Design of a Framework for Supporting the Execution-Management of Small and Medium sized Projects in the AEC-industry

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Abstract: The paper describes a framework for efficiently organizing and managing construction projects, aimed at reducing time and cost overruns. The approach provides concepts and tools to constantly monitor the actual progress of a project, so as to identify problems early on and to take corrective action by replanning and rescheduling.

The framework combines three correlated modules: (1) Process Modeling, where high-level information about the structure of the building, the tasks to be performed and their interdependencies, the qualifications of the workforce needed, and the expected performance is collected; (2) Scheduling, where the daily or weekly work assignment to the crews is determined, based on the modeling information and the actual progress; (3) Actualization, where the actual work performed on site is recorded, using the concepts of the process model.

We show how the framework can be translated into the architecture of an IT system to support the approach and report on a prototype that is currently under development.

Keywords: AEC, SME, Process Modeling, Scheduling, Building Execution Process

Introduction

The construction sector is worldwide one of the main sectors of economy. Considering small- and medium sized construction projects, they have limited time and cost margins for planning a project in a detailed way. Therefore, budget overruns (in terms of time and cost) are identified just in a late stage of a project where intervention options become limited. This results in cost and time explosions which endanger the survival of SMEs.

To prevent such a scenario, a construction project needs to be executed in a more efficient way. Efficiency can be improved by defining, in the early stage of the project, the process to be executed on-site in a detailed way and by scheduling the activities to be performed on-site according to the actual progress of the work. This idea is at the basis of the PRECISE methodology (Dallasega *et al.* 2013), that foresees three phases: a) a detailed modeling of the main elements of a construction process (i.e. the building, the resources, and the working activities to be performed); b) a daily or weekly scheduling of the activities to be performed on-site; and c) the monitoring of the progress on-site and the corresponding actualization of the construction process. Performing these activities would allow enterprises to promptly identify possible sources of delay or of extra costs, and adopt suitable actions to limit them. This methodology has been successfully applied in the context of two real construction projects, for the enlargement of the Hospital of Bolzano in Italy and the construction of a new library of the St. Antony College in Oxford (Dallasega *et al.* 2015a, 2015b). The methodology was applied with the limited support of IT tools. More precisely, the modeling phase was carried out by organizing cooperative meetings among the parties involved in the construction project and by using magnetic whiteboards for the process design. The scheduling and the actualization were carried out by means of excel spreadsheets, ad-hoc designed for the two projects.

To the best of our knowledge, none of the existing research approaches or commercial solutions allows to deal with these three phases in a satisfactory way. Building Information Modeling (BIM), for instance, has an important role in nowadays research and practice for optimizing the construction project process. However, the focus of BIM is on the design phase, especially on how to enrich the building model with information like time, cost, sustainability, and so on. Up to now, BIM software tools are conceived just for visualizing rather than for managing the execution process.

As a result, nowadays, project management heavily relies on the knowledge and the capabilities of the foreman on-site, who is the main responsible for the success or the failure of the project. This is risky for the companies involved, in the first place because it makes the project depend on one person, with severe consequences in case he leaves the project. Additionally, this makes the approach error prone. We believe that IT can support the project management in construction in a profitable way, by implementing the PRECISE methodology and by assisting the activities of the foreman on-site. In particular, IT can supply tools for i) the graphical modeling of a construction process; ii) the automatic configuration of scheduling and actualization according to the data coming from the process modeling; iii) the real-time propagation of the information coming from the actualization, so to ensure that scheduling is always performed according to the most up-to-date data; iv) easy access to the information on the current progress of the work, possibly accessible from everywhere and synchronized among different users; v) automatic check of data consistency and of process constraints (e.g. a task cannot be scheduled in an area where it is not foreseen); vi) signaling possible sources of delay or extra costs.

In this paper we discuss how IT can support construction project management. We present a formalization of the main elements that are involved in a construction project according to the PRECISE methodology and discuss a first prototype currently under development for supporting it.

Current State of Research in the Design and Managing of Construction Projects

According to El Asmar *et al.* (2013) the most commonly used delivery systems in the construction industry are Design-Bid-Build (DBB), Construction Management at Risk (CMR), Design-Build (DB) and Multiple Prime. An alternative method consists of the Integrated Project Delivery (IPD) system which brings all participants together early with collaborative incentives to maximize value for the customer as opposed to the traditional approach where every project participant is focused to maximize its own profit share (AIA 2014). IPD defines 7 phases and the needed professional figures of a construction project: 1) Pre-design, 2) schematic design, 3) design development, 4) construction documents, 5) agency permit/bidding, 6) construction, 7) closeout (AIA 2014). The cooperative approach defined in the IPD resulted to be effective in project management, allowing to reduce costs and delays (AIA 2010, Mossman *et al.* 2010). However, IPD does not rely on a specific IT-support.

Nowadays, the most common IT-support is BIM, which plays an important role in the construction industry especially by defining standards for the design process. The Level of Development (LOD) Specification is a reference that enables practitioners in the Architect Engineering and Construction (AEC) industry to specify and articulate with a high level of clarity the content and reliability of BIMs at various stages in the design and construction process (BIM Forum 2013). It allows authors to define what their models can be relied on for, and allows downstream users to clearly understand the usability and the limitations of models they are receiving (BIM Forum 2013).

According to figure 1 the LOD descriptions identify the specific minimum content requirements and associated Authorized Uses for each Model Element at five progressively detailed levels of completeness.

In *LOD100* and *LOD200* the Model Element is represented within the model by not detailed geometry (AIA 2013). In *LOD300* the Model Element is graphically represented within the Model as a specific system, object, or assembly in terms of quantity, size, shape, location and orientation (AIA 2013). In *LOD400* the Model Element contains further detailing, fabrication, assembly and installation information (AIA 2013). Finally, the *LOD500* element is a field verified representation in terms of shape, location, quantity and orientation (AIA 2013).

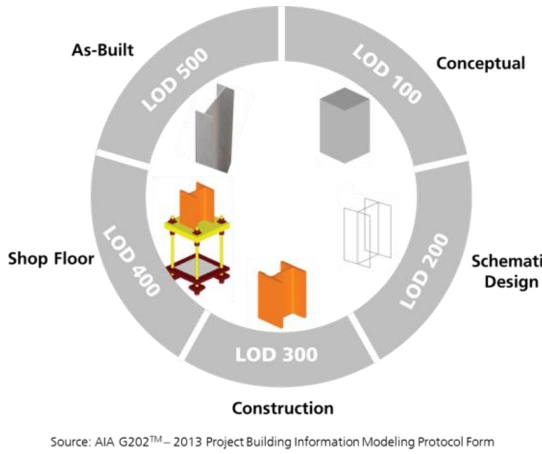

Figure 1. BIM Level of Development (AIA 2013)

In BIM the dimensions from level 3 to level 7 specify the purpose and kind of information needed in every level (figure 2).

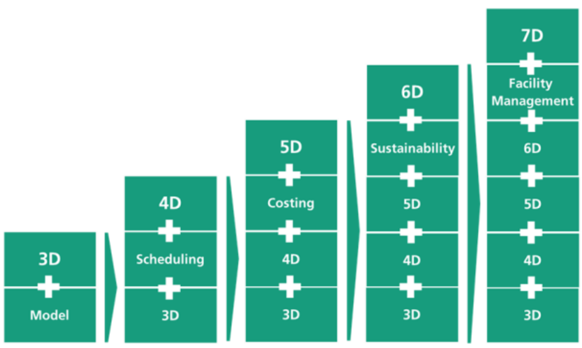

Figure 2. BIM dimensions

The *3D-Model* is the lowest dimension and it is used for the detection of clashes in the design phase before going on-site (Out Law 2015). The *4D-Scheduling* dimension is used to visualize and to simulate the construction execution process, especially the logistics plan (lorries and cranes). Rather than to manage, this dimension it is used to visualize the construction execution process (Out Law 2015). The *5D-Cost* dimension incorporates costing information which allows performing automatically essential estimating information like material quantities, costs, size and area estimates (Out Law 2015). The *6D-Sustainability* dimension helps to perform energy consumption analysis which results in more complete and accurate energy estimates early in the design phase (Out Law 2015). Finally, the *7D-Facility Management* dimension can be used as an "as built" model being able to contain all of the specifications, operations and maintenance manuals and warranty information useful for future maintenance (Out Law 2015). At the moment public and private agencies from some European countries (UK, Netherlands, Denmark, Finland and Norway) request a LOD of 300 and corresponding BIM-dimension of 3D and optionally 4D. According to the European Union Public Procurement Directive (EUPPD) all 28 European Member States may encourage, specify or mandate the use of BIM for publicly funded construction and building projects in the European Union by 2016 (BIMobject 2015). In the mid-term future LOD 300, LOD 400, LOD 500 and BIM-dimensions 3D and 4D will be requested as obligatory and BIM-dimension 5D and 6D as optional. From 1985 to 1990 in the so called CAD era, geometry based formats (like DXF or IGES) were used to interchange design information. Later on, from around 1990 till 1995 the STEP data exchange format was used to exchange product model data. This standard allows for the first time engineering applications to exchange information about product and process designs (Loffredo 1999). The scope of the data exchange format includes mechanical and electrical CAD, manufacturing processes and specialty domains such as composite materials and shipbuilding (Loffredo 1999).
From 1995 till today the Industry Foundation Classes (IFC) file format is used to exchange information between AEC software applications. It relies on the ISO-STEP EXPRESS language and concepts (Eastman *et al.* 2008).

Tools for Construction Management On-Site

According to Sacks *et al.* (2010), most of the academic and industrial research on computer-aided design and visualization in construction deals with building design and with pre-construction planning. There has been far less effort to develop BIM based tools to support coherent production management on site. Nowadays the planning and management of construction processes is carried on by relying on techniques such as the Critical Path Method (CPM). These techniques are the basis of commercial systems that are quite diffuse in construction project management, such as Microsoft Project (Microsoft Project 2015) and Oracle Primavera (Oracle Primavera 2015).
Systems especially conceived for Construction Management can be categorized in those for planning and visualizing and those for managing the work process on-site.

Systems for planning and visualizing
In the article Akinci *et al.* (2002) the authors demonstrated how work spaces and temporary facilities could be generated and added to 3D models to enable evaluation of construction plans for space conflicts.
The Lean Enterprise Web-based Information System (LEWIS) is a platform which integrates a building model, a decision support system which elaborates optimization of construction plans and 4D visualization delivered on a web-based information system (Sriprasert and Dawood 2003) (Sriprasert and Dawood 2002). According to Sacks *et al.* (2010), the implementation includes graphical visualization of constraints, like material deliveries, by color-coding objects in a building model view.
Moreover, some systems, like VICO software, add also costs to the model providing so BIM-5D compatibility (VICO 2015).
According to Akinci et al. (2002), these systems are appropriate for pre-construction planning and monitoring schedules but not for day to day production management due to the following causes:
- they do not support fine-grained collaborative task negotiation and planning between teams (collaborative process planning);
- they do not support pull flow control and explicit checking and removal of constraints (lean construction methods);
- they do not define activities with sufficient degrees of detail (e.g. number of workers and crews needed for executing a task, qualification, needed materials and so on);

Systems for Construction Management
On the other hand, there are systems which implement lean construction flow control without using building models for increasing visualization. In the article (Choo *et al.* 1999) WorkPLAN was conceived to provide appropriate support to field crews in construction scheduling. According to Sacks *et al.* (2010) the system uses a database of work packages and constraints to support the Last Planner System (LPS) process. Today the commercial

software version of WorkPLAN is an Enterprise Resource Planning (ERP) job-management software solution, especially suited for job shops, custom and make-to-order manufacturers (WorkPLAN 2015).

Strategic Project Solutions Inc. (SPS) developed a web based tool for workflow control, which is called SPS-Production Manager, and a tool for the management of materials at the production level, which is called SPS-Materials Manager (Koerckel and Ballard 2005).

In Sacks *et al.* (2010) the authors describe a software system for construction called KanBIM and based on BIM platforms, which use Kanban card type, pull flow control signals and Andon alerts for supporting construction management.

ConstructSim is a commercial software package, which offers model based work planning, allowing detailing master plan level activities into detailed tasks for production planning (Sacks *et al.* 2010). More in detail, the system performs a constraint checking by associating building model objects with external supply chain information systems (Sacks *et al.* 2010). According to Bentley (2015) ConstructSim is a virtual construction simulation application for creating a virtual construction model (VCM) and automating the creation of installation work packages. Moreover, the system visualizes the progression of production by displaying the current and future state of the building but it is not suitable to show explicitly the locations of work teams or work in progress (Sacks et al. 2010). According to Sacks *et al.* (2010), both LEWIS and ConstructSim are suitable to be used by Engineers but not for trade managers or crew leaders on-site.

According to Starkov (2009) Tokmo enables implementation of a single project schedule, linking master schedule with weekly production plans and daily reports. By searching on the web, it seems that the company Tokmo, which was founded in 2008 in Washington DC, does not exist anymore.

Hewage and Ruwanpura (2009) developed a construction on-site communication tool needed to communicate up-to-date information to workers at the workface level with improved levels of productivity due to less time needed for workers to search information. However, the system was conceived just for communicating product information (and not process information) in a one-directional way (Hewage and Ruwanpura 2009).

In Kubicki *et al.* (2006) the authors developed a prototype web interface to communicate the status of tasks using text, digital photos, a percent complete measure, information about problems and links to relevant documents.

Many research efforts have been made to automate monitoring of operations on-site with the aim to measure actual performance and compare it to the planned one identifying in time appropriate corrective actions (Navon and Goldschmidt 2003) (Sacks et al. 2005) (Bosche and Haas 2007). Here, one system which involves people performing the work providing status reports was developed by Vela Systems and Tekla Corporation (Sawyer 2008).

Capterra is a search engine on the web which helps to find appropriate business software. The search engine allows filtering software categories in construction management with different features (e.g. web-based or installed, job scheduling, subcontractor management, supplier management, task management, subcontractor management and so on). However, by filtering these features the search engine finds applications suitable just for information exchange and document management (Capterra 2015).

As a result, up to now a methodology and IT-support which integrates the following features is missing:

a) *Process modelling*;
b) *Scheduling and monitoring construction tasks (short and medium term)*;
c) *Releasing construction components according to the construction progress (JIT and JIS)*.

The PRECISE methodology

According to Dallasega *et al.* (2013) an essential prerequisite for success in complex construction projects is that architects and specialist planners have access to information from executing companies and suppliers. However, in the AEC sector, contractual and public procurement law requirements, diverging project objectives, and a lack of process understanding impede an early and interdisciplinary collaboration. The PRECISE production system consists of three parts (Dallasega *et al.* 2013).

1) In the Early Interdisciplinary Building Design phase key actors from planning and execution evaluate and optimize the building design taking into consideration relevant aspects (like accessibility or constructability).
2) In the Integral Building Execution Planning (IBEP) phase a process plan for the operations on site is developed by the companies responsible for executing the work and their key suppliers in collaboration with the design actors. Here, the so called "Pitching" concept is applied in order to synchronize all actors on-site and to reach a constant work flow. One Pitch means to subdivide the amount of work in a Job Content of one day (8h) for a specific Craftsmen Team in a specific Construction Area.
3) In the third phase a dynamic planning and controlling tool, called "Dynamic Control Panel" is used to support the daily coordination of all involved crafts on-site.

Phase 2 and phase 3 of the methodology was developed and tested in the context of a collaboration with the company Frener&Reifer GmbH (F&R), which engineers, manufactures and installs high class design facades for well-known international architects.
Up to now, the methodology was applied in two completed projects of the company F&R. The first project concerned the expansion of the central hospital of Bolzano. The enlargement project consisted of an additional erection of a new clinic, which consists of three wings (A, B and C) with respectively four levels, a north-wing with respectively three levels and a new entrance area. The second project concerned the construction of a new library, research center and archive for St. Antony´s College in Oxford (UK) called “Softbridge”. The project consisted of a connection of two existing buildings with a double curved stainless steel sheet façade composed of an electro-polished surface.
For the Integral Building Execution Planning (IBEP) phase, in the context of the two case studies, process planning workshops were organized. During these workshops the participants discussed and agreed on the process model with the help of magnetic white boards (figure 3).
Figure 3 shows the process plan according to the IBEP methodology for the construction of a hotel with an overall cost of 3 million Euros. Here, Make To Order (MTO) processes on-site (like window installation) and their connections to the fabrication shops are visualized and embedded in the whole construction process. Every box visualizes a single construction task containing a specific amount of work and arrows visualize predecessor and successor information.
As explained in (Dallasega *et al.* 2013) the amount of work is defined by using so called quantity of “Pitches” which determine the job content for a craftsmen-team in one specific time interval (day or week) completing it in a defined construction section. Planning and measuring with units of “Pitches”

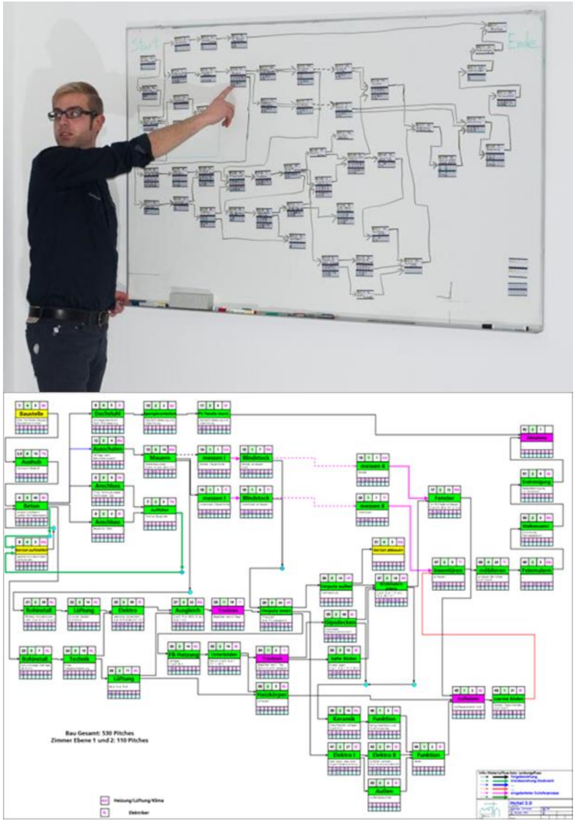

Figure 3. Process Modeling Hospital of Bolzano

within small time intervals, allows measuring later in a detailed way the construction performance on-site.
Furthermore, for the considered projects two MS-Excel based prototypes were developed. The prototype consists of a set of tables, as depicted in figure 4. One table represents the scheduling for a particular day. It shows the list of tasks (rows) and the list of construction units (columns). The cell in the intersection between a task and a construction unit codes whether the task can be scheduled (white cell), it is not foreseen to be performed in that unit (black cell), it is scheduled for the current day (1), or it is completed and thus cannot be scheduled anymore (-1).

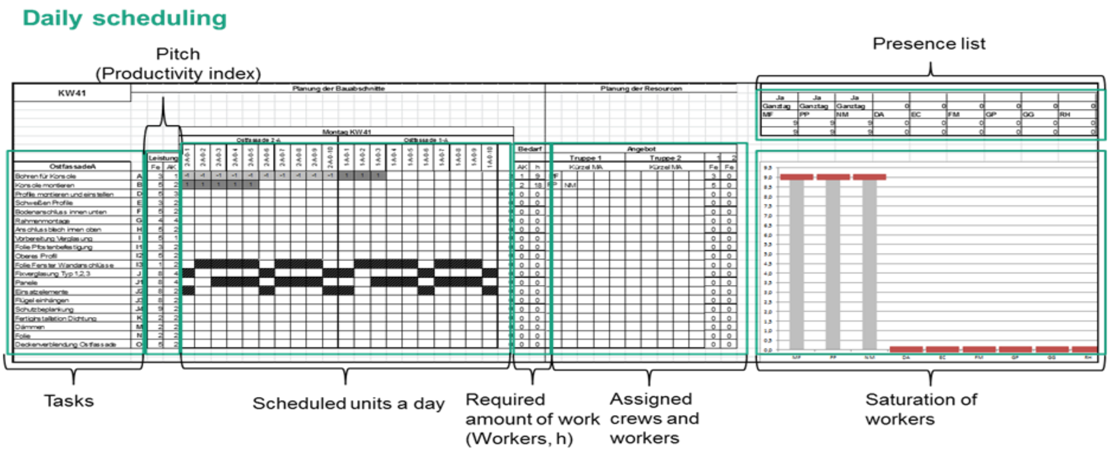

Figure 4. MS-Excel prototype for daily scheduling

When scheduling a task, the user specifies the workers that are assigned to perform it by grouping them into crews (“assigned crews and workers” in figure 4). According to the assignment of the tasks to the workers, the excel prototype computes the worker saturation. The MS-Excel prototype was also used to record the real performed tasks on-site needed for monitoring the construction performance. This was done by comparing the real progress with the planned one.

Description of the Framework

As depicted in figure 5 the modeling, scheduling and actualization phase are tightly connected one another. In particular, information coming from the modeling should be used to automatically configure the scheduling and the actualization. In other words, for each task defined in the modeling phase it must be possible to schedule its execution in the construction units where it has been foreseen and assigning workers compatible with the craft required by the task. Additionally, once a task is scheduled, the system must check that all dependencies on which the current task depends on are satisfied (i.e. those tasks on which the current task depends are scheduled to be performed before). Similarly, information coming from the modeling and the scheduling must be propagated to configure the data for the actualization. The information that comes from the actualization can then be used to better configure the process modeling (e.g. by suggesting the introduction of new tasks in some areas, or suggesting to update the estimated productivity index for a task in a construction area).

For what concerns the process management, in order to have a reliable picture of the current progress of the work on-site it is fundamental that scheduling and actualization are tightly connected. Specifically, as soon as data from the actualization are available they must be propagated to the scheduling. In this way, only tasks that are not completed yet can be scheduled.

In order to build a system supporting these functionalities, the first step consists in identifying and modeling the main concepts occurring in construction project management and the relations among them. This was done based on the two real case studies where the main elements were abstracted.

Conceptual Model

The aim of a conceptual model is to understand and represent, in a non-ambiguous way, the main elements occurring in an application domain and the relations among them. In this section we describe the main concepts that occur in construction project management based on the two case studies. An important aspect is to represent them at the right level of abstraction: general enough to be independent from a particular project and specific enough to capture all the necessary details.

The approach consists of two different loops; one for configuring the process and one for managing the daily production on-site. Within the Configuration Loop the System is configured as explained before. The Management loop is used for scheduling and controlling the daily construction progress on-site. Here, based on the rolling planning approach the work assignment is scheduled and monitored in a specific time interval (day or week).

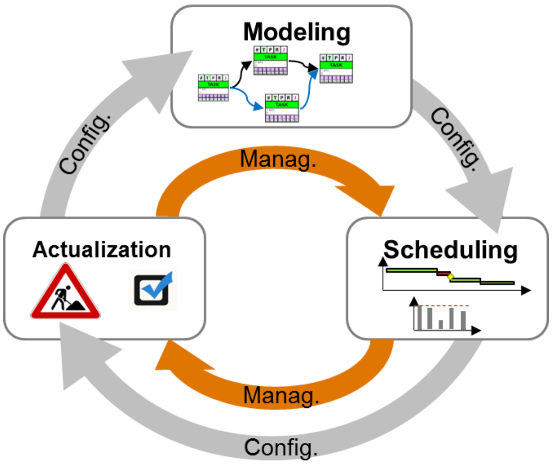

Figure 5. System modules

1) **Modeling:** In this module/phase the construction process is configured. Here, the different tasks and their dependencies are defined.

   Construction Phase. The Construction Execution Process, which contains Planning and Construction, is subdivided in three different and subsequent construction phases:

   a) *Skeleton* Phase: means the first construction phase where the basic structure of the building is erected. As a practical example the concreting of the building can be mentioned where the different levels are built upon each other.
   b) *Envelope* Phase. Concerns the installation of the facades.
   c) *Interior* Phase. Concerns the erection of the internal part of the building.

   Construction Area. A construction area identifies the different areas of the building where tasks can be performed. According to the construction phase, a different level of detail is needed in representing a construction area.

   Figure 6 shows the approach for dividing the structure of the building in construction areas.

For the **Skeleton** phase a higher level of abstraction for the construction area is necessary. The concept *Sector* represents separate parts of the building that can be managed independently one from the other. In this phase the construction area consists of *Sector* and *Level* (*Sector-Level*).
Within the **Envelope** phase the construction *Sectors* are divided based on the sun *Orientation*. Additionally, the construction area is divided per levels and every *Level* is subdivided in *Construction Units (Sector-Orientation-Level-Unit)*.
In the Phase **Interior** different construction areas are identified based on the horizontal section of the building and differentiated by their specific technology content.

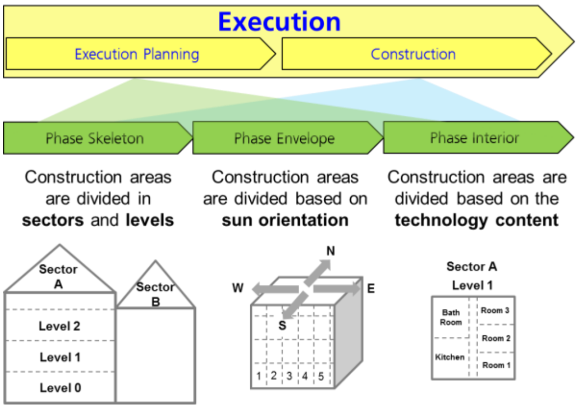

Figure 6. Subdivision of construction areas

Therefore, the concept of Sections (e.g. a section can be a room, a swimming pool and such like) is introduced. For every *Section* there could be a number of units (e.g. in figure 6 there are three units for the section room). A construction area is identified first by the *Sector*, and by the *Level*. Then, a construction area refers to a particular *Section* and to a specific *Unit* for that Section (*Sector-Level-Section-Unit*). Figure 7 summarizes the logic of structuring construction areas in a conceptual hierarchy.

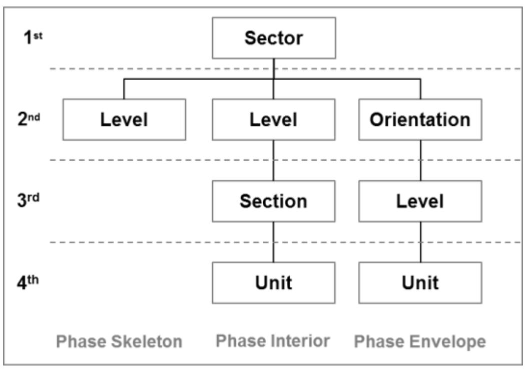

Figure 7. Hierarchy of Construction Areas

Task. A Task represents an activity to be performed on-site. It specifies: a) the activity to be performed; b) to which construction phase the task belongs to; and c) the craft required to perform it.

Dependencies. A dependency represents an ordering relation between two tasks. Dependencies can be of different types, specifying the kind of relation between two tasks (e.g. workflow, information flow, material flow).
Additionally hard and soft dependences are identified, where respectively mandatory and preference requirements on the execution of two tasks are distinguished.

Task Instance. This concept is used to instantiate the Tasks, by specifying in which Construction Units they are expected to be performed.

2) **Scheduling:** In this phase the work assignment for a construction crew is scheduled for a specific time period (a day or a week). The scheduling part has the aim to define work assignments for a construction crew for a specific time period (a day or a week) by focusing on value adding activities. The following concepts (to be considered together with those identified above) are defined:

Time Period. It defines the period for which a particular scheduling (or actualization) is defined. A weekly granularity is suitable for tasks that require some days to be completed. This is particularly frequent for the skeleton phase, while for envelope and interior a daily granularity for the tasks is usually more appropriate.

Worker. The entity contains the information about a worker that has a contract for the current project. It also captures the information on the worker's qualification.

Presence List. It contains the list of workers present on-site in a specific time period.

Crew. It defines a team of workers that can be assigned to perform a task. A crew is defined for a particular time period, and the workers can be selected among those from the Presence List of that period.

Scheduled Task. This entity contains the information concerning the scheduling of a Task: i) the Construction Phase to which the task belongs to; ii) the Construction Unit where the task is scheduled to be performed; and iii) the Crew that is responsible of performing this task.

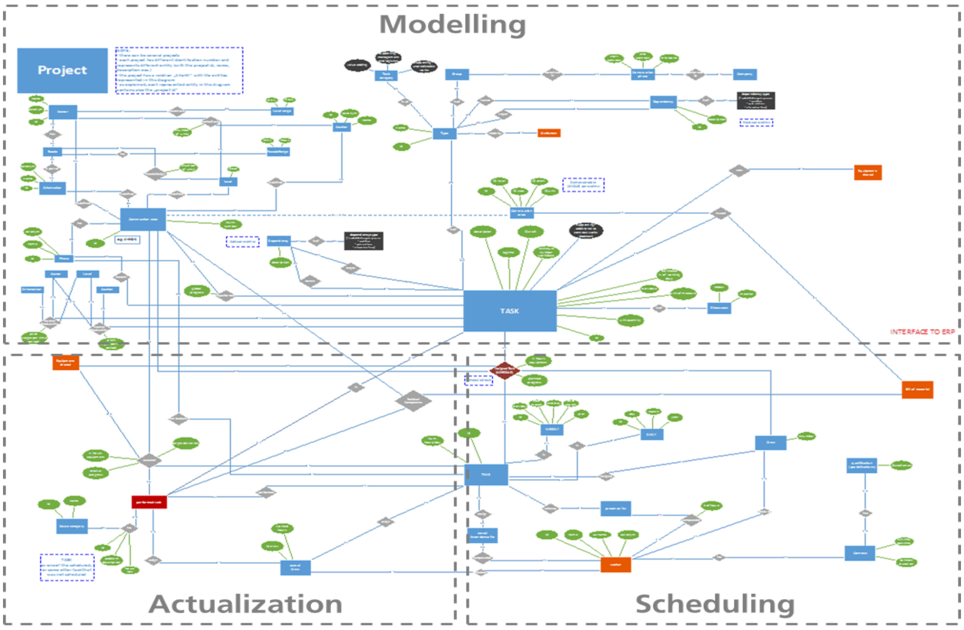

Figure 8 The Conceptual Model

3) **Actualization:** In this phase the construction progress on-site is measured by recording the tasks actually performed on-site. This information is then used as a starting point for the scheduling of a new time period (Dallasega *et al.* 2015). Furthermore, the actualization part is used for calculating different Key Performance Indicators (KPI's) needed for supervising the construction performance on-site. One KPI for example compares the needed amount of work with the planned one.
The concepts that occur in the actualization are very similar to those in the scheduling. Also for the actualization, indeed, there is the concept of Presence List, which in this case represents the list of workers that are actually present on-site for a certain time period. Based on the actual presence list, the Crews actually performing the tasks are defined. The concept of Actualized Task is similarly to the concept of Scheduled Task, but it is used to represent a task that has actually been performed on-site, together with the information on how long it took to perform it.
We represent the conceptual model as an Entity-Relationship (ER) diagram, reported in figure 8. Here, entities are linked with each other by relationships that express the dependencies and requirements between them.

Prototype architecture and current development

When developing a system different architectural solutions are possible. One possibility is the development of a standalone application, i.e. a software application that is installed on a computer and that, once configured, is ready to be used. An alternative solution is the development of a web application, i.e. a system that runs on a server and that is accessible remotely over the internet via a web browser.

The choice on one or the other is driven by the user requirements. In our case we wanted our system to support the following requirements:

a) *Easy to access and configure*: We want our application to be accessible and configured with the less effort possible.
b) *Platform Independence*: The system should work with every operative system and independently on the hardware.
c) *Synchronized View*: The same information should be available by different users accessing the system at the same time.
d) *Availability of the Project Information*: The information on a project should be always available and from everywhere.
e) *Mobile Devices*: We want our system to be eventually used with mobile devices to be used on-site.

Given these requirements, our choice was the development of a web application, with a client-server architecture. Figure 9 sketches the system architecture and summarizes the used technologies. In this architecture, the client handles the interaction with the user, according to which requests are sent to the server. The communication with the server is transparent to the user, who accesses the system by means of a web browser.

The Server handles the requests from a client, retrieves (stores) information from (into) the database

and sends responses to the client which visualizes them in a suitable and user friendly way.
The Database stores data about several construction projects, concerning the modeling, scheduling and actualization phases.
In this architecture, the project management is based on the idea of Software as a Service (SaaS). More in detail, it consists of an on-demand software concept accessed by users using a client via a web browser. This means in practice that a company in the construction industry procures a license which is based on a current construction project. So, laborious installations disappear. Furthermore, fixed costs from traditionally licensing disappear, which allow Small and Medium sized Enterprises (SMEs) in the construction industry to adopt the software.
One of the advantages of this solution is that a number of clients (possibly of different kind, like laptops, mobile phones and tablets) can access the service at the same time. Moreover, any change or insertion of new data into the system is immediately available to all the connected users. Finally, the access via web browser entails that no installation or configuration is needed.

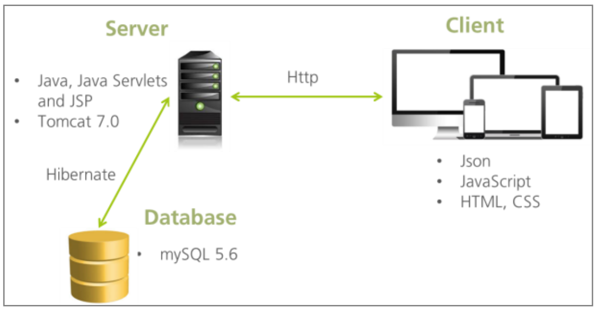

Figure 9. Client-Server Architecture

The web application we are currently developing will support the different phases of a construction project. At the moment a first IT-based prototype for the Modeling phase was developed. The aim is to support the process design that is performed during the process planning workshops (Dallasega *et al.* 2013). The software prototype was tested on a suitable hardware solution. For supporting a collaborative process planning a Smart Touch Table was chosen (figure 10). In comparison to a planning white-board a touch table should foster collaboration because the participants sit around it in a face-to-face orientation as opposed on the planning board where the participants show each other their shoulders. Additionally, at the end of the workshop the resulting process can be immediately shared among all the participants and can be used to configure the scheduling and the actualization phases. This approach avoids the introduction of errors resulting from the transformation of the process into a digital format.

Figure 10 Smart Touch Table for Process Modeling

Figure 11 User Interface Scheduling Steps 1 and 2

Furthermore, a first version of the Software Module for the Scheduling was developed. In the following the implemented functionalities are presented, describing the steps from 1 to 7 that lead to the creation of a scheduling.

In Step 1 the user has to input his credentials for accessing the system. Next, in Step 2 the user can select a current or completed project or create a new one (figure 11).

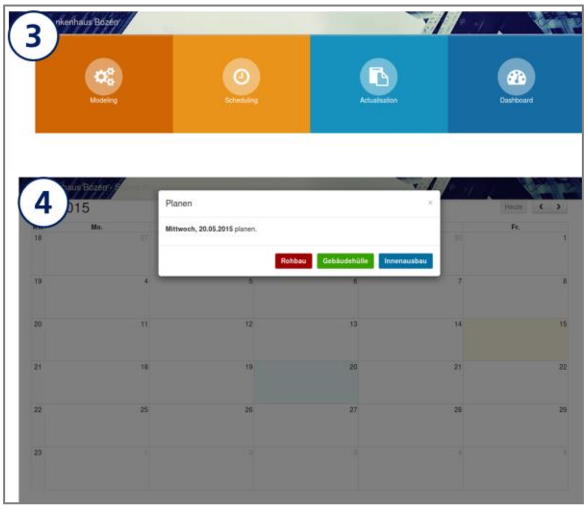

Figure 12 User Interface Scheduling Steps 3 and 4

In Step 3 the User can select one of the system modules (Modeling, Scheduling or Actualization) or visualize a dashboard showing different Key performance Indicators (KPIs). When selecting the Scheduling module, the system presents a calendar from which, in Step 4, the user can select the day or the week for which he wants to perform the scheduling. After clicking on the day or the week, the system asks the user to choose a construction phase for the scheduling (Skeleton, Envelope or Interior). These steps are reported in figure 12.

In Step 5 the user can select the workers present on-site to create the presence list. Furthermore, he can define how many hours a worker is present on-site in a defined time period.

In Step 6 the user can define crews of workers that can be assigned to perform a task in a construction unit. A crew can be defined by selecting the workers from the presence list (figure 13).

In Step 7, the user selects a construction area where he wants to schedule the execution of some task. The possible construction areas are visualized according to the construction phase selected at Step 4. For instance, if Envelope is selected, then the system shows a list of Sector and then, according to the

Figure 13 User Interface Scheduling Steps 5 and 6

selected one, it shows the list of Orientation foreseen there. Finally, it shows the list of Levels foreseen for the selected Sector and Orientation.

Once a construction area is selected, the system visualizes the list of tasks foreseen in that area, together with the current progress of the work. The user can click on a cell between a task and a Unit to assign a crew, meaning that a task will be scheduled to be performed in that Unit for the selected time period. A crew can be assigned only if the task is foreseen in the Unit and it is not completed yet. If these requirements are satisfied, a window for the assignment of a crew pops-up. This window is the same of Step 6 and it allows the user to select an existing crew or create a new one (figure 14).

As depicted at the bottom of figure 14, the system also visualizes the saturation for each worker from the presence list. The graph shows the number of hours of work that have been assigned to him, compared to the number of working hours foreseen by the contract.

Once the user has completed the scheduling in a construction area he can select another one or return to the calendar. From here he can decide to perform the scheduling for another week or day.

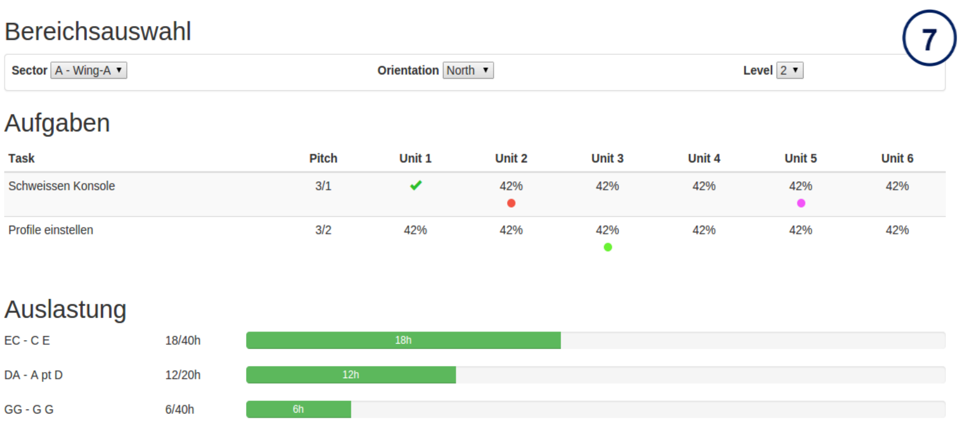

Figure 14 User Interface Scheduling Step 7

Conclusions and Outlook

The paper presents an approach for construction project management, which foresees a modeling, a scheduling and an actualization phase of the process. The approach relies on the PRECISE methodology that fosters a collaborative construction project management, as foreseen in the IPD and LPS approaches. More in detail, it aims at supporting small- and medium sized construction projects where the limited cost- and time budget requires for an effective management of the project.

The current development of a web application for supporting the methodology is presented. To the best of our knowledge, the state of the art in research in the design and management of construction projects lacks a methodology and IT-support for preventing costly interruptions and delays on-site.

The presented approach allows for the management of construction projects with a minimum time effort.

The system under development supports a user interface that permits to handle the software in an efficient and intuitive way. Furthermore, considering that during a construction project different actors have to interact with the software, the application will allow concurrent accesses as well as different privileges (like the possibility to modify or to visualize only a project) to different users.

The presented work arose by a collaboration of the Free University of Bolzano (Faculty of Computer Science), Fraunhofer Italia and Frener & Reifer GmbH within an applied research project. The future work consists of implementing the actualization functionality in the Software System and as soon as all modules and functionalities will be ready it will be tested on a specific construction project. In this way we expect to collect feedbacks on the system from the foreman on-site, who is supposed to be one of the final users of it.

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