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METOD SEÇİMİNİN İNŞAAT SÜRESİNE ETKİSİ: KADIKÖY KARTAL METRO PROJESİ ÖRNEĞİ

YÜKSEK LİSANS TEZİ

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Tez Danışmanı: Doç. Dr. Sema ERGÖNÜL

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EFFECT OF METHOD SELECTION ON CONSTRUCTION DURATION: CASE OF KADIKOY KARTAL METRO PROJECT

Graduate Thesis By

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EK C KABUL VE ONAY SAYFASI ÖRNEĞİ

Ali Oben SABUNCUOĞLU tarafından hazırlanan İNŞAAT METHODU SEÇİMİNİN İNŞAAT SÜRESİNE ETKİSİ VAKA ANALİZİ: KADIKÖY KARTAL METROSU adlı bu tezin ..... tezi olarak uygun olduğunu onaylarım.

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ÖZET

METHOD SEÇİMİNİN İNŞAAT SÜRESİNE ETKİSİ: KADIKÖY KARTAL METRO PROJESİ ÖRNEĞİ

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Danışman: Doç.Dr. Sema Ergönül

Eylül, 2011

Artan ulaşım sorunu çözmek için İstanbul Büyükşehir Belediyesi (İBB) metro yatırımlarına önemli bir bütçe ayırmıştır. Son on senedir bütçedeki payı artarak devam eden yatırımlarına 2011 yılında 6.7 milyar liralık belediye bütçesinden 3.4 milyar liralık kaynak kullandırılmış ve bu payı önümüzdeki senelerde artırmayı hedeflemektedir.

Metro projelerinde temel politika inşaatın hızlı bir şekilde bitirilerek hattın işletmeye açılmasıdır. Karmaşık ve birbirini etkileyen bir çok iş kaleminden oluşan metro inşaatlarında tünel kazıları, işin süresi ve maliyetini, ihale keşfinin %40- %55 lik kısmı ile etkileyen en önemli iş kalemidir.

Çalışmada inşaat yönetiminde yapım yöntemi seçiminin önemi ve proje süresine etkileri incelenmiştir. Vaka analizi olarak Kadıköy Kartal Metrosu tünellerinde uygulanan Yeni Avusturya Tünel Açma Yöntemi (YATAY) ve Tünel Açma Makinesi (TAM) iki tip yapım metodu incelenerek süreç performansları karşılaştırılmıştır.

Vaka analizinde TAM ve YATAY metotlarının iş programları hazırlanmış, yapım sırasında gerçekleşen veriler alınmış, karşılaşılan sorunların sürece etkisi göz önüne alınarak oluşturulan iş programları modellenmiş ve hangi şartlar altında metro inşaatları için daha etkili olacağı tartışılmıştır.

SUMMARY

EFFECT OF CONSTRUCTION METHOD SELECTION ON CONSTRUCTION DURATION: CASE OF KADIKOY KARTAL METRO PROJECT

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Division of Structural Engineering

Programme of Construction Project Management
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September 2011

In order to solve increasing transportation problems, Istanbul Metropolitan Municipality consigned an important amount of its budget for the metro works. The main goal of the construction is to complete and commission the project on time. Metro constructions are composed of many complex and interdependent activities. Tunnel excavations are important work items as they affect the time, cost, and 40-55% of the contract price of the project.

In this study, the importance of the selection of the construction method and the effects of selected method on work schedule has been analyzed.
Kadıköy Kartal Metro project is examined. A case study is carried out with two tunneling methods [New Austrian Tunneling Method (NATM) and Tunnel Boring Machine (TBM)] used in Kadıköy Kartal Metro Project. Their performance in terms of time and effectiveness are compared.

In the case analysis, construction plans for the TBM and NATM methods are prepared and modeled by using the data collected from completed works.

ACKNOWLEDGMENTS

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I also wish to thank my colleagues in Avrasya Metro Group for their direct and indirect encouragements for their support during this study. Especially Mr Faruk YILDIRIM, Mr. Sandro CAPADONA, Mr. Gökhan AŞÇIOGLU, Mr. Cenk ÖZERDEM, Mr.Onur YILDIZ, Mr. Yaşar ÇULHAOĞLU, Mr. Şükrü ŞENOL and Mr. Abdullah Kürşat EROL for their supports

Last but not least, I would like to thank to my mother and all of my family for the emotional support throughout my graduate studies.

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LIST OF ABBRAVIATION

OBS: Organizational Breakdown Structure
WBS: Work Breakdown Structure
NATM: New Australia Tunneling Method
TBM: Tunnel Boring Machine
CPM: Critical Path Method
PERT: Programme Evaluation and Review Technic
MMI: Metropolitan Municipality Istanbul
IBB: Istanbul Büyükşehir Belediyesi (Istanbul Municipality)
Ch.: Chainage
ITA: International Tunneling Association
PV: Planned Value (PV).
EV: Earned Value (EV).
PMB: Performance Measurement Baseline (PMB)
ES: Earned Schedule
SIP: Schedule Performance Index
IETT: Istanbul Electric Tramway And Tunnel Establishments

INTRODUCTION

Construction planning sounds like just a little part of allwork, but it is far more important. Effective planning is the one of the most important aspects of a construction (Chevallier and Russell, 1998). Construction planning lets builders estimate and purchase the correct amount of tools and materials needed for the job at hand.A plan shows activities and their logic relationships and temporal information, which enables project duration to be defined.

Developing the construction plan is a critical task in the management of a construction (Hendricson, 2000). During the formulation complete construction schedule, planners and site managers are required to simulate various construction method process to build the project. Construction managers efforts are currently focused at effective construction method for the finishing project on time. Construction method enables managers to predict potential, cost and time implications.

It is obvious that there is a relation between the project progress chart the most important task in the success of a project is the selection of construction method.

As far as on the construction method selection is concerned,

- How can we determine the method for the construction?
- How can we confirm the efficiency of the construction method?
- Is the choosen construction method effective?
- Which method is suitable for the conditions of the project?

Growth of Turkish economy, infrastructural investment is increasing day by day. Tunnel works in these investments are important factor which effects the completion of metros, highways and dams in terms of its risks. Completion time of the tunnels have high importance in this kind of investments. There are a few methods for tunnel constructions that affect the control of time and cost.

In the analysis of the tunnel construction methods, it is seen that the New Austria Tunneling Method(NATM) which is used since 1950s and the other tunnel drilling method namely Tunnel Boring Machine (TBM) which is improved for the last 20 years are used for lots of projects.

Performance of the using tunnel method has an important place in the completion of the construction project on time. The main goal in metro constructions is to complete the construction and commissioning on time. Metro constructions have complex and interactive activities. According to the interview with the managers of Kadıköy Kartal Metro construction tunnel excavations create the %40-%50 part of the tender price.

The selection of tunnel excavation method become crucial. In this respect, municipal corporations make investments for metro constructions in Istanbul to solve th transportation problem.

Metropolitan Municipality of Istanbul uses 3.4 billion Turkish Liras out of 6.7 billion Turkish Liras budget to the metro investments. Kadıkoy Kartal Metro project is one of these investments In order to solve the transportation problem between Kadıköy and Kartal, this amount is aimed to be increased.

In this study, Kadıköy- Kartal Metro project is undertaken to analyze the effect of construction method chosen on work schedule.

AIM OF THE STUDY

The aim of this study is to investigate the impact of construction methods and techniques on the schedule performance by taking into account the resource requirements and speed.

Kadıköy Kartal Metro Project is chosen as a case study to analyze the effects of construction methods on project completion time.

RESEARCH METHOD

In order to achieve the aim of the study, following research methods are used:

- Literature search on Construction Method and Construction Planning.
- Analysis of Metro projects and tunnel construction methods especially NATM and TBM.
- Carrying out a case study for Kadıköy-Kartal Metro Project by using NATM and TBM.
- Determining actual and planned average excavation speed of NATM and TBM methods.
- Comparison of TBM and NATM tunneling methods and suggestions for future metro projects.

1. CONSTRUCTION PLANNING

Construction planning is a fundamental and challenging activity in the management and execution of construction projects. It involves the choice of technology, the definition of work tasks, the estimation of the required resources and durations for individual tasks, and the identification of any interactions among the different work tasks. A good construction plan is the basis for developing the budget and the schedule for work. Developing the construction plan is a critical task in the management of construction (Hendrickson 2001). In addition to these technical aspects of construction planning, it may also be necessary to make organizational decisions about the relationships between project participants and even which organizations to include in a project.

1.1 FUNDAMENTALS OF CONSTRUCTION PLANNING

In developing a construction plan, it is common to adopt a primary emphasis on either cost control or on schedule control. Some projects are primarily divided into expense categories with associated costs. In these cases, construction planning is cost or expense oriented. Within the categories of expenditure, a distinction is made between costs incurred directly in the performance of an activity and indirectly for the accomplishment of the project. Projects, scheduling of work activities over time is critical and is emphasized in the planning process (Figure 1.1). In this case, the planner insures that the activities are classified over precedence among each other. The construction schedule is prepared according to task priority or usage of resources efficiently during the construction period. Finally, most complex projects require consideration of cost and scheduling over time, so that planning, monitoring and record keeping must consider both dimensions. In these cases, the integration of schedule information is a major concern.

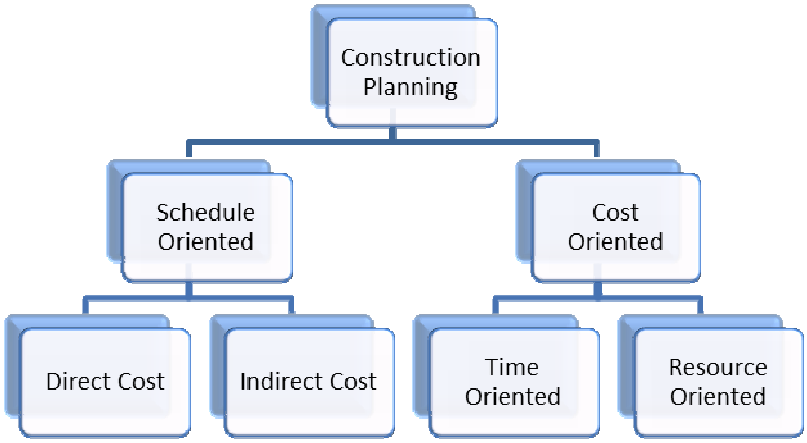


Figure 1.1 The Construction Planning (Hendrickson)

To complete the planning phase for a project, the following subjects are to be tackled.

- Estimate the duration and starting times of activities, and their relationship to other activities. This will provide the first tentative plan, which can be further adjusted and tested with various network analysis methods. The time-related information is obtained from the people responsible for the activities.
- Integrate the planning system with the other systems. A scheduling system alone is insufficient; links with the personnel and financial system must exist, and above all the activities and their tasks must be connected with the product information, i.e. the technical database.
- Study the various sources of risks, i.e. execute risk assessment. Possible risks concerning project environment, management, personnel or technical solutions must be listed and studied.
- Provide procedures for risk control. Nominate a person to be responsible for each major risk. Create risk reduction procedures through better information, risk transfer and communication. Study the sensitivity of the project plan to major risks detected.
- Define operational planning and control procedures for the assembly phase. The transition from preparatory to operational project management phases requires the definition of managerial principles for the everyday project control operations.

1.2 BEFORE PLANNING PHASE

Before the planning phase the product and the site must be studied to describe activity definition for the work breakdown structure, which is then adjusted according to the Organizational Breakdown Structure (OBS). The Work Breakdown Structure (WBS) is then used to build up the first plan of the project (Figure 1.2).

The Programme Evaluation and Review Technic (PERT) Coordinating Group defines a WBS as a family-tree subdivision of a program that begins with the end objectives, and subdivides these objectives into successive smaller subdivisions. This means that a project is decomposed into objectives, which are actually a mixture of activity and component information described by OBS. These structures are cross-referenced to form the WBS, which provides the framework for defining the work to be accomplished and for constructing the network plan. In addition to this it sets the infrastructure for cost and schedule control (PMI 2006).

First, the WBS is constructed, managed and controlled. The WBS is the same as a bill-of-material or resource list. They may not be completed down to the last detail. Then the organizational breakdown structure (OBS) is defined from the WBS. The actual project planning phase may commence after the WBS is defined, yet it cannot be completed until the OBS is available (Bachy; Hameri 1997).

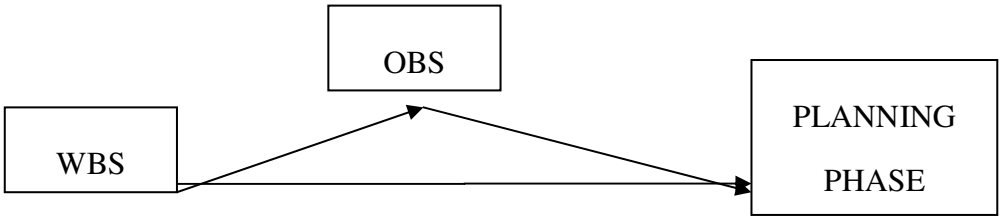


Figure 1.2 Main Procedures Establish The Project Management Plan Bachy And Hameri

1.2.1 Work Breakdown Structure

A work breakdown structure (WBS) in project management and systems engineering, is a tool used to define and group a project's discrete work elements in a way that helps organize and define the total work scope of the project (Booz,Allen 2008).

The Work Breakdown Structure is a tree structure, which shows a subdivision of effort required to achieve an objective; for example a program or a project. In a

project or contract, the WBS is developed by starting with the end objective and successively subdividing it into manageable components in terms of size, duration, and responsibility (e.g., systems, subsystems, components, tasks, subtasks, and work packages) which include all steps necessary to achieve the objective.

The Work Breakdown Structure provides a common framework for the natural development of the overall planning and control of a contract and is the basis for dividing work into definable increments from which the statement of work can be developed and technical, schedule, cost, and labor hour reporting can be established (NASA 2001).

A well-designed WBS makes it easy to assign each project activity to one and only one terminal element of the WBS. In addition to its function in cost accounting, the WBS also helps map requirements from one level of system specification to another, for example a requirements cross reference matrix mapping functional requirements to high level or low level design documents (Haugan, Gregory T. 2003). To summarize, the main tasks in creating the WBS for project are as follows;

- To define the WBS to the required level of detail. To construct the WBS for the project, two breakdowns are needed: the first based on the functions: design, manufacturing, purchase, personnel, financing, etc. Whatever the breakdown of the project structure, each work package should have clear and simply stated objectives. Objectives are to be assigned to every level of the structure.
- To provide the necessary tools to manage and control the WBS. Project management tools and the WBS are integrated to build up a worktable to maintain the project configuration and the links between external systems, such as the financial and personnel systems. The project documentation should be made simple and accessible.
- To define the activities and possibly also the tasks needed to complete each work package. Each work package requires activity specification in order to achieve the imposed objectives. Activities may be further divided into tasks if needed. In practice these tasks may relate to safety and other instructional issues.

- To assign the responsible individuals or work groups to each work package. This overlaps with the definition of the project's organizational structure, but it is important to commit the key persons to the work as early as possible. Their responsibilities include not only the achievement of the objectives but also documentation and financial obligations.
- To establish project configuration management. The project management plan will certainly face several changes and adjustments during the project. This calls for special project management skills to restructure and reorganize the project configuration without any major disturbances in operational project work.
- In addition, the project management must provide all collaborators with an easily accessible source of information containing the current understanding of the system configuration (key parameters, measures and standards of the system, status of the various component configurations, quality requirements, responsible people, etc.).
- To provide financial estimates concerning work load and other related project costs. The WBS is used for the first budget plan, which can be further studied and adjusted.

1.2.2 Organizational Breakdown Structure

A new project is usually to nominate a project team to work on the preparatory phases: producing the WBS, the OBS and the first detailed plan. This team is usually responsible for the whole project.

During the building of the project management plan the active involvement of the participants is necessary, which is more or less a democratic process. Once the implementation phase commences the management should act increasingly in authoritarian manner to ensure that the plan is executed in a goal-directed manner. This requires leadership skills from the project management team in addition to technical and administrative competence.

- Identify the natural parts of the existing organization to be used in the project.
- Inform people of the common goals and management principles.

- Generate an organizational chart with personnel, component and functional dimensions.
- Generation of communication procedures and documentation protocols.

1.3 TIME ORIENTED PLANNING AND DESIGN PROCESS

In the planning phase, the work packages and activities in the WBS are viewed against the project time scale. Every activity gets its starting and ending dates, and any relationships with other activities, e.g. one activity may not be started before another is finished. With sophisticated planning software in use the allocation of activities is usually seen as a rather trivial task once all the activities are listed together with their time attributes and the project calendar, with vacation and other time-related information. Various network analyses are easily processed within the model and critical paths are easily detected.

In PMBOK Project Time Management includes the processes required to ensure timely completion of the project and it involves;

- Activity Definition: Identifies the specific activities that must be performed to produce the various project deliverables. WBS is used in planning for activity definition.
- Activity Sequencing: Identifying and documenting inter activity dependencies.
- Activities Resource Requirements
- Activity Duration Estimating: Estimates the number of work periods which will be needed to complete individual activities.
- Schedule Development: Analyzes activity sequences, activity durations, and resource requirements to create the project schedule.
- Schedule Control: Controls changes to the project schedule.
- These processes interact with each other and with the processes in the other knowledge areas as well. Each process may involve effort from one or more individuals or groups of individuals based on the needs of the project. Each process generally occurs at least once in every project phase.

1.3.1 Estimating Resource Requirements for Work Activities

From the planning perspective, the important decisions in estimating resource requirements are to determine the type of technology and equipment to employ and the number of crews to allocate to each task. Clearly, assigning additional crews might result in faster completion of a particular activity. However, additional crews might result in congestion and coordination problems, so that work productivity might decline. In this case organizational breakdown structure can be revised.

1.3.2 Estimating Activity Durations

Generally in construction planning two types of duration estimating method used, these are Historical and Performance based duration estimation;

1.3.2.1 Historical Experience

In most scheduling procedures, each work activity has associated time duration. These durations are used extensively in preparing a schedule.

A straightforward approach to the estimation of activity durations is to keep historical records of particular activities and rely on the average durations from this experience in making new duration estimates. Since the scopes of activities are unlikely to be identical between different projects, unit productivity rates are typically employed for this purpose (Figure 1.3).

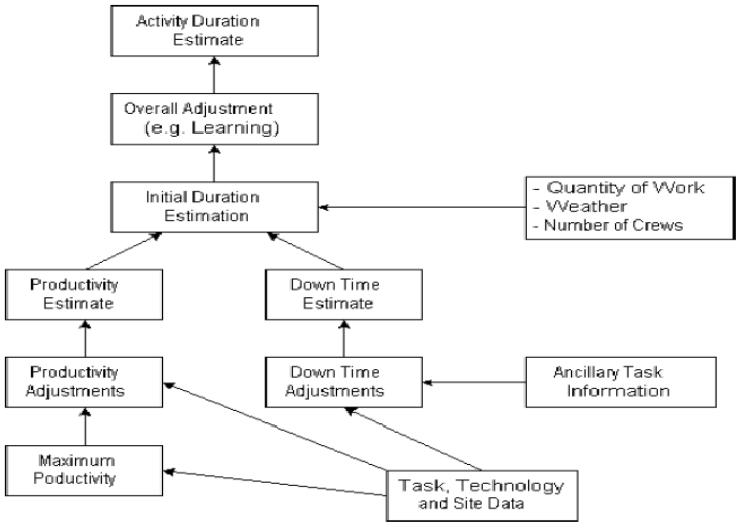


Figure 1.3 Activity Duration Estimating By Hendrickson 2001

Variations in the durations of activities are commonplace in the construction industry. This is due to the fact that the construction industry is influenced greatly by variations in weather, productivity of labor and plant, and quality of materials. The duration of activities and their dependence on risk factors is discussed. It is assumed that there are a number of risk factors that might cause variation in activity duration, and their influence can differ from one activity to another.

1.3.2.2 Performance Based Duration Estimating

Performance based duration estimation depends mainly on prediction of required man-hours for a certain well determined work. Efforts invested in a construction project are probably one of the most important variables in the process of project management. Determination of this variable allows us to plan adequately any forthcoming activities.

Estimating the effort with a high grade of reliability is a problem a general problem and the project manager have to deal with it during overall project phase. In order to achieve good results in determining man-hour requirement, it is essential to take into consideration any previous projects (J.J. Dolado 2000), (Q.Hu1997), (M.Rodriguez 1999).

1.4 SCHEDULING

Project planning is part of project management, which relates to the use of schedules such as Gantt charts to plan and subsequently report progress within the Project environment (Harold Kerzner 2003).

Initially, the project scope is defined and the appropriate methods for completing the project are determined. Following this step, the durations for the various tasks necessary to complete the work are listed and grouped into a work breakdown structure. The logical dependencies between tasks are defined using an activity network diagram that enables identification of the critical path. Float or slack time in the schedule can be calculated using project management software. (Figure1.4) Then the necessary resources can be estimated and costs for each activity can be allocated to each resource, giving the total project cost. At this stage, the project plan may be

optimized to achieve the appropriate balance between resource usage and project duration to comply with the project objectives. Once established and agreed, the plan becomes what is known as the baseline. Progress will be measured against the baseline throughout the life of the project. Analyzing progress compared to the baseline is known as earned value management (Fleming, Quentin 2005).

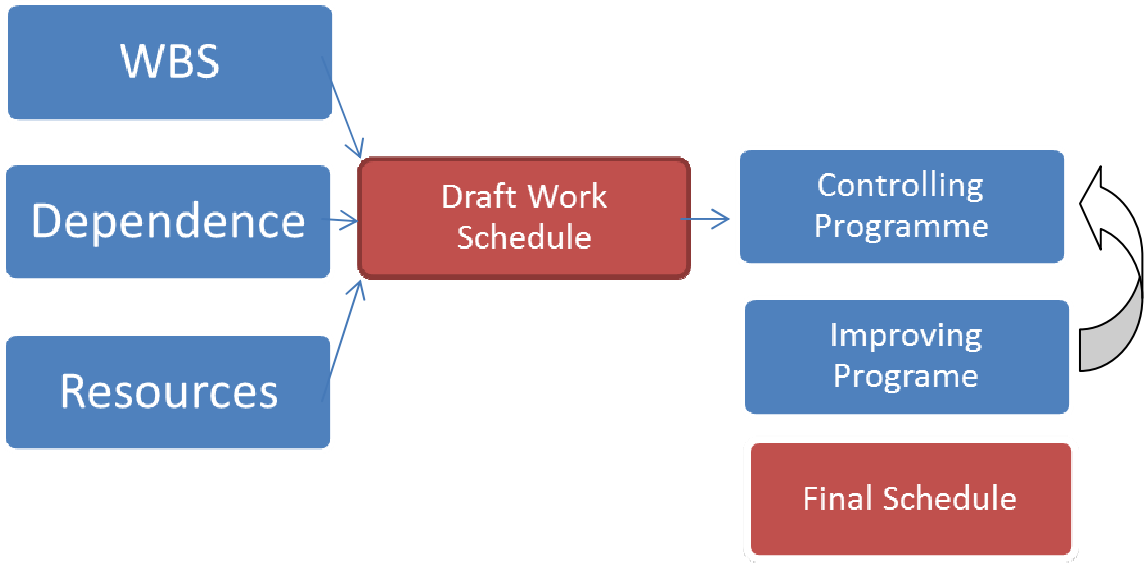


Figure 1.4 Proposal Scheduling Process

Proposal scheduling process is schematized at Figure 1.4 by evaluating the outcomes of interviews with planning specialists Yaşar ÇULHAOĞLU, Onur YILDIZ and Gökhan AŞÇIOĞLU, who have distinct experiences at different firms and projects. This process is widely used by many practitioners in the entire construction sector.

1.5 SCHEDULE CONTROLLING

Project management technique that shows the time taken by each component of a project had the total time required for its completion.

Many questions or myth have been raised about the speed of the construction (Kumaraswamy 1995). For example:

1. How does the speed affect the construction schedule?
2. Is the speed of the construction create higher costs? Is the labour more productive? Is the technology superior?

3. Have we reached a point of diminishing returns in terms of time compression? (Alternatively, is it possible to build even faster without compromising quality and safety, or significantly enhancing costs; in other words, achieving continuous improvement?)

Project scheduling methods focus on various network techniques such as the Critical-Path Method (CPM), Program Evaluation and Review Technique (PERT), Event Chain and Earned Value applications for analyzing schedule. This schedule analyzing techniques focuses on those three questions above.

1.5.1 Critical Path Method

The critical path method (CPM) is an algorithm for scheduling a set of project activities (Kelley 1961). It is an important tool for effective project management.

CPM is commonly used with all forms of projects, including construction, aerospace and defense, software development, research projects, product development, engineering, and plant maintenance, among others. Any project with interdependent activities can apply this method of mathematical analysis. Although the original CPM program and approach is no longer used, the term is generally applied to any approach used to analyze a project network logic diagram.

The essential technique for using CPM is to construct a model of the project that includes the following (Samuel L. 1996):

1. A list of all activities required to complete the project (typically categorized within a work breakdown structure),
2. The time (duration) that each activity will take to completion, and
3. The dependencies between the activities

Using these values, CPM calculates the longest path of planned activities to the end of the project, and the earliest and latest that each activity can start and finish without making the project longer (Figure 1.5) This process determines which activities are "critical" (i.e., on the longest path) and which have "total float" (i.e., can be delayed without making the project longer). In project management, a critical path is the

sequence of project network activities which add up to the longest overall duration. This determines the shortest time possible to complete the project.

Any delay of an activity on the critical path directly impacts the planned project completion date (i.e. there is no float on the critical path). A project can have several, parallel, near critical paths. An additional parallel path through the network with the total durations shorter than the critical path is called a sub-critical or non-critical path.

These results allow managers to prioritize activities for the effective management of project completion, and to shorten the planned critical path of a project by pruning critical path activities, by "fast tracking" (i.e., performing more activities in parallel), and/or by "crashing the critical path" (i.e., shortening the durations of critical path activities by adding resources).

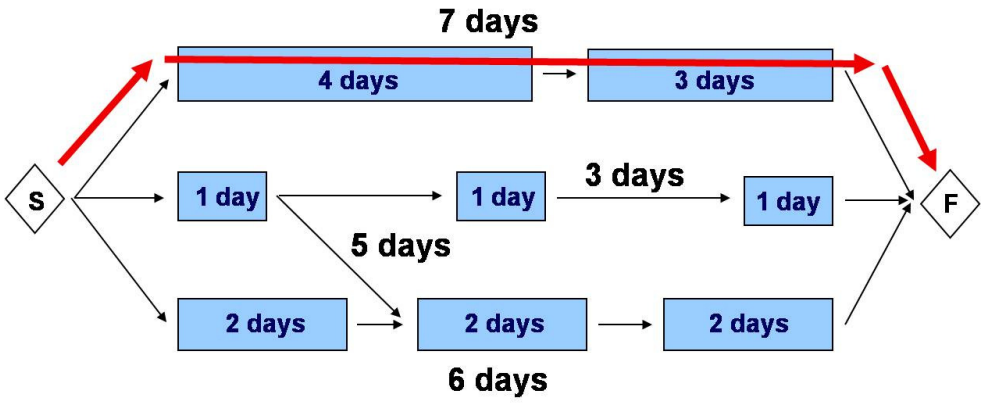


Figure 1.5 Critical Path Method

Since project schedules change on a regular basis, CPM allows continuous monitoring of the schedule, allows the project manager to track the critical activities, and alerts the project manager to the possibility that non-critical activities may be delayed beyond their total float, thus creating a new critical path and delaying project completion. In addition, the method can easily incorporate the concepts of stochastic predictions, using the Program Evaluation and Review Technique (PERT) .

A schedule generated using critical path techniques often is not realized precisely, as estimations are used to calculate times: if one mistake is made, the results of the analysis may change. This could cause an upset in the implementation of a project if the estimates are blindly believed, and if changes are not addressed promptly. However, the structure of critical path analysis is such that the variance from the

original schedule caused by any change can be measured, and its impact either ameliorated or adjusted for. Indeed, an important element of project investigation analysis is the Earned Value Analysis which analyzes the specific causes and impacts of changes between the planned schedule and eventual schedule as actually implemented.

1.5.2 Programme Evaluation and Review Technique

The Program (or Project) Evaluation and Review Technique, commonly abbreviated PERT, is a model for project management designed to analyze and represent the tasks involved in completing a given project. It is commonly used in conjunction with the critical path method or CPM.

PERT is a method to analyze the involved tasks in completing a given project, especially the time needed to complete each task, and identifying the minimum time needed to complete the total project.

PERT breaks down the project into events and activities, and lays down their proper sequence relationships, and duration in the form of a network. Lines connecting the events are called paths, and the longest path resulting from connection all events is called the critical path. The length (duration) of the critical path is the duration of the project, and any delay occurring along it delays the whole project. PERT is a scheduling tool, and does not help in finding the best or the shortest way to complete a project.

PERT was developed primarily to simplify the planning and scheduling of large and complex projects. It was developed for the U.S. Navy Special Projects Office in 1957 to support the U.S. Navy's Polaris nuclear submarine project (Malcolm 1959). It was able to incorporate uncertainty by making it possible to schedule a project while not knowing precisely the details and durations of all the activities. It is more of an event-oriented technique rather than start- and completion-oriented, and is used more in projects where time, rather than cost, is the major factor. It is applied to very large-scale, one-time, complex, non-routine infrastructure and Research and Development projects. An example of this was for the 1968 Winter Olympics in Grenoble which applied PERT from 1965 until the opening of the 1968 Games (1968 Winter).

Advantages

- PERT chart explicitly defines and makes visible dependencies (precedence relationships) between the WBS elements
- PERT facilitates identification of the critical path and makes this visible
- PERT facilitates identification of early start, late start, and slack for each activity,
- PERT provides for potentially reduced project duration due to better understanding of dependencies leading to improved overlapping of activities and tasks where feasible.
- The large amount of project data can be organized & presented in diagram for use in decision making.

During project execution, however, a real-life project will never execute exactly as it was planned due to uncertainty. It can be ambiguity resulting from subjective estimates that are prone to human errors or it can be variability arising from unexpected events or risks. The main reason that the Project Evaluation and Review Technique (PERT) may provide inaccurate information about the project completion time is due to this schedule uncertainty. This inaccuracy is large enough to render such estimates as not helpful (Milosevic 2003).

One possibility to maximize solution robustness is to include safety in the baseline schedule in order to absorb the anticipated disruptions. This is called proactive scheduling. A pure proactive scheduling is a utopia; incorporating safety in a baseline schedule that allows coping with every possible disruption would lead to a baseline schedule with a very large make-span. A second approach, reactive scheduling, consists of defining a procedure to react to disruptions that cannot be absorbed by the baseline schedule (Kerzner 2003).

1.5.3 Event Chain Analysis

Event chain methodology is an uncertainty modeling and schedule network analysis technique that is focused on identifying and managing events and event chains that affect project schedules. Event chain methodology is the next advance beyond

critical path method and critical chain project management (Virine, L. and Trumper 2007).

Event chain methodology helps to mitigate effect motivational and cognitive biases in estimating and scheduling**.** (Robyn 1974)**,** (Tversky 1972). In many cases, project managers intentionally or unintentionally create project schedules that are impossible to implement . The methodology also simplifies the process of defining risks and uncertainties in project schedules, particularly by improving the ability to provide reality checks and to visualize multiple events. Event chain methodology is used to perform more accurate quantitative analysis while taking into account such factors as relationships between different events and actual moments of the events.

Events can cause other events, which will create event chains. These event chains can significantly affect the course of the project. For example, requirement changes can cause an activity to be delayed. To accelerate the activity, the project manager allocates a resource from another activity, which then leads to a missed deadline. Eventually, this can lead to the failure of the project.

In transportation projects such as motorway and railway construction there is a special case of event chain methodology named as time-chainage (Figure 1.6) method is applied. In this method work schedule is displayed on a time vs. chainage (distance) diagram with each work item being a line or rectangle. This representation simplifies the tracking process and underlines dependencies among consequential work items.

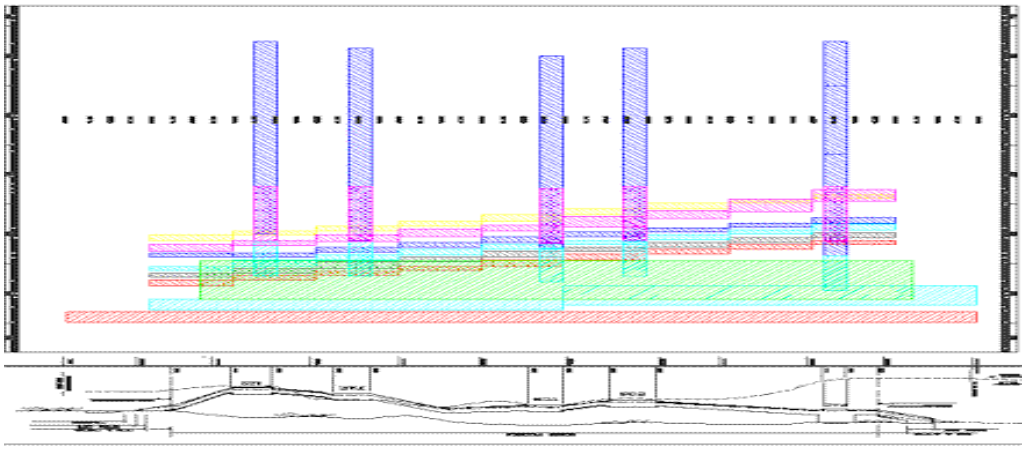


Figure 1.6 Time-Chainage Schedule Example

1.5.4 Earned Value Management

Earned Value Management (EVM) is a project management technique for measuring project performance and progress in an objective manner. EVM has the ability to combine measurements of scope, schedule, and cost in a single integrated system. Earned Value Management is notable for its ability to provide accurate forecasts of project performance problems. Early EVM research showed that the areas of planning and control are significantly impacted by its use; and similarly, using the methodology improves both scope definition as well as the analysis of overall project performance. More recent research studies have shown that the principles of EVM are positive predictors of project success (Marshall 2007). Interest and use of EVM have grown significantly in recent years.

Earned Schedule (ES) prediction technique is one of the components of EVM.

An understanding of EVM and its terminology is assumed in above. For convenience, the EVM terminology used to portray project status and forecast final duration is defined in the following:

• Planned Value (PV).

• Earned Value (EV).

• Performance Measurement Baseline (PMB), which is the cumulative PV over time.

A recent extension to EVM, ES, has emerged to provide reliable, useful schedule performance management information. In brief, the method yields time based indicators, unlike the cost-based indicators for schedule performance offered by EVM. Figure 1.13 is an illustration for understanding the concept. The ES measure identifies when the amount of EV accrued should have occurred. As depicted by the diagram, this is the point on the PMB where PV equals the EV accrued. The vertical line from the point on the PMB to the time axis determines the earned portion of the schedule. The duration from the beginning of the project to the intersection of the time axis is the amount of ES. With ES and AT defined, the schedule performance efficiency is formulated as depicted in Figure 1.7, Schedule Performance Index (SIP).

[SPI(t)] = ES/AT

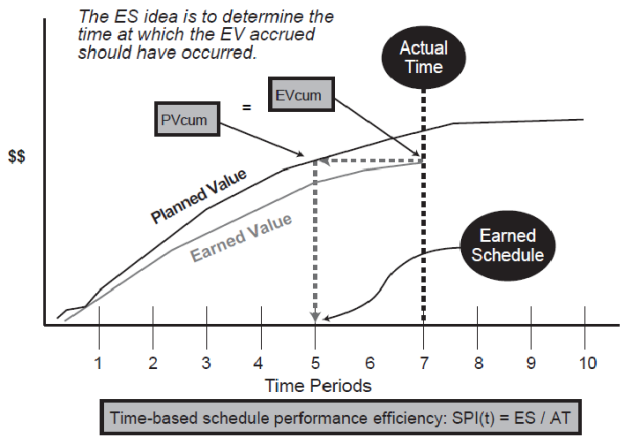


Figure 1.7 Time Based Schedule Performance Efficiency

1.6 CONSTRUCTION METHOD

Construction method; is predominately used in construction to describe specific instructions on how to perform construction work related tasks, or operate construction equipment. Choosing of method for construction is the most important component in the success of the project.

Every project has own conditions and this conditions describe the edge of some variables such as cost, time and quality. In Construction projects, construction method can lessen those (Figure1.8).

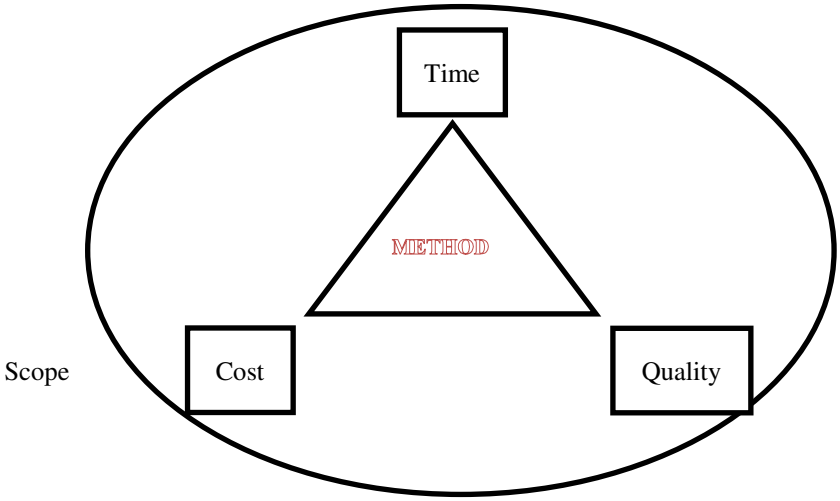


Figure 1.8 Project Management Triangle

In order to finish the project on time, the projects need to be managed successfully, without exceeding the project budget. Planning phase is also significant factor such as the experience and expertise of workers or the particular underground conditions at the site (Barutçugil 1988).

1.6.1 Importance of Method in Planning

The project mission model shows the components that are important items on choosing the construction method in construction management(Figure1.9);

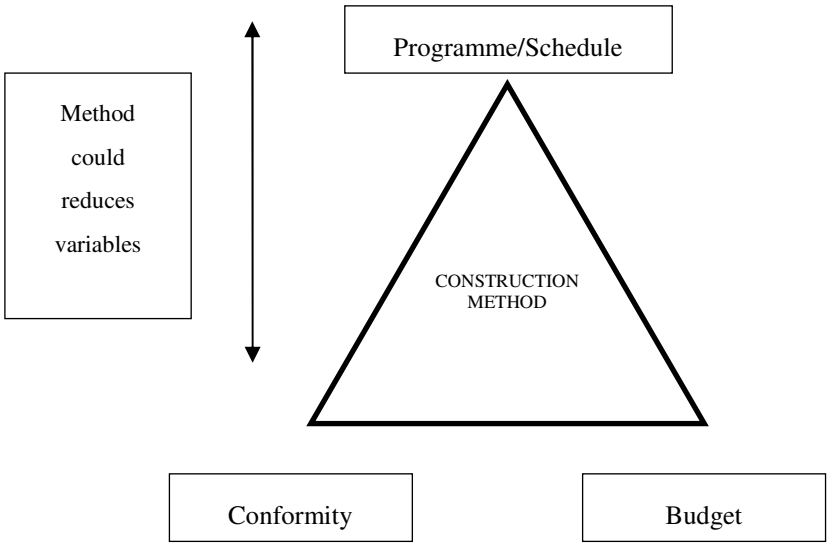


Figure 1.9 The Project Mission Model and Construction Method

Project management is the coordinating effort to fulfill the goals of the project. For this purpose project managers use knowledge, skills, tools, and methodologies to do the following (Chatfield and Johnson 2007):

- Determining the goals, objectives, requirements, and limitations of the project.
- Coordinating the different needs and expectations of the various project stakeholders, including team members, resource managers, senior management, and costumers.
- Planning, executing, and controling the tasks, phases, and deliverables of the project based on the identified project goals and objectives (Figure 1.9).

● Capturing the knowledge when the project completed.

The schedule phase of the project management is shown Figure 1.10 below;

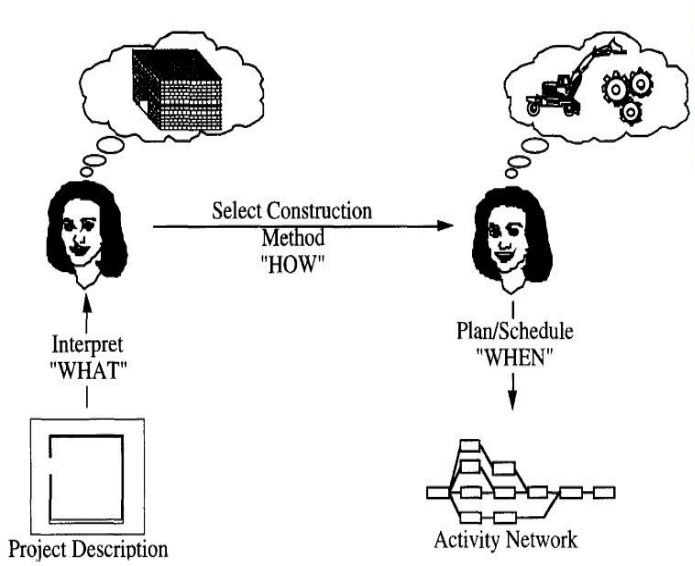


Figure 1.10 The Schedule Phase of the Project Management (Chatfield 2007)

After interpreting the scope of the project, written in Project Description, construction method is chosen. Planning of the project will be done by setting up a activity network.

1.6.2 Construction Method Statements

A construction method statement, sometimes referred to as a safe work method statement or a safe work procedure, is a part of a workplace safety plan (NSW 1998). It is predominately used in construction to describe a document that gives specific instructions on how to safely perform a work related task, or operate a piece of plant or equipment. In many countries it is law to have work method statements, or similar, in place to advice employees and contractors on how to perform selected construction method safely (NSW 1998).

A construction method statement is prepared for each task on a particular worksite; the group of work method statements are then packaged and included in the overall

Construction Safety Plan. This plan (or document) is typically submitted at the beginning of a project for approval by the client or their representative.

The construction method statement encompasses the following:

1. purpose
2. scope
3. references
4. definitions
5. responsibilities
6. equipment
7. risk assessment
8. safety
9. procedure
10. attachments (if any)

1.7 PROPOSAL METHOD SELECTION PROCESS

The process of selecting the construction method obtained by the senior manager [1]reviews are shown at Figure 1.11. In selection of the correct method experience have the priority. If one choose to make use of alternative construction methods, it is important to prepare conformity analyses in which the feasibility of budget and work program of alternatives is detailed according to the results of field investigations and labor availabilities.

[1]Mr. Gökhan Aşçıoğlu Planning Department Manager of Şişhane Yenikapı Metro Project.
Mr. Yaşar Çulhaoğlu Cost Control Department Manager of Astaldi Turkey

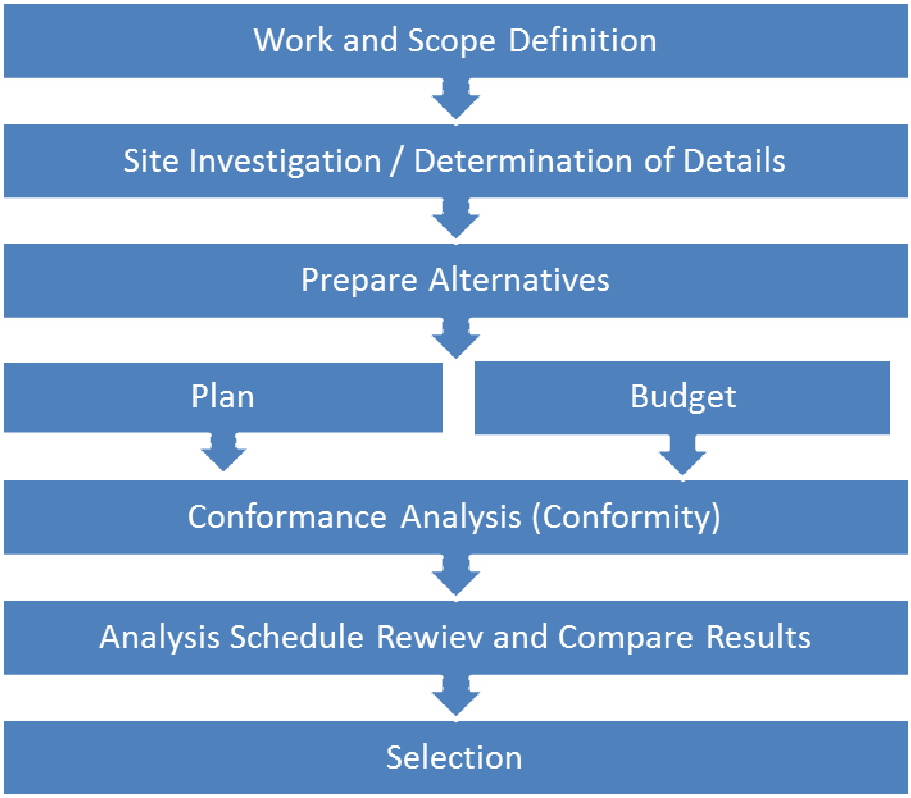


Figure 1.11 Proposal Construction Method Selection Process

1.7.1 Project Scope – Work Definition

Project Scope "The work that needs to be accomplished to deliver a product, service, or result with the specified features and functions" (PMBOK 2008).

1.7.2 Site Investigations

In parallel with other preliminary deciding methods, investigation of the site is conducted at varying levels of detail. After preliminary examination of the drawings and specifications, the construction site must be visited. Information is needed concerning a wide variety of site and local conditions. (Clough and Sears 1994) Some examples are as follow;

- Project Location
- Probable weather conditions
- Availability of electricity, water, telephone and other services

- Access to the site
- Local ordinances and regulations
- Storage and construction operation facilities
- Surface topography and drainage
- Subsurface soil, rock and water conditions
- Material prices and delivery information
- Rental of construction equipment
- Local Subcontractors
- Condition affecting the housing of workers
- Site cleaning

When several alternatives are still under consideration, the potential sites will be studied from the stand point of general conditions, topography, access and cost. As the options are narrowed, further details will be developed on the preferred option or options. The geotechnical specialist will provide major input at this step.

For instance, tunnel method can be predicted at this step. Environmental aspects of site, including potential underground contaminants, are important. Site investigation also includes options for preserving existing vegetation and existing improvements, if any, various ways for accessing the site and interfacing with off-site traffic flow off vehicles on site. In addition, property surveys may be needed to establish corners and boundaries and investigation into ownership records may be required to establish who owns title to land and what form.

1.7.3 Planning and Budget

Planning is an essential function of project management. Yet, many small- and medium-sized contractors do a relatively poor job of operational planning. Better pre-plans will reduce costs, shorten schedules, and improve labor productivity by deciding construction methods (Ralph and Ellis 2007).

In selecting among alternative methods and technologies, it may be necessary to formulate a number of construction plans (Figure1.12) based on alternative methods or assumptions and environmental conditions. Once the full plan is available, then

the cost, time and reliability impacts of the alternative approaches can be reviewed. This examination of several alternatives is often made explicit in bidding competitions in which several alternative designs may be proposed or Value Engineering-Constructability for alternative construction methods may be permitted(Hendrickson 2001) .

In this case, potential constructors may wish to prepare plans for each alternative design using the suggested construction method as well as to prepare plans for alternative construction methods which would be proposed as part of the value engineering process. In forming a construction plan, a useful approach is to simulate the construction process either in the imagination of the planner or with a formal computer based simulation technique. By observing the result, comparisons among different plans or problems with the existing plan can be identified.

1.7.4 Conformance Analysis

Conformance analysis is the study of the constructability of the selected construction method. Applicability of the selected construction method should be analyzed in detail. Important topics that are discussed on conformance analysis are, availability of the subcontractors and equipment, keeping the quality of the manufacturing above the standards, constructability, safety and risks, rework risk, public input and practicability of codes.

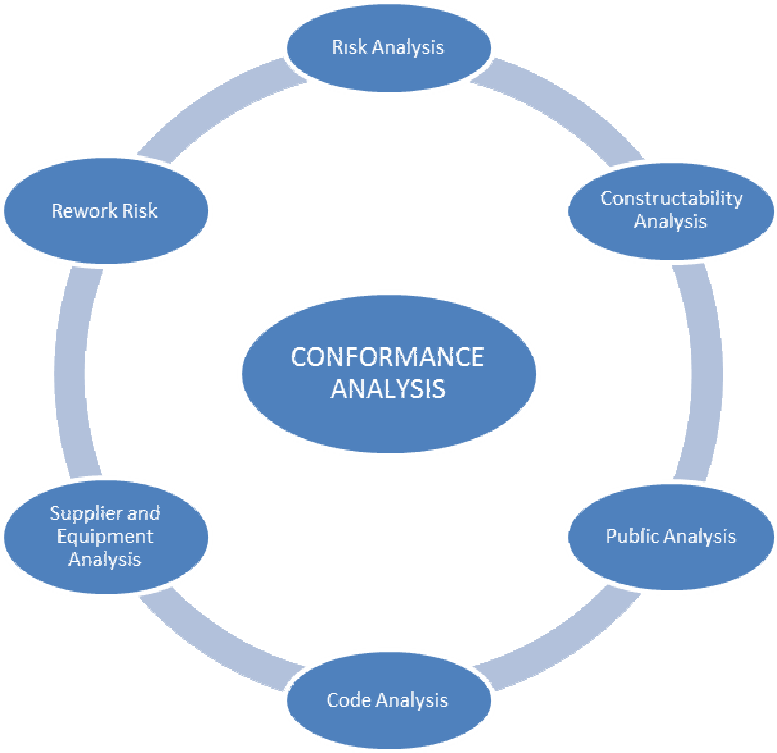


Figure 1.12 : Conformance Analysis

After checking the suitability of the selected method to the initial budget and plan, the conformity to the field and risk analyses are needed to be considered. In these analyses risks during the construction process, needed labor work and suitability to the standards are included. Conformance analysis detail are given indi sections below.

1.7.4.1 Risk Analysis

Risk analysis should be performed as part of the risk management process for each project. The data of which would be based on risk discussion workshops to identify potential issues and risks ahead of time before these were to pose cost and/ or schedule negative.

In method choosing a risk workshops should be chaired by a qualified individuals from the various departmental functions (e.g. project manager, construction manager, site superintendent, and representatives from operations, procurement, project

controls, etc.) so as to cover every risk element from different perspectives (URL 1 2010).

The outcome of the risk analysis would be the creation or review of the risk register to identify and quantify risk elements and their potential impact. By constantly monitoring risks these can be successfully mitigated, resulting in a cost and schedule savings with a positive impact on the project.

In general, the following are considered to be the risk factors (Hendrickson 2001);

- Type of soil and site condition
- Weather conditions
- Material and equipment failure
- Incomplete design scope
- Defective design
- Design changes
- Fluctuation in labour productivity
- Artificial obstruction
- Subcontractors default
- Landslide

1.7.4.2 Rework Risk

Poor production quality may result with low class product which is not possess required specification. Such products is useless and to be re-done or reworked. In construction industry this often means that breaking of the wrong-done product and re-construction.

Construction projects are often experience rework related cost and schedule overruns. Research by the Construction Industry Institute reveals that direct costs caused by rework average 5% of total construction costs (CII 2005).

For Instance: Timber and Steel Concrete Forms, using steel form elements obstruct concrete connection joints errors.

Rework can be identified by comparing the impacts of rework according to method characteristics and by measuring sources of rework. Additionally, those sources of rework have the biggest impact on construction cost performance. After the analysis of the cost impact of rework is summarized, the root causes of rework will be assessed and possible total cost of method can be defined (Thomas and Has 2009).

By recognizing the impacts of rework and its sources, the construction industry can reduce rework and ultimately improve project cost and schedule performance.

1.7.4.3 Constructability Analysis

Throughout planning and design, it is essential to consider whether proposed alternatives can be built and whether they can be built efficiently. The term 'constructability' is used for this evaluation, which is continuing process, perhaps more active during the design stage.

Experts with knowledge and experience play an important role in achieving superior constructability. Constructability analysis will help to eliminate hidden costs and change orders, ensure schedule, improve construction quality and enhance safety in construction project (Anderson,S.D. et al,1999). Improving constructability could also reduce the rework risk.

1.7.4.4 Public Input (Analysis)

Especially for the government projects, big scale housing or commercial projects may appeal public interest. People may have questions about the project. They can got enthusiastic or anxious about it. Therefore, effect of the chosen construction method over the public had to be unmistakably predetermined.

For example, the local community can react to the excavation works in the city that affects the traffic or create dangerous situations. Even though all the precautions are taken, presentation of the project may induce negative influence on the public view. The main purpose of the Public Input analysis is to minimize effect of the constriction works on local community and create a positive vision.

1.7.4.5 Code Analysis

Building codes, fire codes, safety codes and a number of other codes and regulations may apply to the project. During method choosing stage, it is important that all alternatives under construction can be made comply with these codes. Selected construction alternatives must be answered. The answer will impact on the various alternatives as they emerge from the planning process and will thus influence the cost of each (Lawrence Bennett 2003). And during construction some environmental codes can be obstruct construction this stage have to be analyses carefully.

1.7.4.6 Supplier, Equipment and Crew Availability

Suppliers that have enough supply, manpower, equipment plays important role on construction method selection. For example, in some countries suppliers have been limited by the government by using only certain type of material or equipment. This causes delays on the project completion time.

Additionally subcontracting has a big role in construction industry. If the subject work would be given to a subcontractor, qualification and experience of available subcontractors has to be considered in method selection.

2. TUNNEL AND METRO CONSTRUCTION AND METHODS

A tunnel is an underground passageway, completely enclosed except for openings for egress, commonly at each end. A tunnel may be for foot or vehicular road traffic, for rail traffic, or for a canal. Some tunnels are aqueducts to supply water for consumption or for hydroelectric stations or are sewers. Other uses include routing power or telecommunication cables, some are to permit wildlife such as European badgers to cross highways.

2.1 TUNNEL CONSTRUCTION

Tunnels are dug in types of materials varying from soft clay to hard rock. The method of tunnel construction depends on such factors as the ground conditions, the ground water conditions, the length and diameter of the tunnel drive, the depth of the tunnel, the logistics of supporting the tunnel excavation, the final use and shape of the tunnel and appropriate risk management.

2.1.1 Benefits of Underground

The use of underground space has lots of benefits. Tunneling may offer important contributions to highly populated areas. The benefits of using the underground are evident in the foreseeable future for the following main reasons (Sellberg 1996):

- Noise - The noise from traffic tunnels underground is not heard on the surface.
- Traffic - The location of the through routes underground adds space for local traffic on the ground.
- Space - The impression of adding “one extra dimension” by building underground is of great importance.
- Energy conservation - The low temperature in underground is favorable for cold storage. And the excellent insulation properties of the underground should not be underestimated.

- Saving material - Excavated rock masses from caverns could be used as ballast materials for various constructions, such as roads, railways, and dams.

Underground transportation systems may be proposed to improve the quality of life in urban areas (Guertin 1996). Tunneling can be part of a sustainable development strategy by providing the necessary infrastructure (Guertin 1996). Abd El Salam (1999) indicated that, "those countries that have suitable geological conditions for underground structures should take advantage of this natural resource, which should be utilized fully in the same way as other natural resource such as water, mineral ores, etc. Tunnels and underground works are now used to fulfill the daily needs of the citizens, mainly for transportation, public utilities, storage and parking garages". Several countries have already proposed different laws concerning the right to make use of the subsurface. Different regulations of participating countries relating to the development of the subsurface for different applications have been developed by International Tunneling Association (ITA): "National, regional and local policies should be prepared to provide guidelines, criteria and classifications for assessing appropriate uses of underground space, identifying geological conditions, defining priority uses and resolving potential utilization conflicts.

2.1.2 Systems in Tunneling

The concept of system is unfamiliar to the tunneling industry. The various engineering activities (planning, site investigation, design, construction, and operation) of a tunneling project are generally subdivided and performed separately, with only limited coordination. This ensures that appropriate interaction cannot occur and some specific needs cannot be addressed in the early phases of the project.

A systems approach to tunneling may address optimal interaction during the overall tunneling project (Wood 2000). When the key elements of the project are fragmented (separated and uncoordinated), the responsibility for risk assessment becomes unclear. Progress in site investigation affects not only other aspects of design and construction but also possible changes in the site investigation itself. Site investigation is an integral element of the project: in design and construction. Site investigation needs to be developed in association with the other project components: planning and conceptual design (Wood 2000).

The tunnel design cannot be separated from the anticipated construction processes. The tunnel designer may be able to anticipate the potential construction methods in order to include them into the design (Wood 2000). Moreover, the tunnel design may be adjusted during construction. The design should anticipate potential unexpected conditions and to propose the technical options to control those unexpected conditions. Potential problems in construction can be avoided by an adjustment in design (Wood 2000).

The whole tunneling project should be visualized as a system whose elements interact with each other in order to obtain the maximum performance. The contractual relationships need to be compatible with the system approach in order to prevent the project fragmentation (Wood 2000).

Unfortunately, in practice, many organizations are becoming more entrenched in the practice of project fragmentation. Wood (Muir Wood 1975) mentioned that: "the process of planning, design, construction and maintenance of tunnels are (or should be) closely inter-related. In certain countries, current practices tend towards artificial barriers and discontinuities between certain of these aspects, particularly that of time separation between design and construction; it is not surprising there to find a high frequency of avoidable hazards and frustrated contracts".

2.1.3 Tunneling: a Special Discipline

Tunneling deals with unpredictable underground conditions. Knowledge of geological conditions (based on geotechnical investigations and studies which are the basis for overall project design decisions and are invariably based on a limited sampling of the total geologic mass at the project site) and construction costs and duration can only be expressed with margins of uncertainty which are highly dependent on the specific project.

Tunnel construction is different—sometimes, vastly different—from construction that takes place at the ground level. Construction below the ground surface involves many risks that simply do not exist for above ground structures such as (Gary S. Brierley 1998):

1. The ground cannot be anticipated. The whole purpose of a subsurface investigation is, therefore, to determine the nature of the underground conditions well enough so that a project can be implemented in a satisfactory manner. The subsurface investigation represents a 'forecast' of subsurface conditions at a subject site;

2. The ground can be changed during construction. The ground can be changed, for better or for worse, as a result of the contractor's selected construction means and methods utilized during the process of construction. Hence, competent ground can be damaged by careless or inappropriate construction operations, or relatively unstable ground might be improved by construction dewatering or grouting;

3. Construction methods. Construction methods also need to be considered in the context of ground conditions. Contractors can be quite innovative at taking short cuts or using new procedures or techniques for the purpose of facilitating underground construction. Conversely, inappropriate construction methods can result in highly adverse ground behaviors that can damage a site, cause injuries to third parties, or result in differing site conditions claims or other expensive problems for an owner;

4. Third party impacts. For subsurface construction, however, instances exist where construction dewatering results in the settling of adjacent properties, an unanticipated loss of ground results in damage to nearby structures or utilities, or vibrations from pile driving or blasting result in class action lawsuits for damages.

But, what is special in tunneling? Tunneling is characterized by these following features (Thom 1998):

• Extreme dependence on the ground, the interpretation of its characteristics in terms of risk;

• High degree of interdependence between planning and project design, arising from provisions for containing the ground and excluding groundwater;

• Domination of the methods of construction on the design of the project;

• Effect of restrictions of access on logistics, particularly in dealing with construction problems;

Subsurface conditions determine the degree of difficulty, the cost, and the schedule for designing and constructing subsurface projects (Marshall 2007). The primary

purpose of a subsurface investigation is to obtain factual information about the distribution and engineering characteristics of soil and rock deposits (Flyvbjerg 2006). The geotechnical investigation provides the basis for estimating the ground mass and intact rock and soil characteristics to evaluate loads, ground interaction, bearing capacity, and other pertinent design parameters. In addition, the geotechnical investigation provides the foundation for the preparation of data in interpretive reports, and establishes baselines or other contractual mechanisms to define and allocate risk for site conditions between the owner and contractor. In brief, geotechnical investigations and studies are the basis for overall project design decisions and are invariably based on a limited sampling of the total geologic mass at the project site. In consequence, there is an unavoidable risk in tunneling and risks effecting to project duration.

2.1.4 Effects of Geological Condition in Tunneling

Design Through Construction

The basic components of tunneling construction include the following items: (Deere 1989) excavation (by blasting or by mechanical means); (Deere 1998) initial ground support; and (Pantelidis 2009) final ground support. The method of excavation affects the loads and displacements that will be supported by the initial and final ground supports. Rock Quality Designation (RQD) is a significative parameter for geological conditions of ground. Geological conditions will be discussed in detail on Risks of tunnel.

Rock-quality designation (RQD) Rough measure of the degree of jointing or fracture in a rock mass, measured as a percentage of the drill core in lengths of 10 cm or more. High-quality rock has an RQD of more than 75%, low quality of less than 50%. Rock quality designation (RQD) has several definitions. The most widely used definition was developed in 1964 by D. U. Deere. It is the borehole core recovery percentage incorporating only pieces of solid core that are longer than 100 mm in length measured along the centerline of the core. In this respect pieces of core that are not hard and sound should not be counted though they are 100 mm in length. RQD was originally introduced for use with core diameters of 54.7 mm (NX-size core). RQD has considerable value in estimating support of tunnels (Table 2.1).

RQD is defined as the quotient:

$$RQD = \left(\frac{l_{\text{sum of 100}}}{l_{\text{tot core run}}} \right) \times 100 \%$$

$l_{\text{sum of 100}}$= Sum of length of core sticks longer than 100 mm measured along the center line of the core

$l_{\text{tot core run}}$= Total length of core run

From the RQD index the rock mass can be classified as follows

Table 2.1 RQD and Rock Quality

RQD	**Rock mass quality**
<25%	Very Poor
25-50%	Poor
50-75%	Fair
75-90%	Good
90-100%	Excellent

2.2 TUNNEL EXCAVATION METHODS

There are three basic types of tunnel construction in common use:

- Cut and cover tunnels, constructed in a shallow trench and then covered over.
- Bored tunnels, constructed in situ, without removing the ground above. They are usually of circular or horseshoe cross-section.
- Immersed tube tunnels, sunk into a body of water and sit on, or are buried just under, its bed.

In this study we will analyze bored tunnels and its subtypes Tunnel Boring Machine (TBM) and New Austria Tunneling Method (NATM).

2.2.1 Shaft Construction

To build a tunnel, the first step is to build a working shaft. The working shaft is usually circular in shape, although in some cases it is square.. Tunnel level is obtained by shaft excavation (see Figure 2.1)

Figure 2.1 S14 Shaft Excavation in Kadıkoy Kartal Metro Project

Crews use drills to excavate a circular shaft, and then use hand tunneling to expand it to the desired diameter. In the case of square shafts, they usually use hand tunneling or a backhoe. Once the shaft reaches the desired depth, the crew starts excavating the tail tunnel and the undercut. (Figure 2.2).

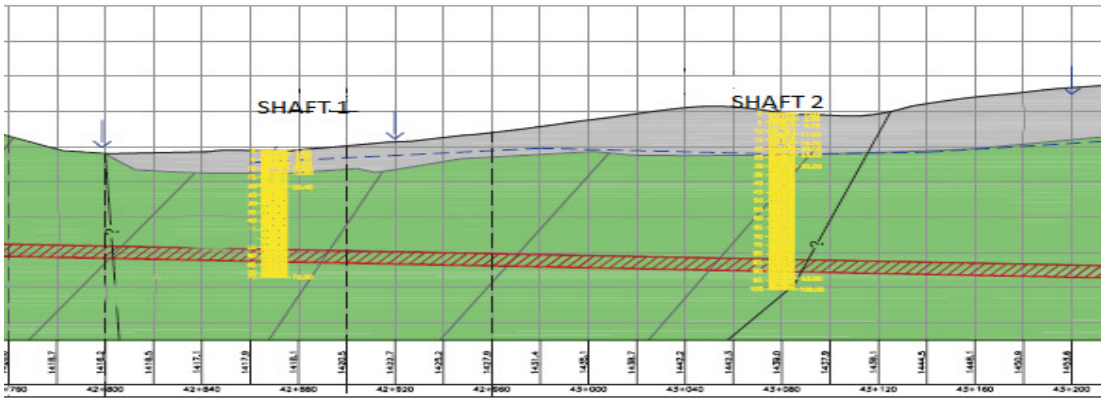


Figure 2.2 Shaft and Tunnels on Profile

2.2.2 NATM Tunneling Methods

A very well-known method is the New Austrian Tunneling Method (NATM) which has been used in poor ground (mainly using non-circular cross sections) and where the ground support must be installed immediately. The method was developed between 1957 and 1965 in Austrian. Its name was given in 1962 to distinguish it from old Austrian tunneling approach. The main contributors to the development were Rabcewicz, Muller, and Pacher (Ascioglu 2007).

The NATM has been used successfully for the construction of large tunnel cross sections in very poor ground.

According to the U. S. Army Corps of Engineers (Ascioglu 2007), NATM usually involves the following components:

- Heading-and-bench or multi-drift excavation (no shield or TBM). Excavation by blasting or, more commonly, by road-header or other mechanical means.
- Initial ground support usually consisting of a combination of shotcrete, dowels, steel sets, or (now more commonly) lattice girders, installed quickly after exposure by excavation.
- Forepoling or spilling where the ground requires it.
- Stabilizing the face temporarily, using shotcrete and possibly grass-fiber dowels.
- Ground improvement (grouting, freezing, dewatering).
- Extensive use of monitoring to ascertain the stability and rate of convergence of the opening.

What distinguishes the method from other methods is in the extensive use of instrumentation and monitoring. They are used to assess the stability and deformation state of the system: rock mass and support elements. Traditionally, monitoring involves the use of the following devices (Ascioglu 2007):

- Convergence measurements, wall to wall and wall to crown.
- Surveying techniques, floor heave, crown sag.
- Multi-position borehole extensometers.
- Strain gages or load cells in the shotcrete, at the rock-shotcrete interface, or on dowels or steel sets, or lattice girders.

In the event that: (Wood 2000) the rates of displacement maintain their rate or accelerate; the loads are reaching values greater than the support capacity; and if instability is virtually observed, the following scenarios must be considered:

1. Increase the intensity of the initial support elements—number of rock dowels, thickness of shotcrete, and spacing of steel sets or lattice girders.

2. The overall cross section can also be varied according to conditions. Sequences of excavation can be changed, for example, from heading-and-bench excavation to multiple drifting.

Due to the multi-stage excavation process and the extensive use of monitoring, NATM is considered a not high-speed tunneling method. For this reason, the method has not being fully applied in countries (USA, for instance), where high-speed techniques and conservative ground support are preferred. However, NATM provides successful and economic solutions in tunnels located in poor ground that requires flexible and immediate support.

2.2.2.1 Method Statement of NATM Tunneling

The Tunnel Construction Procedures (see Figure2.10) are carried out according to the criteria defined in the New Austrian Tunneling Method in which the excavation process is due to the encountered ground condition.

The WBS of the New Austrian Tunneling Method obtain by the senior manager[2] is as stated here below:

A) Excavation

B) Support Systems

1) Sealing

2) Steel Rib

3) Shotcrete Lining

4) Rock Bolts

5) Forepoling

[2] Mr. Sandro CAPODONA ; Quality Assurance Manager of Kadıkoy Kartal Metro Project

C) Formwork

A) Excavation

According to the New Austrian Tunneling Method, tunnel excavation is carried out in three stages: top heading, bench and invert. (Figure 2.3)

Each stage is performed according to a defined construction sequence and several working activities.

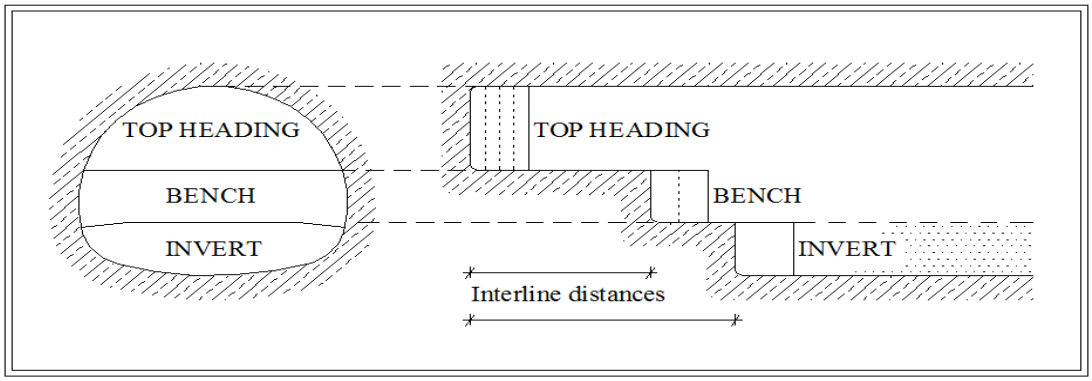


Figure 2.3 NATM Excavation Phases

The excavation phases of each stage are performed in different time to avoid any uncontrollable structural stress distribution due to the rock loading pressure and tectonic systems. (Figure 2.4)

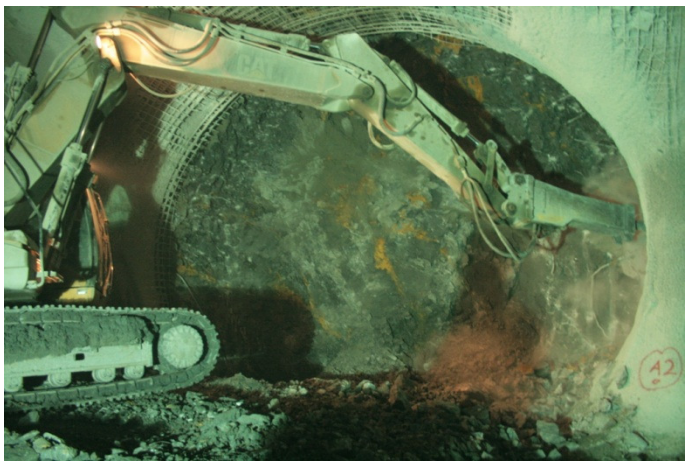


Figure 2.4 NATM Bostancı Line Tunnel Excavation in Kadıkoy Kartal Metro Project

B) Support System

Most underground excavation in rock is still performed using blasting techniques. Initial ground support is usually installed after the sequence of excavation. It may include the following elements: steel ribs, lattice girder, shotcrete, rock dowels, and steel wire mesh. The main purposes of these support elements are stabilizing and preserving the tunnel after excavation and providing worker safety.

Untensioned rock dowels (occasionally, tensioned rock bolts) works as ground reinforcement. They are referred as reinforcement because their function is to help the rock mass to support itself and to improve the inherent strength. Shotcrete, today, plays a vital role in tunneling construction due to its versatility, adaptability, and economy. As a brittle material, shotcrete used for ground support requires reinforcement (wire mesh or steel fibers) to give it strain capacity in tension. Finally, steel ribs (and most recently, Rock Bolts) are used in conjunction with shotcrete.

Depending on ground conditions and, specially, in operational requirements, final support may be installed. Basically, the final support consists of reinforced, cast-in-

place concrete lining, with a waterproofing membrane between the cast-in-place concrete lining and the initial ground support.

1. Sealing

The Shotcrete sealing is a support measure to stabilize and to minimize the risk of collapses of the excavated tunnel face and round.

When the excavation is completed the excavated round must be sealed by shotcrete. This operation consists in covering the whole exposed surface by a steel fiber reinforced shotcrete layer (thickness round) using sodium-silicate shotcrete. Thickness round: 5cm; Thickness face 10cm. Shotcrete sealing is a work safety matter.

2. Steel Rib

Profiles are originated from mining are hot rolled and have bell shaped cross section. The connections of the rib sections are done with an overlap of the profiles fitting into each other and are connected with clamps (according to approved design

drawings) (Figure 2.5). These types of connections are arranged in order to compensate large deformations due to friction in the clamp connections. Steel ribs performs a primary support immediately after excavation and shall subsequently act as reinforcement and load distributing part inside of the shotcrete lining.

Figure 2.5 Still Rib Application Goztepe Station in Kadıköy Kartal Metro Project

3. Shotcrete Lining

The Shotcrete lining performs the major primary tunnel support system. Shotcrete is applied as wet mix Shotcrete (Figure 2.6). This is batched according to the mix design stated in the specifications. The followings factors shall be taken into consideration:

- cement
- accelerating admixtures (MBT)
- setting and strength development
- temperature of the mix
- usage of steel fibers

Figure 2.6 Shotcrete in Kadıköy Kartal Project Station Tunnel

Shotcrete thickness depends on applied support class as stated in the approved design drawings.

4. Rock Bolts

Rock bolts perform a support system items for the Tunnel Construction (Figure 2.7). During the tunnel construction rock bolts are used for:

- Face Bolting for stability
- Radial Rock Bolting as preventive action against deformations
- Forepoling as method in view of work safety and measure against larger over breaks.

Figure 2.7 Station Tunnel Rock Bolt application in Kadıköy Kartal Metro Project

The numbers of the rock bolts are defined by the TDR Memorandum or approved design drawings. Surveying team shall mark the position of each bolt.

The face-bolts shall be installed by using a jumbo, two hydraulic mobile cranes, a pneumatic water pump (as water supply for drilling procedures) and an electric concrete pump.

The installation procedure is divided in the following activities:

1) Drilling
2) Grouting
3) Tightening

5. Forepoling

Forepoling is a pre-excavation support element required for the tunnel excavation works.

Prior to every forepoling installation, the tunnel profile at top heading has to be stepped up by using steel ribs.

Forepoling shall be applied in rock and soil conditions, which tend to produce overbreak, collapses or material inflows immediately following excavation. Forepoling may be applied locally or systematically according to the circumstances required for the safety of the works and to prevent overbreak which may occur during top heading excavation (Figure 2.8).

Figure 2.8 Forepoling on Tunnel Face

The work shall be carried out by using a jumbo, two hydraulic mobile cranes, a pneumatic water pump and a concrete pump.

In case of unstable ground conditions for application of pipe roof umbrella as forepoling system can be applied. This umbrella system is built up by installing grouted pipes.

C) Formwork

Formwork shall be sufficiently rigid to maintain the forms in their correct position, shape and profile so that the final concrete structure is within the limits of tolerances (± 10mm). Formwork shall be held to comprise all temporary stages and it is required and used for the construction of the final lining. The formwork is moving on a rail system along the tunnel. The formwork contains openings along each sidewall and in the crown. The openings shall be designed to permit the use of vibrators for the compaction of concrete in order to permit inspection of the concrete during pouring and to test the strength of the concrete surface prior to the removal of the formwork. The openings shall be square shaped depends on designs. The openings shall be located at a height so to prevent segregation of concrete during pouring. Joints in the forms shall be sufficiently tight to prevent leakage of grout and absorption of water from concrete. Some pipes shall be mounted at regular intervals in the top of the formwork roof to allow the filling of the voids behind the in-situ concrete inner lining. The external surface of the formwork shall have facilities for external vibrators at regular intervals to ensure compaction of concrete. (Figure 2.9)

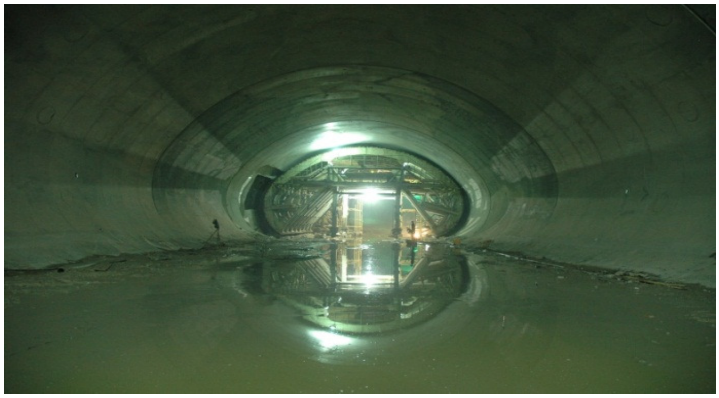


Figure 2.9 Formwork in S13 Layover Tunnel in Kadıköy Kartal Metro Project

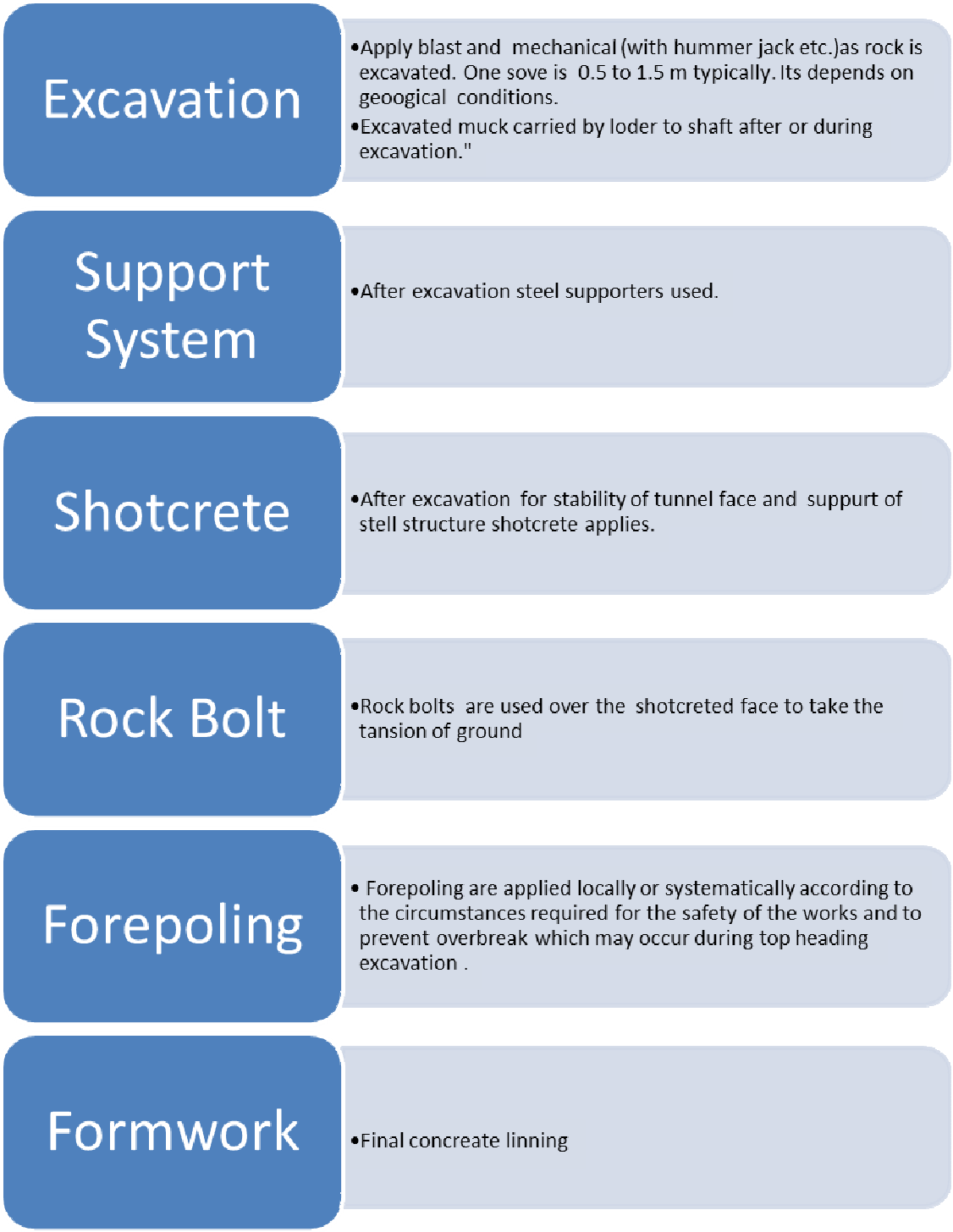


Figure 2.10 NATM Method Statement Process

2.2.3 TBM Tunneling Methods

A tunnel boring machine (TBM) also known as "mole" is a machine used to excavate tunnels with a circular cross section through a variety of soil and rock strata(Figure 2.11). Obtain by the senior manager reviews[3]; TBMs can bore through hard rock, sand, and almost anything in between. Tunnel diameters can range from a meter (done with micro-TBMs) to almost 16 meters per day.

Figure 2.11 TBM in Kadıköy Kartal Metro Project before installation

Tunnel boring machines are used as an alternative to drilling and blasting (D&B) or NATM methods in rock and in soil. TBMs have the advantages of limiting the disturbance to the surrounding ground and producing a smooth tunnel wall. This significantly reduces the cost of lining the tunnel, and makes them suitable to use in heavily urbanized areas. The major disadvantage is the upfront cost. TBMs are expensive to construct, and can be difficult to transport and inflexible for design change.

[3] Interview with Abdullah Kurşat EROL Tunnel Engineer at Kadıköy Kartal Metro Project experience more then 20 years;

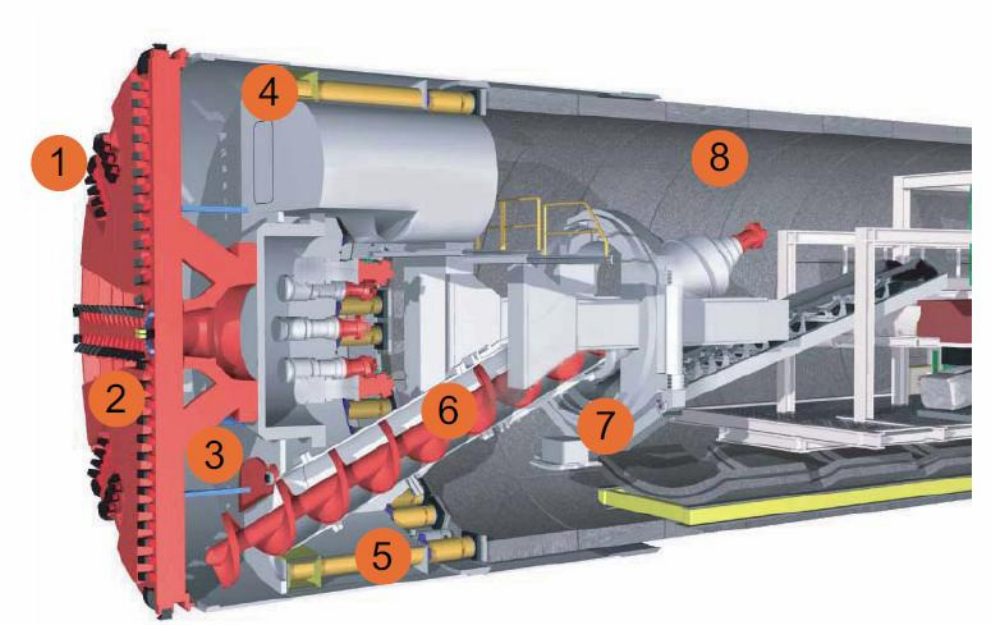


Figure 2.12 TBM parts from Kadıkoy Kartal Method Statement (1) Tunnel Face (2) Cutter Head (3) Excavation Area (4) Pressure Room (5) Drive Shaft (6) Conveyor (7) Segments (8) Shield

2.2.3.1 Method Statement of TBM Tunneling

A typical set of activities is presented in table...

Activities during TBM tunnel excavation can be briefly described as follows: the cutter head rotates and applies pressure at the cutters, making concentric grooves on tunnel face, and by such normal and rolling force application, crushing and rock chipping is achieved.(see Figure 2.12) The muck(broken rock) is taken into the cutter head by(fig) buckets, which drop the muck on the tbm conveyor belt, which in turn dumps the muck to hopper at the end of TBM(or onto another conveyor belt).From the hopper, the muck is evacuated from tunnel. After the cutterhead has started cutting and extending the thrust pistons, the grippers are retreated after the support legs are lowered, the TBM is moved forward, and site pads (grippers) are extended, and the cutting cycle is repeated.(Figure 2.14) There are activities that go on in parallel with cutting and advancing: muck removal, placing initial and final support (though at different location in the tunnel), ventilation and dust suppression, laying rail, surveying, muck excavation from stock pile, and material and crew

transportation to the face of tunnel (Figure 2.13). The process of TBM is shown on Figure2.13

Figure 2.13 TBM utilities and Tunnels in Kadıköy Kartal Metro Project

Boring	•Apply thrust and torque at the cutterhead forward as rock is cut. One sove is 1.2 to 1.5 m typically. Its depends on segments lenght.
Excavation of muck within TBM	•Move muck(broken rock) from tunnel invert by buckets in the cutterhead to the end of TBM using TBM conveyor
Install a initial support	•Apply ground stabilization and support elements, such as rock bolts, steel ribs , or concrete segments.
Install final lining	•Apply final pass in tunnel lining(precast concrete segments) some distance behind TBM
Survey position and location of TBM	•Use different kind of survey eqipment to locate TBM cutterhead position along tunnel, and orientation
Bring material to TBM, from portal/shaft	•Use train /truck to transport llining materials, supplies for other activities, and spare parts, to the end of TBM.

Figure 2.14 TBM Method Statement Process

2.3 RISKS IN TUNNELING

Risk is the main cause of increased cost and delay in tunneling projects. In practice, risk is enhanced by the absence of effective management (when responsibilities are fragmented) and fair allocation of risk by owners and contractors. A critical step in risk management for complex underground projects is the formal identification and definition of potential sources of risk, i.e., uncertainty related to achieving scope, schedule, and budget milestones for all project tasks.

Risk management is a continuous process, starting from planning through construction. Moreover, a risk management program ideally is accomplished through the identification, assessment, and allocation of project risks and a careful preparation of unambiguous contract specifications, a good design, and a clear allocation of risks in accordance with the owner's risk management objectives.

Management of risks in a tunneling project requires application of all of the owner's and professional's experience and resources coupled with clear, definitive contract documents, which contain fair and equitable allocation of project risks between the owner and contractor.

2.3.1 Sources of Uncertainty and Risk in Tunnels

An appreciation of the potential hazards/risks is necessary to control them. In fact, the driving force for a good design is the intention to "anticipate and forestall controllable causes of risk". But, what is the difference between hazard and risk? The

BS 4778(British standards 1991) provides the following definitions:

- hazard—is a situation that could occur during the lifetime of a product, system or plant that has the potential for human injury, damage to property, damage to the environment or economic loss; and
- risk—a combination of the probability, or frequency, of occurrence of a defined hazard and the magnitude of the consequences of the occurrence.

In tunneling, however, it is important to have in mind that geological features (on their own) may not cause any particular hazard. But, the association between several geological features may become a hazard or concern. Moreover, a hazard can become a great risk considering a specific and particular construction method.In the Table 2.1, the representative key uncertainties/risks in tunneling are indicated,

and thereafter, a brief discussion of each item is provided.

Geologic Profile:

• The practicability and efficiency of all tunneling processes depend on the reliability of the assumptions made about the ground characteristics: the ground model. However, there is a chance that wrong assumptions (and information) made in early phases of interpretation can pass to a contractor;

• Another factor of great importance is related to the variability of the ground. Ground variability may need to be considered more coherently than only by the use of Rock Mass Classification Systems. For instance, in sedimentary rocks, strata represent depositional layers of coarser grained material, more permeable than the fine-grained layers. Characteristics combined of coarse and fine materials will induce problems of roof support and break-down of the weaker material;

• Statistical evidence of geotechnical variability should be presented in a reliable manner to permit the designation of the most probable condition;

• The location of boundaries between soils and rocks (within the horizontal and vertical extent) is very difficult to anticipate;

• The purpose of the ground model is not only to provide the basis of a generally satisfactorily scheme of construction but also to indicate the nature of potential hazards for which special precautions may be needed. Another consideration would be “failure to express features of geology in aspects or terms significant or comprehensive for engineering” (Wood 2000).

• The ground can be unstable. Effects of ground movement on structures or srvices can affect other parties (Wood 2000);

• If the ground conditions could not be appropriately anticipated, “design

each tunnel length as excavation advances" (Wood 2000);

• "One of the most potentially hazardous episodes in tunneling in weak rock is that of the initial break-out from the access shaft" (Wood 2000). Ground into the shaft during sinking operations may cause voids against the shaft wall, affecting not only the stability of the shaft, also the stability of the ground close to the shaft/tunnel junction.

Groundwater conditions and waterproofing:

• Groundwater conditions within the soil and rock layers have a great influence on the tunneling project. And they are considered a source of uncertainty/risk: "amount of water, chemical properties of the water, static and dynamic pressures within the entire groundwater regime, and ability of the water to flow through the various soil/rock layers when subjected to pressures differences" (Tversky 1972);

• Ground and groundwater have to interact with the construction means and methods. Therefore, it is important to consider that "changes to groundwater regime on structures or services can affect other parties" (M.Rodriguez 1999);

• Variations in the water table need to be considered. "Inflow may be objectionable on affecting local water supply or on settlement of buildings or structures" (Wood 2000)**;**

*Natural and man-made obstructions**:***

• Occurrence and nature of both natural obstructions (boulders) and manmade obstructions (rubble fill, old piles, old foundations, wharf structures etc.) within the soil deposits are a source of uncertainty/risk (Tversky 1972);

• In urban tunneling projects, the presence of pre-existing service pipes and cables is a concern (Wood 2000);

• Obstruction caused by pipes, services, wells, shafts, foundations or boreholes needs to be considered (M.Rodriguez 1999);

• "There may be natural obstructions that need to be considered: open boreholes; wells and geological features filled with water or loose water

bearing soil" (Wood 2000). This hazard requires considerable attention: they are very expensive.

Expansion and/or construction joints:

• "Where a tunnel is approached from the surface directly to an entrance portal, the initial tunneling will often by through ground decomposed by weathering, possibly water-bearing and affected by superficial movement, introducing problems atypical of the general features of the tunnel" (Wood 2000);

• Tunneling projects often entail interactions between separate operations (and contracts). Delays caused by inter-contracts are normally very expensive (Wood 2000). For instance, the rate of deterioration of exposed ground may be important where rock bolts are expected to support the ground for an extended period;

• Installing steel arches, a typical failure includes the lack of 'foot-blocks' without considering the limited strength of the ground and ignoring the following excavation steps. "Where arches are to be supported as the bench to a top heading is removed, leg extensions must be in place and loaded prior to undermining the local section of the bench support" (Wood 2000);

Fire:

• Risk assessment should consider the possible consequences of fire and their mitigation (Wood 2000);

• A spectacular fire occurred in the Channel Tunnel (November 18, 1996): "a feature of this fire was that within the tunnel the temperature arose to 1000 (Celsious degrees) or more and caused spalling of the reinforced concrete lining over a length of about 500 m and for part of this length back to the rear reinforcement in the 400 mm thick segments

	Risk	Description
1	Geologic Profile	Uncertainty about the ground is a hazard to be understood and circumscribed. Within a wide geological context, the geological model is based on sampling of a very small fraction of the ground, and indirect interpretations of geophysical records.
2	Engineering and Chemical Properties	The engineering and chemical properties control ground behavior under excavation operations. Ground move chemical properties meant and unacceptable settlements need to be carefully controlled during construction.
3	Groundwater and Waterproofing	Groundwater conditions have a great impact on ground behavior. Moreover, unanticipated inflows may have considerable impacts on costs. For operations purposes, waterproofing may need to be warranted.
4	Natural and Man-Made Obstructions	Unanticipated obstructions (natural or man-made) need to be carefully controlled. In urban areas, the main concern is "liability" with third parties (or stakeholders).
5	Expansion and/or Construction Joint	Interactions of a tunneling project with separate and simultaneously operations are risks which have great impacts on delays and costs. Moreover, installation of support elements needs to satisfy strict QA/QC constructability standards.
6	Environmental Issues	Environmental regulations have a great impact on the construction techniques to be considered in the specific project. For tunnels in urban areas, more environmental issues need to be considered.
7	Compatibility with Adjacent Facilities	The acceptability of ground movements needs to be compatible with adjacent facilities. Moreover, the "geometrical" or internal cross section needs to consider the provisions by each of the potential construction techniques.
8	Design Through Construction Joints	Lack of continuity from design through construction should be considered a "high" risk when the ground is very "sensitive" to construction operations.
9	Fire	Fire potential and precautions may require detail technical considerations. Lack of anticipated risks assessment (and provisions) may have a great impact on both during construction and during tunnel operation.
10	Management and Workmanship Failure	Non-physical risks concern the failure of to unmeet the tunnel project objectives. They are related, mainly,to defective contract documents and inappropriate risk allocation between the parties involved.
11	Detericration	Swelling potential (during construction) and aggressive groundwater (during operation) are risks that need to be anticipated in the planning stage. Failure to recognize this risk potential may include unanticipated and expensive remedial works.

Table 2.2 Risk in Tunneling (Bataineh 2008) modified by author

Environmental issues:

• The disposal of the excavated material is a matter of considerable importance. It needs to be explored by the owner prior to inviting tenders. The spoil disposal is a complex problem in mountainous countries, and where there are strict environmental restrict

ions;

• Environmental aspects of the construction area (traffic, noise, dust, vibrations, and effect of climatic conditions) are sources of uncertainty/risk;

• Site specific conditions (including the nature of the ground) will affect the transmission of noise and vibration. Limits on vibration are based on the combination of particle velocity and frequency at the affected point, related to risk of annoyance or causing structural damage. Vibrations caused by mechanical tunneling plant, establishing personal sensitivities to vibration, are described by. For Metro tunnels, the transmitted vibrations during operation need to be limited;

• Compressed air is a tunneling technique which has declined in recent years

due to medical concerns (Wood 2000). The containment of compressed air depends

on the degree of homogeneity and continuity of the ground. Effects of compressed air or chemical agents traveling through the ground provide additional concerns. Another feature associated with compressed air arises when the air (driven through organic and chemically soils) causes deoxygenating (Hillier 1997).

Compatibility with adjacent facilities:

• Compatibility of schemes with planned subsurface structures is other source

of uncertainty/risk (Tversky 1972);

• Different tunneling techniques offer different (and limited) internal cross sections (Wood 2000). For instance, a drill-and-blast tunnel (using several support elements) may require consider provisions for local enlargements and it should not be a problem. In contrast, a TBM tunnel, the problems are more

complex, particularly where a segmental lining is employed in water-bearing ground;

• Ground movement may cause a direct damage: the costs of rebuilding in finding alternative solutions are likely high.

Continuity from design through construction:

• Continuity and coordination throughout the processes of design an construction are required. For instance, conceptual design and construction in New Austrian Tunneling Method (NATM) projects are particularly interdependent: the project success requires that conceptual design must be rigorously implemented during construction;

• The increasing diversity of construction methods (and their dependence on particular characteristics of the ground) is setting construction in a more prominent and interactive position in the whole design process;

• Project design may depend critically on an assumed spacing between parallel tunnels. However, the spacing assumed prior to detailed consideration for the scheme of construction may eliminate what would be the most economic means of construction ;

Deterioration

• Certain hazards may only become apparent when the tunnel is already in service. There are many examples of natural deterioration with time due to undetected factors: particularly aggressive groundwater. "Corrosion of reinforced concrete tunnel linings by saline water" (Wood 2000) needs to be considered;

• Bopeep Tunnel provides an example of a tunnel collapse when remedial work was not undertaken on time (Wood 2000);

• Swelling potential of gypsum may result in an increase of volume of about 60%. The most common form of swelling damage is "invert heave".

2.4 METRO CONSTRUCTION

Metro projects are the most modern solution for urban transportation problems while reducing the environmental impacts, underground transportation projects reduce carbon dioxide emission, and lessens the travel duration while increases the comfort of the journey. Thanks to high capacity and frequency underground transportation networks, metropolitan citizens can efficiently commute between locations.

2.4.1 Structure of Metro Project

Metro projects are composed of different aspects and have complex processes. The WBS of a finished metro system is shown on Figure 2.14

These are;

- Stations
- Tunnels
- General Control Systems
- Railway
- Operation Maintains and Storage Facilities
- Emergency Systems

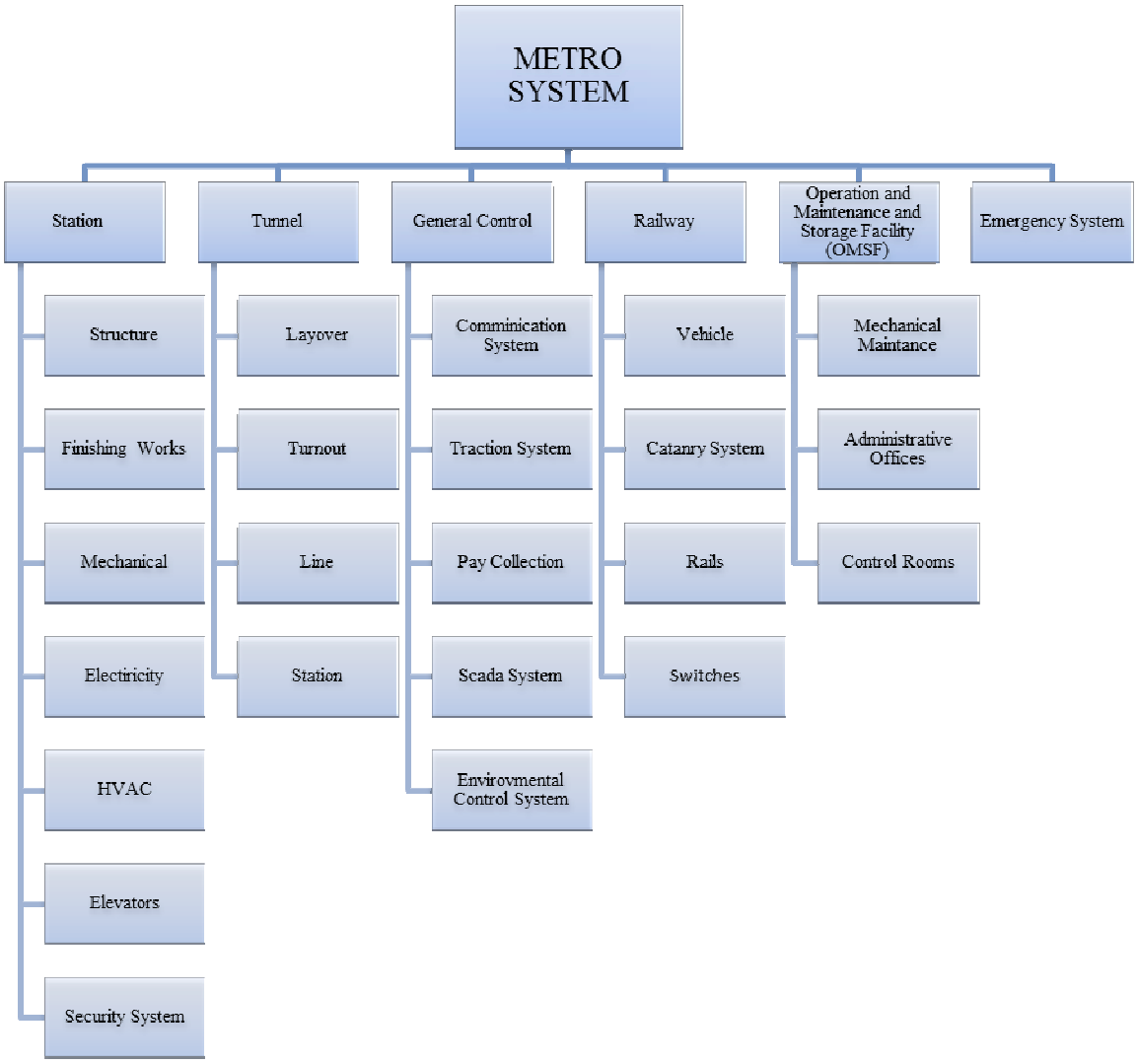


Figure 2.15 Metro System WBS (Prepared from tender documentation of Kadıkoy Kartal Project)

2.4.2. Importance of Tunnel Excavation in a Metro Project

Preconstruction; during this step, the project team discusses all issues related to project construction and proposes a number of scenarios to execute the project. These scenarios are then evaluated based on number of criteria, such as production, cost, schedule, Conformity, etc.

Tunnel excavations are generally the most risky activities in metro construction. A tunnel excavation affects the budget and duration. In planning phase mile stones generally described by tunnel excavation.

When the tender estimation is examined, tunnel works is the %45 of the main work load on Kadıköy-Kartal Metro Project. On tender specifications, it is asked from the companies to have compliance certificate. Two different types of excavation methods are used commonly in tunneling. These are Tunnel Boring Machine (TBM) and New Austrian Tunneling Method (NATM).

The method chosen can affect the project finishing time and project budget. Table 2.3 shows the metro constructions on different locations with cost per km, period of time and method used.

2.4.3 Overview of Metro Projects

In this section some important metro projects around the world are selected to give a general view of duration and cost rates of the projects. The range of duration of a metro project may differ with respect to many factors. In selected metro projects in the table, costs per kilometer is between 40 and 400 million US Dollars. Among these Kadıköy-Kartal Metro Project is the most efficient project having the shortest duration with very smallest cost of 44 million US Dollars. Moreover it is the only project by which both NATM and TBM methods are simultaneously used in line tunnels.

Table 2.3 Metro projects with cost per km and duration (Relly) modified by author

Project	Station	Length(km.)	Duration(yrs.)	Rate km/yrs.	Cost (M.US.$/Km)	Tunneling Method
London Jubilee	11	16	9	1,8	375	TBM
Athens Metro	21	18	12	1,5	156	TBM
Lisbon	18	37.5	8	2,2	69	TBM
Kadıköy Kartal	***16***	***21***	***3***	***7,3***	***44***	***NATM TBM***
Izmir Metro	13	11,6	5,5	2,1	51,62	TBM
Taksim Hacıosman	11	20,5	13	1.58	55	NATM

3.CASE STUDY: KADIKOY KARTAL METRO PROJECT

3.1 ISTANBUL AND METRO

Istanbul, a mega-city of over 13 million (nearly 20% of the national population) plays a vital role in Turkey's economic and social life, producing about 27% of the national GDP, generating around 40% of national taxes and accounting for half of all Turkish exports.(URL-3 2011) Population growth in the City has been one of the highest among large The Organization for Economic Co-operation and Development (URL5) metro-regions. Metropolitan Municipality of Istanbul, one of the largest of Turkey's 16 metro municipalities, is the local government body responsible for providing city-wide infrastructure services, including public transport, to the metropolitan area.

In Istanbul, after removal of the tram voyages in 1966 (URL-4 2011) land transportation became insufficient due to the rapid growth of the population, caused by the immigration. In metropolitan cities all over the world, generally, efficiency of the railway systems are measured and monitored considering the percentage of the railway transportation to total transportation. According to the data of the last couple of years, these rates were; 60% for Tokyo, 31% for New York, %25 for Paris, 22% for London, while it was 3,6% in Istanbul (URL-2 2011). These numbers clearly shows that, in Istanbul, considering the opportunities that are supplied to the public in utilization of railways in daily transportation, there is a deficiency in metro transportation.

Since railway transportation is fast, economic, safe, environmental-friendly and contemporary systems, for Istanbul as well as the other metropolitan cities are the firstly thought solutions for in-city transportation problems.

3.2 RAILED SYSTEMS AND THEIR PRIORITIES IN ISTANBUL

In Istanbul, a total of 177 km long new railed system line is required to be built, this being 89 km metro and 88 km of light metro. In case such projects are implemented,

the present railed system network of 97 km long in Istanbul will increase up to 274 km. Construction of the 22 km long light metro line in addition to these lines should be considered as depending on the future development of the trip demands.

The priorities of the railed system have been completed and planed by IBB as follows(Figure 3.1);

From 1986 to 2010 constructed metros in Istanbul;

- 20,3 km.'lik Aksaray-Havalimanı Light Railway,
- 3,9 km.'lik Topkapı-Zeytinburnu Light Railway,
- 8,5 km.'lik Taksim-4.Levent Metro ,
- 0,64 km.'lik Taksim-Kabataş Funikuler System,
- 5,12 km'lik Zeytinburnu-Güngören-Bağcılar Light Railway,
- 6,77 km'lik 4.Levent-Darüşşafaka Metro Line,
- 1,65 km.'lik Taksim-Şişhane Metro Line,
- 1,67 km.'lik Sanayi – Seyrantepe Metro Line.

On construction lines in Istanbul;

- 3,7 km.lik Şişhane–Yenikapı Metro Line,
- 0,7 km'lik Aksaray–Yenikapı Light Metro to Metro Connection Line,
- ***21,7 km.lik Kadıköy-Kartal Metro Hattı*, *16 Stations***
- 4,5 km.lik Kartal-Kaynarca Metro Line, 4 Stations
- 1,35 km'lik Darüşşafaka –Hacıosman Metro Line.

New Projects which will wating for tender in Istanbul;

Üsküdar-Ümraniye-Çekmeköy Metro Line : 20 Km. 17 Stations

Bakırköy İDO Sahili-Bağcılar (Kirazlı) Metro Line : 9 Km. 8 Stations

Kabataş-Beşiktaş-Alibeyköy-Mahmutbey Metro Line : 25 Km. 19 Stations

Bakırköy- Beylikdüzü Metro Line : 25 Km. 18 Stations

Yenikapı – İncirli Metro Line : 7 Km. 6 Stations

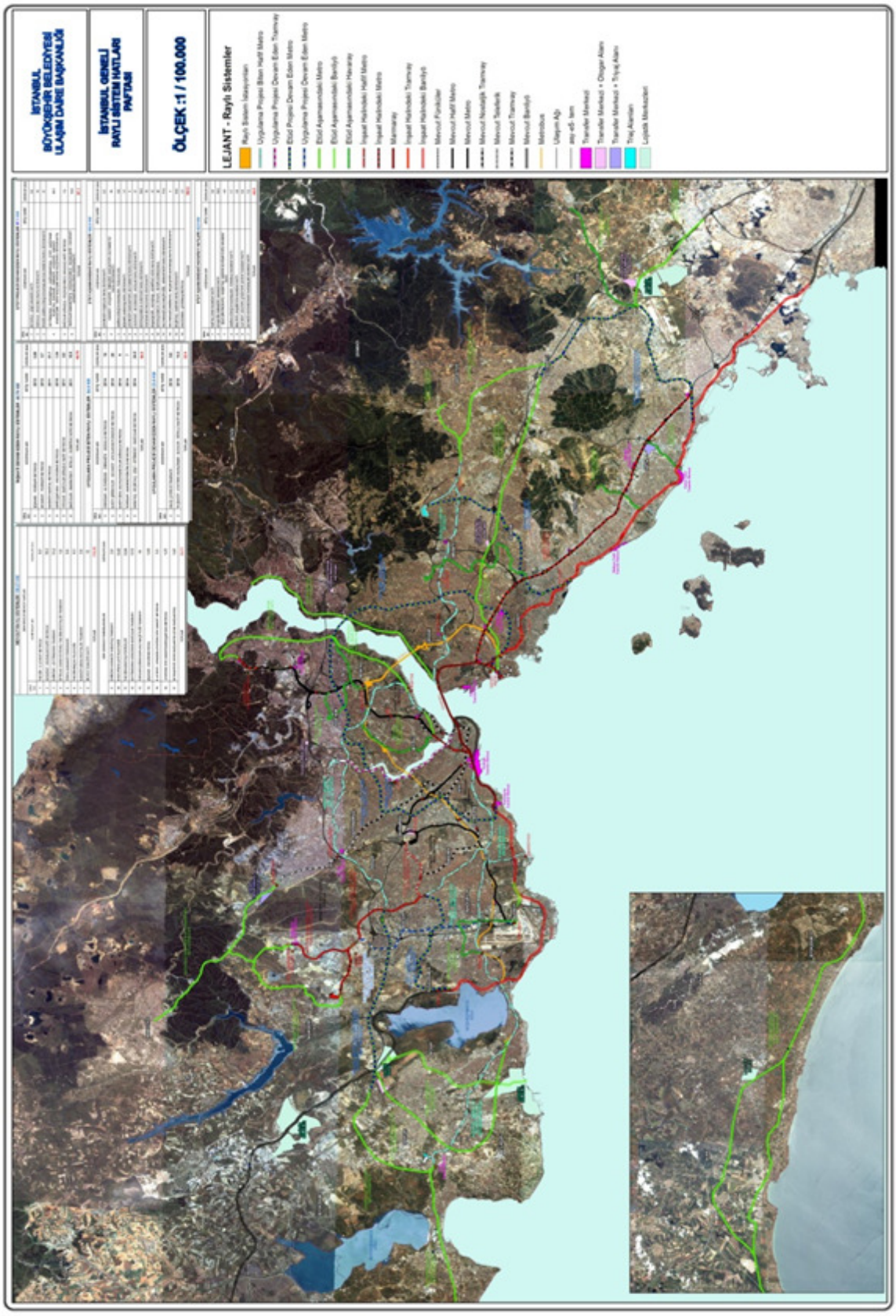


Figure 3.1 Istanbul Metro System And Planned Lines

3.3 CASE STUDY PROJECT OVERVIEW

Project Name: *Kadikoy-Kartal Metro Completion Construction, Electro Mechanic Systems Supply, Montage And Operation Project*

Location of the project in the city of Istanbul is given in the Figure 1, line cross section and plans are given in Figure 3.1.

Figure 3.2 General Overview of Project

3.3.1 Project History

Kadıköy-Kartal Metro Line was tendered for the first time on 30.12.2004 by the IETT (Istanbul Electric Tramway And Tunnel Establishments). The Contract was awarded to Yapı Merkezi-Doğuş-Yüksel-Yenigün-Belen Construction J.V, named "Anadolu Ray Consortium on 28.01.2005. The scope comprised an underground tunnel between Kadıköy-Acıbadem connected to a Light Railway System towards Kartal. The first contract value was 135 million USD. Anadolu Ray began the works on 11.02.2005.

The Tender was handed over to the Istanbul Municipality (IBB). Due to the decision of the local authorities and universities report, the full scope in underground and the contractual amount is increased. According to the new Bid Law, IBB had to re-tender the Project due to the new scope.

Istanbul Greater Metropolitan Municipality (IBB), decided to construct a railway transportation system in line with the D-100 motorway, which is one of the most important arterials. This direction is currently utilized for daily in-city traffic between Gebze - Kartal - Maltepe - Göztepe – Harem instead of intercity transport.

For this purpose, IBB, Transportation Division, Railway System Directorate is tendered the construction works to Avrasya Metro Group Joint Venture (Astaldi-Makyol-Gülermak Ortak Girişimi) which proposed the most appropriate proposal.

The scope of construction tender is consisted of, construction of all of the tunnels, direction structures, basic construction works of the station buildings, rail placement works, and construction of storage area and workshops. The scope of this project can be summarized as; construction and operation of the railway public transportation including 43,447 km tunnel alignment respectively divided as right alignment 21,694 km, left alignment 21,753 km as well as 16 metro station buildings construction 3 layover place and 5 turnout structures.

The project is planned to be operated in 30 months. The flow chart, capacity, total area, used technology, the number of personnel that will work at the planned facility are planned by the Avrasya Metro Group Joint Venture which is the contractor of the work. This Project forms the most important part of the Istanbul Anatolian side Metro system.

The project covers construction and operation works of the Kadıköy-Kartal Metro Line. It is planned to be a total of 16 station and 1 storage facility in this line which is approximately 21.4 km length.

3.3.2 Technical Specifications of the Project

Maximum capacity of the system is 65,000 (passenger/direction/hour). This shows that, this project will considerably decrease the traffic and air pollution problems of Istanbul.

In tunnel construction and excavation works will be precede simultaneously with the tunnel construction. Explanations of construction of tunnels can be found excavation section. Thus, it is not reiterated here. In stations, after the excavations, construction works will be proceeding in conventional manner in two stages: rough and finishing works. Electro-magnetic equipment will be installed during finishing works.

All of the underground stations are designed to allow receiving the metro 185 m length.

Total construction duration is planned to be 30 months. General framework of the project contract is given below:

All of the 16 stations will be underground. All of them will be constructed as tunnel yet its components such as ticket halls and entrance exits will be built with open/close method.

The alignment which is 43,447 km tunnel alignment respectively divided as right alignment 21,694 km, left alignment 21,753 km as well as 16 metro station buildings construction 3 layover place and 5 turnout structure. The alignment (see figure 3.2) between Kadıköy and Kartal will cross the following station structures:

Kadıköy, Ayrılıkçeşme, Acıbadem, Ünalan, Göztepe, Yenisahra, Kozyatağı, Bostancı, Küçükyalı, Maltepe, Huzurevi, Gülsuyu, Esenkent, Hastahane-Adliye, Soğanlık, Kartal.

3.3.3 Geological Conditions of Kadıköy Kartal Metro Project

In tunnel works geological condition is most effective on speed of construction. KADIKOY-KARTAL Metro Project will be carried in the entire Paleozoic (Lower Ordovician-Lower Carboniferous) ancient sedimentary which forms the geological foundation of Kocaeli Peninsula (From İzmit to the Bosporus access).

Being set-up from rock groups with various different characters-qualities the undulated structure of the solid units forming the Paleozoic ancient sedimentary exhibits an heterogeneous geological structure along the Metro Alignment due to the reason that these cut each other and are being cut by volcanic rocks with faults and contact borderlines of different groups of rocks.

The alignment passes through various local formations known as the Kartal formation (shale /limestone), Kurtkoy formation (sandstone conglomerates), Dolayoba formation (Limestone), Aydos formation (Quartzsite) and Gözdağ formation (Laminated mudstone).

In this study we focused between Altayçeşme Layover tunnel to Kartal Station tunnel in terms of works schedules.

The rock quality classification varies from “poor” to “good” (medium rock conditions) in this study. (table3.1) Study area formation listed on Table 3.1 and Figure 3.3

Table 3.1 The Geological Conditions of The Case Study.**(Geological Rep.)**

		Geological Condition		
Ch. Between	RQD	Poor	Medium	Good
8+600~13+170	80%			
13+170~15+170	50%			
15+170~16+000	20%			
16+000~21+780	80%			

3.4 MODEL INPUTS

In this Case study Altayçeşme Layover to Kartal Station (13+740-21+700) is taken into consideration. The work program for HAT1 (right side tube) in between Altayçeşme to Kartal is prepared according to construction by different tunneling methods.

Parameters assumed in work schedule preparation are;

Tunnel Boring Machines are used only in line tunnels[4].

TBM may commence on 6th month after purchase order [5]

TBM has to wait for layover, turnover, and excavation works of station tunnels done by NATM.

NATM excavation works can start after the shaft excavation and approach tunnel construction is finished.

The concrete works in NATM tunnels can start after the TBM’s part is finished[6].

[4] TBM has just one diameter and it couldn’t change by type of tunnel.
[5] This duration is the earliest duration given by manifactures.

The data for Rate of propagation in NATM and TBM tunnels are taken from the excavation cycle which is calculated by geological conditions and tunnel types.

In both methods, the rate of propagation is acknowledged as 2 work shifts (24 hours)

3.5 TUNNEL SPECIFICATIONS AND DURATION OF EXCAVATION ESTIMATING OF CASE STUDY

In this section actual and planned average excavation speed according to ground type have been evaluated by tunnel site reports and calculated from projects.

3.5.1 NATM Tunnel Specifications and Production Cycle

In case study, there are 3 types of NATM Tunnel Section, including line tunnels (A2.2 section), Station Tunnels (P1 Section) and Layover and Turnover Tunnel (T1.2 Section). The specifications of NATM Tunnel Sections are listed table 3.3 below;

Turnover tunnels and line tunnels sections are differ from each other in the project. The excavation speeds can be changed due to ground conditions and type of tunnels.

The list of tunnels location NATM tunnels given below (for detail, see table 3.22):

Table 3.2 Chainage of ,P1 and T1.2 type tunnels

LOCATION	Ch.	LOCATION	Ch.
MALTEPE LAYOVER(T1.2)	13+740	HASTAHANE STATION(P1)	18+276
MALTEPE STATION(P1)	14+249	SOGANLIK LAYOVER(T1.2)	18+803
HUZUREVI STATION(P1)	15+171	SOGANLIK STASTION(P1)	19+541
HUZUREVI TURNOVER(T1.2)	15+679	KARTAL TURNOVER(T1.2)	20+560
GULSUYU STATION(P1)	16+116	KARTAL STATION(P1)	21+270
CEVIZLI STATION(P1)	17+174		

[6] TBM has its own supplier systems through the excavation line and during TBM operating NATM works can not continue on this excavation line.

Table 3.3 Project NATM Tunnels and Material Resources

<				
Work Defination	Qnty.	Tunnel Type		
		A2.2	P1	T1.2
Excavation	m³	38,83	73,60	171,72
Shotcrete (d=25)	m²	24,10	30,86	55,02
Wiremesh	Kg	98,26	298,22	598,55
Rock Bolt	no	6,00	11,00	32,00
Steel Rib	Kg	155,63	235,82	1132,00
Forepoling	no	6,50	14,50	35,00
Formwork	m²	13,25	20,05	35,50
Tunnel Invert Concrete	m³	8,90	12,70	35,18
Concrete reinforcing bar	tons	0,65	1,00	3,50
Water Shield	m²	20,97	28,90	45,74
Water Keeper	m	5,26	4,90	10,72

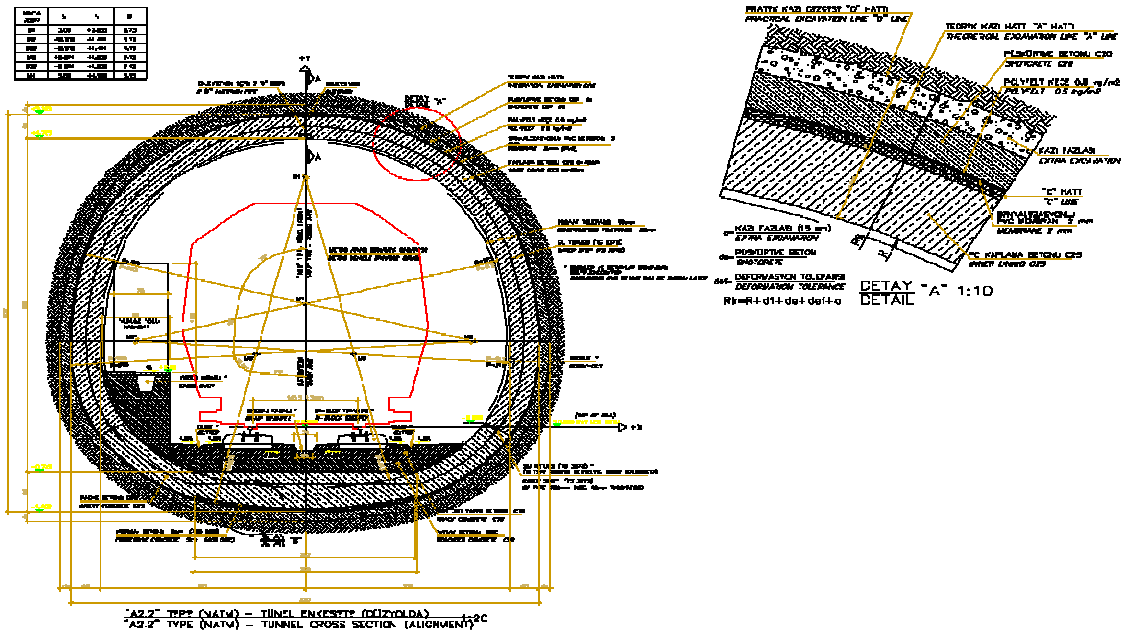


Figure 3.4 NATM Line Tunnel Section Type A2.2

Table 3.4 Production cycle of tunnel type A2.2 in poor ground condition

A2.2 Tunnel Producing Cycle at Poor Ground (per 1 mt)			
Work Definition	Unit	Qty.	Duration (hr.)
Excavation	m^3	38,83	6,0
Shotcrete (d=25)	m^2	24,1	6,0
Wiremesh	kg	98,26	2,0
Rock Bolt	no	6	2,0
Steel Rib	tons	155,63	1,0
Forepoling	no	6,5	3,0
Total Excavation Duration			20,0
Formwork	m^2	13,25	0,2
Tunnel Invert Concrete	m^3	8,9	0,5
Concrete reinforcing bar	tons	0,65	1,0
Water Shield	m^2	20,97	0,2
Water Keeper	m	5,26	0,1
Total Formwork Duration			2,0

Table 3.5 Production cycle ofs tunnel type a2.2 in medium ground condition

A2.2 Tunnel Producing Cycle at Medium Ground (for 1 mt)			
Work Definition	Unit	Qty.	Duration (hr.)
Excavation	m^3	38,83	4,0
Shotcrete (d=25)	m^2	24,1	3,0
Wiremesh	kg	98,26	2,0
Rock Bolt	no	6	2,0
Steel Rib	kg	155,63	1,0
Forepoling	no	6,5	2,0
Total Excavation Duration			14,0
Formwork	m^2	13,25	0,2
Tunnel Invert Concrete	m^3	8,9	0,5
Concrete reinforcing bar	tons	0,65	1,0
Water Shield	m^2	20,97	0,2
Water Keeper	m	5,26	0,1
Total Formwork Duration			2,0

Table 3.6 Production cycle of type A2.2 at good ground condition

A2.2 Tunnel Producing Cycle at Good Ground (for 1 mt)			
Work Definition	Unit	Qty.	Duration (hr.)
Excavation	m^3	38,83	3,0
Shotcrete (d=25)	m^2	24,1	3,0
Wiremesh	kg	98,26	2,0
Rock Bolt	no	6	1,0
Steel Rib	kg	155,63	1,0
Forepoling	no	6,5	1,0
Total Excavation Duration			11,0
Formwork	m^2	13,25	0,2
Tunnel Invert Concrete	m^3	8,9	0,5
Concrete reinforcing bar	tons	0,65	1,0
Water Shield	m^2	20,97	0,2
Water Keeper	m	5,26	0,1
Total Formwork Duration			2,0

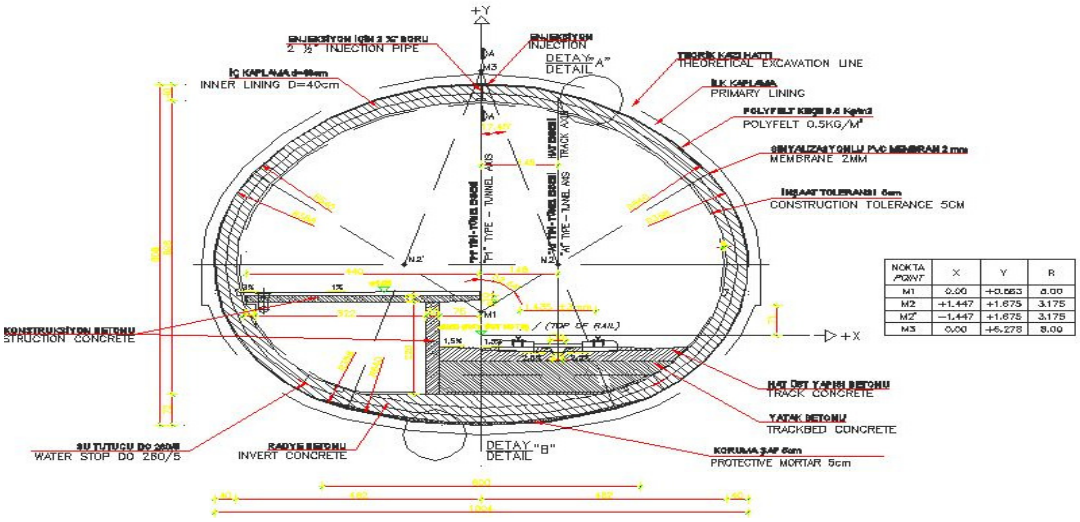


Figure 3.5 NATM Line Tunnel Section Type P1

Table 3.7 Production Cycle of Type P1 in good ground condition

P1 Tunnel Producing Cycle at Poor Ground (for 1 mt)			
Work Definition	Unit	Qty.	Duration (hr.)
Excavation	m³	73,6	9,0
Shotcrete (d=25)	m²	30,86	5,0
Wiremesh	kg	298,22	3,0
Rock Bolt	no	11	2,0
Steel Rib	kg	235,82	2,0
Forepoling	no	14,5	3,0
Total Excavation Duration			24,0
Formwork	m²	20,05	1,0
Tunnel Invert Concrete	m³	12,7	1,0
Concrete reinforcing bar	tons	1	1,0
Water Shield	m²	28,9	0,5
Water Keeper	m	4,9	0,5
Total Formwork Duration			4,0

Table 3.8 Production Cycle Of Type P1 In Good Ground Condition

P1 Tunnel Producing Cycle at Medium Ground (for 1 mt)			
Work Definition	Unit	Qty.	Duration (hr.)
Excavation	m^3	73,6	8,0
Shotcrete (d=25)	m^2	30,86	4,0
Wiremesh	kg	298,22	2,0
Rock Bolt	no	11	2,0
Steel Rib	kg	235,82	2,0
Forepoling	no	14,5	2,0
Total Excavation Duration			20,0
Formwork	m^2	20,05	1,0
Tunnel Invert Concreate	m^3	12,7	1,0
Concrete reinforcing bar	tons	1	1,0
Water Shield	m^2	28,9	0,5
Water Keeper	m	4,9	0,5
Total Formwork Duration			4,0

Table 3.9 Production Cycle of Type P1 in Good Ground Condition

P1 Tunnel Producing Cycle at Good Ground (for 1 mt)			
Work Defination	Unit	Qnty.	Duration (hr.)
Excavation	m^3	73,6	4,0
Shotcrete (d=25)	m^2	30,86	3,0
Wiremesh	kg	298,22	1,5
Rock Bolt	no	11	1,0
Steel Rib	kg	235,82	1,5
Forepoling	no	14,5	1,0
Total Excavation Duration			12,0
Formwork	m^2	20,05	1,0
Tunnel Invert Concreate	m^3	12,7	1,0
Concrete reinforcing bar	tons	1	1,0
Water Shield	m^2	28,9	0,5
Water Keeper	m	4,9	0,5
Total Formwork Duration			4,0

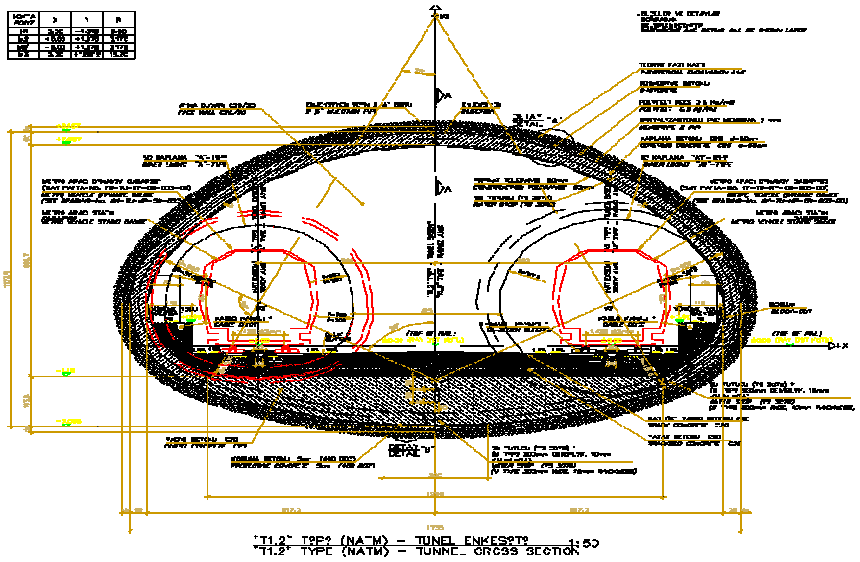


Figure 3.6 NATM line tunnel section type T1

Table 3.10 Production cycle of type T1 in poor ground condition

T1.2 Tunnel Producing Cycle at Poor Ground (for 1 mt)			
Work Definition	Unit	Qty.	Duration (hr.)
Excavation	m³	171,72	18,0
Shotcrete (d=25)	m²	55,02	10,0
Wiremesh	kg	598,55	6,0
Rock Bolt	no	32	4,0
Steel Rib	kg	1132	4,0
Forepoling	no	35	6,0
Total Excavation Duration			48,0
Formwork	m²	35,5	1,0
Tunnel Invert Concrete	m³	35,18	2,0
Concrete reinforcing bar	tons	3,5	2,0
Water Shield	m²	45,74	0,5
Water Keeper	m	10,72	0,5
Total Formwork Duration			6,0

Table 3.11 Production cycle of type T1 in medium ground condition

T1.2 Tunnel Producing Cycle at Medium Ground (for 1 mt)			
Work Definition	Unit	Qty.	Duration (hr.)
Excavation	m^3	171,72	8,0
Shotcrete (d=25)	m^2	55,02	6,0
Wiremesh	kg	598,55	3,0
Rock Bolt	no	32	2,0
Steel Rib	kg	1132	3,0
Forepoling	no	35	2,0
Total Excavation Duration			24,0
Formwork	m^2	35,5	1,0
Tunnel Invert Concrete	m^3	35,18	2,0
Concrete reinforcing bar	tons	3,5	2,0
Water Shield	m^2	45,74	0,5
Water Keeper	m	10,72	0,5
Total Formwork Duration			6,0

Table 3.12 Production cycle of type P1 in good ground condition

T1.2 Tunnel Producing Cycle at Good Ground (for 1 mt)			
Work Definition	Unit	Qty.	Duration (hr.)
Excavation	m³	171,72	8,0
Shotcrete (d=25)	m²	55,02	6,0
Wiremesh	kg	598,55	3,0
Rock Bolt	no	32	2,0
Steel Rib	kg	1132	3,0
Forepoling	no	35	2,0
Total Excavation Duration			24,0
Formwork	m²	35,5	1,0
Tunnel Invert Concrete	m³	35,18	2,0
Concrete reinforcing bar	tons	3,5	2,0
Water Shield	m²	45,74	0,5
Water Keeper	m	10,72	0,5
Total Formwork Duration			6,0

Table 3.13 Production capacity of NATM tunnel type according to ground condition

NATM Tunnel Excavation Speed For Models (mt./day)			
Geo. Cond.	A2.2	P1	T1.2
Poor	1,2	1	0,5
Medium	1,7	1,12	1
Good	2,2	2	1,5

Table 3.14 Concrete cycle of tunnel type according to ground condition

NATM Tunnel Formwork Speed For Models (mt./d)			
Geo. Cond.	A2.2	P1	T1.2
Poor	12	6	6
Medium	12	6	6
Good	12	6	6

3.5.2 TBM Tunnel Specifications and Production Cycles

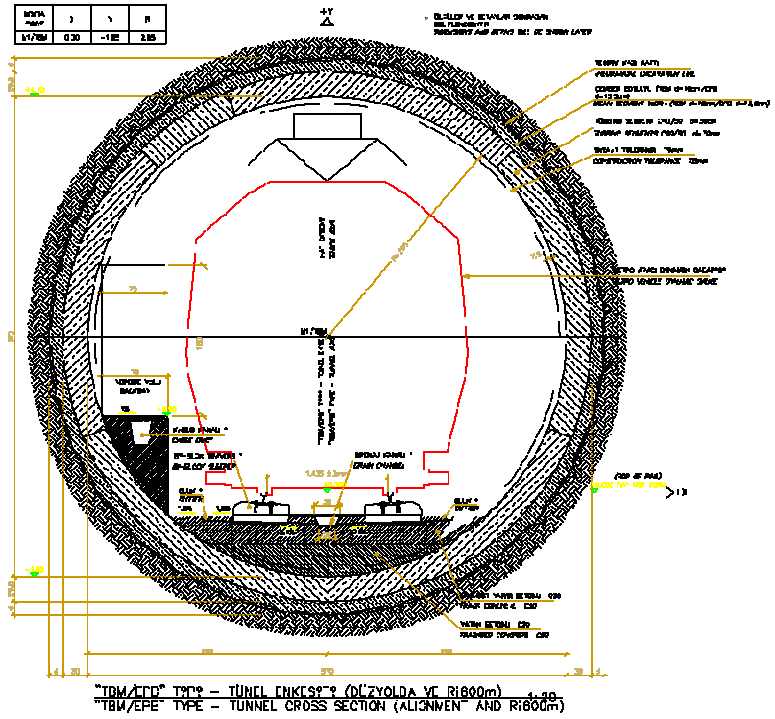


Figure 3.7 TBM line tunnel section type A1

Table 3.15 Production Cycle Of Type A1 At Good Ground Condition

A1.1 TBM Tunnel Producing Cycle (per 1.5 mt)	
Work Definition	Duration (min)
Boring	30
Install a initial support	15
Install final lining	30
Survey position and location	15
Total Duration	90

Table 3.16 NATM Tunnels Types location and distance in the Time Chainage Graphic

Tunnel Type	From	To	Dıstance	Durations(day)		
	LOCATION			Excavation		Formwork
T1.2	13740	13575	165		165	28
S13 Shaft	13740			50		
T1.2	13740	14010	270		270	45
Line(A1-Line(A1-Line(A1-A2.2)))	14010	14249	239		141	20
Maltepe Station	14249	14283	34		24	6
S14 Shaft	14283			50		
Maltepe Station	14283	14512	229		164	38
Line(A1-Line(A1-A2.2))	14512	15165	653		384	54
S15 Shaft	15165			50		
Line(A1-Line(A1-A2.2))	15165	15171	6		5	1
Huzurevi Station	15171	15429	258		258	
Line(A1-Line(A1-A2.2))	15429	15679	250		208	21
T1.2	15679	15720	41		82	7
S15 B	15720			50		
T1.2	15720	15805	85		170	14
Line(A1-Line(A1-A2.2))	15805	16116	311		259	26
Gulsuyu Station	16116	16377	261		131	44
S16 Shaft	16377			50		
Line(A1-Line(A1-A2.2))	16377	16874	497		226	41
S17A	16874			50		
Line(A1-Line(A1-A2.2))	16874	17174	300		136	25
Cevili Station	17174	17404	230		115	38
Line(A1-Line(A1-A2.2))	17404	17489	85		43	14
S17 Shaft	17489			50		
Line(A1-Line(A1-A2.2))	17489	18276	787		358	66
S17B				50		
Hastahane Station	18276	18373	97		49	16

S18 Yaklaşım	18373			50		
Hastahane Station	18373	18559	186		93	31
Line(A1-Line(A1-A2.2))	18559	18803	244		111	20
T1.2	18803	18878	75		50	13
S18A	18878			50		
T1.2	18878	19233	355		237	59
Line(A1-Line(A1-A2.2))	19233	19265	32		15	3
S18B	19265			50		
Line(A1-Line(A1-A2.2))	19265	19541	276		125	23
Soğanlık Station	19541	19750	209		105	17
S19 Shaft	19750			50		
Soğanlık Station	19750	19765	15		8	3
Line(A1-Line(A1-A2.2))	19765	20560	795		361	66
T1.2	20560	20679	119		79	20
Yaklaşım	20679			50		
T1.2	20679	20841	162		108	27
Line(A1-Line(A1-A2.2))	20841	21270	429		195	36
Kartal Station	21270	21533	263		132	44
Line(A1-Line(A1-A2.2))	21533	21624	91		41	8
S20B	21624			50		
Line(A1-Line(A1-A2.2))	21624	21700	76		35	6

Geo. Cond.
Poor
Medium
Good

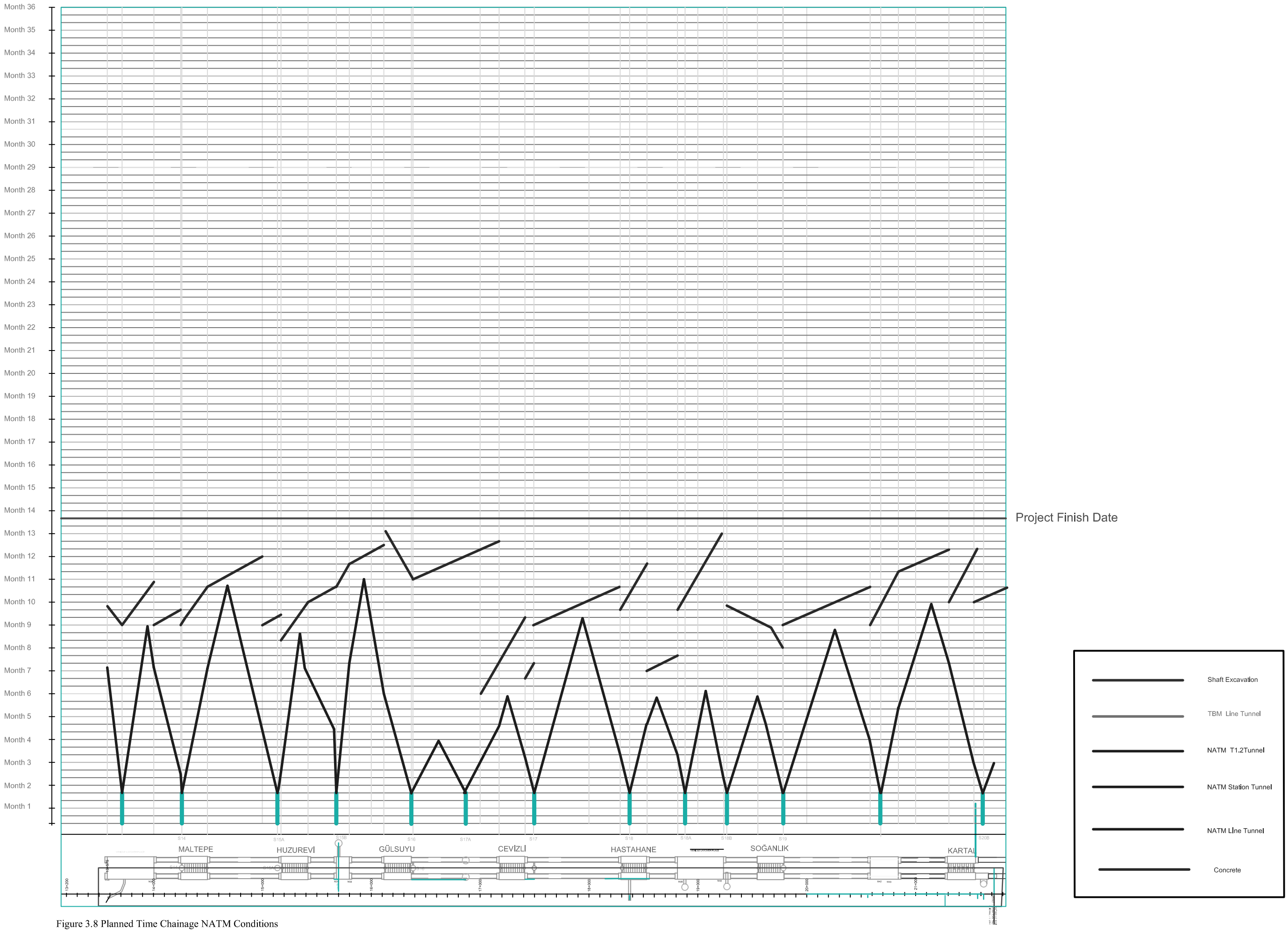


Figure 3.8 Planned Time Chainage NATM Conditions

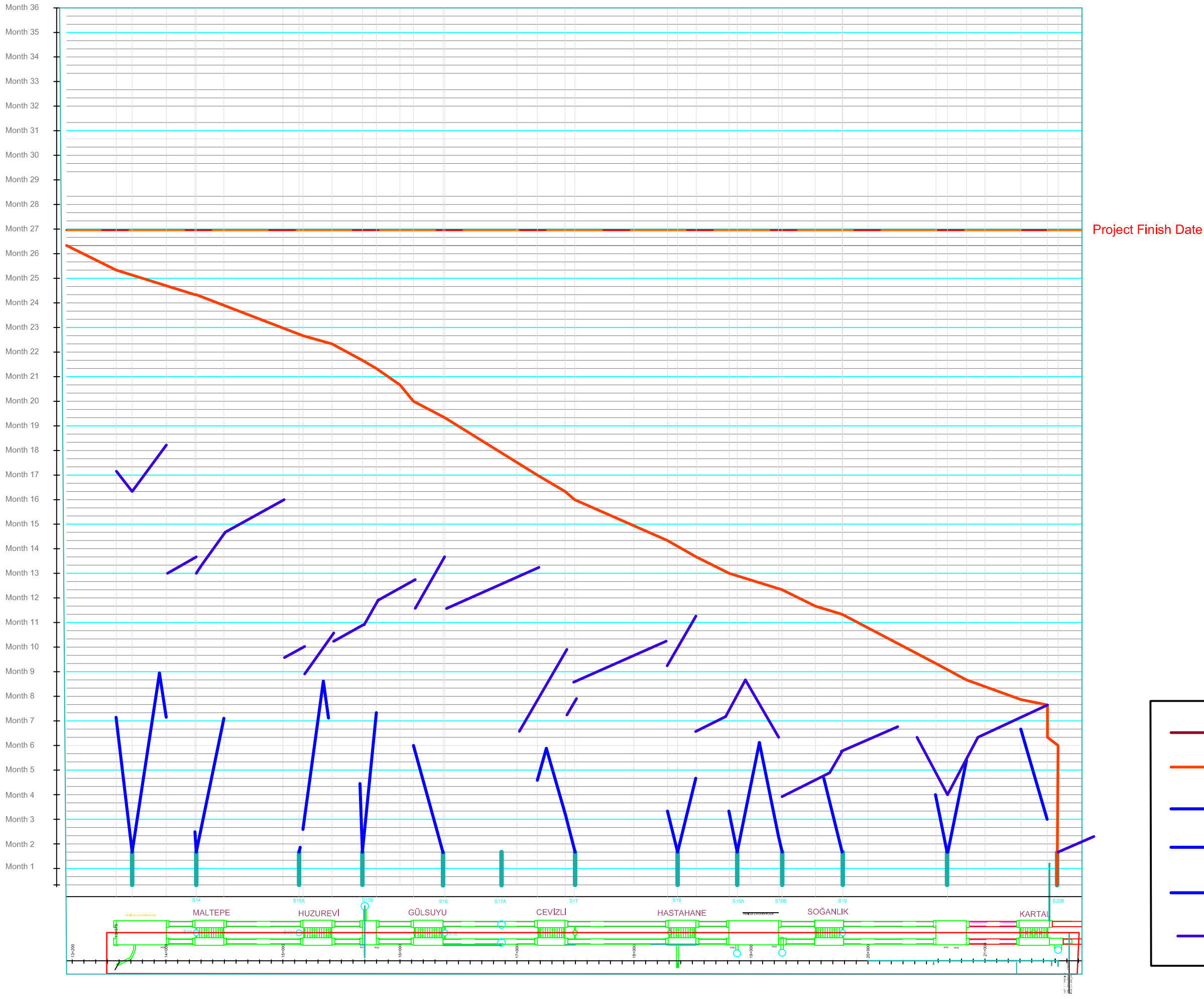


Figure 3.9 Planned Time Chainage TBM Conditions

3.5.3 Tunneling Speeds of NATM and TBM acquired from the Actual Data of the Case Study

The NATM and TBM excavation speeds on three geological conditions are acquired from the progress payment and daily reports from Kadıköy-Kartal metro are shown on by poor geological condition (Table 3.17), medium geological condition (Table3.18) and good geological condition (Table3.19)

Table 3.17 Actual speed of NATM Tunnel On Poor Geological Conditions In Project

POOR GEOLOGICAL CONDITION							
Tunnel	Duration		Kilometers				
	Start	Finish	From	To	Duration	Length	Daily Avr.
T1,2	26.05.2009	03.10.2009	15678	15743	130	65	0,50
A1.1	05.09.2009	02.01.2010	15423	15597	119	174	1,46
Station	20.02.2009	17.01.2010	15227	15422	331	195	0,59

Table 3.18 Actual speed of NATM tunnel on medium geological conditions in project

MEDIUM GEOLOGICAL CONDITION							
Tunnel	Duration		Kilometers				
	Start	Finish	From	To	Duration	Length	Daily Avr.
T1,2	01.04.2009	16.12.2009	13484	13901	259	417	1,61
A1.1	28.07.2009	11.05.2010	12966	13484	287	518	1,80
Station	19.03.2009	11.01.2010	14333	14534	298	201	0,67

Table 3.19 Actual speed of NATM tunnel on good geological conditions in project

GOOD GEOLOGICAL CONDITION							
Tunnel	Dutarion		Kilometers				
	Start	Finish	From	To	Duration	Lenght	Daily Avr.
T1,2	16.03.2010	15.04.2010	20139	20169	30	30	1,00
A1.1	02.10.2009	31.10.2009	20322	20386	29	64	2,21
Station	03.08.2009	31.08.2009	21426	21485	28	59	2,11

TBM Performance

Table 3.20 Actual speed of TBM tunnel by geological conditions in project

GEOLOGICAL CONDITION							
Tunnel	Dutarion		Kilometers				
	Start	Finish	From	To	Duration	Length	Daily Avr.
A1.1 (Kozyatağı) (Poor Jeo)	31.08.2007	30.04.2008	8554	7599	243	955	3,93
A1.1 (Göztepe) (Medium)	30.06.2008	31.01.2009	7331	5711	215	1620	7,53
A1.1 (Kartal)	03.08.2009	01.06.2010	20885	26056	302	5171	17,12

Table 3.21 Actual speed of Tunnels in project

	SPEED of TUNNEL TYPES m/day			
Geological Conditions	NATM Line	NATM T1.2	NATM Station	TBM Line
Poor	0,50	0,50	0,59	3,93
Medium	1.80	1.61	0.67	7,53
Good	2,21			17,12

Table 3.22 NATM Tunnels Types Location Distance And Actual Durations In

Tunnel Type	From	To	Dıstance	Duratıons(day)		
	LOCATION			Excavation		Formwork
T1.2	13740	13575	165		103	39
S13 Shaft	13740			50		
T1.2	13740	14010	270		169	64
Line(A1-Line(A1-Line(A1-A2.2)))	14010	14249	239		133	25
Maltepe Station	14249	14283	34		49	7
S14 Shaft	14283			50		
Maltepe Station	14283	14512	229		327	44
Line(A1-Line(A1-A2.2))	14512	15165	653		363	69
S15 Shaft	15165			50		
Line(A1-Line(A1-A2.2))	15165	15171	6		4	1
Huzurevi Station	15171	15429	258		258	
Line(A1-Line(A1-A2.2))	15429	15679	250		167	26
T1.2	15679	15720	41		82	10
S15 B	15720			50		
T1.2	15720	15805	85		170	20
Line(A1-Line(A1-A2.2))	15805	16116	311		207	33
Gulsuyu Station	16116	16377	261		124	50
S16 Shaft	16377			50		
Line(A1-Line(A1-A2.2))	16377	16874	497		226	52
S17A	16874			50		
Line(A1-Line(A1-A2.2))	16874	17174	300		136	32
Cevili Station	17174	17404	230		110	44
Line(A1-Line(A1-A2.2))	17404	17489	85		40	9
S17 Shaft	17489			50		
Line(A1-Line(A1-A2.2))	17489	18276	787		358	83
S17B				50		

Hastahane Station	18276	18373	97		46	19
S18 Yaklaşım	18373			50		
Hastahane Station	18373	18559	186		89	36
Line(A1-Line(A1-A2.2))	18559	18803	244		111	20
T1.2	18803	18878	75		75	18
S18A	18878			50		
T1.2	18878	19233	355		355	85
Line(A1-Line(A1-A2.2))	19233	19265	32		15	3
S18B	19265			50		
Line(A1-Line(A1-A2.2))	19265	19541	276		125	29
Soğanlık Station	19541	19750	209		100	40
S19 Shaft	19750			50		
Soğanlık Station	19750	19765	15		7	3
Line(A1-Line(A1-A2.2))	19765	20560	795		361	84
T1.2	20560	20679	119		119	28
Yaklaşım	20679			50		
T1.2	20679	20841	162		162	39
Line(A1-Line(A1-A2.2))	20841	21270	429		195	45
Kartal Station	21270	21533	263		125	51
Line(A1-Line(A1-A2.2))	21533	21624	91		41	8
S20B	21624			50		
Line(A1-Line(A1-A2.2))	21624	21700	76		35	8

Geo. Cond.
Poor
Medium
Good

Table 3.23 Actual Site Delivery Dates

Shaft	Site Delivered Date	Start Date	Tender Date	Elapsed Time From Tender Date
S13 Yaklaşım	06.05.2008	01.09.2008	01.03.2008	2
S14	30.10.2008	01.12.2008	01.03.2008	8
S15A	03.11.2008	01.12.2008	01.03.2008	8
S15B	26.12.2008	01.02.2009	01.03.2008	10
S16	16.03.2009	01.04.2009	01.03.2008	13
S17A	20.03.2009	01.04.2009	01.03.2008	13
S17	25.11.2008	01.04.2009	01.03.2008	9
S17B	25.08.2009	01.11.2009	01.03.2008	18
S18	09.02.2009	01.09.2009	01.03.2008	12
S18A	13.11.2008	01.12.2008	01.03.2008	9
S18B	13.11.2008	01.12.2008	01.03.2008	9
S19	20.10.2008	01.11.2008	01.03.2008	8
Kartal yak.	06.05.2008	01.09.2008	01.03.2008	2
S20A&B	01.04.2009	01.05.2009	01.03.2008	13

The Time Chainage graphs acquired from the actual data are shown below:

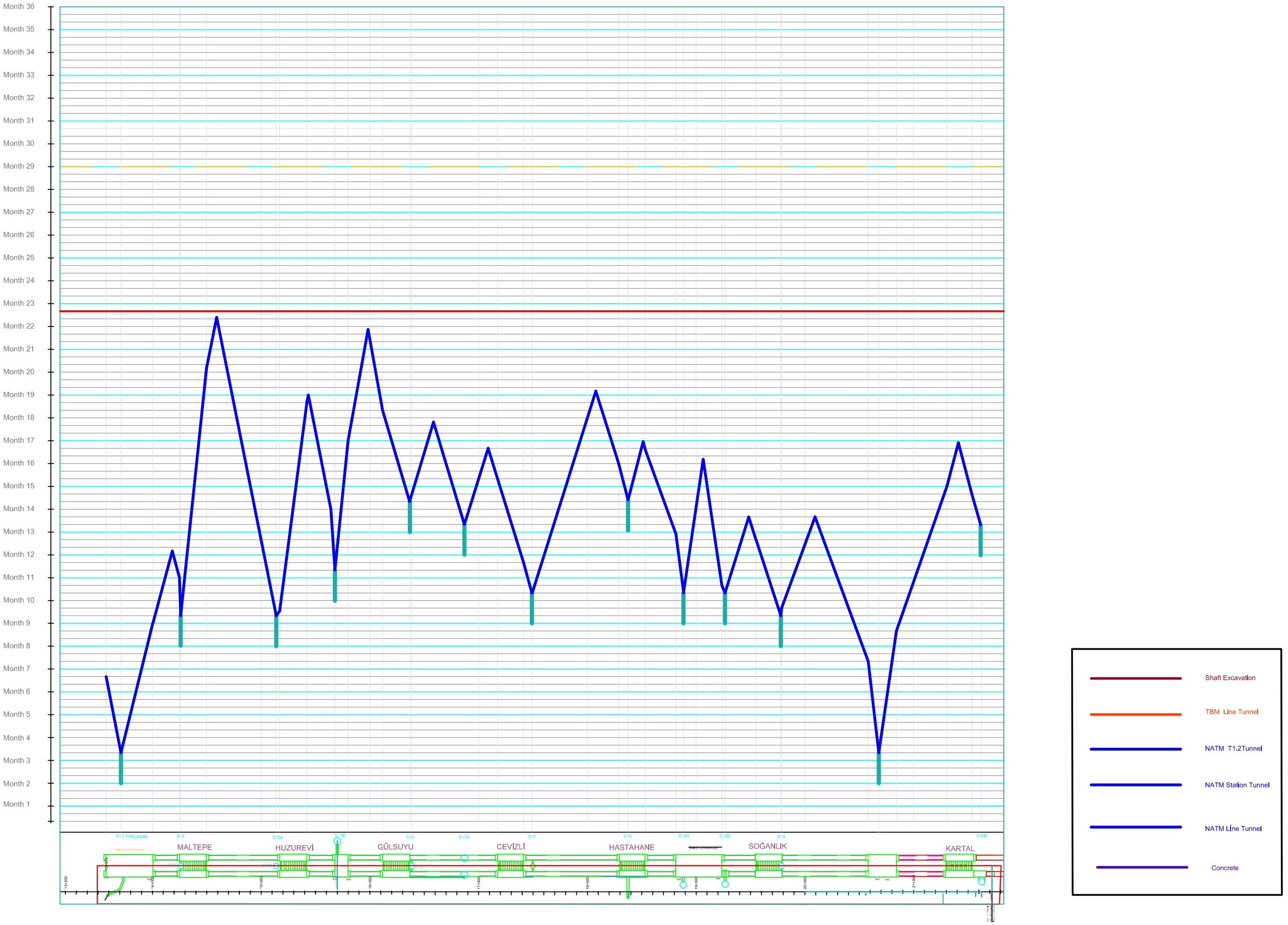


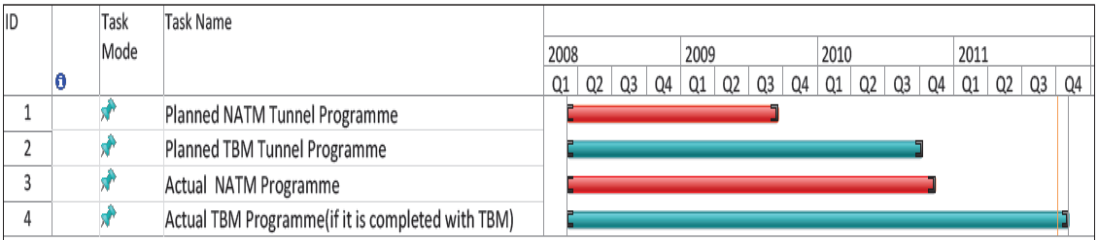
Figure 3.10 Actual Time Chainage NATM Conditions

Figure 3.11 Actual Time Chainage TBM Conditions

RESULTS

The data collected from the work progress acquired by the WBS of tunnel methods show that even though the NATM methods rate of propagation is lower than the TBM. If there is enough amount of shaft, in cases where there are different tunnel cross-sections, the tunnels constructed by NATM method finished on 13 months whereas the tunnels constructed by TBM method finished on 27 months. NATM has more advantages than TBM when we compare them.

In actual, NATM tunnels have been finished in 23.5 months (including risk and delays during commissioning) whereas with the same circumstances TBM would have been taken 32 months to finish.



When the planned and actual work programmes are compared, it has been found that there are average of 11 months difference between the two programmes. If the right method is chosen, the project completion can reduce up to 11 months as seen in the Kadıköy-Kartal Metro case study. Comparison of the two methods is shown below;

	NATM	TBM
Scope of Work	It is advantageous on projects where different types of tunnel cross sections are combined and multiple numbers of access shafts or galleries are available.	Provides high speed for single type of tunnel section. Changes in tunnel cross sections and geological conditions may bring delays or requires local NATM solutions.
Site Conditions	Equipment demand is low, adaptable to different types of site	Initial investment amount is much higher.
Time Advantage	Low speed on two direction Multiple points	High speed on one direction
Risk Analysis	High hazard risk. But easy adaptable new conditions.	Low risk and safe working environment.

Rework Analysis	High failure risk due to human oriented	Low failure risk due to machinery oriented
Supplier Availability	Requires basic suppliers. Where there is high competition about suppliers. Therefore it is easy to reach cheaper supplies.	Requires specific and technologically advanced suppliers. Therefore it is harder and expensive to supply TBM parts and consumables.
Equipment Availability	Low cost equipment and spare parts	High cost and long delivery time to the site.
Crew Availability	Applied since1972 in Turkey and expert team	Due to new technology lack of expert team
Public Input	More noise due to blasts and excavation works	Less sound due to TBM mode of operation

This result shows that the commissioning of the project is 11 months earlier than planned.

The feasibility report of IBB shows that the metro line will have 1.260.000 passenger daily in the metro line which has a capacity of 459.900.000 passenger per year capacity.

This time possession will bring 688.500.000 TL yearly income where the ticket prices are approximately 1.5 TL (URL4 2011). If the line is on 50% capacity, the income will be 481.950.000 TL. If the project commissioning is 1 year earlier than planned, with 700 personnel working with up to 70.000.000TL expenditure, the income will be 400.000.000 TL (INT).

There will be 5.5% profit which is 22.000.000 TL from interest and insurance expenditures by payment of the credit from the World Bank one year earlier. The profit from the interest can be an income for employment of 2164 people, where the minimum wage is 385 € (URL8 2011).

When we take into account the metro construction, there are a lot of benefits on the environment and pollution of like constructions. For instance Automobiles take part 24%, Minibus 26%, and bus 52% of the transportation in Istanbul (URL4 2011). The

relationship between the fuel oil consumption and people to be transported is shown in the table below:

Vehicle	Average	Number of passengers per year	Number of voyages per year
Bus(60 per)	% 52	119.327.000	1.988.783
Minibus(12 per)	% 26	59.657.000	4.971.416
Automobile (2 per)	% 24	55.068.000	27.534.000

The fuel oil savings from the 21 km route will be:

	The fuel oil consumption on 21 km route (lt)	Fuel oil saving per year (lt)	CO_2 Emission per year (ton)
Bus (0,486 lt/km)	10,26	20.404.913	59.294
Minibus (0,130 lt/km)	2,73	13.571.965	39.437
Automobile (0,07 lt/km)	1,47	40.749.980	117.617

In order to absorb this amount of CO_2 emission 649.000 trees are needed which is equivalent to 6 km² forestland (URL9 2011).

As a result of the study, it can be said that increase the investment on metro projects and the selection of appropriate construction method can contribute to environment and national economy.

CONCLUSION

Construction planning is very important for the management and execution of construction projects. A proper plan should combine the choice of technology, the definition of work tasks, the estimation of the required resources and durations for individual tasks, and the identification of any interactions among the different work tasks. All this will affect the construction plan that will be a base for developing both the budget and work schedule.

The method and techniques used during the construction process are important considerations of the proper construction plan as they will be very much effective on the work schedule and the cost. This study investigates the impact of construction methods and techniques on the schedule performance by means of the resource requirements and construction speed.

In order to complete the project on time, it is required to select the effective construction method to be conducted multi-directionally and analyze this selected method carefully. Kadıköy Kartal Metro Project has chosen as a case study to analyze the effects of construction methods on project completion time.

In tunnel projects the selected method is the most important component as it directly affects the construction duration. NATM and TBM methods are compared ,n terms of schedule performance. It is seen that if there are enough amount of shafts and different tunnel cross-sections, good planning and enough resources, the tunnels constructed by NATM method are completed the job earlier than the tunnels constructed by TBM method.

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