Situation Picture Through Construction Information Management

Risto Kärkkäinen, Rita Lavikka, Olli Seppänen and Antti Peltokorpi
Department of Civil Engineering, Aalto University, Espoo, Finland

Abstract

Purpose – Low productivity in construction is typically blamed on the seemingly complex and chaotic nature of construction, which emerges as the stakeholders do not have an adequate picture of the evolving situation. The ever-increasing volume of situation data owing to the recent advances in IoT devices and reality capture platforms provide a unique opportunity to capture the actual situation data of construction projects accurately at a fraction of the cost compared to manual status tracking and reporting. This paper aims to investigate the concept of a situation picture, challenges in collecting situation data and its benefits.

Design/Methodology/Approach – Empirical data is collected through interviews in California and Finland, and by organizing workshops.

Findings – We contribute to literature on managing operational information by defining the concept of a situation picture in the context of construction, specifically from the blue-collar's perspective during on-site activities. We present the key components of a conceptual information model that represents a situation picture in construction.

Research limitations/implications – The applicability of conceptual information model of situation picture is not tested in practice, but the model will provide a starting point for research to comprehensively integrate social and digital information exchange for improving workflow.

Practical implications – The paper claims that designing and building comprehensive information management infrastructure would contribute to solving the problems of low productivity, quality and safety in construction projects.

Originality/value – Research on situation picture and situation awareness is scarce in the context of construction. The study links various information management technologies and practices to actual construction productivity.

Keywords Situation picture, Situation awareness, Common operational picture, Construction information management, Visual management, Data acquisition, Knowledge management, Lean construction

All papers within this proceedings volume have been peer reviewed by the scientific committee of the 10th Nordic Conference on Construction Economics and Organization (CEO 2019).

1. Introduction

Typically, the seemingly complex and chaotic nature of construction is blamed for the low-productivity problem. Complexity arises from temporary teams that are set up for

Emerald Reach Proceedings Series
Vol. 2
pp. 155–161
Emerald Publishing Limited
2516-2853
DOI 10.1108/S2516-285320190000002028

individual projects and contracting models that have caused the fragmentation of the sector and encouraged sub-optimization (Dubois and Gadde, 2000; Pekuri *et al.*, 2015). As a result, the current situation in many construction projects is that no one has adequate and accurate information about which design and construction activities have already been completed, what is happening at the moment, and what will happen in the next two weeks.

Currently, adequate information on a situation cannot be automatically or manually obtained from construction workflows. One reason is that companies do not have proper information management systems. Furthermore, acquiring a sufficient amount of situation information for understanding the actual situation is a time-consuming task, and therefore, it is often only performed weekly or even on a monthly basis. Additionally, status information is not real time, and it is not in a format that would help stakeholders (Soibelman *et al.*, 2008). Also, the captured data is prone to be incomplete, inaccurate and inadequate (Zhong *et al.*, 2015). For instance, only a fraction of operational disturbances are recorded in site meetings, and the progress reports are often subjective (Seppänen, 2009). There are also challenges related to visual situation information distribution, which is closely associated with visual management and lean construction. Visual management is commonly used in manufacturing industries and is one of the fundamental enablers of the lean production philosophy (Liker and Morgan 2006).

On the basis of the above description of the current situation, research is needed to understand what information actors need in the construction project context for better production control and decision-making. Our hypothesis is that if the information needs are mapped and categorized, we can start constructing methods for collecting, refining and delivering just the right information at the right time and for the right people.

We argue that a holistic information and communication management in construction operations has not received sufficient attention neither in the academia nor in practice. Therefore, this paper explores the current strategies for leveraging emerging situation data in construction and related industries, and aims to propose a model of construction information management for achieving a situation picture.

2. Theoretical departure

The concept of situation awareness (SA) is a widely researched topic in dynamic and complex system environments where fast and accurate decisions are critical for safety. Endsley (1995a) introduced the (SA) framework where individual, task and environmental factors affect the individual's SA. In the framework the SA consist of three stages: perception, comprehension and projection. In this study, we focus on environmental factors in construction environment and especially on how information flow could be designed holistically to increase individual SA.

Dynamic and complex environments can be found in aviation, air traffic control, ship navigation (Craig, 2012), health care (Schulz *et al.*, 2013), emergency response, military command and control operations (Cooke and Winner, 2007), and offshore oil and nuclear power plant management (Mearns *et al.*, 2001). Most of the SA research is conducted in the military context. There is only one research paper where a theoretical framework of situation awareness has been applied in the context of the construction industry. The researchers developed and implemented technologies for vehicle tracking and collision detection (Oloufa *et al.*, 2003).

Construction projects are also identified as a complex and dynamic system where safety is critical (Pekuri *et al.*, 2015). However, in construction, the adaptation to changing conditions and workflow control decisions and actions is not considered time critical as, for instance, in air traffic control. The slower pace of adaptive decision-making might be the reason why SA is an overlooked aspect in construction management literature.

A Common Operational Picture (COP) is commonly used in emergency management (Wolbers and Boersma, 2007). COP acknowledges two aims: systems design and capabilities of information dissemination and humans that need to reach a sufficient level of shared understanding (Copeland, 2008).

Neither the concept of SA nor COP seemed to answer to the information needs of the construction project context where learning should take place during and after construction. An umbrella concept is needed to gain a better understanding about what has happened, what is happening and what will happen in construction projects. Therefore, we suggest a concept of a situation picture (SP) that indicates the level of accessible workflow data to be stored, refined and distributed. In this research, we focus on improving the construction project system's capabilities of achieving SP through better operational information management. In the empirical study, we aim to understand the challenges, benefits and methods for forming a SP on a construction site. The concept of SP also focuses on describing what information is needed, and when and how to acquire and distribute it so that it enhances situation awareness and cross-project learning.

3. Methods

We conducted 16 semi-structured interviews between January and June 2018. Ten interviews were conducted in California, and the rest four interviews were conducted in Finland. We asked how the interviewees collected data for forming situation awareness, how they would like to collect data, what kind of challenges they have confronted when collecting data and what kinds of benefits they see in a more comprehensive understanding about the situation in construction sites.

We interviewed construction and information technology professionals, researchers and professors from the following categories: an information technology provider, a modular architecture provider, modular building system provider (two), construction software providers (four), a drone technology provider, general contractors (three), a researcher, and two university professors. Each interview took about an hour. Eight interviews were audio-recorded by the permission from the interviewee and transcribed verbatim. We took detailed notes in other interviews that were not audio-recorded. During the workshops, we identified that some professionals used and understand the term situation picture when describing the state of comprehensive understanding of the construction flows. We adopted the term in subsequent interviews and workshops.

We analyzed the interview transcriptions using Atlas.ti qualitative data analysis software. We used the following codes to categorize the interview data: the current challenges in forming a situation picture (SP) in construction, benefits of the SP, methods and technologies for collecting data for the SP, and interviewees' definitions for the SP.

In addition to interviews, we arranged four workshops with professionals to co-develop the concept of an SP in construction. Each workshop lasted three hours, and the researchers facilitated the discussion and group work in the workshops and documented all the results. The workshops provided researchers with understanding about the components of a situation picture, and how those components should be linked to form a situation picture.

4. Findings and discussion

4.1. Challenges in forming a situation picture in construction

On the basis of the interviews, the current way of working does not support the creation of an adequate situation picture because the actual workflow deviates from the planned workflow constantly. The available digital tools do not meet the needs of the blue-collar workers. Also, the workers do not understand the restrictions of the digital tools, what the tools are designed to do in construction.

During the past few years, many digital tools have emerged, which makes it challenging for the construction companies to know which technologies to adapt to and how to make the data linked.

The blue-collar workers usually know the detail-level problems on-site, but they do not have a voice. Currently, construction projects do not support learning; the feedback loop from previous projects to new projects is missing. The absence of a situation picture also leads to the lack of feedback loops. In the end, large quantities of data exist, but the challenge is to combine that data and make it meaningful. Some companies have started to combine the data in "data warehouses" and various project dashboards, which eventually enables data analytics.

4.2. Benefits of a situation picture in construction

Many of the interviewees mentioned that a better situation picture would improve workers' safety. Another reported benefit of a situation picture is better designs based on feedback from on-site operations. The interviewees also mentioned other benefits of a situation picture, such as better use of worker's time, possibility to standardize work activities, cross-project learning, fewer disputes, better logistical plans and uncovering of hidden work.

4.3. A conceptual model of construction information management for achieving situation picture

Based on the literature study and empirical evidence from the interviews and workshops, we define an SP in construction, as a state where the scope, quality and accessibility of produced operational information is adequate for controlling the workflow and improving production processes. The SP is an indication of the quality of construction information management processes. SP needs to be formed throughout a construction project, design, construction and post-construction when learning from the project should take place.

Figure 1 presents a synthesis of the concepts and knowledge presented in literature and the empirical findings from interviews and workshops. The concepts that emerged from the interviews and workshop were analysed in connection to the theoretical concepts of SA and common operational picture (COP) to present the conceptual information flow. The main finding when synthesizing empirical data and existing research is that data acquisition and distribution are divided into manual and automated processes and they are interconnected, and it needs to be taken into account when designing information management systems that aim to improve the situation picture in construction.

The conceptual information management model suggests that the process of data collection and analysis for understanding productivity consists of three phases: (1) data acquisition through change tracking, sensoring or perceiving; (2) information storage and refinement in human or computer memory systems; and (3) data distribution in the form of user interfaces and social interaction. The first step is to record the actual activities of each resource, such as people, materials and tools in real time. The recording can take place manually or automatically through sensors. Manual data collection is much more expensive than automatic in the long-term. The second step is to connect actual activities to planned activities. The third step includes an analysis of data to find out whether and where improvised or non-value adding activities exist.

The Individual situation picture is acquired through perception and enhanced through automated and social information distribution systems. Within the memory systems,

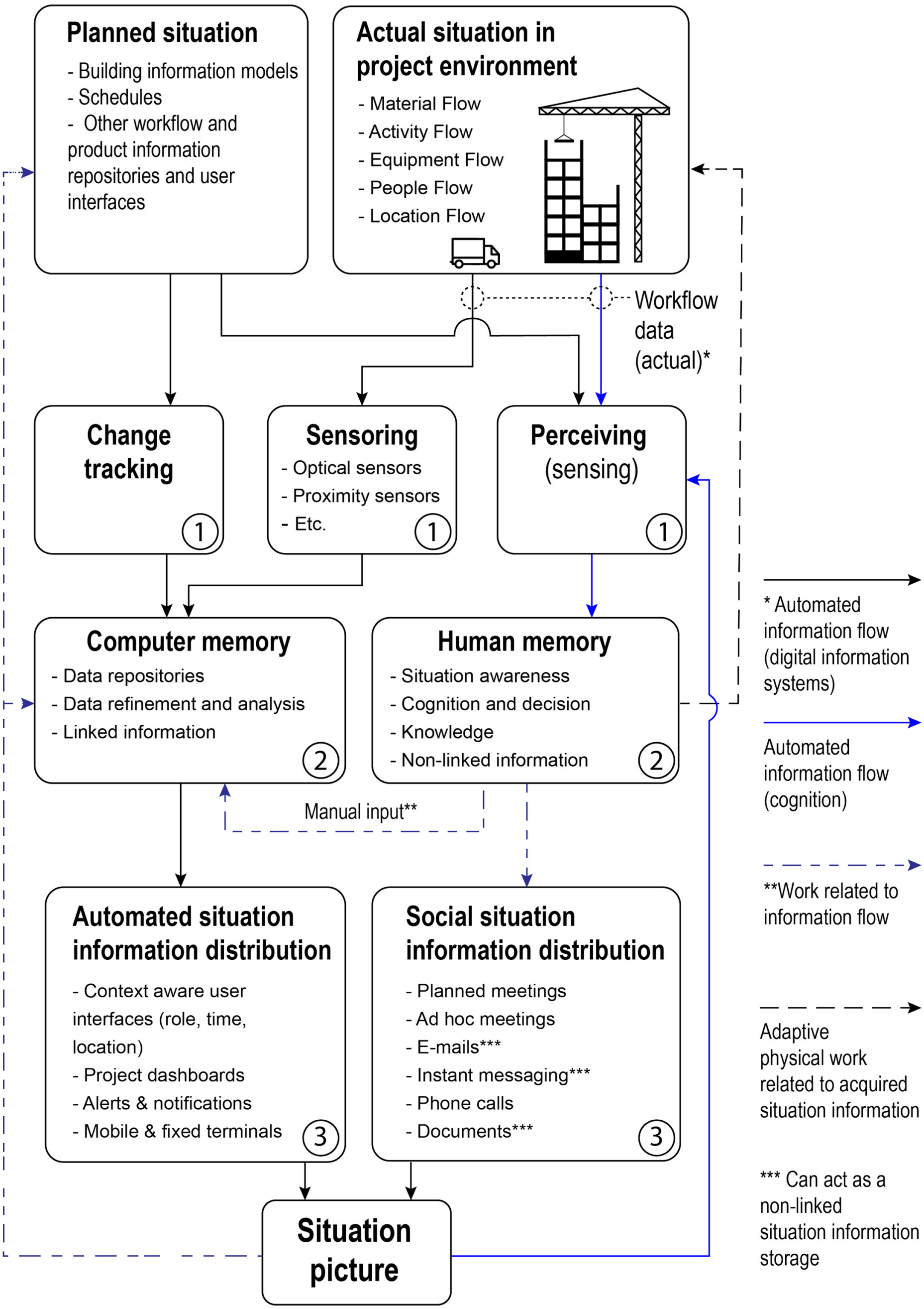

Figure 1.
A Conceptual Model of Construction Information Management for Achieving Situation Picture.

human cognition or computer algorithms refine the actual workflow data so that workflow forecasts can be distributed and potential production disturbances identified. The situation data can also be refined for analytical cross-project learning. The information flow infrastructure illustrated in Figure 1 should enable sufficient situation picture for all actors, which ideally will lead to more proactive and less wasteful information or construction work.

5. Conclusions

This paper introduces the concept of an SP in the context of construction operations management and shows how it is related to the concepts of SA and COP. This paper expands Endsley's SA framework (Endsley [1995a] and Endsley *et al.* [2000]) and describes the environmental factors related to information flow in construction project environment.

The study argues that situation picture is an essential concept for understanding the unique characteristics of construction and production management. This study focused on SP in the construction phase and particularly tracking the flows of activities, locations and resources (workers, tools and materials) in a project environment. This study also revealed that a situation picture would allow many benefits to construction operations management.

We argue that in construction projects, the sources for production disturbances cannot be controlled as efficiently as in a factory environment, and therefore, it is essential to manage construction supply chains so that production can better adapt to the changing conditions. Beneficial purposive adaptation can only happen if there is accessible information. The right situation information can be delivered at the right time if we have a holistic understanding of information flows.

Numerous startups have started to develop solutions for improving the situation picture in construction. Many general contractors have also initiated development programs to acquire a better situation picture, for example, by using drones for data collection, developing data platforms for data storage and refinement and building and testing various digital user interfaces for data visualization.

Future research endeavours should focus on quantitatively understanding what situation information is needed by every construction stakeholder. Also, it needs to be studied what is the optimal automated and manual information distribution system that makes situation information accessible to all stakeholders. Furthermore, it would be interesting to study whether a better situation picture can improve subsequent construction plans, and what the productivity and financial benefits of an improved construction information management and situation picture are.

References

Cooke, N. J. and Winner, J. L. (2007) "Human Factors of Homeland Security", *Reviews of Human Factors and Ergonomics*, 3(1), pp. 79–110.

Copeland, J. (2008) "Emergency response: unity of effort through a common operational picture", *Higher Education*.

Craig, C. (2012) "Improving flight condition situational awareness through Human Centered Design", *Work*, 41(SUPPL.1), pp. 4,523–4,531.

Dubois, A. and Gadde, L.-E. (2000) "Supply strategy and network effects — purchasing behaviour in the construction industry", *European Journal of Purchasing & Supply Management*, 6(3–4), pp. 207–215.

Endsley, M. R. (1995). "Toward a theory of situation awareness in dynamic systems", *Human Factors*, 37(1), pp. 32–64.

Endsley, M. R. (2000b). "Theoretical underpinnings of situation awareness: A critical review", in M. R. Endsley & D. J. Garland (Eds.), Situation awareness analysis and measurement (pp. 3–32). Mahwah, NJ: LEA.

Mearns, K. *et al.* (2001) 'Sharing ' worlds of risk '; improving communication with crew resource management Sharing " worlds of risk "; improving communication with crew resource management *', *Journal of Risk Research*, 4(4), pp. 377–392.

Oloufa, A. A., Ikeda, M. and Oda, H. (2003) "Situational awareness of construction equipment using GPS, wireless and web technologies", *Automation in Construction*, 12(6), pp. 737–748.

Pekuri, A., Pekuri, L. and Haapasalo, H. (2015) "Business models and project selection in construction companies", *Construction Innovation*, 15(2), pp. 180–197.

Schulz, C. M. *et al.* (2013) "Situation Awareness in Anesthesia", *Anesthesiology*, 118(3), pp. 729–742.

Seppänen, O. (2009) "*Empirical research on the success of production control in building construction projects*." Ph.D. Diss. Helsinki University of technology, Finland, 187 (available at: https://aaltodoc.aalto.fi/handle/123456789/4668).

Soibelman, L. *et al.* (2008) "Management and analysis of unstructured construction data types", *Advanced Engineering Informatics*, 22(1), pp. 15–27. Wolbers, J. and Boersma, K. (2007) "Sensemaking", 2(4).

Zhong, R. Y. *et al.* (2015) "A big data approach for logistics trajectory discovery from RFID-enabled production data", *International Journal of Production§ Economics*. Elsevier, 165, pp. 260–272.