Process Management in Construction

Expansion of the Bolzano Hospital

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Abstract

(a) **Situation faced**: Frener and Reifer (F&R) is a leader in engineering, fabricating, and installing facades with non-standard designs. The company was looking for comprehensive, domain-specific approaches to improve the company's control over facade processes, from design to execution and monitoring. What makes process management particularly challenging in this setting are some peculiarities of the domain, such as high levels of variability, unpredictability, and inter-organizational synchronization (vom Brocke et al., 2015), as well as the non-standard and non-repetitive nature of the designs, which complicates the ability to formulate reliable estimates. Indeed, in many cases the installation department exceeded the number of hours that were initially estimated.

(b) **Action taken**: A group of researchers developed a domain-specific methodology, called PRECISE, that provides methods with which to support the process lifecycle (Dumas et al., 2013) in construction. F&R applied the methodology to construction of the hospital in Bolzano, Italy, by implementing three steps: *i)* collaborative process design, with the main figures taking part in the construction project (e..g the project manager, the architect and the foreman on site); *ii)* process implementation, which involves defining short-term (i.e., daily or weekly) schedules for tasks based on actual data on the progress of the work; and *iii)* continuous monitoring and measurement of the progress of the work on site.

(c) **Results achieved**: By applying the methodology, which supports a detailed modelling and monitoring of the activities, F&R could perform reliable estimates of progress on tasks and expected cost to completion. For instance, F&R recognized that the budget it had initially estimated was too tight. By analyzing the up-to-date data on the progress of the work and consulting with the workers on the construction site, the company could identify problems and sources of delay promptly and act to mitigate their effects. During the application of PRECISE, F&R recorded an increase in productivity that was estimated to have saved four hundred man hours.

(d) **Lessons learned**: Application of the methodology singled out some aspects of the process that should be addressed to improve process management. Flexibility, which is required in dealing with the domain variability, is achieved by defining a process model and a short-term schedule, while the availability of reliable and up-to-date data on the progress of the work is obtained by applying continuous, detailed process monitoring. Engagement of the workers in the process management allows the project to benefit from their expertise (Rosemann and vom Brocke, 2015), which is the basis of the collaborative approach. However, better IT support for the methodology is needed (Rosemann and vom Brocke, 2015; Dumas et al., 2013).

1. Introduction

Frener and Reifer (F&R), a medium-sized enterprise, is a leader in engineering, fabricating, and installing facades with non-standard designs. The context in which the company works is characterized by non-repetitive processes that have a high level of originality (vom Brocke et al., 2015). As a consequence, management of the façade-realization process cannot be standardized and can rely only partially on experience gained from other projects. Among the main challenges are *i)* the engineering and construction of non-standard components; *ii)* their fabrication; *iii)* the need for specialized manpower for all of the phases, from engineering to physical installation; and *iv)* the need for on-site training of the installation workers. These issues make the overall project management challenging for the company, complicating aspects of the project like the estimation of the resources required. Additional challenges come from peculiarities of the construction sector, including high variability (vom Brocke et al., 2015) because of customers' changing requirements and unavoidable, unpredictable events, such as bad weather conditions that preclude installation. In addition, multiple trades must be on site simultaneously, which requires that they synchronize their activities.

It is important for the company to make an accurate budget estimate and to respect it while executing the process. While the budget should be sufficient to carry out the project, the company has to make appealing offers that beat its competitors, so it usually designs tight budgets for which the process must be efficient and planned carefully.

In this setting, F&R had a problem with lack of control over the project's execution. When the company's installation department exceeded the estimated man hours needed to perform the work on site, the company could not identify the causes of the delay or predict them in advance in order to mitigate them. Traditionally, the execution plan is not defined in detail but only identifies the main milestones to be achieved. It is then refined on a daily basis by the foreperson on site, who has inadequate IT support and no way to analyze the project's overall progress. As a consequence, a delay is discovered only when the established deadline is not met.

With the aim of improving the project management, F&R collaborated with the Faculties of Science and Technology and the Faculty of Computer Science at the Free University of Bozen–Bolzano and with the Fraunhofer Italia Research Center in the context of the research project *build4future*. During that project a methodology called PRECISE was defined (Dallasega et al., 2013) that the company applied to the Bolzano hospital project. The methodology provides methods that support the construction process (Rosemann and vom Brocke, 2015; Dumas et al., 2013) by focusing on *i) process design*, supporting the definition of a process model; *ii) process implementation*, defining a short-term and detailed scheduling of the activities; and *iii)* a continuous *process monitoring and controlling*.

2. Situation faced

In 1998, the province of Bolzano issued a call for refurbishing and then expanding its hospital by building a new clinic composed of three wings and a new entrance area. The work started in 2008 and was estimated to end in 2015 with an overall budget of 480 million Euros, later updated to 610 million Euros (Bolzano Hospital). F&R was responsible for the design, engineering, fabrication and installation of the facades of the three wings of the new clinic, which were planned for completion by the end of 2016.

F&R proposed a solution that was tailored to the project. For instance, the company designed large, high glazing instead of single windows to improve both the internal lighting and the view of the landscape. To guarantee optimal illumination, several customized solutions were designed for the facades based on their orientation to the sun. Sliding sun-protection elements were also built that could operate both individually and via the building automation system. The single semi-finished components for the facades were delivered separately to the site and then integrated into it.

A number of issues made the management of this project challenging for F&R. Specifically, the process is non-repetitive and requires a high level of creativity (vom Brocke et al., 2015), as the components for each part of the facade differ. The company had to ensure that the components were available when needed and that they were unloaded at the right place on site. In addition, to avoid delays, F&R had to synchronize its activities with those of the other companies that were working on site. For instance, the installation of the high glazing required the use of the tower crane that is shared among the companies working on the site, so F&R had to agree on a plan with the other companies regarding its use. This need emerged only when the project had already begun, and since the companies did not define a usage plan up front, the crane was not available for F&R when it was needed for facade installation. F&R also had to synchronize plans with the company that installed the building's automation system, which had to be connected with the sun-protection elements installed by F&R. Synchronization among the companies is needed also to avoid that two companies work at the same time in the same area. This in order to avoid interferences among them.

Overall, F&R wanted to improve different aspects of the process management, to improve its control over the execution process. With the traditional approach, the company compared the costs incurred with the planned costs to determine whether a process was running on time, although these two values rarely coincided, and F&R wanted to understand the causes for the discrepancy. The company also wanted to know about potential delays sufficiently in advance to implement recovery plans that would prevent or to limit them. In short, the company wanted to improve the process design, implementation, and monitoring phases of their process management lifecycle (Dumas et al., 2013).

Process Design: lack of a detailed process model. The aims of a process model are to communicate with the customer and to synchronize at a high level the work of multiple companies. Traditional process models rely on Gantt charts or similar, but because of strict budgets and few resources, such process models often contain few details, thus providing only an abstract idea of the process execution. Moreover, these models typically focus on the long term without accounting for the actual progress of the work or the performance estimate, so they are rarely used as guides in the process execution. A more detailed process model could support the early discovery of potential problems or inconsistencies in the process, thus allowing the company to define more feasible milestones and more effective plans to achieve them. Such a model could also be used as a basis for synchronizing the work of multiple companies.

Process Design: difficult synchronization among the company's departments. F&R not only installs facades but also engineers and fabricates the facade components. However, the company's departments work with tasks at differing levels of granularity: the engineering department focuses on elaborating floor drawings, the fabrication department focuses on producing components, and the installation department focuses on performing all of the required tasks on site. This misalignment among the departments complicates the internal synchronization and the alignment with the construction site. One way to achieve the desired coordination was to rely on a common process model according to which the three departments could synchronize their activities.

Process Implementation: lack of support for detailed scheduling. In most cases, detailed scheduling of the activities to be performed on site is left to the foreperson, who has inadequate IT support so must rely on oral communication with the workers and on pen and paper to define a daily schedule. F&R could rely on experienced forepersons who can manage complex processes, but this approach introduces risks because it is prone to error and binds the success of the project closely to the abilities of one person. For instance, if a foreperson leaves the company mid-project, fundamental knowledge about the project leaves with her.

Process Monitoring: unreliable measuring of the project's progress. In general, the progress of the work on site is measured in terms of expenses incurred rather than in terms of the work performed. This approach has two main consequences for the project management: First, delays are discovered only when a task that should be finished is not, but by then it is often too late to identify the causes and define repair mechanisms, so the delay typically delays the end of the project. Second, aligning the production of components with the progress of the work on site is difficult, although it would allow F&R to avoid both the expenses of storing the produced components and interruptions in the process when components are not ready when they are needed. Such alignment is possible only when the company has a reliable way to monitor the process.

3. Action taken

In the context of the project *build4future*, the research partners and twelve small and medium-sized enterprises (SMEs) from the Bolzano province, developed a methodology called PRECISE (Dallasega et al., 2013), the purpose of which was to support and improve the phases of the construction process-management lifecycle (Dumas et al., 2013). The PRECISE methodology supports primarily three interconnected project phases: *i) process design*, by supporting collaborative process modelling; *ii) process implementation*, by supporting detailed short-term *scheduling* of the activities; and *iii) process monitoring*, by supporting short-term monitoring and measurement of the construction progress.

3.1 Development of the PRECISE Methodology

Process Design. The first phase of the methodology is the process design, which consists of defining a process model that captures the set of tasks to be executed on site and the temporal dependencies among them. The aim of a process model is twofold: to synchronize the activities of the various companies involved and to synchronize the activities of one company's departments.

To achieve a reliable process model that organizes the work to improve the final result, the methodology suggests the involvement of experts from the various companies involved (Rosemann and vom Brocke, 2015). They define the model in a collaborative way based on the methodology, organizing collaborative workshops in the project's early stages, once the overall design of the building is clear and when the participating companies are established. The workshops are orchestrated by a neutral moderator who has no economic interest in the project.

As a first step, starting from the approval and the shop floor drawings, the companies define an abstract representation of the building by identifying precisely the *locations* in which the tasks are performed (Dallasega et al., 2015). For instance, a building can be organized in sectors (identifying the different parts of the building like wings), each of which is organized in levels (floors) and sections (identifying the technological content of an area), which are then enumerated with unit numbers. Based on this definition, a location would be identified by a sector (e.g., sector A), a level (e.g., level one), a section (e.g., room), and a unit (e.g., unit 4).

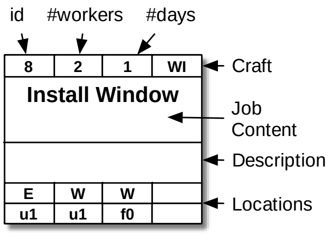


Fig. 1. Task representation.

As a second step, the companies discuss the main *tasks* to be performed based on which their activities are synchronized. Each task is defined by *i)* the specification of the job's content, *ii)* the responsible trade and the skills required to execute it, *iii)* the (shared) resources needed, *iv)* the location(s) where it must be executed, and *v)* the expected productivity, i.e. the amount of work that should be completed in a certain period of time. To represent the expected productivity, the methodology introduces the concept of *pitch* (Dallasega, 2016) which defines the number of locations in which work has to be performed by what kind of crew and its size (e.g., three locations with a crew of two plumbers) during a specific period (e.g., one day).

The final step of the process modelling concerns the definition of the temporal *dependencies* among the tasks on which the companies involved have to agree. The dependencies are conceived as a set of mandatory constraints that rule the temporal execution of the tasks—for example, the floor has to be installed before the window in each location—but they do not define a strict sequence according to which other tasks should be performed—that is, other tasks can be performed between the floor and the window installation. All that is not specified by a process model, such as when a task should start, is left to the companies.

To support the collaborative nature of the approach, PRECISE defines a graphic representation of the process models (Marengo et al., 2016). Figure 1 reports the representation of a task. A temporal dependency among two tasks is defined by drawing an arrow between them to indicate that one should be performed before the other.

Process Implementation. The second phase is the process implementation, which, starting from a process model, details it with additional information. The result is a *short-term schedule* that specifies *i)* at what points in time work on tasks is to commence and *ii)* how many workers are needed per day, including who is to work on individual tasks or groups of tasks, which determines the duration of the tasks. In addition, decisions are made concerning when to make resources like cranes and materials available.

Information about the tasks, such as the job content, the locations where they are performed, the required skills, and the expected productivities (pitch), is specified in the process model. However, collaborative models usually specify only the main tasks among which synchronization problems among the companies involved may arise. When schedules are set, it might be necessary to refine the tasks by specifying them in terms of subtasks, with their corresponding expected productivities and dependencies.

To specify a schedule, the foreperson defines: *i)* the period of *time* (a specific day or week), *ii) which* activities to perform in that period, *iii)* by *whom* they should be performed, and *iv) where* to perform them. The foreperson also considers the temporal dependencies from the process model in order to schedule tasks in such a way as to satisfy them.

The PRECISE methodology defines certain criteria to support the schedules' reliability. In particular, in order for a schedule to be reliable, it must cover only a short period of time and be based on actual data from the site, such as information about the tasks that have been completed. Long-term schedules rely heavily on forecasts of the progress of the work and are inevitably less detailed since less information is available to the foreperson at scheduling time. Accordingly, the methodology suggests defining daily or weekly activity scheduling such that a weekly schedule best suits the initial phases of a construction process, when there are fewer interactions among the companies and the tasks' execution takes longer (e.g., excavating or pouring concrete). In the subsequent phases of the process execution, more companies have to work in the same locations (such as when companies work on the facade and the interior), and the tasks usually require less time to be completed. In this case, a daily activity schedule is more reliable and is better for task synchronization among companies.

When making a schedule, the foreperson also defines the crews of workers and assigns them to the tasks. To facilitate this activity, the methodology suggests a *presence list*—that is, a list of workers who are expected to be present on site on that particular day/week.

Monitoring the Construction Process. The aim of monitoring is to collect data on the progress of the work on site. The methodology suggests using this data as a starting point for scheduling so the scheduler has updated information on the tasks that are not yet completed. For instance, if the schedule for the following week is defined at the end of the current week, then it must be based on the data from monitoring the current week. Relying on the information on the schedule rather than on the monitoring may lead to incorrect assumptions about the progress of the work and to a schedule that is not feasible. It is often the case that unpredictable events like bad weather conditions introduce significant delays, in which case, the scheduled activities may progress more slowly than foreseen or be postponed in favor of other activities.

The data from the monitoring is also used to update the expected productivity for the tasks in the process model. The expected productivity is initially estimated in the collaborative workshops by defining the pitch for each task. It is continually refined based on current data and considering the learning curve effect when multiple instances of the same task are performed by the same crew, and thus the task is performed faster.

The companies can take advantage of the monitoring data by performing various kinds of analysis to evaluate the project's overall progress. Among other kinds of analyses, they can determine whether the project is progressing on time and within the estimated budget by comparing the budgeted hours with the number of completed locations, the resources used, and hours consumed. Based on this information, they can forecast the amount of work yet to completed in a detailed and reliable way.

3.2 Application of the Methodology

This section presents how the PRECISE methodology was applied in the Bolzano hospital project.

Bolzano hospital process design. The PRECISE methodology was developed in the context of the build4future project. As one of the participating companies, F&R decided to apply the methodology to its Bolzano hospital project. However, since none of the other companies that were working on the hospital project was also taking part in build4future, they did not participate in the collaborative process modelling phase.

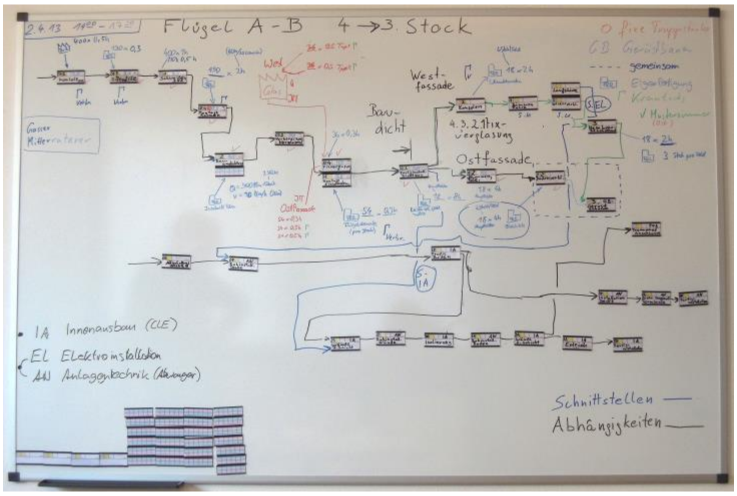
Before F&R executed the process on site, the Free University of Bozen-Bolzano and the Fraunhofer Italia Research Center, as scientific partners of the project, organized a collaborative workshop involving the project manager and the foreperson. The workshop participants first agreed on how to represent the locations by identifying four elements as characterizing the building's locations (Dallasega et al., 2015): *a) level*: four levels, identified as 1-4, from the ground floor to the fourth floor; *b) wing*: three wings, identified as A, B, and C; *c) orientation*: four facades, identified as north, east, south, and west facades based on their orientation to the sun; and *d) units*: small parts of similar size, where the space between the two main axes of the building was used as a reference to define the units.

After this phase, the main tasks were identified in keeping with the seven main phases of facade installation: substructure, frame assembly, inner connection, sealing and insulation, glazing and installation of panels, paneling, and final assembly. The tasks were represented as in Figure 1. The information on the tasks (e.g., location, productivity) was specified, along with the dependencies among the tasks, as shown in Figure 2.

When modelling the dependencies among the tasks, the participants found that the modelling language lacked some details needed to capture the nature of a dependency. In particular, only one kind of temporal relationship was provided in the language. As a result, the language was extended to define three kinds of dependencies: *workflow*, which captures a temporal dependency on the execution of two tasks; *information flow*, which captures whether tasks need specific information, such as detailed measurements, in order to be performed; and *material flow*, which captures whether tasks need specific components in order to be performed. Magnetic white-boards were used as a support for the definition of

Fig. 2. Excerpt of the Bolzano hospital process model defined on a magnetic board.

the process model. At the end of the workshop, the process model was copied and transformed into a digital document.



Scheduling of the tasks. Once the process model was defined, it provided a significant amount of detailed information on the tasks (e.g., the locations where a task needs to be performed, the resources needed to execute them). The next step was to plan the tasks' execution based on the process model and the dependencies among the tasks. When the process model defined no strict temporal constraints on a task, the company could decide when to schedule the task according to internal priorities and preferences.

When the methodology was applied, there was no specific IT support, so the scientific partners provided the foreperson with tables like the one shown in Figure 3 to support scheduling. The tables were generated ad hoc, relying on the information from the process model and using Microsoft Excel. Each table concerns a specific period of time according to which a schedule had to be specified. In line with the methodology, short-term (weekly or daily) schedules were required. By filling in these tables, the foreperson could schedule the activities to be executed in that period, the locations where they would be executed, and the crews assigned to them. In particular, a table obtains from the process model the list of tasks, the expected productivity, and the possible locations.

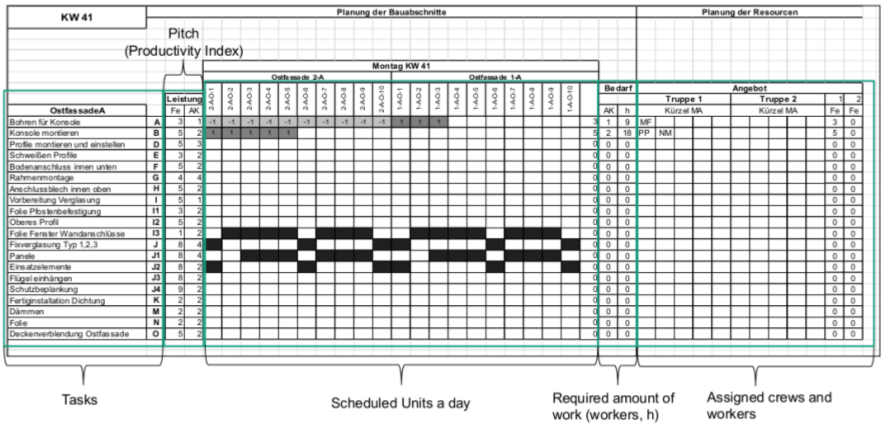


Fig. 3. Excel spreadsheet used to support F&R's daily schedule.

The foreperson could schedule a task to be completed at a location by filling in the cell at the intersection of the row corresponding to the task and the column corresponding to the location. If the cell is not empty, the task cannot be scheduled there.

After defining the tasks to be performed, the foreperson defines the presence list—that is, the list of workers who are expected to be present on site at that particular time—and the number of hours they are expected to work. Then, the foreperson forms the crews by assigning workers to the scheduled tasks.

The foreperson usually defined the schedules on Friday afternoon for the upcoming week using Microsoft Excel, filling in the tables that were prepared by a researcher from the scientific partners. Excel allowed the foreperson to visualize the *saturation* of the workers, which was generated automatically, as a chart plotted a comparison between the number of hours a worker was available and the hours spent on tasks he or she was assigned. The tables were linked to each other so scheduling information could be propagated to the subsequent periods. For instance, a task scheduled for one day could not be scheduled for the next day as well.

On Monday morning, the foreperson hung the scheduling tables at the construction site, where workers could see to which tasks they were assigned.

Monitoring of the work on site. In line with the methodology, the progress of the work was monitored daily and at the end of each day's work hours, the installation teams met to record the tasks performed, the hours spent, and the completed construction units. When the productivity for a task was lower than that which had been estimated, the reason was noted. Tables similar to those used for the scheduling (Figure 3) were used for this purpose, and every Friday afternoon a researcher from the scientific partners collected the data and copied it into Excel spreadsheets. The information on the (un)completed tasks was automatically propagated to the tables so the foreperson could plan the activities for the next week using the most current information. Then the tables for the next week's scheduling and monitoring were printed and hung.

The Excel spreadsheets allowed the monitoring data to be elaborated in order to support analysis of the project's overall progress. In particular, the data was used to compare the actual progress of the work with the initial project forecasts; to plot the number of hours consumed and the estimates to completion for each location; to compare the hours that should have been consumed on the completed tasks with the number of hours actually consumed; and to plot the difference between the estimated and the effective hours. A positive difference corresponded to an increase in productivity.

All of these charts were hung at the construction site so every worker had an overview of the project's progress.

Continuous Improvement Workshop On Site. Four "continuous improvement workshops" were held to analyze the data collected from the construction site and the charts produced from it. During these meetings, the project director, the project manager, the construction foreperson, and the vice-foreperson discussed the general overview of the construction performance, focusing on the most recent four weeks. Causes of problems and delays were discussed to avoid their recurrence and estimated productivity for the tasks (pitch) was adapted to the actual conditions on site.

4. Results achieved

F&R's employees were initially skeptical about using the new methodology, but after the initial phase they saw that it did not require significant time expenditure in addition to their other activities, nor was it used to control them. On the contrary, it was used so the workers could have *more* control over the process management. F&R was satisfied with the results it obtained and has already applied it to other projects (e.g., the construction of a new library, research center, and archive for St. Antony's College in Oxford).

By applying the methodology, F&R was able to see that its estimated budget had been too tight, although the approach was applied to the Bolzano hospital project when an initial budget estimate for cost and time had already been made. However, when implementing the collaborative planning phase, the foreperson could provide cost and time estimates at the task level, based on which the estimated budget for the overall project could be computed and compared to the initial one. Of course, the tasks' level of productivity provided by the foreperson was an estimate, so it could also have led to wrong conclusions, but by monitoring the actual progress on site, it was possible to refine the estimated productivity to make it increasingly close to the real conditions on site. Without the monitoring, F&R could rely only on the budget estimate, and the only way to determine its reliability would have been to wait until the end of the project or, in the best case, to check the progress at predefined milestones that occurred approximately every six months. This kind of infrequent monitoring would have limited the possibilities for intervention in the process execution or for adjusting the budget.

Another important result was an *increase in the productivity* as a result of improved scheduling of the activities, monitoring the progress of the work, and holding the continuous improvement workshops, where problems and solutions were discussed collaboratively. During the four months in which these workshops took place, indeed, there was an increase in the productivity on site, estimated as saving four hundred man hours (Dallasega, 2016). Once the workshops were halted, productivity began to decrease.

Our analysis could not quantify how much of the savings in man hours were thanks to the application of the methodology and how much was applicable to other factors (e.g., good weather conditions, greater availability of the resources). However, improved control over the process and schedules that covered short time periods allowed the company to react promptly to problems that arose during the process execution. For instance, the company discovered a decrease in productivity that was attributable to the lack of synchronization with the other companies for the use of the crane, which was sometimes unavailability for relatively long periods of time. The problem affected several tasks since materials to be installed could not be unloaded from the trucks. After a synchronization plan was established with the other companies, productivity began increasing again.

Applying the methodology allowed F&R to identify one of the main causes of variation in productivity, as the company concluded that the *learning curve effect* had an impact on individual tasks. The company compared the productivity when the same crew performed a task several times with the productivity when a new crew was assigned to the same task for the first time. Using an experienced crew may result in performing activities faster, but it could also cause a misalignment between the production line and the construction site when productivity for a task increases too much. By monitoring the progress of the work, the company discovered several such possibilities in advance and increased the production of certain components or scheduled different tasks according to the resource availability. The effect of the learning curve is an important aspect of the process that should be investigated by the company and its scientific partners.

The methodology also improved the synchronization among F&R's departments. Each task was labelled with the components required, and thanks to the process model and the detailed scheduling of the activities, it was possible to relate the engineering department's drawings, the components to be produced by the fabrication department, and the tasks for the installation department and to synchronize the scheduling with the production line (e.g., to start the production early enough to supply the necessary material for a scheduled task, or to prevent the scheduling of tasks for which the components were not ready).

Another effect of applying the methodology was improved transparency of the process's execution. Information was consistently available on the planning board, where the daily schedule, the tables for monitoring the progress, the charts on the overall process, and the issues identified to that point were posted and accessible by every worker. This kind of approach improved the working environment, as the workers felt engaged and like important contributors to the project's success, rather than just like executors of tasks (Rosemann and vom Brocke, 2015).

5. Lessons learned

One of the main characteristics of the methodology is its *collaborative* nature, which support the active involvement of the main figures that take part in the project. This collaboration was done in the course of the Bolzano hospital project by involving the main figures from F&R in the process modelling and in the continuous improvement workshops. Ideally, the methodology also fosters collaboration across companies. One of the advantages of this approach is that each worker all of the companies are experts in their own areas of competence. By involving them in the process management, F&R could take advantage of their expertise and put them in the position of agreeing on a strategy that benefits both the project and the companies themselves (Rosemann and vom Brocke, 2015). Collaboration supports inter- and intra-organizational synchronization (vom Brocke et al., 2015), as the methodology supplies a way for companies to discuss how they want to execute the process and find an agreement that suits all of them while still guaranteeing the quality of the final result. A company can also discuss the process model internally in order to identify possible problems in advance and implement ways to overcome them.

Another important aspect of the methodology is that the process management must be *flexible* in order to address the variability of the processes that are part of construction projects (vom Brocke et al., 2015). Given the number of unpredictable events that often occur on site and that are often responsible for delays, if the process is flexible, such delays can be reduced more easily by defining a process model that, by capturing only the main dependencies among the tasks, can be changed easily if needed. The methodology also foresees the need for defining short-term, detailed schedules. Traditional approaches usually use long-term schedules for bidding purposes or for communicating with the customer, who is probably not interested in the details of how the process will be carried out, but these schedules are less precise than are schedules with shorter terms, so when a problem occurs, how to address its cause to limit delays is often unclear.

A *reliable measurement* of the progress of the work on site is a prerequisite for making reliable schedules. If these schedules are based on forecasts of the construction project's progress, they are likely to become inapplicable soon. Reliable measurement of progress also allows a company to identify and limit possible sources of delays, thanks to the approach's flexibility. Finally, reliable measurement makes multiple kinds of analysis possible that can suggest how to improve the process, how to redistribute or acquire new resources, whether the deadlines are going to be met, and so on.

Workers' *empowerment* is an aspect of the methodology that is seldom considered to be important. However, such empowerment can improve the process's overall execution (Rosemann and vom Brocke, 2015). Giving people responsibility and helping them to feel actively involved in the process creates a working environment in which workers are motivated and feel like important elements in the project's success. Empowerment in the Bolzano hospital project was achieved by implementing the collaborative approach and transparency of the process execution. At any time, workers could access the planning board on site to see the schedule for the week, the daily progress reports, the charts that plotted the productivity analysis, and so on.

The application of the methodology also showed that good systems for process management are lacking, so *IT support* needs work (Rosemann and vom Brocke, 2015). An IT system must be easy to use and non-intrusive if it is to be adopted by employees. The workers in the Bolzano hospital project expressed some skepticism when the new approach was introduced because they perceived that it would require additional work. The non-intrusiveness of the methodology and its ease of use helped to overcome this resistance: The process modelling was performed with the support of a graphic and intuitive language, which allowed the process designers to use it with little additional effort, and the scheduling and monitoring were realized by means of Excel. Thus, workers were asked to work with tools with which they were already familiar.

The Excel spreadsheets were developed in an ad-hoc way for the project, but the approach can be generalized to any construction project and automated with the support of suitable technologies (Dumas et al., 2013; Rosemann and vom Brocke, 2015). In particular, we are developing a software prototype (Dallasega et al., 2015; Marengo et al., 2016) that will generalize the concepts of the PRECISE methodology; support the graphic process modelling; generalize the Excel spreadsheets by automatically gathering the data from the process model to configure the scheduling and the monitoring; implement some automatic checks, such as a check on the process model's feasibility and the schedule's compliance of a schedule with the model; suggest schedules that are optimal with regard to desired criteria; and generate charts and reports for the productivity and progress analyses as soon as data from the monitoring is inserted in the system.

The prototype is designed to be used with digital touch boards that reproduce the planning boards that are currently used on site so the workers will have concepts and tools with which they are already familiar. The prototype will have fewer functionalities than commercial tools like ConstructSim Planner (Bentley), Sitesimeditor (Sitesimeditor), and Vico Software (Vico), but these commercial tools are often complicated to use and require specific competencies. From this perspective, the approach that we will adopt is less intrusive since it will not require specific training for its adoption nor long configuration procedures in order to start working on a project. For this reason, we believe that this solution will better suit SMEs, which often lack the resources to invest in expensive products (vom Brocke et al., 2015).

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References

Bentley. ConstructSim Planner. https://www.bentley.com/en/products/product-line/construction-software/constructsim (Last access: April 2016).

Bolzano Hospital. http://www.provincia.bz.it/edilizia/progettazione/385.asp (Last access: April 2016).

Build4Future. http://www.fraunhofer.it/en/focus/projects/build4future.html (Last access: April 2016).

Dallasega, 2016. Dallasega, P. (2016). A Method and IT-Framework for On-Demand Delivery in Make-To-Order Construction Supply Chain. PhD thesis, Submitted to the University of Stuttgart - Germany.

Dallasega et al., 2015. Dallasega, P., Marengo, E., Nutt, W., Rescic, L., Matt, D.T., and Rauch, E. (2015). Design of a Framework for Supporting the Execution Management of Small and Medium sized Projects in the AEC-Industry. In 4th International Workshop on Design in Civil and Environmental Engineering.

Dallasega et al., 2013. Dallasega, P., Matt, D.T., and Krause, D. (2013). Design of the Building Execution Process in SME Construction Networks. In 2nd International Workshop on Design in Civil and Environmental Engineering.

Dumas et al., 2013. Dumas, M., La Rosa, M., Mendling, J., and Reijers, H. A. (2013). Fundamentals of Business Process Management. Springer, Berlin.

Frener&Reifer. http://www.frener-reifer.com/home-en/ (Last access: April 2016).

Marengo et al., 2016. Marengo, E., Dallasega, P., Montali, M., and Nutt, W. (2016). Towards a Graphical Language for Process Modelling in Construction. In CAiSE Forum.

Rosemann and vom Brocke, 2015. Rosemann, M. and vom Brocke, J. (2015). The Six Core Elements of Business Process Management. In vom Brocke, J. and Rosemann, M., editors, Handbook on Business Process Management, Introduction, Methods, and Information Systems, 2nd Ed., volume 1, pages 105{122. Springer, Berlin.

Sitesimeditor. https://www.inf.bi.ruhr-uni-bochum.de/index.php?lang=de&Itemid=361 (Last access: April 2016).

Vico. Vico Software. http://www.vicosoftware.com/ (Last access: April 2016).

vom Brocke et al., 2015. vom Brocke, J., Zelt, S., and Schmiedel, T. (2015). Considering Context in Business Process Management: The BPM Context Framework. BPTrends.