Information Technologies (IT) Applications for Construction: (Case Study: The Tallest Silo of the World in Zurich)

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Abstract: Computing and communication technology, also commonly known as information technology (IT) which is expanding fast becomes to be an important assistant tool to assign priorities in all aspects of project planning of systems. While the use of IT systems have received great attention during the last decades, there have been few studies with focus on the relationship between information technology and using of such systems in organization of construction projects. Construction projects are specific, unique, and many are complex with varied time constraints and budgets. Often the discussion of IT technologies of interest to construction is centered on the most recent tools that general developments in commercial IT or in Computer science research have to offer. The correct and relevant management of information resources within construction impacts both the success of projects and overall performance of the individual project participants which can make sure that all participants execute and control project plans in appropriate time. This is significantly influenced by how project managers acquire, use, store, re-use and integrate relevant information to assist in the production of project estimates. The present paper describes literature related to IT implementation and its services in the construction industry with the purpose of highlighting the suitable conceptual IT model in the context of the construction of the world tallest silo in Zurich. It also presents some of the structured methods such as computer aided design (CAD) and computer aided manufacturing (CAM) that have significant importance in the management of the construction processes. The focus of this research was to gather the experiences of the Swissmill project management team in the use and application of IT programs to assess the benefits realized by all project participants. Finally, the study reveals that using the decision-tree-plan would be a more sustainable way of selecting the best alternative which can help executives manage issues faced in large-scale, complex projects more effectively. Results obtained by implementing IT methods, demonstrate great capabilities of this approach for complicated challenging problems in the Silo construction project.

Keywords: Information Technology (IT), Construction, Construction Management, CAD, CAM, The World Tallest Silo in Zurich

1. Introduction

Using electronic machines and software for the processing, storage, transfer, and presentation of information is referred to as information technology (IT) [1]. The applications of information technology in construction still remains weak since managers are not aware of the fact that high levels of capital investment directed to computer systems and communication networks guarantee significant gains in productivity and economic returns [2, 3].

Although engineering works have complete specifications from the start, change management and some of the IT works utilize a more iterative approach to define what needs to be done. In some cases, the work is modeled and detailed timing is carried out by precise techniques. Other cases, however, require broad initial estimations with constant refinement as more information becomes available [3]. The flow and
control of information are also of great importance for teamwork environments, where professionals are simultaneously working on different aspects of a project and share their information. However, the application of IT in the construction industry is not effective as in other industries. The most prominent problems occur in tools software and information communication.

Collaborative work environments demand facilities for sharing information, tracing decisions, and an area of internal or external communication networks. The data-stores in these collaborative work environments may become very large. The ability to exchange data and information between all those involved in a building project depends on the communication networks. When the flow of information improves, teamwork and coordination may be enhanced. It’s meant building documents can be exchanged in digital form [4]. The application of office automation may improve internal management efficiency, and control cost. During the construction phase, computer-aided design (CAD), computer-aided manufacturing (CAM) aids, tools software including cost evaluation software, quota management software, quantity calculation software, steel quantity calculation software, and communication networks are available to the project manager and used in almost all construction offices. As changes or repairs are needed, plans for the facility can be accessed from the database [5]. In this respect, Flanagan and Marsh [6] discussed some information management problems in construction and existing solutions. Sacks et al. [7] proposed the lean construction methods such as the last planner system to tackle common problems related to construction management by involving site teams into the decision making process and having them report back to the production management system. Froese et al. [8] presented the conceptual stage of Computer-Aided design tools that support construction management and provided a partial listing of project documents and functional categories for project management. Ding et al. [9] described the key elements of the information management process in construction and discussed the use of Building Information Modelling (BIM) to substantially improve the information environment for the construction risk identification and prevention.

The focus of this research was to gather the experiences of the Swissmill project management team in the use and application of IT programs to assess the effectiveness of these methods. In order to arrive at such a approach we first present a brief explanation of the world tallest Silo project in Zurich.

2. Case Study: Construction of the World Tallest Silo in Zurich

In the center of the Zurich, beside the Zurich River, there was an old, 40 meters high silo, used for grain storage. Recently, it was decided to reconstruct and retrofit this old silo in order to increase its capacity. For this purpose, the silo’s height should be increased from 40 meters to around 120 meters (exactly 118 meters). The weight of the new silo reached 80000 tons. This issue was extremely critical for several reasons. First, in the vicinity of the river, the soil was loose to medium sand; therefore, 49 new piles was designed and implemented to be able to withstand such a large weight. Second, at a distance of 15 meters from the silo, there is a railway viaduct on which trains cross every few minutes. Based on the importance of the trains passing northward through Switzerland and to the north of Germany, this bridge is very sensitive to the displacement and settlement of the foundation. Hence, during the construction of the silo, no disturbance must occur to the bridge performance.

Figure 1 shows the old silo near the Zurich River and a schematic figure of the reconstructed silo. The new silo stores the required amount of grains for the six-month consumptions of Zurich and the surrounding areas. A significant point in the design was the feasibility of the silo’s operation in case of earthquakes. For this purpose, about three years ago, we were requested to carry out the seismic design of the silo, the following paragraphs introduce the procedure of this design project [10].

![Figure 1. The old and the new silo in Zurich.](image-url)
2.1. Silo Description

As mentioned, the height of the new silo is 118 meters and the weight is 80000 tons. The silo’s dimensions are 20 meters times 24 meters, and the internal structure is honeycomb and lattice-like. The volume of concrete used was 18000 cubic meters. Further, 2700 tons reinforcements were used. The silo is located on 49 concrete piles that are 120 centimeters in diameter and 40-45 meters in length. The lengths of the piles are selected as such to reach the bedrock. The tip of each pile was designed to penetrate about 5 meters inside the bed-rock. The maximum pile cap thickness is 480 centimeters. Figure 2 shows the approximate geometry of the old and the retrofitted silo, and Figure 3 presents the layout of the piles under the pile caps. The amount of soil excavated to implement the piles and pile caps was about 5000 cubic meters. The plan of the silo is shown in Figure 4.

Figure 2. Cross section of existing and the new silo.

Figure 3. The foundation of the retrofitted silo and the position of the piles.
2.2. Analysis and Seismic Design

As such structures are unconventional, and their operation is of great importance, the seismic analysis of these structures is highly challenging and sensitive. Based on the ratio of the dimension to the height, the silo should be considered as a slender structure with a small frequency and large period. The prominent period of the structure is also dependent on the foundation modeling. If the foundation is simulated as a rigid one with fixed supports, the structure would be stiffer. While if the piles and the surrounding soil be considered in the modeling, the period would increase. In the case of foundations located on piles, the dynamic interaction between soil and pile and the effect of the piles groups cause a substantial issue. As a pioneer work, Professor John Wolf from ETH Zurich realized the importance of the dynamic interaction of soil and piles and the dynamic effect of piles group especially in sandy soils, when he was performing the seismic analysis of a nuclear power plant in Brazil with 200 piles [11]. If the number of piles is large and the distance are small, the dynamic effect of the entire group would reduce the pile-group stiffness up to 80 percent. Hence, considering this point, the structure foundation was modeled using a high accuracy analysis tool (e.g. FEM); as a result the responses are closer to the reality. Further, it was decided for modeling of the soil to utilize also the CONE model. Following this procedure, the piles were replaced and modeled with springs and dampers. Figure 5 displays the piles’ lateral displacement pattern in finite element modeling of the silo (Mode Shape 1). In fact, 49 piles are placed under the two pile caps at both sides of the silo, and as it was mentioned, it is essential to consider the dynamic interaction and the effect of the whole group as well. Foundation section and position of piles are depicted in Figure 6.
3. Providing Information

More elaborate methods of construction planning and control can be categorized into six main classes: scheduling, cost control, and budget management, resource allocation, communication, quality management and documentation (or administration systems).

Resource scheduling is one of the critical management tasks as it dictates the time frames in which the project will be completed, the budgets/costs in terms of resource requirements and the sequence of events which depends on one another in different ways or dependencies. A number of alternative ways of formulating the scheduling problem exist in the literature. Arranging tasks to meet various deadlines is an important design and implementation concern. With process analysis, a project manager could systematically diagnose schedule and juggle multiple projects at the same time to meet a variety of requirements. Moreover, project planning tools and scheduling methods can effectively deal with uncertainties in the estimates of the duration of each task in relatively stable environments [5, 12].

Project planning software needs to provide a lot of information to various people, to justify the time spent using it. Typical requirements might include:
1. Task list for people, and allocation schedules for resources
2. Overview information on how long tasks will take to complete
3. Early warning of any risks to the project
4. Evidence
5. Historical information on how projects have progressed, and in particular how actual and planned performances are related [13].

4. Project Management Software

Today, file-based and web-based project management tools and database of project accounts exist in most firms. Desktop applications normally store their data either in a file (with ability to collaborate with others), or stored in central database. File-based (or desktop tools) often provide most responsive and graphically intense style of interface by which only a particular user can access it at any given time [14].

More general tools use the data dictionary as the information source for anything dealing with the database systems. It documents the specification and uses of the information database: what data are stored, how the data is related, what are the allowable values for data items, etc.

Rapid technological developments in external networks especially web-based programs have extended IT support to a much comprehensive coverage of the communication and information retrieval activities. Internet-based programs can be accessed from any type of computer without installing software and has all the usual and unusual advantages and disadvantages of web applications [15]:
1. Ease of access control
2. Naturally multi-user
3. Only one software version and installation to maintain
4. Typically slower to respond than desktop applications
5. More limited graphical capability than desktop applications
6. Project information not available when the user (or server) is offline
7. Some packages do allow the user to go “offline”

5. IT Management Applications in Construction of the Silo

The Swissmill Tower (Silo) construction as a major new international project had confronted significant challenges in control of accuracy and efficiency of the information exchange process throughout this project. Several parties (including owner, general contractor, city officials, Insurance, design engineer, export group, Stanford university, Exponent Ltd USA) were involved in completing the construction process. Therefore, another great challenge of this project was the difficulty to understand the huge amount of informations and collaborate with the local contractors and engineers in this multi-interface environment.

The process of improving design quality and avoiding uncertainty in primary stages is essential and it would help to achieve higher quality of the final consequens. Changing the final schedule of each construction phases can quickly become misleading without accurate updating.

During the construction in the lower part of Silo, several cracks occured and the initial plan of project faced with serious challenges. The main question was whether we should have stopped the construction in order to retrofit the damaged components of the structure or should have continued the first designed plan. Due to the large number of individuals and construction site equipment being involved in the project, ceasing the construction operation entirely would have led to devastating financial consequences (about 30000 USD per day), especially for general contractor. On the other hand, by continuing the initial implementation plan, the employees would have been exposed to greater safety risks associated with fatal and serious injuries in their workplace.

The main issue for retrofitting the Swissmill Tower at risk of collapse (at height of 30 meters) was identifying the damage mechanisms involved and finding ways to prevent their occurrence. Hence, an international group was assigned to find out the cause of cracks. The preliminary investigations was carried out, then various retrofitting/re-construction strategies have been suggested with regard to the mitigation of progressive cracks extension. The decision tree analysis (Figure 7) as a powerful decision-making tool makes explicit all potential solutions of the aforementioned problem and the probable consequences of each in a single view, allowing for easy comparison among the various alternatives. It is usually built starting with the initial decision option, and moving through choices and chance events until all outcomes are reached. Once the tree is developed, you work backward from the outcomes to determine the values used to find the “best path” or “set of choices” to move through the tree [16, 17].

The contractor’s strategies, which included a change to the original plans and the use of prestressed cables in the lobby level, met with opposition from the executive management team, due to extreme cost and time overruns. The risk management group then compiled the probabilities and risk factors of each choices that affect time, cost and quality achievement of construction work. In this case, it was decided to continue the construction and retrofit the damaged parts of the structure during the construction phase by increasing the wall thickness in the cracked areas and also by embedding 11 threads of 10-meters long cables as reinforcement in the cracked zone. Therefore, the path (ABCDEFG) was considered as the optimal decision among all possible choices (Figure 7).
Figure 8 shows the schematic view of flow information through a network of team members executing the construction project in large-scaled engineering design projects. In the project organization stage, the project is first to be examined in regards of its complexity, need analysis, design and development goals, and engineering and economical requirements. One of the noticeable proceedings of this step is the determination of the main executive team to assign relevant tasks to them. The second phase includes planning project in which with the aid of Computer aid design (CAD) programs (like Autocad and various FEM softwares: ABAQUS, ETABS, ADINA, etc) strategic certain functions are designed and modified, and in the next phase, by using CAM (computer aid manufacturing) tools these plans are executed and controled through either direct or indirect computer interface. Considering all, the Swissmill tower is completed in six different stages. They could be summarized as follows [18, 19]:

1. Stage 1: Demolition of existing workshop, foundation, new cell row on Sihlquai side (roadside) and first part of the new eastern sidewall up to 42m height
2. Stage 2: Demolition of existing cell row, foundation, new cell row on Limmat side (riverside) and second part of the new eastern sidewall up to 42m height
3. This stage includes construction works in the river Limmat.
4. Stage 3: Replacement of the intermediate part with new western transverse wall
5. Stage 4: Mounting construction of eastern part of new upper silo
6. Stage 5: Mounting construction of western part of new upper silo
7. Stage 6: Construction of ceiling part of new upper silo

Changing the initial building-construction plans is the most important cause of project delivery delays and hence significant cost overruns. These changes will require a re-draw and submit the plans to the City Official and will stop construction until it has been submitted [20]. However, due to the implementations of retrofitting techniques, there was 1 million dollar extra “unwanted” costs which was absorbed by the Engineer’s insurance and the Engineering Company.

At the end, the quality control and flow of information is also important for collaborative work environments, where many professionals are working on different aspects of a project and sharing information.
Despite the vast amount of information available to projects, the majority of the information shared by construction teams never ends up actually adding value to the project. In order to exchange essential information between different parties of such chain-construction, there are two critical steps need to take place. First, Information needs to be shared by an individual on the project team across various stages of project.

Second, the exchanged information needs to be qualified and accepted by others on the project team. Therefore, whenever there is a change in one special stage, the other project stages should be checked and updated by a project manager. Information that is ignored or rejected becomes waste and essentially disappears from the project unless shared again under different circumstances.

6. Conclusion

Effective management of different project phases and semantic analysis of information flow are key strategic priorities for each construction project, which present conditions that are much favorable for its application.

In this case, the Silo project was not an ordinary construction work, rather it involved retrofitting measures simultaneously. Therefore, unlike other typical construction projects, interruptions and time delays during the project could significantly affect the sustainability of the structure and would have a high impact on cost overruns. The analysis of the Silo project investigating in this study shows the utilization of the new types of IT tools offering potential process re-engineering benefits which is essential to facilitate efficient data flow.

References


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