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# METHODS AND TOOLS TO SUPPORT ON-SITE KNOWLEDGE MANAGEMENT IN INFRASTRUCTURE PROJECTS

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A method describes the way of doing something with a definite plan, while a tool can support the method by using information technologies (IT). Knowledge management provides thousands of methods and tools to assist the process of creating, sharing, using, and managing knowledge. This approach is well-known in Austria's industrial sector and only applied in major construction companies – especially not during the execution phase. Even though the building industry is characterized by routine processes, renovation projects cause unpredictable conditions leading to knowledge-intensive processes, which indicates the potential of knowledge management. A case study was conducted to identify the requirements for knowledge management tools or methods suitable for infrastructure projects focusing on highway construction sites. It points out that the needs of the interviewees working on-site are not very complex but very fundamental. The investigation shows that the most important needs include connecting, transparency, and team building. After this first step, research of methods and tools commonly used for knowledge management was completed. Those fulfilling at least one of the identified requirements were considered, evaluated, and examined for their applicability. This paper presents a selection of methods and tools to meet the identified needs on highway construction sites in Austria.

*Keywords:* Knowledge transfer, Tacit knowledge, Explicit knowledge, Communication, Construction phase, Connectivity, Team building.

## 1 INTRODUCTION

Knowledge management is an approach for getting the right knowledge to the right person at the right time and helping them to share it and put information into action to improve organizational performance (O'Dell and Grayson 1998). In this context, knowledge is the theoretical and practical skill a person owns and uses to solve problems. It is based on data and information but is, in contrast, linked to a person. This approach combines different insights from various individual disciplines – such as business administration, management theory, computer science, psychology, and philosophy – and provides a large number of methods and tools to support the process of creating, sharing, using, and managing knowledge (Oberschmid 2007). In this regard, a method or knowledge management technique describes the way of doing something with a definite plan, while a tool or knowledge management technology assists the method by using information technologies (IT). Techniques like brainstorming, communities of practice (CoPs) and others are not new, but they are implemented under the heading of management approaches (Anumba *et al.* 2014, Oberschmid 2007). Knowledge management and its methods and tools are

well-known in Austria's industrial sectors, but only applied in major construction companies even though they can improve any phase of a construction project from the contract award to handover and operation (Wais 2006). This method is only used to share knowledge between different departments, but it is not commonly applied on-site during the execution phase (Rathswohl 2014). An obstacle to implementing knowledge management in this phase is the lack of pragmatic and simple methods and tools usable on construction sites (Cüppers 2006). A survey from Germany (Waizenegger *et al.* 2016) showed that knowledge transfer in the construction industry is inhibited through temporal, spatial, contextual, and social barriers. Tools supported by mobile devices (smartphones or tablets) could increase connectivity and, thus, also knowledge transfer. Thoughts on knowledge management often lead to traditional information and communication technologies, including databases, but beneath the technical surface, the human element (willingness to share knowledge) and organizational aspect (conditions for knowledge management provided by the company) are also pillars essential for success (Bullinger *et al.* 1997). Even though the building industry is characterized by routine processes, a study (Ninaus 2019) comprising 78 interviews established that almost a quarter of the processes are knowledge-intensive, which indicates a potential for on-site knowledge management. We also recognize that projects with many companies unfamiliar with each other get a higher benefit-cost ratio than small sites such as detached houses. Contrary to initial expectations, work experience does not correlate with the number of knowledge-intensive processes. The lack of a well-structured, multidisciplinary organization and open-minded workers can be considered the most important barrier to on-site knowledge management and its highest potential. The interviewees' willingness to use digital devices indicates the potential for IT-based knowledge management tools. The biggest effort can be seen in connecting the people because the different trades working on-site create a temporary organization during the execution phase, but they do not usually form a team. Based on these findings, this study was conducted on an infrastructure project site to identify knowledge management methods and tools usable on-site during the construction phase.

## 2 METHOD

To enable the use of knowledge management in the execution phase of highway construction in Austria, a study was carried out to identify applicable tools and methods. This investigation was divided into two parts: (1) a case study to determine the requirements of infrastructure sites, followed by (2) a literature review to identify appropriate methods and tools to meet these needs. The case study evaluated a highway construction site in Styria, which reflects the author's research focus. This project involved a thorough renovation of a highway section with complete roadway renewal in both directions and the overhaul of nine bridges ranging from minor reconstruction to comprehensive renovation. A large Austrian construction company acted as the general contractor of this project. The site was overseen by three construction managers responsible for three separate sections: (1) bridge construction, (2) roadway construction, and (3) construction of noise barriers. The company carried out the majority of the activities. Only special tasks such as guardrail construction were commissioned to subcontractors. To take all perspectives into account, people from the client (project manager, purchaser), the site supervision team (project manager), and the contractor ((1) bridge construction: construction manager, foreman; (2) roadway construction: construction manager, site supervisor, foreman; (3) construction of noise barriers: construction manager, deputy site supervisor) were interviewed. The interview guideline was divided into five sections: (1) general information about the construction site including the current situation regarding the distribution of knowledge and information, (2) problems during the execution phase, (3) routine and knowledge-intensive

processes during the interviewee's daily work, (4) multidisciplinary knowledge exchange as a result of learning from other trades and companies, (5) the person to take on the role of the on-site knowledge manager. The interview guideline was designed to be very open so that the interviewee could give additional information. The semi-structured interviews (Corbin and Strauss 2015) were carried out by the author face-to-face and were audio-recorded. The audio recordings were subsequently transcribed, cleaned, coded, and analyzed through qualitative content analysis. The second part of this study involved the research of common knowledge management methods and tools. Only those fulfilling at least one of the requirements identified in the interviews and usable on infrastructure project sites were considered, with the aim to reach theoretical saturation. The requirements derived from the interviews were summarized into three sections, and the selected methods and tools were evaluated in these three categories. One to three points could be achieved in each category, with three being the best result. Finally, points were added up. Any method or tool that achieved more than four points was useful. Knowledge management techniques or technologies that achieved fewer than four points but earned full number of three points in one of the categories were also considered for further investigation.

## 3 RESULTS

### 3.1 Case Study

The interviews showed that an efficient transfer of knowledge and information is essential, particularly refurbishing existing buildings. Since preliminary tests can only be carried out on a random basis, other conditions are often found during the construction process, causing unforeseen situations that, in turn, require knowledge to respond quickly. Communication channels need to be kept short, and new findings must be documented and distributed with only little effort for everyone involved. Communication on infrastructure sites reveals a strongly hierarchical pattern. Knowledge is thus often lost, or its use is very time-consuming. According to the respondents, disseminating experience is particularly important, but the hierarchical structure makes this aim very difficult to achieve. On the client-side, it was emphasized that it is sufficient to participate in the regular meetings on-site. But future construction sites could be made more efficient if the client got more insight into practical handling. The amount of knowledge-intensive processes is higher than the findings of the 78 interviews conducted only with contractors (Ninaus 2019). The interviewees rated the opportunity to learn from other trades and companies during the execution phase as extremely positive and useful. However, collaborative learning can only occur if people are open to this approach or if the working atmosphere is good. Team-building methods requested by the client can be the first step toward reaching this goal. Successful knowledge management needs to be practiced by everyone. Therefore, the position of a knowledge manager must be created who oversees processes and people. Most interviewees would attribute this role to the on-site supervisor, although this work would also have to be remunerated separately. Another 30% only see the option of contracting an external company since their internal resources are already overused.

#### *3.1.1 Requirements*

Table 1 gives an overview of the knowledge management requirements during the execution phase identified through the interviews.

### 3.2 Selected Methods and Tools

Table 2 shows the methods and tools commonly used for knowledge management that achieved more than four points in total or three points in one category during the evaluation.

Table 1. Categorized requirements for knowledge management during the execution phase.

| | |
|---|---|
| **(1) Connecting**<br>• To connect the people working during the execution phase<br>• To distribute contact details to everyone involved<br>• To facilitate short communication paths to save time | **(2) Transparency**<br>• To indicate responsibilities clearly<br>• To distribute rights<br>• To give an overview of the knowledge base<br>• To provide more insights<br>• To enable a simple documentation<br>• To enable knowledge exchange |
| **(3) Team Building**<br>• To strengthen trust between the different companies working on-site<br>• To increase the sense of belonging to the project among the people involved<br>• To enable communication between the different parties within the different parties involved | |

Table 2. Selected methods and tools for knowledge management on infrastructure construction sites.

| Knowledge Management Tool/Method | Connecting | Transparency | Team Building | Total |
|---|---|---|---|---|
| BIM and Socio BIM (Grover and Froese 2016) | 2 | 3 | 0 | 5 |
| Discussion forums (Cüppers 2006) | 3 | 2 | 1 | 6 |
| Groupware (Voigt 2019) | 3 | 2 | 1 | 6 |
| Social networks (Gabriel and Röhrs 2017) | 3 | 2 | 1 | 6 |
| Knowledge dictionary (Orth 2019) | 0 | 3 | 0 | 3 |
| Checklists (Orth 2019) | 1 | 3 | 0 | 4 |
| Document templates (Orth 2019) | 0 | 3 | 0 | 3 |
| Ideas management (Orth 2019) | 2 | 1 | 2 | 5 |
| Room management (Orth 2019) | 2 | 1 | 3 | 6 |
| Surface workshop (Orth 2019) | 2 | 2 | 3 | 7 |
| Communities of Practice (North 2011) | 1 | 2 | 3 | 6 |
| Info center (Voigt 2019) | 2 | 1 | 3 | 6 |
| Competence matrix (Schlink 2019) | 1 | 3 | 0 | 4 |
| Creative techniques (North 2011) | 1 | 1 | 2 | 4 |
| Micro articles (Voigt 2019) | 1 | 3 | 0 | 4 |
| Open space (Orth 2019) | 2 | 1 | 3 | 6 |
| Knowledge map (Cüppers 2006) | 2 | 3 | 0 | 5 |
| Lean management (Kaiser 2013) | 2 | 3 | 2 | 7 |

## 4 DISCUSSION

The case study showed that a holistic view involving client, contractor, and site supervision entailed more knowledge-intensive activities than the interviews conducted only with contractors

(Ninaus 2019). The construction industry is characterized by unpredictable conditions causing knowledge-intensive processes. Furthermore, we can assume that the nature of renovation projects leads to more knowledge-intensive activities because preliminary tests can only be carried out randomly. The case study points out that the needs of the interviewees are not very complex but very fundamental. Nowadays, the construction industry is concerned with the need for digitization, but the requirements are more in-depth. Connecting the employees is one of the required pillars. The problem is that the trades working on-site are not familiar with each other. Thus, a tool needs to facilitate the connection between different companies to keep communication paths as short and simple as possible. Social networks, discussion forums, or groupware are IT-supported tools to ensure that. Social rooms equipped with tablets and the tools mentioned above provide access to everyone involved. The second aspect is the need for greater transparency. On the client-side, it was emphasized that it is sufficient to participate in the regular meetings on-site, but it could be more efficient if the client had more insight into practical handling. Nowadays, the reviews carried out on construction sites in Austria are inadequate for the client to get sufficient insight. Some of the interviewees mentioned that they were not part of every meeting, but they wished to have the option of reading the minutes. This particularly applies to the people working on-site without having access to a computer in their daily work, who wish to have greater insight into the meetings. Furthermore, responsibilities are known only to an insufficient extent, which causes time to be wasted by having to identify the responsible person. BIM, Socio BIM, and lean management can provide the parties involved with greater insight into the construction process. The BIM model equipped with knowledge and information provides transparency across all processes, while lean management offers transparency through regular face-to-face meetings with all those involved. Competence matrices and knowledge maps show the tasks and skills of the people working on-site. Individuals can use these tools, which are also installed on tablets in social rooms, to identify the responsibilities and find and use existing knowledge. Micro articles are a way to spread relevant knowledge quickly. Knowledge dictionaries, checklists, and document templates can lend greater transparency and efficiency to individual work steps translating into fewer mistakes and time savings. Interviewees considered learning from other trades and companies during the execution phase to be extremely positive and useful. However, collaborative learning can only occur if people are open to this approach or if the working atmosphere is good. Therefore, the course must be set at the organizational level, which leads to the third part of the requirements, i.e., the team-building methods to be requested by the client. Even though knowledge management is often associated with information and communication technologies, the people with their willingness to share knowledge and the organizational boundaries are fundamental for success. Well-thought-out room management or info center (social room, rest area etc.) can promote informal knowledge sharing, leading to the distribution of explicit knowledge. The formation of Communities of Practice encourages the exchange and development of knowledge. Events like surface workshops or open-space meetings strengthen the team spirit and create a better understanding of others, instilling trust and fostering the willingness to share knowledge. Ideas management and creative techniques are methods and tools not assigned to one of the three pillars, but they are useful in the construction industry. They can be very efficient, particularly in the context of problem-solving in the execution phase.

## 5 CONCLUSION

Randomly conducted preliminary tests are typical of renovation projects, but they lead to more knowledge-intensive processes being identified, which generates the greater potential for knowledge management than in new construction projects. Disseminating experience is very

important for the execution phase, but Austria's highway construction projects' hierarchical structure makes this aim very difficult to achieve. It is important to keep the communication channels short to document and distribute new findings with only little effort for everyone involved. The case study points out that the needs of the people working on-site are not very complex but very fundamental. Nowadays, the construction industry is concerned digitization, but the requirements are more in-depth. Connecting people, ensuring transparency, and facilitating the team-building process are the main needs for highway construction sites in Austria. Knowledge management provides thousands of methods and tools, but only some of them can be implemented on-site. Table 2 shows usable technologies and techniques that meet the requirements and can be applied to Austrian highway construction sites under certain conditions. Further research is needed to develop a technology combining the collection methods and tools to overcome the challenges Austria's construction industry is facing.

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