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IMPLEMENTING DIGITAL VISUAL MANAGEMENT: A CASE STUDY ON CHALLENGES AND BARRIERS

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ABSTRACT

The construction industry (CI) has an increasing interest in achieving better situational awareness (SA) in complex projects, by focusing on sharing real-time information among project participants, allowing decision-making based on the project development's up-to-date situation and status. The implementation of digital visual management (DVM) tools as means of communication to increase SA in CI projects has the potential to simplify information dissemination. This paper identifies the challenges and barriers faced during the implementation of a DVM tool. The authors interviewed nine project management professionals who were part of the client organization in a complex infrastructure project of the western part of the Metro in Helsinki and Espoo, Finland. The findings show that the lack of digital tools for collecting and analyzing project data, the focus of the DVM on the top management, and the lack of trust among the actors involved in the project undermine the success of DVM implementation. Thus, digitalizing data collection, increasing trust among project participants, and disseminating information are crucial for successful DVM implementation.

KEYWORDS

Visual management, digital visual management, situational awareness, construction reporting

INTRODUCTION

The complexity of construction projects requires information sharing to increase and spread situational awareness (SA) among project participants. An important component of lean philosophy is the visualization of the flow of production activities, which also allows waste identification and elimination (Koskela, 1992). Shared SA in complex projects in the construction industry (CI) results in a better understanding of the task flow and an easier identification of problems, combined with a more efficient decision-making process. In recent years, the academic community and practitioners have increased their interest in studies and applications of SA models and systems in the CI (Lappalainen et al., 2021). Such interest stems

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from the fact that the information bottlenecks, as well as the costs and time involved in collecting, updating, and sharing data, are also symptoms of the lack of SA in construction projects (Akinci, 2014).

During military operations, SA began to be defined as the perception of environmental elements in time and space, comprehension of their meanings, and projection of outcomes in the near future (Endsley, 1995). In the CI, SA was initially related to safety management (Gheisari et al., 2010), but the term has also been applied to the construction phase of projects, with different areas of focus, such as the role of building information modeling (BIM) in SA (Li et al., 2018), location-based construction planning and controlling (Dror et al., 2019; Reinbold et al., 2019; Görsch et al., 2020), and construction logistics management (Seppänen & Peltokorpi, 2016; Tetik et al., 2020).

To increase SA, visual communication, and visual management (VM) have been successfully implemented and documented in distinct phases of construction projects (Tezel, 2011; Pedó et al., 2022). As part of the Toyota Production System, VM focuses on the visual representation of information that can be retrieved at a glance during the execution of tasks and is often connected to Lean Management (Koskela, 1992; Galsworth, 1997; Liker, 1997; Formoso et al., 2002).

Controlling the status of complex projects is an essential element to create and distribute SA. Usually, projects rely on the use of key performance indicators (KPI's) to share the current situation among project participants. Performance indicators are compilations of information applied to measure and assess performance (Edwards and Thomas, 2005). The indicators used can be leading or lagging. Lagging indicators represent realised outcomes of a process. Leading indicators represent likelihood of a particular outcome (Moore, 1983).

The use of performance dashboards to display and share KPI's had been continuously applied during complex projects, creating an important link between the project controlling activities and the use of VM in the distribution of shared SA. Through a dashboard, staff members can stay in touch with the strategic direction of the company and present their contribution to it (Shermach, 2005). Effective dashboards provide important data that can be rapidly read and understood (Few, 2006; Middleton 2005).

Other promising tools capable of increasing SA in construction projects are related to digitalization and information technology (Olivieri et al., 2017; Dror et al., 2019; Pica & Abanda, 2019). These tools allow system-to-system, human-to-system, and system-to-human communication, enabling more effective data collection and sharing with the right person at the right time (Dave et al., 2015). These tools have different areas of focus and applications, including 3D laser scanning, location-based information from construction crews, and display and management information systems.

Naturally, with the progress of research and application of VM and digital tools in the CI, the possible connection between both approaches has also raised interest among scholars and practitioners, opening the field to digital visual management (DVM) concepts and tools. Previous research has found that to select the right mobile computing strategy for managing information in construction sites, it is necessary to clarify the information management process, create an overview for mobile computing, and choose the appropriate technology (Chen & Kamara, 2008). A set of VM requirements applicable to digital support and control during the design phase has also been examined (Pedó et al., 2022). Nevertheless, the investigation into the challenges of and barriers to DVM adoption in CI projects continues to be limited (Reinbold et al., 2022).

Current developments show DVM's potential to both provide information in a visual manner and allow more effective data collection and display in the CI's complex projects. However, so far, mostly the benefits of DVM have been discussed. Because these systems are

not yet widely used, there is a need for more knowledge about the challenges and barriers related to implementing such systems.

This paper aims to identify the challenges of and barriers to the adoption of such tools and to understand the current stage of DVM adoption in the CI. This investigation is conducted in the context of a case study that explores the adoption of DVM during the reporting of a complex infrastructure project in Helsinki and Espoo, Finland. To identify the challenges of and barriers to DVM implementation, the researchers analyzed the visual reports produced by seven different contractors and interviewed nine project management professionals involved in the project.

METHODS

The chosen research method was a case study of a Finnish subway construction project encompassing seven separate sites. Case study involved a public project company building a subway project. The case was selected because the project had experienced considerable difficulties in managing the project status information in the previous stages of the construction. Disruption and recovery are often research opportunities worth documenting and analyzing since the findings often reveal insights into general processes (Yin, 2018). The project management team, which had progressed to its second phase, had been involved in developing a system to combine the collected data into a central dashboard and use it to manage the whole project.

In the prevailing literature, increasing the availability of visual information is a significant contributory factor for operations in complex and dynamic systems (Beynon-Davies & Lederman, 2017; Koskela et al., 2018). According to Beynon-Davies and Lederman (2017), VM systems are associated with concrete artifacts designed for informational purposes, the possibility to manipulate them for information and choice, and the location of the function in a physical space. The selected case addresses all these essential elements of VM, with the addition of digitalization.

A physical control room had touchscreens displaying the main Key Performance Indicators (KPIs) of the project, updated at 1–2-week intervals, depending on the data source. The data were collected mainly by the project management contractors working on site and a separate five-member status team, mostly using spreadsheets and web-based data, with no software integration or automation of data collection or use of sensors. A team ensured the quality, availability, and analysis of the data for the biweekly management sessions. During the sessions, the project management team assessed the situation and made decisions accordingly. The DVM system focused on the schedule, cost forecasting, and health and safety level of the project. At the time of this study, the system was used to manage the status of the final documentation and testing. The project had an 8-year duration and a budget of M€ 1,200.

The case study's location in Finland allowed the researchers access to the research data and enabled them to conduct face-to-face semi-structured interviews with DVM users. The preferred method of interviewing in this study was face-to-face, which the researchers considered a more effective way of observing body language and facial expressions than digital interviewing (Irvine et al., 2013). These observations were made during the interviews to the extent practicable. One of the factors that influenced this was whether or not the interview occurred in a room with VM tool/system access. Observations were documented during the interview. The informants were also interviewed in their familiar work environments. All interviews were conducted in Finnish by two researchers, one interviewing and the other observing and taking notes. Interviewees were asked to describe the DVM they use, including its functions, applicability, and the information it provides. They were also asked to describe the connections between the DVM and different aspects of the project, such as design, procurement, and logistics, and to identify any functionality that was automated. Interviewees

were also asked to describe recent cases where they or someone else had used DVM in a user role. Table 1 provides background information of the interviewees.

Table 1. Informant description.

NO.	ROLE	EMPLOYER	INTERVIEW DURATION (MINUTES)
1	Project director	Consulting company	107
2	Construction director	Owner	107
3	Site manager	Owner	76
4	Project engineer	Consulting company	77
5	Project engineer	Consulting company	82
6	Project engineer	Consulting company	74
7	Scheduling manager	Consulting company	78
8	Financial director	Owner	62
9	Project manager	Consulting company	50

The durations of the responses reflect the fact that the research project included also other questions and themes than DVM. The durations of the interviews include all themes, not just the time spent by the respondent on the DVM theme.

The research data thus consisted of visual reports generated by the digital system and the interviews. The approach used in this study aims to gain an in-depth understanding of the use of DVM in project management (Fellows & Liu, 2021). Data triangulation was employed, utilizing both interviews and observations during the interview as sources of data. The crucial aspect in this case was to have two interviewers, allowing one to concentrate on doing the interview while the other focused on observing. Before the interviews, a methodology for observation was created, consisting of two sections: descriptive observation and reflective observation. The observations were documented in interview notes, which consisted of handwritten records that contained both the notes taken during the interview and the observations made. To effectively triangulate, careful analyze of any inconsistencies or similarities between the statements by the interviewees and the observations were made by the researchers.

DVM REPORT

Considering the complexity of the project and the communication channels among the seven contractors and the project owner the involved understood the need for standardizing the reporting of construction site key performance indicators (KPI's) as a tool to improve and increase the stakeholders SA sharing.

The chosen type of report was a dashboard and the efforts resulted in a standard reporting system that followed up seven lagging KPI's:1) the percentage of work planned, 2) the percentage of the work completed, 3) the deviation between planned and executed work in percentage, 4) planned costs in million euros (M€), 5) executed costs (M€), 6) health and safety in percentage, and 7) collaboration work in percentage. Concerns were raised about ensuring the report's comprehensibility and accessibility to all stakeholders. Consequently, elements that enhance visualization and colour codes were implemented.

The report adopted is represented in Figure 1. If there were no delays, the schedule report had a green circle. If the work was delayed, the circle was red. A Finnish method was used to

measure occupational health and safety. The measure is based on the share of successful health and safety observations of total observations. For this health and safety KPI (Key performance indicators) green colour was used for indicator values above 95%, otherwise the KPI was red. Collaboration was measured via a questionnaire responded by those involved in the project, and the KPI measured the share of positive answers. For the collaboration KPI, the circle would be represented in green colour for indicator values above 80%, otherwise the circle would be represented in red colour. Other KPI's related to quantity of work executed and quantities were also followed. The report adopted is represented in Figure 1.

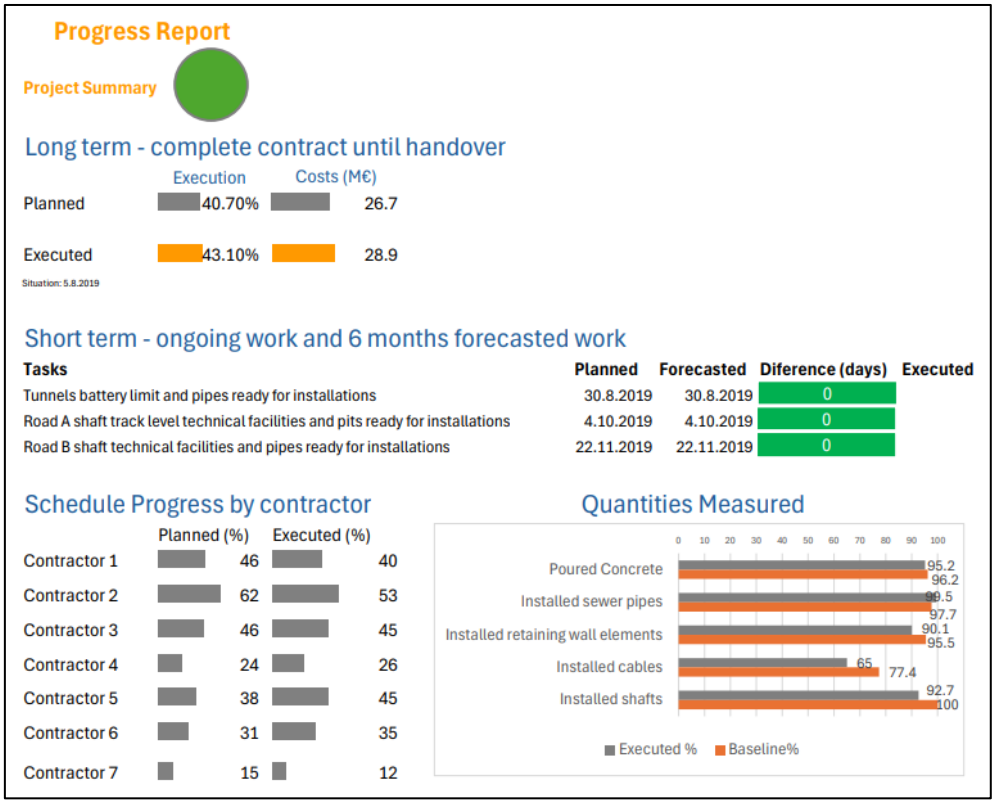

Figure 1: Visual Report of KPI's adopted during the project (source: adapted and translated from Finnish to English by the authors)

Having in mind the shared SA, the reports were displayed digitally in a "War Room", a management room for the project, that was accessible to the stakeholders. A picture of the digital displaying of the reports is seen in Figure 2.

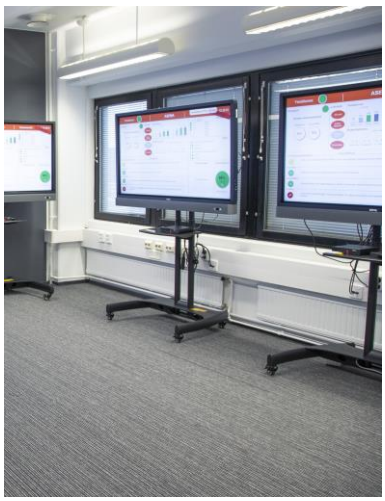

Figure 2: Digital display of visual report (Original photo: Timo Kauppila, NDAV)

BARRIERS AND CHALLENGES OF DVM IMPLEMENTATION

The interviews were transcribed, and the quotes were open-coded and categorized using Atlas.ti software. The authors then selected the quotations that mentioned reporting, automation of data collection, and collaboration. From this first handling of the quotations, 73 were subcategorized.

The authors created the following subcategories: 1) information and communication technology (ICT) and tools, 2) process and 3) people and culture. The following sections provide descriptions and examples of the categories with quotations from the interview transcripts and categorization. Some of the quotations were assigned to more than one subcategory. For example, the quotations that mentioned data collection and lack of trust in the reported data were categorized as *both* ICT and tools *and* people and culture because they pointed to the lack of digitalization in the data collection and analysis and emphasized that the data reported and collected were not always trustworthy.

Lack of ICT tools leading to manual workload

All quotations that mentioned tools for data collection and analysis, adoption of new tools and systems, information systems, information silos, and interoperability issues were classified under the ICT and tools subcategory. In total, 50 quotations were linked to this subcategory.

Several interviewees expressed their concern that the lack of a standard and unified tool for reporting increased the workload for this function, as illustrated in this quote:

"Well, yeah, there are, there are clearly flaws in the thinking, that no one had thought through to the end, all those reporting templates…".

The adoption of a standardized DVM report required training of the project members involved in the reporting phase, their work tools and processes adaptation and adjustments in the reporting process. These points created resistance to the adoption of DVM reporting. The change process was not considered a smooth transition but a contractual obligation.

Two other significant barriers to the adoption of the DVM report were manual data collection and analysis. Different systems are used to follow up on the various aspects of the construction progress. An interviewee mentioned the use of five different data collection and reporting systems, one each for financial reports, schedule monitoring, health and safety data and reporting, and tracking the quantities completed on the construction site. To consolidate all the information into the DVM report, the data were extracted manually from different systems, which required time and was considered inaccurate by the interviewees.

It was clear that the systems used were not interoperable and the extraction and exchange of information had to be processed manually, which is an important challenge to be addressed when digitalizing reporting and implementing DVM approaches in construction projects.

"From what you've heard, the situation picture is quite manual, and its updating has evolved a lot during the time I was involved. Initially, I was involved in maintenance, and then quite quickly, also in development, both technical solutions and things like, well, I don't know, maybe not so much in processes, but if you think about quantity tracking and KPI tracking, in their deployment, the contractors didn't have information about what it practically means and how it works".

Inconsistent process of collecting and publishing data

This subcategory includes mentions of necessary changes in both the data collection and reporting processes. Reporting process issues such as the contractors' neglect and delay in publishing information and the increased workload in processing the reports are covered as well. With the implementation of the DVM reporting system that was new to the project participants,

the processes for creating reports and collecting data were not well defined, and their development occurred simultaneously with the implementation phase.

The processes for creating the DVM reports were only developed due to the contractual obligations to produce and update such reports, which generated negative feedback related to project reporting. Many of the interviewees stated that the DVM reports contained unnecessary information, the updating of the information was often inaccurate, the same status was repeated over the weeks, and the reporting was not prioritized.

"When facing a tight schedule, reporting is often the first thing to be neglected. People just try to get through each day, and reporting is seen as an extra task."

"They often feel like, 'Why do we have to create this report?' And if your response is, 'Because it's in our contract that you provide it,' it immediately becomes additional work for them."

This resistance to the implementation of DVM reporting was also often perceived by an underrating about the utility and importance of the report. Some of the interviewees involved in the DVM reporting perceived it as an extra task to repeat the same information that had been reported previously, but in a different way. This reflects the lack of standards in the CI, as well as how management and tools differ from one project to another.

As project organizations change from one project to another, the implementation of DVM tools and reporting is not a standard process, which poses a barrier to the consolidation of the adoption of such approaches.

Culture of mistrust and resistance

All mentions of resistance to the implementation of a new process, mistrust in the reporting partners, the belief that someone was hiding information, the lack of information sharing with others, and the change of behaviors toward the DVM after its implementation were classified under the *culture of mistrust and resistance* subcategory.

In the interviews, the mention of the resistance to the implementation of the DVM reports was identified for different reasons. The resistance to the adoption of a new process and a novel manner of reporting, which belongs to the *people and culture* subcategory, concerns matters that need to be addressed. The changes should be dealt with before the implementation phase, and the discussions must clearly state the importance of the DVM and its benefits to the project. The contractual obligation is not enough to ensure the success of the implementation and can even contribute to the resistance to it, resulting in an attitude of adoption only due to contractual enforcement.

The most common mention regarding people and culture is related to the lack of trust. The existing culture of mistrust in the CI was also identified in this project by the authors. Several interviewees brought up the issue that contractors concealed information or tried to do so while manipulating the shared data and information. This mistrust encompassed how data were collected and by whom; the interviewees stated that when the data were collected and analyzed manually, the reports often contained outdated information, or the published information did not reflect reality. It came to light that mistrust also originated from people's behavior, with the interviewees admitting that they had also hidden information in some situations.

The mistrust culture is a major barrier to be overcome during DVM implementation, as it undermines trust in both the information and the SA shared. It also raises doubts about the decision-making process since the parties involved might make decisions based on outdated and mistrusted information.

Counterbalancing the mentions of the barriers and challenges during the DVM implementation, several interviewees identified two positive aspects that can be classified (under the people and culture subcategory) as enablers of the implementation. The first one was that when the project stakeholders were committed to the DVM implementation, the positive feeling about such adoption increased, and it was more often recognized as successful.

"In my opinion, it's important that if you go through it together, you can get the contractor more easily committed to it. So, we agreed that we would go through it together and streamline it in a way. In my opinion, it's a good commitment model in that sense then."

The second positive aspect was that after implementation, the interviewees felt that the DVM report facilitated their work, information sharing, and understanding of the project, thus increasing the SA of the project participants.

"In that, I feel that there was a very good, very strong; if we didn't have such a system, we would have been completely lost there, where those specific sites [were] going. Perhaps, with the traditional model, we wouldn't have obtained so much [information]."

These two points emphasize that involving the stakeholders and assuring their commitment to the DVM implementation create an environment conducive to making the transition and overcoming the initial struggles. The DVM implementation also increases the trust and understanding of the project SA.

Table 2 summarizes this study's findings.

Table 2. Identified barriers and enablers to DVM adoption.

Category	Barriers	Enablers
ICT and Tools	- Lack of standards for information sharing; - Use of different systems for different data; - Lack of interoperability among systems.	-
Data Collection and publishing	- Increased work for manual data collection and analysis; - Publication of outdated data; - Lack of clear understanding of the report utility.	-
Culture and People	- Lack of trust among project members; - Mistrust on data collection methods; - Lack of commitment from the project actors towards the reporting; - A shared culture of hiding information; - Resistance to the adoption of new methods and tools at work.	- The commitment of project stakeholders to the DVM adoption increased the positive feeling about the process and it was more often considered successful; - After the initial struggle with the report implementation, participants felt that the DVM report facilitated information sharing, project understanding and increased their SA.

DISCUSSION

This study aims to bring clarity to the barriers and challenges encountered while implementing DVM in a complex infrastructure project. During their research, the authors realized that the data were collected and analyzed manually for the purpose of generating the DVM report. Although the creation and sharing of a standard report facilitated the understanding and dissemination of information using DVM, there was noticeable mistrust in the data quality and the data reported. This is not a new discovery; despite the modest progress made in the digital evolution of construction projects, there remains a lack of trust in digital workflows (Soman & Whyte, 2020).

The lack of interoperability among the systems, which emerged from the interviews in this case study, requires much more advanced digital infrastructure and interoperability (Shibeika & Harty, 2015). For example, the traditional monthly reporting schedule and compilation of the data in the DVM reporting system used in this study appear to constitute a process that lags behind the digital era. The lack of interoperability among the different systems used could be addressed through digital systems that have the ability to connect and exchange information with one another. However, specialization in the construction sector continues to be a trend in terms of both professional roles and systems, and the integration of different systems and skills cannot be avoided (Turk, 2020). Therefore, the critical comments of the interviewees in this study can also be assessed as opportunities rather than just threats.

In this study, the process of creating and standardizing reports with a DVM approach, involving seven different contractors, provides evidence that systems lacking interoperability considerably increase the time required for reporting. This issue creates barriers to the adoption of such an approach, resulting in the neglect of the reporting when the project activities are urgent. Another interesting finding is that with information scattered in different systems, the increased time for reporting also hinders the implementation of DVM approaches. The underlying reason is that the involved parties might analyze the situation as entailing additional work without financial compensation. This perception reflects DVM practices' limitations regarding their simplicity and presentation of excessive information, as well as the lack of prioritization of information (Pedó et al., 2022).

This study's findings corroborate previously noted challenges in the adoption of DVM during construction projects. The DVM report followed an analog logic, where the data were collected and handled manually, with the digital format used only to display information (Reinbold et al., 2022).

The cycle of mistrust in the CI was a barrier to the implementation of DVM applications. This mistrust was also expressed as a lack of confidence in the reported data. Once a new process and a novel approach to reporting are implemented, engaging in constant work, with the commitment of the parties involved, as well as taking actions to increase trust among the participants in the process of data collection and reporting, become essential for the successful implementation of DVM.

CONCLUSIONS

In this paper, the authors have investigated and analyzed the impacts of creating a DVM process when reporting different KPIs for a complex infrastructure project, involving seven different contractors and client representatives.

The commitment of the stakeholders involved in the project is paramount for the success of DVM implementation. The present culture of mistrust in the CI is fueled by the lack of digitalization of processes. If data are analyzed and reported manually, even when generating a digital report, there is constant mistrust that the data are incorrectly collected or gathered at the wrong time. Due to such manipulation of data and reporting, there is also a persistent suspicion that contractors hide information.

In the studied case, the project stakeholders' resistance to the implementation of the DVM tool diminished after they overcame the initial challenges, identified the increase of shared SA, and acknowledged that the report supported their work.

This paper was limited to one complex infrastructure project in Finland and focused on the implementation of a specific DVM report, the generalization of results should be carefully considered. Further investigation of the information needs from users and the disparities between those and the information displayed is necessary.

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