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# The Impact Logic of Mobile Technology Usage on Job Production

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### ABSTRACT

Research on mobile technologies is met with increasing attention. Most of the existing literature focuses on the use of mobile technologies on a managerial level, with technology as a device for information and communication exchange. The impact potential and their corresponding functionalities on the worker level have not yet been analyzed. This study is trying to fill this gap. It is the key objective to develop a theoretical model of how mobile technologies influence business processes in job production (construction industry) on the operational level. Thus, a generic model will be developed on the basis of existing literature, especially the concept of Task-Technology-Fit. It emphasizes how task complexity affects the required effort of individual information access, information capturing as well as the timeliness of information. These mediators will influence the utilization of information for resource planning and coordination, which in turn will affect the performance of operational processes. Subsequently, it will be deduced how mobile technologies affect the forces and relationships in this model. There is a trade-off between the increasing effort to capture information and the reduced effort of accessing information. Moreover, the way the captured information is utilized for status tracking, resource utilization and resource coordination is considered to be the key factor in improving operational process performance.

### Keywords

Mobile technology, job production, construction processes, operational impact, coordination effectiveness, process performance

### INTRODUCTION

In the job production industry, different professionals work in different locations. Since a lot of information is necessary for coordinating these professionals, the job production industry can be characterized as highly *information-intensive* (Kajewski and Alwi, 2006). Thus, the success or failure of a project largely depends on the available information of the resources involved as well as on the distribution of this information, i.e. the communication among the project participants, depending on the quality, quantity and timing of information (Bowden and Thorpe, 2002; Dong, Maher and Daruwala, 2006). However, the information access and capturing is largely person-bound. Automating information capturing and access by using mobile technologies is considered the first step in improving process performance (Bowden, Dorr, Thorpe and Anumba, 2004). A key characteristic of job production processes, such as the construction industry, is the inherent *mobility* of materials, equipment and the required operational workforce. To provide all participants of a project with timely and reliable information about the location and status of these resources, the information must be captured, i.e. stored, and easily accessible (Liu, Soibelman, and Trupp, 2004). Another characteristic of this process domain is the occurrence exceptions and disruptions, such as missing materials, machines failures or unfinished work items. Mobile technology provides the opportunity for managers and foremen to be immediately informed about unexpected events (Rupnik and Krisper, 2003) in order to respond to these exceptions within a short period of time (Gebauer and Shaw, 2004).

Being non-responsive to emerging disruptions is one of the main factors for delays in job production processes. Since projects plans are often complex and activities involved highly interdependent, smaller disruptions may accumulate into significant time and cost overruns. In this vein, many articles describe mobile technologies that support site managers. However, coordination problems regarding the effective and efficient utilization of labor, materials, and equipment are largely solved by hand (Gumpp, Paulus, and Pousttchi, 2004; Kajewski et al., 2006), without computerized project planning and scheduling tools. In this context, mobile technologies facilitate the faster delivery of the required information in order to better coordinate work items as well as to respond to unexpected events. On a construction site, for instance, the fast and interactive communication between the site professionals is very important, especially when unanticipated events or critical problems occur (Loefgren, 2005). Nevertheless, problem resolution is still conducted through mutual adjustments of professionals, neglecting the potential of computerized planning tools.

To sum up, the use of mobile technologies has been analyzed in general, but there is little literature which focuses on the connection between information access, information capturing and information timeliness for providing better methods of resource utilization and coordination in interdependent and concurrent project structures from a theoretical angle. Furthermore, the existing literature does not take into account that the operational impact of mobile technologies may be as significant as the managerial impact. Moreover, only a few contributions take specific processes like plant or building construction into account (Saidi et al. 2002). It is not clearly understood how mobile technologies influence operational processes (Gebauer, Shaw and Zhao, 2002a), what processes would benefit most from the use of a mobile technology and how mobile technologies should be designed. The existing literature also assumes that work and resource coordination still takes place through mutual adjustment and that the adaptation as well as the re-scheduling of work plans only takes place in periodic cycles, i.e. once a week. Information about the work progress is only gathered weekly or less frequently (Bowden et al., 2004; Liu et al., 2004). In this context, mobile technologies offer the potential of exactly monitoring the status of the activities on the project site at all times , while providing information which is easy to access and available in time. In addition, mobile technologies may not only provide accurate and easy-to-access information. They may offer access to centralized, i.e. host-based planning and coordination tools which in turn enable better resource utilization and coordination procedures. In this context, the negative consequences of unexpected events (e.g., stock-outs, delays of preceding activities, etc.) may be reduced or circumvented. Both, better information supply and better coordination will enable an improved process performance, compared to conventional information supply and coordination.

## RESEARCH QUESTIONS AND METHODOLOGY

In order to analyze the potential of mobile technologies in processes of job production on a worker level, the following research questions will be addressed:

- Which factors determine process performance from an information processing perspective?
- How does the use of mobile technologies change this cause and effect relationship?
- Are there any trade-off relationships between factors that need to be carefully looked at?

The methodology of this paper is theory emergent. Based on the existing literature, especially the theoretical concept of the Task-Technology-Fit (Gebauer et al. 2004, Goodhue and Thompson, 1995), a theoretical model will be deduced in a first step which captures the relationship between task complexity, information characteristics, coordination effectiveness and process performance with regard to the construction industry. In a second step, mobile information technology will be introduced as an additional factor. It will be analyzed how this construct affects the existing relationships in order to asses the impact logic of mobile technology usage. Thus, the methodological approach followed in this paper is exploratory. It is the first step of a research in progress, which will be complemented by model testing in the future. Nevertheless, since it is the first contribution which focuses on the operational level from the perspective of a specific and relevant process (construction), the gradual development of the theoretical model is considered a valuable approach since it offers a profound perspective toward the impact logic of mobile technologies.

The paper is structured as follows. Section 2 describes the state of the art of mobile technology research in the construction industry. In the main section of this paper, section 3, our research model regarding information and coordination impact of mobile technologies is presented. Section 4 provides an overview of how the extended model will be tested in the near future. The paper ends with an intermediate conclusion of this research in progress.

## STATE OF THE ART OF USING MOBILE TECHNOLOGY IN THE CONSTRUCTION INDUSTRY

(Loefgren, 2006) describes a mobile application which runs on a tablet PC and which is used by construction managers. The mobile technology should reduce redundant work, support the communication and reduce times (distances) to get information. De la Garza and Howitt., 1998, also see mobile technologies as a means for improving information supply and communication on operational site units and the site office. They conclude that information and communication technologies are the basis for a timely and instant access, delivery and processing of information. For Kimoto, Endo, Iwashita and Fujiwara, 2005, the paper-based work on construction sites is one reason for a low efficiency because of the big gap between time and space of information collection and information processing. (Ward, Thorpe, Price and Wren, 2004) use a tool for mobile site information collection. Managers use the system for real-time information collection, which enhances the flow of information throughout the site. With this application, professionals can easily and timely access and manipulate construction data and improve the performance of construction.

Saidi, Haas and Balli, 2002 analyze the use of handheld computers on a construction site. They state that information is often unavailable, inaccurate or simply outdated and that construction projects often experience expensive delays. In order to overcome these problems, mobile technologies are one way of improving operations. Mobile technologies can be used for tracking equipment and material as well as for accessing relevant schedule information. This could allow the workers to devote more time to their actual work and spend less time idly, for instance, while waiting for updated status information or required tools and materials. For Eisenblaetter, 2001, gaining accurate information at the right time and in the right place is crucial for the success of a timely completion of a construction project. Mobile applications on personal digital assistants (PDAs) for construction managers, including a tool for frequent schedule updates, are likely to improve the efficiency and effectiveness of the construction process.

In their paper on novel technologies in construction field data collection, Liu et al., 2004, mention the possibility of updating schedules using a mobile device while the construction is ongoing. They also explain that the normal rate of information collection is weekly and that, in contrast, with the help of mobile technologies, the frequency and periodicity of information collection increases, for example, to a daily basis. This means, on the one hand, that construction management can see the progress in a daily log file. On the other hand, information collection, which is done manually by construction workers, can be assisted by mobile computing. Bowden et al., 2004, confirm that formal reporting on the project's progress takes place in too large periodical increments. This leads to the problem that it takes too long until disruptions are recognized and managed.

Furthermore, Bowden, 2005, points out that mobile technologies can lead to more productivity, especially a shorter construction time. She analyzed a mobile application which supports materials and equipment tracking as well as site monitoring. Materials tracking with RFID chips has been recently researched. For example, Jaselskis and El-Misalami, 2003,, show in a pilot test how time can be saved and whic advances can be made (e.g., no reading problems in spite of dirt) when using RFID tags instead of bar codes on a construction site.

Leclercq and Isaac, 2006a, identify different kinds of benefits which can be gained when using mobile technologies. In their exploratory study, they interviewed 80 managers in order to find different advantages and opportunities of the use of mobile technologies. They found out that mobile technologies lead to a higher responsiveness and reactivity because information can be communicated and received in real time. This has a positive effect on the coordination between co-workers and makes it possible to respond quickly to new situations. In another study, Leclercq, Isaac and Besseyre des Horts, 2006b, analyze the adoption of mobile technologies. They state that individual and organizational levels of the use of mobile technologies are highly related. Thus, the adoption and the use of mobile technologies must be analyzed on both levels to find out the real benefits.

In contrast to the reviewed papers, which,focused solely on the usage of mobile technologies on a managerial level, the purpose of our research is to analyze the potential of mobile technologies on construction sites on the worker level. Thus, it focuses on construction site workers (and not construction managers) using mobile technologies in order to offer timely access to accurate information. This improved information supply offers a better basis for resource utilization and coordination procedures which in turn makes it possible to improve the process performance. Especially the possibility of a faster and more frequent plan adaptation allows for a better exception handling and resource utilization.

## RESEARCH MODEL

Based on the literature on mobile technology and coordination theory, the following model (Figure 1) was developed. It has been carefully deduced with the help of existing studies. Appendix A contains a table which includes the corresponding sources of the constructs we introduce, their respective definitions, how the constructs have been validated as well as potential measures. The model combines task, technology, and information characteristics (Chenhall and Morris, 1986, Daft and Macintosh, 1981) as well as elements of the concept of the Task-Technology-Fit (Goodhue et al., 1995. In general, a good Task-Technology-Fit promises significant performance improvements (Goodhue, 1995, Lee, Lee and Kim, 2004). This type of fit has been analyzed in combination with mobile technologies by different authors (Gebauer, Gribbins and Shaw, 2005; van der Heijden and Valiente, 2002; Lee et al., 2004). They posit that task characteristics (e.g. task size, complexity, uncertainty) and technology characteristics (e.g. display size, input-methods and context) have to be taken into account when analyzing the Task-Technology-Fit while using mobile technologies. Other authors base their research on the coordination theory. The basic argument is that the coordination effort increases with a higher complexity of the task (Gebauer et al., 2005; Malone et al., 1994, O'Reilly, 1982, Shin, 1999). Due to a higher task complexity there are more work items to complete as well as more dependencies between work items. Managing dependencies between tasks is the goal of coordination. Moreover, every additional task dependency produces more information which must be processed for coordination. Thus, with a higher task complexity, the coordination effort increases due to additional information requirements.

The benefit of mobile technology utilization will be measured by the increase in process performance, i.e. the reduction of the finishing time for the building or the plant. In order to do this, both theories mentioned before are integrated into the developed model. A trade-off can be found between effort for capturing information and reduced effort for information access. Moreover, the use of mobile technology to support coordination mechanisms to gain a benefit is included. The result is a reduced overall processing time (Gebauer and Shaw, 2002b, van der Heijden and Valiente, 2002). In contrast to the reviewed literature, the role of the user who applies the mobile technology is not only managerial but primarily operational. Thus, the technology will be used by workers and handymen. In the following, the different constructs and relationships will be explained. Proposition 1-6 explain the basic model for a construction or plant site without the use of mobile technology (Figure 1), reflecting on the relationship between the task complexity, information characteristics, and its impact on coordination effectiveness and process performance. Hypotheses 7-12 take into account the impact logic of an extended model where mobile technologies are being used (Figure 2).

**Basic Model**

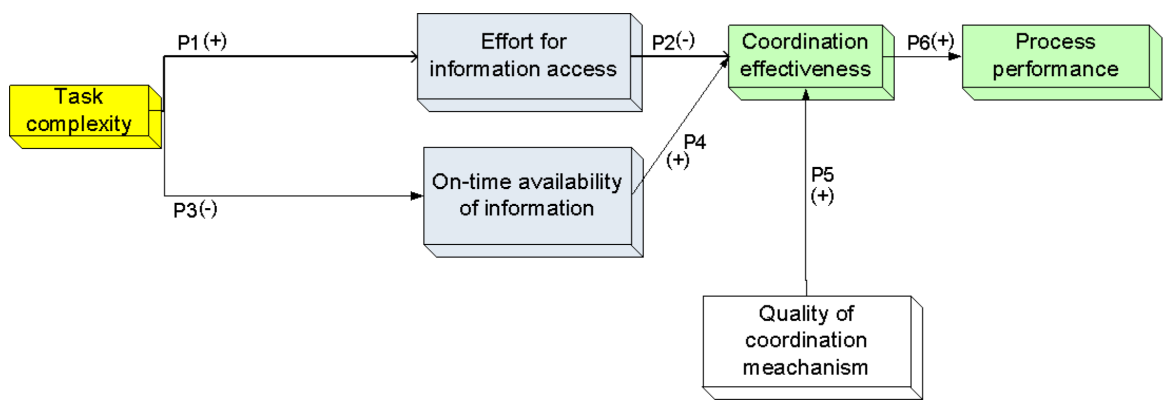


**Figure 1. Basic Model without Mobile Technology Usage**

*P1: The higher the task complexity, the higher the effort for information access.*

Task complexity in the building or plant construction industry can be expressed with different factors like size of a building (Tawfik, H., Fernando, T. 2001) (number of rooms and floors), number of workers, number of assembly sections as well as the number of dependencies between tasks. In this model, "*information*" means information about the work progress and the status and position of machines, material and workers. Dong et al., 2006; Oglesby, Parker and Howell, 1989, state that the size and the complexity of a site influence the management requirements of information. In order to get information in a building (e.g. about the work status in different rooms or the status of machines), the worker has to walk around and/or ask other workers. If the building is large, getting information means walking longer distances and/or asking more people. Thus, the effort for accessing the required information increases. Bowden et al., 2004, point out that the collection of information from different sources is time consuming. With a growing number of rooms, the number of sources increases and so does the time for collecting this information. Before having access to the information it must be collected. Furthermore, with a growing size of the building or plant, the complexity of the task grows and the respective information needs to increase as well (Dong et al. 2006). Shin, 1999 states a correlation between the size of a task, which leads to a higher coordination effort, and the amount of required information to achieve proper coordination. If more information is necessary, it takes longer until it is accessed and the coordination can be done.

*P2: The higher the effort for information access, the higher the coordination effectiveness.*

Coordination effectiveness means the well-organized utilization and orchestration of resources as well as the immediate and useful reaction to unexpected events. For a high-quality coordination, a specific and comprehensive information supply is necessary (Gebauer et al., 2005; Malone et al., 1994, O'Reilly, 1982, Shin, 1999). A too high effort for information access can have two consequences on coordination effectiveness. On the one hand, coordination time increases because it takes longer until all necessary information is available. On the other hand, the coordination quality decreases due to information gaps or deficits. But with a better access to information, the response to new situations can be improved and also the coordination between co-workers can be facilitated (Leclercq et al., 2006a).

*P3: The higher the task complexity, the lower is the on-time availability of information.*

A worker oversees only one assembly section of the entire construction process. If the building or the plant becomes larger, (s)he oversees a decreasing fraction of the building. In order to obtain all information needed (e.g. the current work status of all rooms), (s)he needs to walk around. For this reason, the on-time availability of information becomes less likely because (s)he cannot physically oversee the status of all information in different locations of the site. Bowden et al., 2004, point out that reporting only occurs periodically and that the information transfer is done manually, which in the best case leads to a delay until everyone has the required information. In the worst case, the information will never reach the right person. For Dong et al., 2006, the management of information is more complicated with a larger site, which induces more complex tasks. More complicated information management requirements result in reduced on-time availability of information. Likewise, Kajewski et al., 2006, state that it is important to have real-time access to information which means that the right information should be in the right place at the right time (Ward et al., 2004).

*P4: The higher the on-time availability of information, the higher the coordination effectiveness.*

A high coordination quality requires timely information. Every time an unexpected problem occurs, negative consequences can be avoided if status information is provided in time and up-to date. The occurrence of problems does not differ with the availability of information; however, with timely information, problems are recognized earlier and adjustments can be made immediately. In construction engineering, delays often occur because of poor planning and incomplete information (Boussabaine, Grew and Currin, 1999). Moreover, Kajewski et al., 2006, state that timely and successful construction requires the timeliness of information. Thus, on-time available information provides the basis for better resource coordination, reducing delays on site.

*P5: The higher the quality of the coordination mechanism, the higher is the coordination effectiveness*

The quality of the coordination mechanism refers to the quality of managing uncertainties and complexity with the help of human or technical coordination mechanisms and has a direct influence on the effectiveness of coordination (Malone et al., 1994, Tilson 2005, 2007). Coordination itself refers to the orchestration of divided labor activities. Since a higher task complexity leads to a higher division of labor, more coordination efforts are necessary in order to re-integrate the divided labor activities. This is time consuming and requires additional work. In addition, the work effort and the quality of the results depend on the coordination mechanism used (Crowston, Rubleske and Howison, 2004). A sophisticated and high-quality coordination mechanism usually leads to a higher coordination effectiveness. (Shin, 1999).

*P6: The higher the coordination effectiveness, the higher the process performance.*

Process performance is represented by the time which is necessary to finish a process (Gebauer et al., 2002b). In a construction site scenario, process examples are coating and tiling. If the effort for information access increases, coordination effectiveness decreases, and so does process performance (Bowden et al. 2004). Low quality coordination leads to more idle time and longer finishing time. Work items cannot be started immediately and workers have to wait until information is available or prerequisites are met. With a high quality of coordination mechanism which accesses timely information, resources can be scheduled, i.e. coordinated, in proactive and efficient way. A sound schedule implies that the time between different work items and idle time of workers are minimized. Due to dependencies, workers often have to wait until the work items of fellow workers are finished (Guenther, Kessler, Salanderer, 2006). With help of effective coordination mechanisms and high quality information, these delays can be reduced or the worker can be sent to another workplace in order to reduce idle time (Oglesby et al., 1989; Saidi et al. 2002). In contrast, if the idle time increases unexpectedly, the process performance decreases considerably (Boussabaine et al., 1999).

### Extended Research Model

Introducing mobile information technology into the basic model has different impacts. On the one hand, an additional effort for information capturing is inevitable. On the other hand, the effort for information access will be reduced. Both effects are influenced by the constructs of task complexity and technology intensity. In order to gain a positive mobile technology impact, it is necessary to realize the trade-off relationship between these two constructs. In the following, the impact of mobile information technology will be outlined in detail.

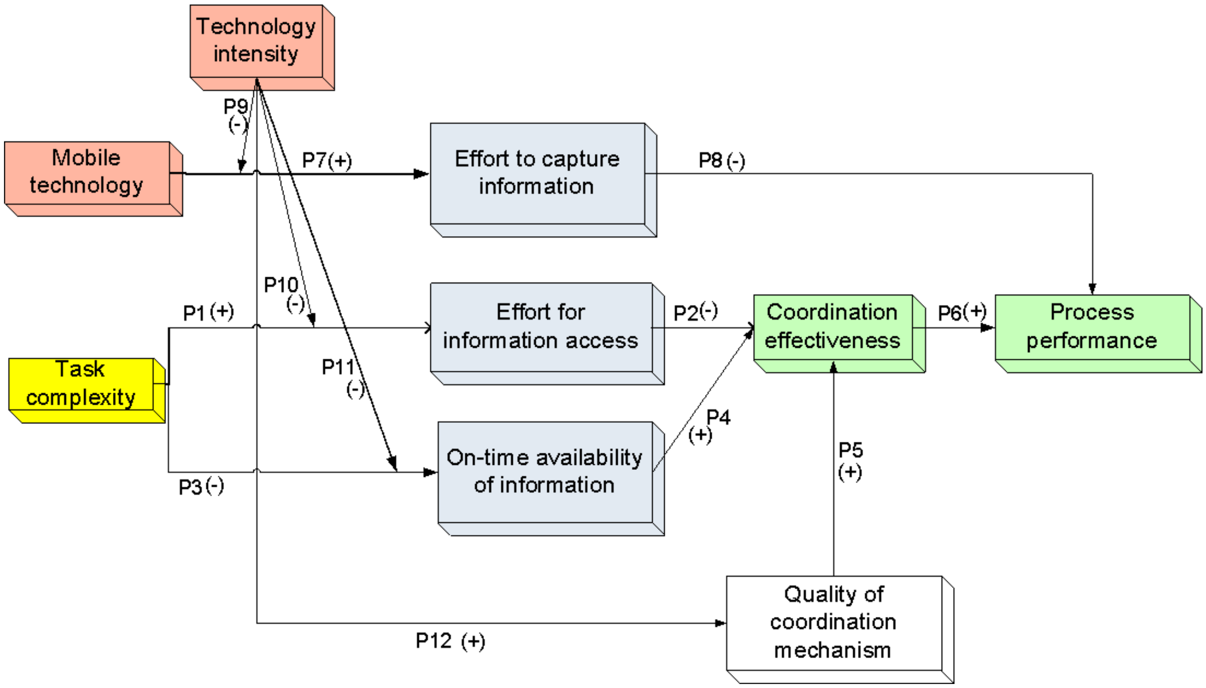


**Figure 2. Extended Model with Mobile Technology Usage**

The dichotomous construct "technology" denotes that a mobile technology (e.g. a personal digital assistant) is either used at one point of time or not. The construct "technology intensity" implies the extent to which information collection is done automatically (e.g., with the help of RFID tags or positioning systems) in order to obtain information about the position, the time, the skills of a worker or the status of material and equipment. Moreover, technology intensity implies the extent to which the handling of the technology is easy (e.g. how comfortable it is to capture information). Therefore, low intensity means no automatically captured information will be used and the use of the technology is less easy. Thus, two different constructs for representing mobile technology are used in the extended model. The construct "technology" refers to the change in effort for a single worker who did not use the technology before. His work process will change with the use of the technology. The construct "technology intensity" takes into account not only one worker but the overall construction site. It is a moderator regarding the relationship between task complexity and the information constructs in our model. This implies that the impact of task complexity on the effort for capturing information and the on-time availability of information will vary across different levels of technology intensity. This property refers to the notion of the 'Task-Technology-Fit' (Goodhue, 1995; Venkatraman, 1989) which claims that different task properties require different technology features. In the following, each of these relationships will be explained in detail.

*P7: If mobile technology is used, the effort to capture information increases.*

Before mobile technology is used, every worker conducted her/his work (e.g. coating, tiling, etc.) in one part of building or site (e.g. room or floor) and then proceeded to the next room. In doing so, (s)he never stores any information about his work progress. When using mobile technology, (s)he now has to enter status information like login information, location, work item, and job starting time. After that the worker starts his/her actual work and after finishing it, (s)he has to type in the corresponding job end time and, the assumed materials consumption. Since mobile technology influences the work of a professional directly, the construct "mobile technology" has a direct impact on the effort for information capturing. The process of capturing information is an additional activity which is inevitable for later use of the information. Thus, the effort for information capturing occurs as a prerequisite of the mobile technology use (Saidi et al., 2002).

*P8: A higher effort of capturing information leads to a decrease in process performance.*

The collection of information is – of course – time consuming (Bowden et al., 2004). With the use of mobile technologies, storing information is an additional activity in the work process of site professionals. Since every work item consumes time for information capturing and more work items need to be conducted in order to finish the work, the performance of the process decreases. The operational work process (e.g. coating, tiling, etc.) is, at best, not influenced by the use of technology.

*P9: The higher the mobile technology intensity, the lower is the (positive) impact of mobile technology regarding the effort to capture information.*

As outlined in the last proposition,, the effort of capturing information increases due to the necessity of entering data for work activities. However, depending on the intensity of the mobile technology used (i.e. the higher the extent of automatic data input and the easier the handling of the technology), the effort of information capturing will moderated, i.e. dampened or reversed. (Bowden, 2005, Loefgren, 2005). Automated information capturing due to the use of barcodes or RFID tags will significantly reduce the corresponding effort (Bowden et al., 2002; Kajewski, 2006).

*P10: The higher the mobile technology intensity, the lower is the (positive) impact of task complexity regarding the effort for information access.*

The usefulness of (mobile) information technology to reduce the effort for information access has already been acknowledged (Shin, 1999, Leclercq et al. 2006a). The quality and quantity of information needed relates to the complexity of the task to be conducted. However, the extent to which this effort is reduced depends on the mobile technology intensity. If the intensity is low, the moderating effect will be weak. For instance, if a worker searches for an equipment tool on the construction site, a low intensive mobile application will deliver a long result list with all idle tools at the site. If the worker wants to choose one of it, he cannot be sure that this resource will be still idle after (s)he has started to walk to the location of the specific tool. If the machine has already been taken by another worker, then (s)he has to start a new search for his/her tool. Thus, finding the required resources as well as walking around is time consuming and the negative moderating effect of technology intensity will be low. In contrast, high intensity technology provides more sophisticated functionalities for information access. With automatically collected information, like the current worker and tool position and the status of the equipment, the result list will be smaller. Only machines which are currently not in use and which are close to the current position of the worker will be displayed. Thus, the worker has less effort for information access since (s)he can faster oversee the condensed result list, which in turn will increase his/her tool changing productivity as well. Nevertheless, the relationship between technology intensity and reduced effort for information access, however, cannot be analyzed independently of the task complexity. If the complexity is small, i.e., the construction building is small, information is easily available and effort for information access is expected to be low. In this case, the effect of technology intensity is negligible. In contrast, a high technology intensity reduces the positive effect of a high task complexity (i.e., the size of a construction building) on the effort for information access. This implies that higher levels of technology intensity lead to a better accessibility of information in larger buildings. Therefore, the impact of technology intensity is modeled as a moderator effect.

*P11: The higher the mobile technology intensity, the lower is the (negative) impact of the task complexity on the on-time availability of information.*

In case of high task complexity due to a large building site, for instance, the timeliness of information suffers since a significant larger amount of information needs to be captured in the system (Kajewski et al., 2006; Rupnik et al., 2003). But if the technology used provides a higher intensity (i.e., the higher the extent of automatic information collection and the easier the handling of the technology), the impact of the task complexity on the on-time availability of information is dampened or overridden because the information can be stored faster. Thus, the impact of technology intensity is another important moderator effect regarding the information characteristics of the construction site.

*P12: The higher the mobile technology intensity, the higher will be the quality of the coordination mechanism.*

The quality of coordination mechanisms refers to the quality of managing uncertainties and complexity with the help of human or technical coordination mechanisms. Tilson 2005, 2007, states that a positive effect of mobile technologies on coordination is visible. Mobile technology has the potential to automate and further improve coordination mechanism by reducing uncertainty and permitting a higher level of complexity and uncertainty (Tilson, 2005, 2007). Moreover, Shin, 1999, states that IT leads to a higher level of coordination and enhances coordination through better coordination mechanisms. Moreover, Leclercq et al., 2006a, describe a positive impact of mobile technology on the coordination between co-workers. Mobile technologies improve the communication and the receiving of information in real time and thus lead to a better and quicker response to new situations.

## EXAMPLE

In this section, two case examples are outlined in order to provide first evidence of our model. The first example describes a work process without the use of a mobile technology. The second example illustrates a construction site worker who makes use of a mobile technology in the form of a personal digital assistant (PDA). The cases are taken from the project VIKOP / BAULOG of the Bavarian Hightech Initiative where PDA technology has been applied for managing and fulfilling order supplements in the construction for new restaurants and retail store buildings.[1]

The scenario takes place in a building with three floors with three rooms on each floor. The worker has to coat the second room on the first floor. He walks into the room and discovers that the floor of the room is not dry yet, so he can not walk in. Thus, the worker has to find another place where he can continue his work.

Since he does not use mobile technology, he has different options for how to proceed. First he can walk around until he finds a dry room where he can start his work or he can search the foreman in order to receive instructions on where to work. The last possibility is to wait until the floor is dry and then to start the work. He chooses the first possibility and walks around to find another working location. This process is time-consuming and bears the risk that the location chosen is not the best place to continue the coating process. In the context of the overall finishing time, choosing the more remote location could have been better for the entire work process.

While using a PDA, the coating professional is able to start a search which directly points out an optimal working location. Thus, he is not forced to walk around but can proceed directly to the new location and start his work immediately, avoiding the significant amount of set-up costs. In addition, the coordination mechanism is implemented in the form of a scheduling module which is run on host-computer and which can be accessed via the PDA, This functionality supports the finding of a new location by updating and extrapolating the master plan of the project. Thus, the overall finishing time will be limited as much as possible.

The coater proceeds to the new workplace and starts the coating process. If had not used his PDA, he just would have started the coating. Since he uses mobile technology, he must key various information into the mobile devices, for instance, where he is (the new location), what he does (the coating process) and when he starts. After finishing the coating process in this room, he has to type in the finishing time. This effort of capturing information occurs in addition to the scenario without a PDA.

The example indicates that mobile technology lowers the efforts of accessing information (at the cost of additional information capturing). If the building is larger (i.e. higher task complexity), this impact becomes stronger because looking for new activities and locations without mobile technology means higher transfer and set-up times. In summary, the process performance (i.e. the finishing time) will improve, compared to the first scenario, with the help of the PDA as a coordination device.

## CONCLUSION

The developed research model for using mobile technology in job processing like construction engineering extends the Task-Technology-Fit and Coordination Theory in order to demonstrate the trade-off between the data capturing effort and information accessibility and timeliness. This trade-off is significantly influenced by the intensity of the mobile technologies used. Thus, the model explicitly integrates the interaction of task complexity and technology intensity. Furthermore, our model focuses on the worker level as the bottom line users of mobile technology. The positive effect of using mobile technologies will be empowered through the potential increase of coordination effectiveness and process performance. It has been outlined that mobile technology itself may serve as a tool for automating and improving coordination mechanisms. Thus, the impact logic of mobile technologies in job processing has been clearly elaborated. Our model helps to explain for which level of task complexity the introduction of a distinct level mobile technology is likely to have a positive impact and how the intensity of mobile technology should be designed (e.g. using context, RFID tags, sensors, etc.). Another point which has to be taken into account is environmental factors at the construction side. This influences the choice of technology as well as the functionality of applications. This aspect will be considered in the evaluation.

The paper focuses solely on the development of a research model. Since it reports research in progress, the next step will be the evaluation of the model. In order to do so, we aim at varying the task complexity as well as the technology. Since this is hard to control in field experiments, laboratory experiments in combination with computer simulations appears to be an appropriate research strategy for testing variations in task complexity and technology. In order to conduct this evaluation, it is necessary to vary contextual factors like the probability of unexpected events or the technology used. In order to get detailed data about the effects of different technologies used (we categorize technology in different groups: context used: yes/no, input: pen/keyboard/voice, display size), it is necessary to control these variables. Other aspects like the users who fulfill the

[1] http://www.bfm-bayreuth.de/index.php?option=com_content&task=view&id=135&Itemid=44

tasks or environmental factors must be held constant so that a comparison of the results is possible. Thus, it is necessary to conduct a laboratory experiment. The evaluation will follow and results will be presented in the near future.

After that, the type/qualification of the user and the intensity of technology usage will be varied. It is proposed that these factors have an impact on the quality of information. But this will not be within the scope of this first research step.

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### Constructs of the research model

| Construct | Definition | Source | Validity / Reliability | Measurement |
|---|---|---|---|---|
| Task complexity | Combination of number of rooms, number of floors, number of assembly sections | – Gebauer et al. (2004): *complexity: structure, frequency, mobility*<br>– Tawik et al. (2001): *size of a building* | – Gebauer: structure – yes, frequency – unclear, mobility – yes<br>– Tawik: - | – number of floors<br>– number of rooms<br>– number of partici-pating assembly sections |
| Effort for infor-mation access | Effort for a worker to get information which is necessary to do the next work step | – Bowden et al. (2002): *improving access to data*<br>– De la Garza et al. (1998): *access...of information*<br>– Saidi et al. (2002)*: access to relevant information, data difficult to access*<br>– Loefgren (2005)*: access to…information*<br>– Lee et al. (2004): *better information access, faster information retrieval* | – Bowden: -<br>– De La Garza: -<br>– Saidi: -<br>– Loefgren: -<br>– Lee: - | – Time to type in data which is necessary for search (what is searched)<br>– Time to choose a result of the result list<br>– Time to search machines/material (time to walk to the machine/material, time to find the machine/material<br>– Time to find a new work place<br>– Time to get an answer to a question (find an expert) |
| Effort to capture information | Effort for a worker to document and store information of his/her work steps (beginning, place, worker information,…) in a database | – Liu et al. (2004): *utilization of resources… must be documented accurately, construction personnel will be able to collect data manually, assisted by advanced data collection technology, such as mobile computing*<br>– Bowden et al. (2002): *improving efficiency of data capture*<br>– Bowden et al. (2004): *collection of data*<br>– Ward et al. (2004): *real-time data capture, data capture on the construction site has proved successful*<br>– Kajewski et al. (2006): *real time data collection, time-consuming process of data collection* | – Liu: -<br>– Bowden (2002): -<br>– Bowden (2004: -<br>– Ward: -<br>– Kajewski: - | – Time to type in information of the start of a work step (who, where, what, when, which material used, which machine used)<br>– Time to type in information of the finishing of a work step (when)<br>– Time to type in information of taking material/machines (who, when, from place, what)<br>– Time to type in the status of all work steps of the whole construction site |
| On-time availability of information | Timeliness of information, which is necessary to respond to unexpected events immediately | – Kajewski et al. (2006): *accurate data at the right time, timeliness of information*<br>– Ward et al. (2004): | – Kajewski: -<br>– Ward: -<br>– De la Garza: -<br>– Loefgren: -<br>– Saidi: - | – At the moment an unexpected event occurs, measure how uo to date the data in the database is |

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| | | *real-time data collection, access…of timely construction data*<br>– De la Garza et al. (1998): *timely instant delivery...of information*<br>– Loefgren (2005): *access to timely...information*<br>– Saidi et al. (2002): *real-time access*<br>– Bowden et al. (2004): *timing of data*<br>– Saidi et al. (2002): *instant access to relevant information, information that is unavailable* | – Bowden: - | |
| Quality of coordination mechanism | Quality of the management of uncertainties and complexity through technical and human mechanisms | – Tilson (2005, 2007): *improve coordination mechanism, reduce uncertainty, permit higher level of complexity and uncertainty* | - | – How often is an optimizer used<br>– How often is optimization done by hand |
| Coordination effectiveness | Managing dependencies and activities performed by humans (or technical artefacts) effectively through reduction of uncertainty and permission of higher complexity and uncertainty | – Tilson (2005, 2007): *effects of mobile computing on coordination* | - | – Idle time of workers<br>– Non-productive time of workers (walking around to find something, someone, reaching a new work place) |
| Process performance | Time which is necessary to do the work on a construction site | – Lee et al. (2004): *improvement of user work process, improve work performance, positive influence on the user work process*<br>– Basole (2005): *benefits of mobilizing the enterprise... …utilize work time more efficiency,…task effectiveness*<br>– Gebauer et al. (2002): *processing time* | – Lee: improvement of user work process – yes, improve work performance – yes, influence on the user work process - yes<br>– Basole: -<br>– Gebauer: - | – Time from the beginning until the end of a work |
| Technology | Use of a mobile technology. The technology is an interface to a database to store information | | | – Using a PDA (yes/no) |
| Technology intensity | The way and intensity the context of the user/machines/material is used and the automatical gathering of status information of machines/material with the help | – Gebauer et al. (2004): *functionality*<br>– Gebauer et al. (forthcoming): *technology performance: form* | – Gebauer (2004): limited<br>– Gebauer (forthcoming): -<br>– Gumpp:- | – Output (screen size) – test two different sizes (Smartphone and PDA)<br>– Input – test cell phone keyboard, |

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| | of sensors like RFID | *factors, input elements, output elements, network access, design, storage,…*<br>– Gumpp et al. (2005): *context sensitivity, identifying functions* | | touchscreen/pen and keyboard<br>– Support through context of the user (data input) – test use and no use<br>– Support through sensors – test no sensors and RFID |