Process Management in Construction

The Expansion of the Bolzano Hospital

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Abstract

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

(b) **Action taken**: A group of researchers developed a domain-specific methodology, called PRECISE, which provides methods (Rosemann and vom Brocke, 2015) to support the process lifecycle (Dumas et al., 2013) in construction. The methodology was applied by F&R to the construction of the hospital of Bolzano (Italy), by implementing the following steps: *i)* Collaborative process design, involving the main figures taking part in the construction project. *ii)* Process implementation, defining a short-term (i.e. daily or weekly) scheduling of the tasks, based on actual data on the progress of the work. *iii)* Continuous monitoring and measurement of the progress of the work on-site.

(c) **Results achieved**: The application of the methodology, by modelling and monitoring the activities in detail, allowed F&R to constantly monitor the progress of the work, to perform reliable estimates on tasks productivity and expected cost to completion. For instance, F&R could recognize that the budget estimated initially was too tight. By analyzing the up-to-date data on the progress of the work together with the workers from the construction site, the company could promptly identify problems and sources of delay, and act to mitigate their effects. Notably, during the application of PRECISE, F&R recorded an increase of the productivity, estimated in a saving of 400 man/hours.

(d) **Lessons learned**: The application of the methodology singled out some aspects that need to be properly tackled towards a better process management. Flexibility is important to face the domain variability. It is achieved by defining a process model and a short-term schedule. Another aspect is the availability of reliable and up-to-date data on the progress of the work, 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). This is at 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) is a medium-sized enterprise, leader in engineering, fabricating and installing facades with non-standard designs (Frener&Reifer).

The context in which the company works is characterized by non-repetitive processes, with a high level of originality (vom Brocke et al., 2015). As a consequence, also the management of the facade realization process cannot be standard, and can only partially rely on the experience gained from other projects. Among the main challenges there are: *i)* the engineering and construction of non-standard components; *ii)* their fabrication; *iii)* the need of specialized manpower for all the phases, from engineering to physical installation; *iv)* the on-site training of the workers for the installation. These aspects make the overall project management extremely challenging for the company, complicating aspects such as the estimation of the needed resources. Additional challenges come from some peculiarities of the construction sector. Specifically, the process is subject to a high variability (vom Brocke et al., 2015) due to changing requirements by the customers and the occurrence of unavoidable unpredictable events (such as bad weather conditions). Moreover, different trades are simultaneously present on-site, which requires them to synchronize their activities.

For the company it is very important to make the right budget estimate and to respect it during the execution of the process. On the one hand, indeed, the budget should be enough to carry out the project. On the other hand, the company has to make appealing offers to beat the competitors. For this reason, usually very tight budgets are promised, to respect which the process must be efficient, and planned carefully.

In this setting, a relevant problem for F&R was a lack of control over the project execution. When the installation department of the company exceeded the estimated man/hours needed to perform the work on-site, the company could not identify the real causes of the delay, nor could predict it in advance and potentially mitigate it. Traditionally, indeed, 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 foreman on-site, without adequate IT-support and without means to analyze the overall progress of the project. 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 started a collaboration with the Faculties of Science and Technology and 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* (Build4Future). During *build4future* a methodology called PRECISE was defined (Dallasega et al., 2013) and the company could successfully apply it in the project for the expansion of the hospital of Bolzano. The methodology provides methods (Rosemann and vom Brocke, 2015) supporting construction processes lifecycle (Dumas et al., 2013). The methodology focuses 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 the hospital and expanding it by realizing a new clinic composed of three wings and a new entrance area. The work started in 2008 and was estimated to end in 2025 with an overall budget of 480 million of Euros, later updated to 610 million of Euros (Bolzano Hospital).

In this project, F&R is responsible for the design, engineering, fabrication and installation of the facades of the three wings of the new clinic, planned to be completed by the end of 2016.

The company proposed a solution tailored to the project. For instance, the company designed large high glazing, instead of single windows, to improve both the illumination and the view on the landscape. To guarantee optimal illumination, different customized solutions were designed for the different facades according to the sun orientation. Additionally, sliding sun protection elements were built, which can 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.

There are a number of aspects that make the management of this project challenging for F&R. Specifically, the process is non-repetitive and requires high creativity (vom Brocke et al., 2015). For instance, components are different for the different facades. Thus, the company has to make sure that they are available when needed and that they are unloaded at the right place on-site. Additionally, to avoid undesirable delays, F&R has to synchronize with the other companies working on-site. For instance, the installation of the high glazing requires the use of the tower crane, which is shared among the different companies. Thus, F&R needs to agree on a plan with the other companies regarding its use. This need explicitly emerged only when the project was already started, and since the companies did not define a usage plan upfront, the crane was not available for F&R when needed for facade installation. F&R also has to synchronize with the company installing the building automation system, which needs to be connected with the sun protection elements installed by F&R. To limit interferences, it is also preferable to avoid that two companies work simultaneously in the same area.

Overall, F&R wanted to improve different phases of the process lifecycle (Dumas et al., 2013) and to have better control over the execution process. With the traditional approach, in order to understand whether a process is running on-time, the company compares the incurred costs with the planned one. However, these two values rarely coincide. For F&R it is important to understand the causes for a discrepancy when it occurs. Additionally, the company would like to discover potential delays sufficiently in advance to implement recovery plans to prevent or to limit them. More in detail, the company wanted to improve the following aspects.

Process Design: lack of a detailed process model. The aim of a process model is both to communicate with the customer and to synchronize, at a high level, the work of different companies. Traditional process models rely on Gantt charts or similar. Often, due to strict budgets and few resources, such process models contain very little details, thus providing only a very abstract idea of the process execution. Moreover, they typically focus on the long term without accounting for the actual progress of the work, nor the performance estimate. As a consequence, these models can rarely be used as a guide in the process execution. A more detailed process model, instead, could support the early discovery of potential problems or inconsistencies in the process, thus allowing companies to define more feasible milestones and effective plans to achieve them. Additionally, it could be used as a basis for the synchronization among the different companies.

Process Design: difficult synchronization among the company's departments. F&R is not only installing facades, but it is also engineering and fabricating the facade components. However, the departments of the company work with tasks represented at different granularity levels: the engineering department is focused on elaborating floor drawings; the fabrication department is focused on producing components; and the installation department is focused on performing all needed 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 would be to rely on a common process model, according to which the different departments can synchronize their activities.

Process Implementation: lack of support for detailed scheduling. In most of the cases the detailed scheduling of the activities to be performed on-site is left to the foreman without adequate IT-support: she can rely on oral communication with the workers, and on pen and paper to define a daily schedule. F&R could rely on experienced foremen, able to manage complex processes in an excellent way. However, this approach introduces big risks for the company because it is error prone and tightly binds the success of the project to the ability of one person. In case a foreman leaves the company, for instance, fundamental knowledge about the projects leaves with her and is not retained within the company.

Process Monitoring: unreliable measuring of the actual progress. In general, the progress of the work on-site is measured in terms of incurred expenses and not in terms of actual work performed. This has two main consequences for the project management. First, delays are discovered only when a task should be finished and it actually is not. At this point, however, it is often too late to identify the causes and to define repair mechanisms. Therefore, the delay typically propagates till the end of the project. Second, the possibility to align the production with the progress of the work on-site is extremely difficult. The alignment of the two, instead, would allow F&R to avoid both the expenses of storing the produced components and interruptions of the process because components are not ready when needed for installation. This, however, is possible only if the company has a reliable way to monitor the process.

3. Action taken

In the context of the project *build4future*, the research partners together with twelve Small and Medium-sized Enterprises (SMEs) from the Bolzano province, developed a new methodology called PRECISE (Dallasega et al., 2013), aiming at supporting and improving different phases of the construction process management lifecycle (Dumas et al., 2013). To this aim, the PRECISE methodology focuses on three main phases which are interconnected with one another: *i) process design*, supporting a collaborative process modelling; *ii) process implementation*, supporting a short-term and detailed *scheduling* of the activities; and *iii) process monitoring*, supporting a 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 the definition of a process model capturing the set of tasks to be executed on-site and the temporal dependencies among them. The aim of a process model is twofold: on the one hand, it represents an agreement among the different companies on the way the construction process will be carried on, and thus serves as a synchronization means between them. For instance, in order to optimize the cleaning operations, F&R agreed with the other companies that the installation of the facades would have been performed from the top floor to the bottom one. On the other hand, a process model is used by the company to plan the intra-organizational process, to synchronize the activities of the different departments.

To achieve a reliable process model, possibly considering how to organize the work in such a way to achieve a better final result, the methodology foresees the involvement of the main experts from the different companies (Rosemann and vom Brocke, 2015). They are expected to define the model in a collaborative way. According to the methodology, collaborative workshops are organized in the early stages of the project, once the overall design of the building is clear and when the participating companies are established. The workshops are orchestrated by a neutral moderator, i.e., someone with 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 different *locations* within it. These are defined in a suitable way to precisely locate the tasks to be performed (Dallasega et al., 2015). For instance, a building can be organized in different sectors (identifying different parts of the building like wings), each organized in levels (floors) and sections (identifying the technological content of an area), which are then enumerated with unit numbers. According to this definition, a location would be identified by a sector (e.g. A), a level (e.g. one), a section (e.g. room) and a unit (e.g. four).

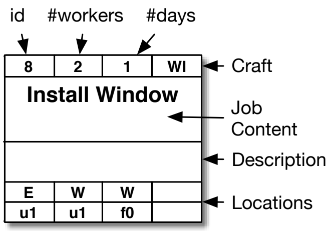

Fig. 1. Task representation.

As a second step, the companies discuss the main *tasks* to be performed and on which they have to synchronize their activities. Each task is defined by *i)* the specification of the job content, *ii)* the responsible trade and the craft required to execute it, *iii)* the (shared) resources needed, *iv)* the locations where it must be executed, and *v)* the expected productivity. To represent the latter, the methodology introduces the concept of *pitch* (Dallasega, 2016) which defines the amount of locations that has to be performed by a specific crew (e.g. three locations with a crew of two workers) in 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 different companies have to agree. The dependencies are conceived as a set of mandatory constraints ruling the temporal execution of the tasks (e.g. the floor has to be installed before the window in each location). However, they do not define a strict sequence according to which tasks should be performed (e.g. other tasks can be performed between the floor and the window installation). All that is not specified by a process model is left to the freedom of the companies. For instance, a process model does not define when a task should start.

To support the collaborative nature of the approach, PRECISE defines a graphical representation for 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 among them, meaning that the former should be performed before the latter.

Process Implementation. This is realized by defining a *short-term scheduling*, essentially specifying *i)* at which points in time work on tasks is to commence, and *ii)* how many workers per day, and who, are to work on individual tasks or groups of tasks, which determines the duration of the tasks. In addition, decisions need to be taken as to when to make resources available, like installing a crane or delivering windows.

The information on the tasks, such as the job content, all the locations where it is foreseen, the required crafts and the expected productivities, are specified in the process model. However, collaborative models usually specify only the main tasks among which synchronization problems among the different companies may arise. At scheduling time, it might be necessary to refine the tasks by further specifying them in terms of subtasks with the corresponding expected productivities and dependencies among them.

To specify a schedule, the foreman has to define: *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 (in which locations). Additionally, he has to consider the temporal dependencies from the process model: tasks should be scheduled in such a way to satisfy them.

To support the reliability of a schedule, the PRECISE methodology defines some criteria. In particular, in order for a schedule to be actual, it must be for a short period of time and, in order to be reliable, it must be based on actual data from the site (such as information on the completed tasks). Long-term schedules, indeed, would rely mainly on forecasts on the progress of the work and would inevitably be less detailed since fewer information would be available to the foreman at scheduling time. Accordingly, the methodology foresees the definition of daily or weekly scheduling of the activities, where a weekly scheduling better suits the initial phases of a construction process when there are fewer interactions among the companies and the tasks execution takes longer (e.g. excavation or pouring of the concrete). In the subsequent phases of the process execution, more companies have to work in the same locations (such as companies working on the facade and on the interior) and the tasks usually require less time to be completed in a location. In this case, a scheduling of the activities on a daily basis is more reliable and allows the companies to better synchronize each other.

When defining a schedule, the foreman also defines the crews of workers and assigns them to the tasks. To facilitate this activity, the methodology foresees the definition of the *presence list*, that is a list of workers that are expected to be present on-site in that particular day/week.

Monitoring of the Construction Process. The aim of the monitoring is to collect data on the progress of the work on-site. The methodology foresees the use of this data as a starting point for the scheduling, in order to have updated information on the (not yet) completed tasks. For instance, if the (daily or weekly) scheduling is defined at the end of the week for the following one, then it must be based on the data from the monitoring of the current week. Relying on the data from the scheduling rather than the monitoring, may lead to wrong assumptions about the progress of the work (such as the completed tasks) and, potentially, to an infeasible schedule. Indeed, it is often the case that due to unpredictable events (e.g. bad weather conditions), the scheduling for a particular time period is actually not implemented. In this case, the scheduled activities can just progress slower than foreseen, or even different activities can be performed.

The data from the monitoring is also used to update the expected productivity for the tasks in the process model. The expected progress is initially estimated in the collaborative workshops and is then constantly refined to rely on better estimation and to consider the learning curve effect. Due to the latter, indeed, the tasks may progressively be performed faster if performed by the same crew.

The companies can take advantage of the data from the monitoring by performing different kinds of analysis aiming at evaluating the overall progress of the process. Among others, they can determine whether the process is progressing on-time and within the estimated budget, by comparing the number of completed locations, the used resources and the hours consumed with the available hours from the budget. Based on this, they can also forecast the amount of work to completion in a detailed and reliable way.

3.2 Application of the Methodology

In this section we present how the PRECISE methodology has been applied in the project of the hospital of Bolzano.

Bolzano hospital process design. The PRECISE methodology was developed in the context of the project build4future. F&R was one among the participating companies and decided to apply it to the Bolzano hospital project. However, none of the other companies working on it was taking part to build4future. For this reason, the other companies did not participate in the collaborative process modelling phase.

Before F&R started the execution of the process on-site, the scientific partners organized a collaborative workshop involving the project manager and the foreman on-site of the company. In order to support the collaborative nature of this phase and to support the discussion among the participants, the workshop was performed with the support of magnetic whiteboards.

During the workshop, the participants first agreed on the representation of the locations by identifying the following elements as characterizing of the building (Dallasega et al., 2015): *a) Level*: from ground floor to the fourth floor. *b) Wing*: the three wings were identified with A, B and C labels. *c) Orientation*: north, east, south and west facades were identified according to the sun orientation. *d) Units*: enumerating small parts of similar size. Here the space between the two main axis of the building was used as a reference to define the units.

After this phase, the main tasks where identified, considering the main phases of facade installation: *i)* substructure, *ii)* frame assembly, *iii)* inner connection, *iv)*

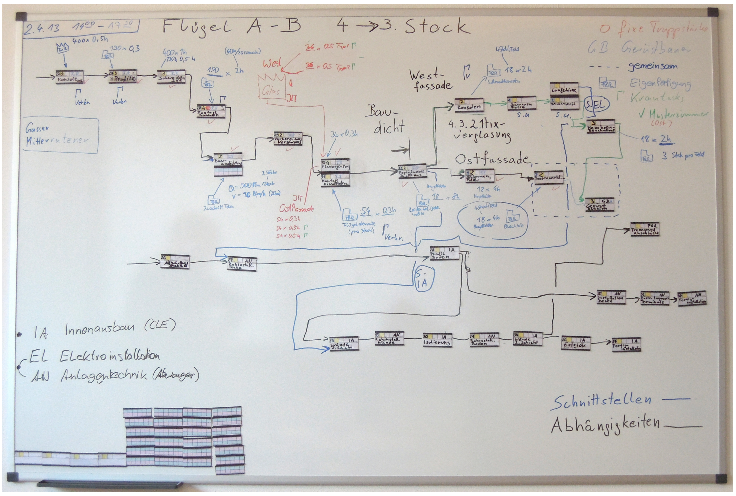

Fig. 2. Excerpt of the Bolzano hospital process model defined on a magnetic board.

sealing and insulation, *v)* glazing and installation of panels, *vi)* paneling, and *vii)* final assembly. The tasks were represented as in Figure 1, by means of magnetic plates and they were hang to a magnetic board. The information on the tasks (e.g. location, productivity) were specified by writing them on the magnetic plates with a marker pen. Finally, the dependencies among the tasks were drawn on the board, as shown in Figure 2. When modelling the dependencies among the tasks, however, the participants found that the modelling language was lacking some details in capturing the nature of a dependency. In particular, only temporal relations of one kind was foreseen. As a result, the language was extended by allowing the definition of three kinds of dependencies: *i) workflow*, capturing a temporal dependency on the execution of two tasks; *ii) information flow*, capturing that certain tasks need specific information to be performed, like detailed measurements; *iii)* and *material flow*, capturing that certain tasks need specific components to be performed. 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 number of detailed information on the tasks (e.g., the locations where a task needs to be performed, the resources needed to execute them and such like). The next step for the company was to plan the execution of the tasks satisfying the process model (and the dependencies among the tasks). For the tasks where no strict temporal constraints were defined in the process model, the company could decide according to internal priorities and preferences.

When the methodology was applied no specific IT-support existed. For the definition of the scheduling, the scientific partners provided the foreman onsite of a number of tables as the one reported in Figure 3. The tables were generated ad hoc, relying on the information coming from the process model and using, as a support, Microsoft Excel. Each table concerns a specific period of time according to which the scheduling must be specified. In line with the methodology, short-term scheduling (weekly or daily) were considered. By filling these tables, the foreman could schedule the activities to be executed in that period, the locations where to execute them and assign the crews. In particular, a table reports ① the list of tasks, ② the expected productivity and ③ the possible locations. This information is obtained from the process model.

A task could be scheduled in a location by filling the cell at the intersection of the row corresponding to the task and the column corresponding to the location (④). In particular, a cell is empty when the task can be scheduled; black when the

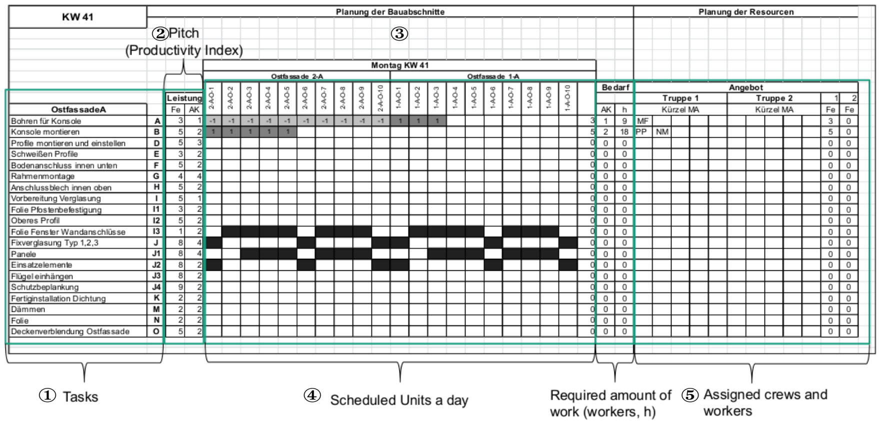

Fig. 3. Excel spreadsheet used to support the daily schedule for the company F&R.

task is not foreseen in that location; labelled with '–1' when it is completed there. To schedule the task the foreman has to fill the cell with '1'.

After defining the tasks to be performed, the foreman defines the presence list, that is the list of workers that are expected to be present on-site on that particular period of time, and the number of hours they are expected to work (e.g., part/full-time). Then, he can form the crews by assigning these workers to the scheduled tasks (⑤).

The scheduling was usually defined by the foreman on Friday afternoon for the upcoming week. It was performed using Microsoft Excel, filling the tables previously prepared by a researcher from the scientific partners. By using Excel, the foreman could also visualize a chart showing the *saturation* of the workers, which was generated automatically. The chart plotted the comparison between the number of hours the worker was available and the tasks he was assigned to. Additionally, the tables were linked to each other, so that the information on the scheduling could be propagated to the subsequent periods. For instance, a task scheduled for one day could not be schedule the next day.

On Monday morning, all scheduling tables were hanged at the construction site. At any time, the workers could check to which tasks they were assigned.

Monitoring of the work on-site. In line with the methodology, the monitoring of the progress of the work was performed on a daily basis. Everyday, at the end of the working hours, the installation teams were meeting at the planning board on-site and every crew leader recorded the tasks performed, the hours spent and the completed construction units. When the productivity for a task was lower than the estimated one, the worker had to annotate the reason for such a delay.

To this aim, tables similar to the ones used for the scheduling (Figure 3), were printed and hanged at the construction site. Every Friday afternoon a researcher from the scientific partners collected the data and copied it into Microsoft Excel spreadsheets. The information on the (un)completed tasks was automatically propagated to the tables for the scheduling, so that the foreman could plan the activities for the next week starting from up-to-date information. Moreover, the tables for the monitoring of the next week were printed and hanged at the management board on-site.

By relying on the Excel spreadsheets, the data from the monitoring could be elaborated so as to support analysis on the overall progress of the process. In particular, the data was used to *i)* compare the actual progress of the work with the initial project forecasts; *ii)* plot, for each location of the building, the number of hours consumed and the estimates to completion; *iii)* compare the hours that should have been consumed considering the completed tasks and the expected productivity, and the number of hours effectively consumed; *iv)* plot the difference between the estimated and the effective hours. A positive difference corresponds to an increase of the productivity.

All these charts were produced by means of Microsoft Excel and were hang at the construction site, so that every worker could have an overview on the progress of the process.

Continuous Improvement Workshop On-Site. A number of workshops, known as "continuous improvement workshops", were organized with the aim to analyze the data collected from the construction site and the charts produced by elaborating them. Overall, four workshops were organized with a monthly frequency. During these meetings, the project director, the project manager, the construction foreman and the vice-construction foreman of F&R discussed the general overview of the construction performances, specifically focusing on the last four weeks. Causes of problems and delays were discussed aiming at preventing their occurrence again in the future. Furthermore, the adaptation of the estimated productivity for the tasks (pitch) to the real conditions on-site was agreed in collaboration.

4. Results achieved

The approach was first introduced to the head of the research and development department of F&R who decided to adopt it in the Bolzano hospital project. The employees of the company were initially skeptical on its adoption. However, after the initial phase, they could experience that the approach does not require a big time expenditure in addition to their daily activities, neither it is used as a means to control them. On the contrary, it is used with the aim of having more control over the process management. F&R was overall satisfied of the obtained results and already applied it to other projects (like the construction of a new library, research center and archive for the St. Antony's College in Oxford).

As a matter of fact, by applying the methodology, the company was able to recognize that the estimated budget was too tight. Indeed, the approach was applied to the project of the hospital of Bolzano when an initial estimate for the budget was already made, both in terms of costs and in terms of hours needed to complete the work. Later, by implementing the collaborative planning phase, the foreman could provide estimates at the level of task. Based on them, it was possible to compute the estimated budget for the overall project and compare it to the initial one. The comparison showed that the initial estimate was tight. Of course, also the tasks productivity given by the foreman was an estimate, and thus it could have lead to wrong conclusions. However, by applying the monitoring of the actual progress on site, it was possible to refine the estimated productivity and to make it closer and closer to the real conditions on-site. This was used to provide the evidence that the budget was too tight. Without the monitoring, F&R could only rely on the budget estimate and the only way to recognize its reliability would be to wait until the end of the project or, in the best case, to check the progress at predefined milestones occurring with low frequency (e.g. one every six months). This would limit the possibilities of intervention (either on the process execution or to adjust the budget).

Another important result was that by applying the methodology the company could observe an *increase of the productivity* given by the better scheduling of the activities, the monitoring of the progress of the work and of the continuous improvement workshops, where problems and possible solutions were discussed collaboratively. During the four months, in which these workshops took place, indeed, there was an increase of the productivity on-site estimated in a saving of 400 man/hours (Dallasega, 2016). After four months, the workshops were not implemented anymore and the productivity started decreasing again. The analysis that has been made could not quantify how much of this savings were thanks to the application of the methodology and which other factors may have influenced it (e.g., good weather conditions or greater availability of the resources). However, a better control over the process and short time scheduling allowed the company to promptly react to problems that arose during the process execution. For instance, the company was able to discover a decrease of the productivity because of the lack of synchronization with the other companies for the use of the tower crane. Its unavailability for relatively long periods of time was reflected by the productivity values that, accordingly, decreased. The problem indeed was affecting several tasks since the material could not be promptly unloaded from the trucks and installed. After a synchronization plan was established with the other companies, the productivity started increasing again, showing that the plan was working well.

The application of the methodology allowed the company to identify one of the main causes of variation (both positive and negative) of the productivity. In particular, they were able to conclude that the *learning curve effect* has a relevant impact on the productivity of a task. This could be observed by comparing the productivity when the same crew was performing a task several times, and when a different one was assigned to that task for the first time. This may be used as a means to perform activities faster, but it could also cause a misalignment between the production line and the construction site, in case the productivity for a task on-site increases too much. By monitoring the progress of the work, the company was able to discover possible situations of this kind in advance and increase the production of certain components or schedule different tasks according to the resource availability. The effect of the learning curve, thus, is an important aspect that needs to be taken into serious consideration and further investigated by the company with the scientific partners.

The methodology also improved the synchronization between the different departments within F&R. Each task, indeed, was labelled with the components required by the task to be performed. Thanks to the process model and the detailed scheduling of the activities it was possible to relate the drawings of the engineering department, the components to be produced by the fabrication department, and the tasks for the installation department. It was possible 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 in applying the methodology was a better transparency on the execution of the process. Different information, indeed, was constantly provided at the planning board, where the daily scheduling, the tables for monitoring the progress and also charts on the overall process and the issues identified up to a certain point were constantly available and accessible by every worker. This kind of approach resulted in a better working environment where the workers felt engaged and felt as contributing to the success of the project, rather than just executors of tasks (Rosemann and vom Brocke, 2015).

5. Lessons learned

One of the main characteristics of the methodology is its *collaborative* nature that consists in supporting an active involvement in the project management of the main figures that take part to it. In the Bolzano hospital project, this was done by involving the main figures from F&R in the process modelling and in the continuous improvement workshops. Ideally, the methodology fosters also the collaboration across companies. One of the advantages of this approach is that each worker and company is expert in its own area of competence. By actively involving them in the process management, it is possible to take advantage of their expertise and make them in the position of agreeing on a strategy that is of interest for the project, besides that for the company itself (Rosemann and vom Brocke, 2015). Collaboration supports the synchronization both inter and intra-organization (vom Brocke et al., 2015). In the first case, indeed, the methodology supplies the means for the different companies to discuss on the way they expect to execute the process and to find an agreement that can suit all of them, still guaranteeing the good quality of the final result. In the second case, a company can discuss internally the process model in order to discover in advance possible problems and ways to overcome them.

Another important aspect is that the process management needs necessarily to be *flexible*, so as to address the high variability of processes in construction (vom Brocke et al., 2015). This aspect is very important given the number of unpredictable events that often occur on-site and that often are responsible for delays. If the process is flexible, such delays can be reduced more easily. The way this is achieved, according to the methodology, is by defining a process model which, capturing only the main dependencies among the tasks, can be easily changed if needed. Also, it foresees the definition of short-term and detailed schedules. In traditional approaches, usually long-term schedules are used for bidding purposes or for communicating with the customer, who is not interested in the details of how the process will be carried on. However, these schedules result to be less precise and when a problem occurs it is not clear how to change it to limit the delays.

A *reliable measurement* of the progress of the work on-site is important for different reasons. First, it is a prerequisite to make reliable schedules. If these latter, indeed, are based on forecasts on the progress of the construction process they are likely to become inapplicable very soon. Second, it will allow a company to discover possible sources of delays that, thanks to the flexibility of the approach, could be limited. Finally, it would make possible to do different kinds of analysis in order to understand 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 that is often considered of less importance. However, it can improve the overall execution of the process (Rosemann and vom Brocke, 2015). Giving responsibility to people and making them feel actively involved in the process, indeed, creates a good working environment where workers are more motivated and feel as an important element for the success of the project. In the Bolzano hospital project this was achieved by implementing the collaborative approach, but also incrementing the transparency over the process execution. At any time, workers could access the planning board on-site reporting the schedule for the entire week, the daily reports on the progress, the different charts plotting the analysis on the productivity and such like.

The application of the methodology also showed that the *IT-support* is very important and that good systems for process management are still missing (Rosemann and vom Brocke, 2015). An IT system, indeed, needs to be easy to use and non-invasive in order to have a chance to be adopted. In the hospital of Bolzano project, for instance, when the approach was introduced to the workers there was some skepticism because it was perceived as additional work to do. An important aspect that helped to overcome this thought was the non-invasiveness of the methodology and its easiness of use. This was achieved in different ways. First of all, the process modelling was performed with the support of a graphical and intuitive language. This allowed the process designers to use it with little additional effort. Concerning the scheduling and the monitoring of the activities, these were realized by adopting Microsoft Excel tables that were printed and hang at the planning board. Thus, workers were asked to work with tools they were already familiar with.

The Microsoft Excel spreadsheets were developed in an ad-hoc way for the project. However, the approach can be generalized 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 would allow to: *i)* generalize the concepts of the PRECISE methodology and make it potentially applicable to any construction process; *ii)* support the graphical process modelling; *iii)* generalize the Microsoft Excel spreadsheets by automatically gathering the data from the process model to configure the scheduling and the monitoring; *iv)* implement some automatic checks, such as the feasibility of a process model, the compliance of a schedule with a model and so on; *v)* possibly suggest schedules that are optimal w.r.t. some desired criteria; *vi)* generate charts and reports for the analysis of the productivity and the progress of the project, as soon as data from the monitoring is inserted in the system.

To support the usability of the system, the prototype is designed to be used with digital touch boards that reproduce the planning boards currently available on-site. This in order to support the workers with concepts and tools they are already familiar with. Compared to commercial tools, like (Bentley), (Sitesimeditor), (Vico Software) the prototype will support less functionalities. However, the commercial tools are often very complicated to use, so that specific competences are needed to use them. From this perspective, the approach that we will adopt is less invasive, since we do not require specific trainings for its adoption, nor long procedures in order to start working on a project. For this reason, we believe that this solution will better suit SMEs, that often do not have the resources to invest in expensive products (vom Brocke et al., 2015), but still play a crucial role in the construction industry.

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