the U.S. were conducted as a part of this study. Finally, it provides a set of recommendations to effectively address the challenges identified and maximize the benefits of utilizing DWR data such as supporting various decisions for highway project development process. The findings of this study are implementable ideas that can aid DOTs in making data-driven decisions throughout the project development processes in the future.***

Keywords: Daily-Work-Report, Highway-Project, Construction-Field-Data, Construction-Site-Log

I. INTRODUCTION

Construction projects are associated with the collection, processing, and exchange of large amounts of data among project stakeholders [1]. Among those data, various data collected by state Department of Transportations (DOTs) in construction sites are usually known as Daily Work Report (DWR) data in the U.S. A DWR includes data such as ongoing construction activities, labor hours, equipment hours, material stockpiles, weather data, and significant communications with contractors. Inspectors and/or Resident Construction Engineers (RCE) collect this data every day in the site to keep track of the work progress, make payments to the contractors, and resolve claims and disputes. DWR data is collected using either traditional paper-based DWR systems or relatively recent electronic DWR systems. Some state DOTs also collect DWR data in paper-based system and transfer it to an electronic system later.

A study showed that as much as 50% of RCEs' time is spent on collecting DWR data in the field [2]. Such efforts have resulted in a significant increase in the amount of DWR data collected and stored over time. In a traditional paper-based environment, state DOTs have collected piles of DWR forms stacked in storage rooms. In an electronic environment, the size of DWR data has been increasing massively over time as well. For example, one DWR database obtained from one of the state DOTs has more than 4,000,000 lines of linguistic remarks along with more than 600,000 records regarding the quantities of work performed every day. In paper-based DWR systems, analysing such massive amounts of data becomes next to impossible. Even in an electronic system, analysing such large data to obtain useful insights from them becomes more challenging with manual and traditional statistical data analysis techniques. The data can be useful for obtaining various benefits and making data-driven decisions, but there are still various challenges in collecting and utilizing DWR data among state DOTs. The objectives of this study are to a) review current practices of collecting and utilizing DWR data, b) identify the benefits that can be obtained from DWR data, c) investigate the challenges for better collection and utilization of DWR data, and d) provide recommendations to improve current practices and make better use of the data.

II. LITERATURE REVIEW

Traditionally, DWR data are collected in paper-based systems. Over time, state DOTs such as Vermont, Utah, Michigan, Kansas as well as AASHTO have developed electronic systems to ease the collection and utilization of DWR data [3]–[7]. This shift from paper-based to electronic DWR system eased the error prone, slow, and intensively manual process of DWR data collection and analyses [6]. It also enabled faster response to problems, opened the possibility of integrated data analyses, and improved schedule certainty [6]–[8]. With the evolution of electronic technologies, more data collection technologies have been studied for DWR data collection. For example, Wang et al. [9] studied the use of Radio Frequency Identification (RFID) and barcode for stockpile management. Sharma [10] studied the use of LiDAR for stockpile monitoring and pavement quality evaluation. Leung et al. [11] and Abid et al. [12] studied the use of camera for construction progress monitoring. Navon and Shpatnitsky [13] and Sobanjo [14]

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studied the use of GPS and GIS for automating construction progress monitoring and visualizing progress data. Similarly, Deere & Company [15] have developed equipment sensors to monitor construction progress. Many such studies have been conducted within the construction industry for implementing modern technologies.

Another side of the ongoing technological development is the issue of interoperability. Interoperability is defined as "the ability to manage and communicate electronic products and project data between collaborating firms' and within individual companies' design, construction, maintenance, and business process systems" [17]. According to the National Institute of Standards and Technology (NIST [17]), a huge amount of funds is wasted due to the lack of data interoperability and information sharing by construction stakeholders over a project lifecycle. For instance, in 2002, $15.8 billion was wasted in U.S. capital facilities because of the inadequate data interoperability. The Iowa DOT Project Development Manual [18] states that the continuity of data flow throughout the project development – which essentially means the use of integrated systems – "optimizes the process and promotes fiscal soundness and project credibility." Caltrans [19] has realized this interoperability issue and the lack of a single reliable system to manage construction project activities. This issue of interoperability also seem to be prevalent in the highway construction industry. Thus, while so much technological advancements have been made, the highway construction industry is far from utilizing those technologies. It is still facing many other challenges that need to be taken care of before such technologies can be implemented. This study identifies various challenges in collecting and utilizing DWR data for improved decision making throughout the highway project life cycle.

III. METHODOLOGY

This study consists of an extensive literature review on current practices of collecting and utilizing DWR data. Two nationwide questionnaire surveys are conducted with state DOT RCEs as a part of the study. The first questionnaire is focused on identifying the current practices of collecting DWR data and benefits that can be obtained from the data. It received 151 responses out of 433 state DOT representatives contacted (35%). The respondents represented 40 out of 50 states contacted. The second questionnaire is focused on understanding the current level of automation of various analyses for obtaining various benefits identified in this study. It received 44 responses out of 115 state DOT representatives contacted (38%). The respondents represented 27 states. The findings of the literature review and surveys are used to identify the current and potential applications of DWR data, to identify challenges associated with the collection and utilization of DWR data, and to provide recommendations for improving the current practices and systems.

IV. RESULTS

This section presents an overview of current DWR data collection and utilization practices followed by the challenges and recommendations for better collection and optimum utilizations of DWR data.

A. Current Practices

Only three states that responded to the first survey are using paper-based DWR systems. Thirty-seven state DOTs are utilizing electronic DWR systems with or without paper-based DWR systems. The survey found eight DWR systems developed and maintained by individual state DOTs and three systems developed and/or maintained by more than one state DOT. The systems developed by combined efforts of multiple states are AASHTOWare SiteManager (ASM), AASHTOWare FieldManager (AFM), and Maintaining Assets for Transportation System (MATS). Overall, the systems developed by combined efforts of multiple states have better functionalities to collect the data needed for making data-driven decisions like effect of weather on various work activities, developing as-built quantities and schedules, etc. Although those systems were developed and maintained by multiple state DOTs, state DOTs have the ability to customize some aspects of the system to suite their need. Electronic DWR systems have enabled cost savings of millions of dollars – the practice of combining efforts from multiple state DOTs to develop and maintain such systems have enabled even more cost savings [20], [21]. Many systems developed and maintained by single state DOTs are generally poorly maintained. Need to update those systems have been noted by DOT representatives.

The study found a list of major data attributes that should be collected in a DWR system. This include pay-item quantities of work performed, crew details, site conditions, equipment usages details, quality control, delay causes, safety incidents, non-compliance with contract terms, traffic control, and significant conversation with contractors. State DOTs were asked whether or not those data attributes are collected in their paper-based or electronic DWR systems. They were also asked to rate the importance of those data attributes to obtain various benefits. Most of the data attributes (12 out of 18 provided listed in the survey) are rated higher than 4 out of 5 by the respondents who collected those data attributes. In general, the data attributes that were rated higher were recorded in electronic DWR system rather than paper-based DWR systems by the state DOTs utilizing paper-based systems and electronic systems together. This enables state DOTs to perform important analysis quicker using DWR data that is already available in electronic format. However, the use of paper-based DWR systems along with electronic DWR systems essentially limits the ease in analyses that requires data collected in paper-based DWR systems. Some of the important data that are recorded in paper-based DWR systems include safety incident details, traffic control data, and non-compliance with contract terms. The traffic control data

and safety incident details can be used for safety analysis as well as the impact of various traffic control methods in the delays and travel time. But, such data is not recorded electronically which makes it more challenging to perform such analysis. This basically results in *duplication of efforts* and increased responsibilities to the *limited resources* available.

Many state DOTs collect the data related to the amount of work being done and the level of effort in terms of labor and equipment hours used by the contractors. However, the level of details collected is not sufficient for many analyses. For example, while many state DOTs collect data regarding the amount of work done to the date, those data are not collected everyday but rather on occasional basis such as weekly. The amount of effort put such as the labor and equipment hours are also collected during the same time on occasional basis. This essentially reduces the granularity of the data available to accurately estimate the production rates. For example, varying crew sizes might be working on different days for the same work activities and different amount of work might have been done on different days because of the crew sizes as well as weather. Additionally, when there are multiple work activities being conducted on the same day, the labor and equipment used for those activities are not necessarily recorded in relation to the activity. As such, the calculation of production rates in relation to crew size becomes approximation rather than accurate reflection of real production rates. Such lack of collecting detailed data linked with activities is also noted in the survey responses. Similarly, many data attributes are still collected in *linguistic format* which is much more challenging for automated analysis. For example, some state DOTs record overall weather information in a remarks section rather than recording temperature and weather conditions in separate fields. When such weather data is recorded in separate fields, it can be used to analyze the effect of weather such as extreme weather on the production rates. Similarly, day time and night time productivity analysis can be performed if the data is recorded regarding the time of work. However, those pieces of information are either not collected or not collected in right format as of now. This practice of not collecting data in right format, in right interval of time, with right amount of detail has resulted in the limited usability of the data being collected. A proper data structure should be developed to enable useful analysis presented in this paper.

B. Challenges and Recommendations

The challenges and recommendations for improving the current DWR data collection and utilization practices are presented in the following six sub-sections.

1. Advanced Data Collection Systems

According to Holler et al. [16], the construction industry has grown at slowest rate compared to other large industries in terms of Information and Communication Technology (ICT). But, there has been slow and steady introduction of various technologies in the construction industry and those technologies can be used to automatically collect DWR data. The concept of Internet of Things (IoTs) is getting more popular and widespread now. Now, the construction industry should also move forward to adapting and implementing such new technologies to improve automated data collection. This aligns tightly with one respondent's imagination of future DWR systems where no data will need to be entered manually [in an electronic system and will be collected automatically]. Some of the currently existing advanced data collection systems that can be adapted for DWR data collection include Radio Frequency Identification (RFID), bar code, LiDAR, mobile devices, camera, and GPS.

2. Integration of Data Collection Systems

On one hand, many data attributes are still recorded in paper-based systems; on the other hand, multiple disconnected systems are used for collecting various pieces of information. Such practices have resulted in reduced usability of data and limited scope for performing DWR data related analysis because of interoperability issues. The asset management system is a good example of a system that is generally not tied with the DWR systems. If those two systems are interoperable, it can possibly be used for improved asset management decision makings. For example, roughness indexes collected after completion of a project to check the quality of the pavement becomes a valuable data which can be used to develop a pavement condition degradation curve. Such curve can then be used for predicting the future pavement conditions and hence for prioritizing pavement projects. Thus, in future, DWR systems should be developed so that it is interoperable with other systems.

3. DWR Data Utilization and Automation of Analysis

The second questionnaire survey was focused on identifying the reason behind the lack of utilization of the data that is already collected. The survey is used to validate the hypothesis that the reason behind the lack of utilization is the lack of automation in the system. State DOT respondents were asked to rate the level of automation of various application benefits previously identified. Various benefits of using DWR data identified in this study are a) contractor payment, b) dispute resolution, c) progress monitoring, d) as-built information, e) identifying project risks, f) activity cost estimation, g) contractor evaluation, h) production rate estimation, i) contract time determination, j) safety analysis, k) evaluating effects of innovative contracting methods l) verification of labor compliance such as prevailing wage rate verification, m) change order analysis, n) identify frequent design issues and inadequate specifications, and o) to comply with Freedom of Information Act (FOIA) (to provide information on public requests based on DWR data). It was found that, generally, the application benefits are not obtained when there is a lower level of automation. For example, progress monitoring was rated with the highest rating of all (3.3 out of 5 on average) and the benefit of DWR data for progress monitoring was obtained by the highest percentage of the respondents (92%). On the other side, the automation rating of safety analysis was only 1.7 and such analysis has been performed by only 29% of the

respondents. The Pearson's correlation coefficient between the percentages of users who are getting the benefits with the average automation ratings is 0.59 which shows a good correlation. The results also showed that contractor payment, dispute resolution, and progress monitoring are three benefits that are obtained by the majority of the state DOTs (91%, 88%, and 92%). All other benefits were obtained by only about half or less of the respondents because of the limited level of automation. Thus, there is a need to automate the analyses for obtaining various benefits using DWR data that is already collected. In other words, a proper methodology and algorithms should be developed for those analysis. This confirms a hypothesis statement presented in Woldesenbet et al. (2014) that poorly defined procedures and mechanism used to extract, process, and analyze the data to generate useable information and knowledge to assist highway project decision makers is one of the possible reasons for poor usage of highway project data.

4. Visualization of Data

The importance of data visualization has been increasingly recognized in many industries. Most of the current analyses performed by the state DOTs are reported using tabular data that is very hard to decipher to make any decisions based on that. Various visualization techniques – be it simple trend line chart showing the number of ongoing activities by date or more advanced and interactive GIS visualization of project progress by location, it is easier to understand and utilize the data once it is visualized. Some of the contractor oriented DWR systems such as Trimble Proliance Analytics [22] have already implemented an eye-candy visualization techniques, but state DOT oriented DWR systems still lack any type of visualization.

5. Managerial Effort

The DWR system is developed primarily by RCEs and inspectors to record daily activities and any issues in a construction site. The data collected can then be used by a) cost estimation team, b) auditing team, c) scheduling team, d) design team, e) accounting team, f) traffic safety team, g) asset management team, and h) planning team. The second survey assessed how well these teams within the state DOTs are utilizing the data and whether or not the respondents believe that these teams can utilize the data. The result showed that there is a huge gap between the possibly benefiting teams and actually benefiting teams. For example, 36 respondents believed that cost estimation team can benefit from the DWR data but only 13 of them believed that they are actually taking the benefit of DWR data. This huge gap of over two-fold difference was noted for all eight but auditing team. Again, this is possibly because of the lack of automation for obtaining the benefits. Such gap can only be filled by managerial effort of increasing the awareness about the level of data being collected among various teams within the state DOTs. Similarly, the managerial effort such as motivation is also an important factor to improve the data collection practices (such as DWR data collection every day with sufficient details). It will be important to improve the data quality issue which is noted by many respondents.

6. Other Technical Aspects

Many respondents of the survey also indicated that the DWR systems currently being used by their state DOTs – be it a system developed and maintained by a single state or from the effort of multiple state DOTs – are *cumbersome to use*. For example, the process of completing change order requests in ASM was considered to be complicated and respondents pointed out the need to simplify the process. Many respondents also pointed out the need to improve the overall user interface. Improved and intuitive user interface not only reduce the training requirements but will also result in the improved data quality as more time can be spent in recording actual data rather than understanding and dealing with the system.

Similarly, due considerations should be given to the use of a proper hardware in terms of its processing capacity and portability. Respondents have reported that their current computers are outdated and slow. When they go to the field, a portable touchscreen tablet or smaller computer would ease the data collection process. This would also improve current practices of the state DOTs which collect DWR data in paper-based format in site and then transform the same data in electronic DWR system later. Such practices will essentially result in a data quality issue as well as *duplication of efforts*. When a proper hardware is provided, RCEs can collect proper data in timely fashion with consistent data quality which will also reduce *duplication of efforts*. Finally, everything is moving to the cloud and web-based technologies and the DWR systems should head in the same direction. AASHTO is already developing a web-based ASM – others can also follow the same path. The benefit of web-based system is the reduced effort to update and maintain the system.

V. CONCLUSION AND RECOMMENDATIONS

There is a great potential to enhance the collection and utilization of DWR data through digital technologies. But, there are many challenges that need to be addressed so that more sophisticated analysis can be performed for better decision makings.

State DOTs have limited resources and yet there is duplication of efforts because of the use of paper-based systems with or without electronic DWR systems. State DOTs have developed their state specific DWR systems using a limited amount of resources but the systems are maintained poorly. It might be better to join effort with other state DOTs to develop more intuitive and flexible systems that meet their needs. This will reduce the state level duplication of efforts and make better use of limited resources. Similarly, the use of advanced and autonomous data collection systems such as LiDAR and integration of DWR systems with other systems such as asset management, accounting, etc. would also be beneficial to make an optimum use of the data collected and the limited amount of resources available.

The current systems do not necessarily collect all the data attributes required for various decision makings in the right format. This necessitates the development of a system with more structured data attributes rather than linguistic data attributes. Once the data is collected properly, its analysis should also be automated so that more benefits can be obtained from the data. The data can also be visualized for easier understanding of the results for decision makings. Finally, managerial effort is required so that quality data can be collected and the data collected is used by all teams within the DOT which can possibly benefit from it.

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