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# Management and planning under complexities of metro construction

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## Abstract

Nowadays, the majority of construction projects can be considered as complex and ambiguous endeavours. Each kind of construction project has its own characteristics and complexities whereas then specific management approaches and solutions are needed. Regarding the rapid development of cities, underground constructions at urban regions, such as metro construction, have been largely used for extending daily human life into underground spaces. Therefore, the recognition of the complex elements of a metro construction can play a significant role in its management and planning. The aim of this study is to investigate these complexities in subway construction. This may develop the possibility of high predictability for these challenges. As metro projects are also urban underground projects, both internal and external issues are studied and their impacts on project management are discussed. It is concluded that exceptional differences in the managing and planning of these constructions is that combined internal and external complexities are carried out simultaneously.

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## 1. Introduction

The variety of construction projects around the world is growing all the time along with changing human life styles and technologies. However, the complexities of new projects provide challenges for project planning and management. According to Baccarini (1966), all construction projects can be categorized as complex projects. This is caused by the direct relation between complexity and involving a variety of interrelated parts which should be managed regarding differentiation and interdependency conditions. New various technologies and methods are used in different types of construction. Each kind of construction project has its own characteristics and complexities

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which lead to related specific ambiguousness. This addresses that being successful in a type of project requires managerial solutions that are selected and fine-tuned according to its complexities.

Therefore, the recognition of the effective and challenging elements of each project in advance can play significant role in successful project planning and management. “There is no doubt that construction projects are becoming increasingly complex undertakings. This may be attributable to clients’ demands and other technological developments” (Mouchi et al., 2011). Regarding the rapid development of cities, underground constructions at urban regions such as metro construction have been largely used for extending the human daily life into underground spaces. Metro rail systems are known as convenient underground transportation solutions amongst citizens. However, those require large investments and take considerable time to be designed and constructed for realising all expected social and regional or even national benefits. Such underground constructions are one of the most vulnerable engineering projects (Leijten, 2009).

This vulnerability should be identified and considered as it can be a significant threat for public trust. As public citizens are the ultimate consumers of all the funded projects either publicly or privately, every construction project can change the level of trust among the society members (Greiman, 2013). Furthermore, a metro system is usually designed to be utilized for crowded area of cities. The process of this construction obviously interrupts civilian daily life. These illustrate the importance of adequate management and planning over whole process of metro project to be delivered on time and on budget with high quality and efficiency. Therefore, the aim of this paper is to explore specific complexities in the construction of an underground metro rail system. Those can be sources of issues for the management and planning of such projects. In this study, the challenges are divided into internal and external complexities as well as the influences of both of them are investigated. The paper and its results are based on the qualitative and quantitative data obtained from the certain real world projects and from the experts of underground construction.

## **2. Internal complexity**

Internal complexities in this study can be seen as issues which are caused by the participants in design and construction processes of a metro rail project.

### *2.1. Changes in construction phase*

Design and engineering phases of a typical construction project produce considerable amount of details and specifications. Designers try to consider all relationships between components and related conditions for presenting details as accurate as possible. However, literally coordinating between hundreds of thousands pages which contain different details of a project specifications is impossible (Callahan, 2005). This leads to expecting some mistakes which will be found in construction phase and must be corrected. As countless details alterations usually are needed after just one change, the ambiguities, gaps and conflicts of each project are expected to be discovered with some kind of change process (Callahan, 2005). In a metro rail system project, many stations and tunnels must be designed in detail. Furthermore, designing a huge project requires so larger human forces to prepare details and maps whereas finding conflicts may not possible. This complexity can rise when different parts of a project are designed by different companies. Due to the variety of needed expertise in metro design, it is necessary that different companies take part in design phase of this wide skill project.

Moreover, metro rail system utilizes highly technology oriented construction delivery with its electrical and mechanical devices and equipment being crucial for the performance of the system itself. Technology is developed every moment and new updated devices and equipment are produced and proposed by inventors and companies to users. Mostly newer products have more productivity in task performance with less energy consumption and higher quality. This may encourage clients, even consultants, to change some designed equipment and devices into newer ones which may require some specific prerequisites to be considered and built. These replacements in construction phase, even in initial steps, can be another cause of changes.

On the other hand, some of the designed performance methods might be infeasible or unrealistic. Some

impractical designs, the designs which are not matched with contract, or impossible ones to be completed, usually provide more challenges for project (Callahan, 2005). Such issues can cause some fundamental changes which occur during construction phase as suitable and feasible methods must be found, all related details should be matched and all prerequisites must be supplied. The high possibility of this matter in metro construction is because of large and various under construction area in these projects. Any change in metro project encountering the method of work, even in initial steps of construction phase, can fordo all the managerial efforts. This may also lead the project management into vague complex conditions according to the rising tension between participants.

A construction project can be seen as an example of vulnerable effort which can be affected by a variety of elements. It is very difficult or almost impossible to predict all the effective events which might be happened unexpectedly in advance. “Unexpected events and surprises are often discovered, such as the existence of subsurface rock, underground obstacles, or unusual soil conditions, unusual weather, unexpected field conditions, or the unavailability or anticipated delay in delivery of materials and equipment” (Callahan, 2005). This leads to related changes either in work scopes, work schedules or work details. These items might not provide considerable challenges for a small project. However, in a large project such as metro project each of them can create a tough complexity because of a high level of interdependency in the project. This is also caused by conditions of both underground uncertainty and urban restrictions. In underground projects, where possibility of unexpected events is more than other projects, manageability problems are the issue (Leijten, 2009).

Each of above mentioned changes in construction process needs making decision, modifying design as well as destroying, rebuilding and reworking at the site. These changes may bewilder contractors and consultants of the project as the process will be time consuming. This wasting time decreases the profit of participants which impacts effective management. “Projects that have change, even small amounts, are much more likely to have worse cost and schedule performance than budgeted” (Ibbs, 2012). In metro project, regarding the fact that all sub-projects are parts of one unique project, any change in just one part of any sub-project can easily impact almost all other sub-projects, either directly or indirectly, and this can be the start point of a change chain. A large number of companies provide their plans and dive into construction to follow the plan and gain their profits. Changing or eliminating a detail in just one site, which is very common event, can be the start point of alteration chain and make planning and management of metro projects more complex.

## 2.2. Experience

The role of experience in all industries is undeniable. Repeating previous task causes less omission and better result. “The impact of experience possessed by project key personnel toward project outcomes has been widely recognized” (Jaselskis and Ashley, 1991; Sanvido et al., 1992). In construction industry, as different projects have different characteristics, having experience of taking part in a kind of construction project can play an effective role in case of participating in similar projects in future. Gaining experience by managers and engineers from a kind of project and its new technology might not be helpful in another type of project with different conditions and circumstances (Leijten, 2009). This is caused by creating realistic view of involving a project practically and being familiar with its specific challenges. The barriers and unanticipated events can be predicted and expected by the experts who took part in similar projects before. The obvious example is a company which builds residential buildings and apartments in a city. This company can be more successful after completing some first projects. This is because of the increasing level of experience in predicting the events of this type of project beforehand.

Experience level of project managers is one of the effective characteristics on construction projects’ success (Ashley and Jaselskis, 1988). Pre recognizing the expected locations of conflicts and omissions to minimize them in design phase are the significant benefit of taking part in designing same projects. This assists designers to prevent repeating the mistakes of previous projects. Another point is matching projects with social conditions and requirements. Every community has specific culture, social behaviour and requirements. These must be considered for public projects on account of serving efficient services. Public transportation systems such as buses and metro lines in the majority of societies are usually designed to facilitate urbanites’ movements. Due to the high required investment of launching a metro line, this system generally is provided for crowded area of city where might be

efficient and capable to cover the majority of the civilians' journeys. The strategies of improving public transport productivity usually provide more attraction for customers as well as operating (Nash, 2006).

Furthermore, the local environment conditions and behaviours are considerable for underground projects. Appropriate reactions against unexpected events must be immediately decided with respect to practical experience and knowledge over local environment. In addition, bureaucracies in different countries are not the same which can affect the project progression both directly and indirectly. This addresses that being successful in management of an enormous city project requires being totally familiar with the local bureaucracy for making correct decisions and choosing right policies during project implementation. Metro is usually designed to be a part of public transportation system and this justifies spending lots of money in this project to be constructed. Designing an efficient and attractive subway requires to be matched with the civilians' preferences and requests. Being familiar with the local underground situations can be helpful in construction process of the project encounter of restrictions of both underground and urban region constructions.

Therefore, the necessity of engaging local managers, experts, and companies whom had taken part in metro project in the past may be beneficial. The challenge in this part is lack of these kinds of practiced managers and participants as limited number of metro rail lines are usually ordered and built in every country. Limited number of required subway in every country may cause restrictions of having local experienced experts. Therefore, almost all of the involved managers and companies in this project may be facing the first experience of participating in metro project. This leads to less knowledge over the specific challenges of this type of project which may provide complex situations in both design and construction phases, and the project management as well.

### 2.3. *Financial issues*

Finance plays a vital role in every construction project. Therefore financial part of project can be an issue in construction management. This section may be divided into two related parts: 1. Project financial estimation; and 2. Project financial management. As the project financial estimation will be a basis for project financial management at construction phase, achieving success in its management requires the estimation to be realistic properly. This level of estimate accuracy will be raised by increasing the quality of cost information (Trost and Oberlender, 2003). This estimation will be tougher for bigger projects, those contain enormous variety of equipment or tasks, as well as having longer duration of construction. Regarding the diversity attributes in different projects, financial estimation for each project needs to be estimated by who is familiar with the project specifications in details.

Constructing a subway line not only contains a wide variety of technologies, equipment, expertise and fields, but also usually takes a decade from design to completion. This increases the unpredictability level of final expenses regarding the far future fluctuations of prices. Furthermore, the high possibility of encountering unexpected events in a construction project such as metro project can provide more complex situation for financial estimation of the project. The local example is ballooning first estimation of Espoo metro extension (Länsimetro project) from 400 million euros to almost 1 billion euros as the latest estimation (Helsinki Times, 22 March 2014).

In addition, dominant situation of the world can affect this issue especially in case of applying some equipment and devices which must be imported from other countries. Petrol fee fluctuations and sanctioning some countries such as Russia can be current illustrative examples. Economic crisis is another effective factor for adding more complexity to financial management of an expensive project like metro. This can cause rising tensions between government, main financial sponsor of metro projects, and construction participants. For clarity, the metro extension of Espoo in Finland has spent almost 1 billion euros since 2007 for adding 13.5 km to the current line (Helsinki Times, 22 March 2014). This means that more than a hundred million euros annually, in average, must be paid by government. Any pause or lag in payment can cause delay in work and progress of the project which leads to more time and cost overrun and complex its management more.

### 2.4. *Integration*

Integration management is a crucial requirement for building and assembling infrastructure construction projects

(Enshassi et. al, 2010). As fragmenting large infrastructure projects is unavoidable, integration is one of the vital issues in those construction projects. Exchanging information between interdependent subsystems as well as knowledge is one of the integration requirements. This also includes joint decision-making (Mitropoulos and Tatum, 2000). However the level of integration depends on multiplicity and diversity of included tasks, work methods, management styles, and expertise.

Metro project is a kind of project which mostly designed to be started from one side to another side of a city by passing a crowded long line of the city to be more efficient and attractive as part of transportation system. Dividing and fragmenting this long project into many sub-projects (sites) by location is a needful behaviour in construction phase. This is caused by increasing simultaneous construction process in whole line of the project to achieve less project duration. Furthermore, various required fields in this project categorizes it into five main expertise, building stations and control centre, tunnelling, rail installing and signalling and electrical tasks as well as mechanicals. Enormous resources are needed and must be allocated for well and fast performance of such wide endeavour.

All these resources usually cannot be supplied by a single company. Therefore, many contractors, various suppliers, consultants and other contributors from various fields need to be involved in the project implementation. However, these companies have usually their own specific schedules, work methods and policies, and they often work in separate sites. All these sites must be connected to each other to provide a unique subway line. This highlights the importance of integration between all the participants especially in metro rail constructions. To make this clear, Table 1 illustrates the approximate number of main participants and subcontractors in three different metro projects.

Table 1. The approximate number of participants in three metro projects

Project	Length of path (km)	Stations No.	Main participants No.	Subcontractors No.
Shiraz metro	21.5	19	68	>500
Espoo metro extension (first phase)	14	8	40	>500
Toronto-York Spadina Subway extension	8.6	6	40	>200

As can be seen a large number of companies and their representatives (e.g. teams of workers) must be duly integrated in subway projects for having a qualified metro system. This means that any matter of any participant may impact whole the project process. Therefore proper integration among such large number of involved companies is one of the complex parts of managing and planning of such giant construction like metro projects. Paying less attention or considering poor management over this harmonization can provide tensions between participants or deliver an unprofitable project. This can thus lead to inability of success in such expensive metro project and, because of recognizing this problem at late stages of construction period, the majority of project's budget will be wasted.

Investigating all the effects of any changes or problem on other sites and participants' schedules, and harmonizing between all of them is a continuous complex effort in whole the project duration from design to completion. This contains scrutinizing those effects between different fields as well. Any late or poor management in this part can cause many rework, wasting money, lag in planning and losing chance of harmonised project.

### 3. External complexity

External complexity of a metro construction project in this paper includes the complexity which is specifically caused by the conditions and situations of metro project.

Location of project and its site boundaries instantiate the big difference between metro rail system and other

constructions. Subways, as a part of transportation system, may commonly be designed for crowded urban regions to be an efficient and attractive transportation system. Therefore, those populous regions of the city involve the tumble situation during the construction phase of metro project. This highlights the external conditions of this project according to the direct effects of the construction process on the citizens and vice versa. The civilians live in their apartments and move on the roads where underground construction is underway, simultaneously. This demonstrates the high potential of danger over human lives in case of any unexpected event. Furthermore, any stop or delay of work during construction phase of metro project caused by financial issues, changes investigation or making new decision can increase the possibility of occurring related damages in the neighbouring roads and residential regions. Making comparison between constructing an airport even at the centre of a city with denoted site boundaries and an underground subway construction which must be passed from under the apartments, roads and historical buildings might be illustrative example.

In addition, the external conditions are usually inconsiderable issues for most of the suburb projects. However, these conditions cause more complexities in underground urban rail project regarding the specific location's conditions of the project. Some of these conditions caused by urban restrictions and citizens' rights as well as civilians' life styles, which must be considered in this kind of project. Construction phase usually provides noise and dust pollutions during the progression which requires to be adjusted with local life style in this project. Time restrictions and traffic jam, on the other hand, influence the site movements and some tasks' time such as explosion and destruction. All complicated elements in metro construction can be significantly affected by involving citizens' daily lives as external conditions. The restrictions and threats of external conditions related to constructing underground subway in urban area get stuck in aforementioned challenging factors to provide an exceptional complex project.

#### 4. Conclusion

Being successful in managing a construction project requires familiarity with its particular challenges and specifications. Underground metro construction, like other projects, has its own circumstances and complexities. In this paper, these complexities have been divided into the two main groups. We consider that the internal unique features of metro rail projects, such as a number of participants, required integration, interrelation between changes and experience can be sources of specific complexities for the management and planning of these efforts. Although, a clear difference of metro projects compared with other construction projects comes from the combined internal and external complexities. External complexities are caused by the nature and characteristics of a specific location where metro construction projects take place. This exceptional feature can manifold and compound the complexities of planning and management in this kind of projects in comparison with other constructions.

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