ASSOCIATION INTERNATIONALE DES TRAVAUX EN SOUTERRAIN
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Towards an improved use of underground Space

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Topic

UNDERGROUND AND ENVIRONMENT

Title

"Underground Works and the Environment" - Working Group 15 Final report

Author

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Abstract: -

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Remarks: This report, "Underground Works and the Environment", develops a theoretical framework and at the same time shows and analyses the results from the international survey and 13 case studies. It is structured in two parts, the main document and three annexes including summaries of answers to the questionnaire, the case studies and a glossary of environmental terms.

The main document is divided into the following chapters:

Environmental legislative framework.

This section summarizes the international opinion surveyed by the questionnaire, including the characteristics of the environmental legislation considered for underground works, the effects of the environmental legislation on different economical agents and the different ways for the new market opportunities to compensate the disadvantages of the environmental legislation.

Inventory of environmental aspects.

In this chapter an inventory of the main environmental aspects classified by inert, biotic and human media is identified.

Based upon the answers to the questionnaire, and the information received from 13 case studies of underground projects a group of the most corrective measures in order to avoid these negative effects, by proper planning or proper active restoration of natural systems and responsible use of natural resources have been identified.

Environmental benefits of underground works.

This chapter deals with three different points related to environmental benefits of underground works: reasons for the selection of the underground solution, new technologies for the construction of underground works that will mean the reduction of impacts, and future demand of underground projects under environmental considerations.

Opportunities and threats of underground works in relationship to environment

A study of the opportunities and threats of underground works in relationship to environment is included in this chapter. In order to accomplish this goal, the first part of the chapter includes several ideas related to sustainable development, underground works and environment. A second part emphasises the incidence of underground works on the environment according to the information provided by the survey for the different stages of the project: planning, construction, and operation. Finally it presents a study of the future market due to environmental implications.

Social-economic context: comparative cross-cultural study

As the result of the questionnaire sent to the ITA members countries and the collected experience with various underground related, a comparative cross-cultural study dealing with economy, social structures, underground works projects and level of development would classify the countries into two different groups. The first group would be the high-technology countries and the rest would be part of the developing ones.

Conclusions.

It remarks the main findings, general conclusions about each one of the analysed in WG15 and some recommendations to take advantage of underground works in the future under the perspective of environmental implications.

The annexes deal with the following tasks:

- A questionnaire form and a summary of the answers.
- The case studies.
- Also a glossary with environmental - tunnelling terms.

International Tunnelling Asssociation
ITA Working Group 15

"Underground Works and the Environment"

Final Report

April 1998

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INTERNATIONALE DES TRAVAUX
EN SOUTERRAIN
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FOREWORD

Environmental awareness has increased in the last few years. This environmental concern has led to the establishment of legislative and political measures to preserve the great treasure of humanity that is the nature where we live.

In the prior stages of this environmentalist process, actions were taken against those human activities that clearly attempted to the environment, such as chemical factories, industrial and nuclear wastes, etc. But the more the environmental concern has grown, the greater the number of activities that have been considered a threat for the environment. In this sense, construction activities consider more and more their environmental implications, and impact analysis and corrective measures are being applied in the more aggressive construction projects as for example dams, linear works, etc.

Within those construction activities, underground works have always stood out by themselves because of their consideration for the environment: As underground works take place inside the subsoil, they eliminate a big number of impacts that the surface alternatives produce.

However, they still produce certain impacts, especially in the construction phase, which are being mitigated with the introduction of new construction techniques. In-depth environmental analysis must be developed from the planning phase to the operation phase to detect the possible impacts and apply the corresponding corrective measures.

It is in this framework that ITA's Working Group 15, "Underground Works and the Environment", was created with the aim of making for the first time in the world, an exhaustive analysis of the current situation regarding the environmental implication of underground works, as well as the future related aspects and their social influence.

Finally, I want to thank ITA and AETOS, for relying on the company that I manage and me to co-ordinate this working group. I do also want to thank all the countries that have contributed to this document with their case studies and questionnaires, without which this work would have never been possible.

Julia Pérez-Cerezo
Animateur of WG 15. Underground Works and the Environment
Managing Director of **Environment, Transport & Planning**

ACKNOWLEDGEMENTS

For the preparation of this document a set of questionnaires was sent to 40 countries worldwide and 13 representative case studies were considered. We want to thank the responsible people from 17 countries that filled in the questionnaire and those who sent us the requested information about the case studies, because without their contribution this paper would have never existed. The name of contact person, company or organisation and origin country are shown following:

- Roberto Kochen. — Brazil
  Bureau de Projetos e Consultoria LTDA
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- Yücel Erdem — Turkey
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- Susan Nelson USA
  American Underground Construction Association

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1 GENERAL INTRODUCTION

The creation of the ITA Working Group 15 under the name of "Underground Works and the Environment" was approved in the General Assembly of ITA held in Stuttgart in May 1995. The Working Group was officially launched in Washington, April 1996, with Julia Pérez-Cerezo, Managing Director of Environment, Transport & Planning, as animateur and José Manuel Serrano, member of the Executive Committee of ITA, as tutor.

The main objective of this group is to help the economic agents that operate in the underground world (developers, consulting companies, construction companies, etc...) to take advantage of the opportunities and to minimise the risks associated with the new environmental culture.

The investigation of WG15 has been based on two main topics:

A.- A State of the Art Analysis on the opportunities and constraints associated with the environment and on the positioning of the underground economic agents on this issue.

B.- An analysis of selected Case Studies that can prove the environmental benefits that can derive from the construction of underground works.

In order to develop these tasks a questionnaire was sent to all the ITA members (42 countries), having a percentage of answers of the 40% (17 countries). Although we miss the contribution of several countries that for their special linkage to underground works would have enriched the study, as for example Switzerland and Austria, whose Alpine tunnels are specially sensible to the environmental issue, and their contribution to the study would have been very important from an environmental point of view. In spite of this, we consider that the sample has a good size and variety.

The second task has been developed according to the information covering 13 representative case studies that have been selected from WG 15 member countries:

- BRAZIL: - Sao Paulo Underground
- EGYPT: - Cairo Waste Water Scheme
  - Al-Salam Siphon under the Suez Canal
- FINLAND: - Viikinmäki Waste Water Treatment Plant in Helsinki
  - Päijänne Water Tunnel
- JAPAN: - Kazunogawa Pumped Storage Plan.
  - Metropolitan Wxpressway Central Circular Route, Tokyo.

- SPAIN: - Pasillo Verde Madrid (Railway)
  - Vallvidrera Road Tunnel

- SWEDEN: - The Royal Library in Stockholm (Expansion of Sweden National Library)
  - The Äspö Hard Rock Laborator (Nuclear Waste Storage)

- THE NETHERLANDS: - Case Delft (Railway)
  - Case Sophia Line Section (Railway)

This report, "Underground Works and the Environment", develops a theoretical framework and at the same time shows and analyses the results from the international survey and 13 case studies. It is structured in two parts, the main document and three annexes including summaries of answers to the questionnaire, the case studies and a glossary of environmental terms.

The main document is divided into the following chapters:

- **Environmental legislative framework.**

  This section summarizes the international opinion surveyed by the questionnaire, including the characteristics of the environmental legislation considered for underground works, the effects of the environmental legislation on different economical agents and the different ways for the new market opportunities to compensate the disadvantages of the environmental legislation.

- **Inventory of environmental aspects.**

  In this chapter an inventory of the main environmental aspects classified by inert, biotic and human media is identified.

  Based upon the answers to the questionnaire, and the information received from 13 case studies of underground projects a group of the most corrective measures in order to avoid these negative effects, by proper planning or proper active restoration of natural systems and responsible use of natural resources have been identified.

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  This chapter deals with three different points related to environmental benefits of underground works: reasons for the selection of the underground solution, new technologies for the construction of underground works that will mean the reduction of impacts, and future demand of underground projects under environmental considerations.

- **Opportunities and threats of underground works in relationship to environment**

  A study of the opportunities and threats of underground works in relationship to environment is included in this chapter. In order to accomplish this goal, the first part of the chapter includes several ideas related to sustainable development, underground works and environment. A second part emphasises the incidence of underground works on the environment according to the information provided by the survey for the different stages of the project: planning, construction, and operation. Finally it presents a study of the future market due to environmental implications.

- **Social-economic context: comparative cross-cultural study**

  As the result of the questionnaire sent to the ITA members countries and the collected experience with various underground related, a comparative cross-cultural study dealing with economy, social structures, underground works projects and level of development would classify the countries into two different groups. The first group would be the high-technology countries and the rest would be part of the developing ones.

- **Conclusions.**

  It remarks the main findings, general conclusions about each one of the analysed in WG15 and some recommendations to take advantage of underground works in the future under the perspective of environmental implications.

The **annexes** deal with the following tasks:

- A questionnaire form and a summary of the answers.
- The case studies.
- Also a glossary with environmental – tunnelling terms.

2 ENVIRONMENTAL LEGISLATIVE FRAMEWORK

2.1 Summary

The present chapter presents a study of the environmental legislative framework based upon objective written regulations, codes and legal procedures as well as on the answers to the questionnaire sent to the surveyed members of ITA.

Underground related activities based upon the environmental legislative framework have been developed in both the European Community and the United States as the most significant patterns of future environmental legislation pattern. These two similar legislative frameworks are studied in this chapter in order to get a general idea of future environmental guidelines, codes and regulations to follow by the international sphere. In addition to this study, a comparison between both patterns gives us ideas for the guidelines in worldwide future environmental legislative framework as presented in this chapter.

According to the answers to the questionnaire, the characteristics of environmental legislation for different types of underground works in the surveyed countries are developed in order to get a general idea about the order of importance of regulations on different areas and agents, such as consulting companies, construction companies, underground works management organisations and machinery and products companies.

Decisions and actions based on environmental reasons do not take place entirely within a technical sphere of influence. As a matter of fact legislative, social, political and economic factors strongly influence the direction of the underground work and its environmental solutions. In order to summarise these frame of influence, a brief study of global effects and disadvantages / advantages of environmental legislative framework is added to this chapter.

The environmental regulations connected with environmental impact assessment (EIA, EIEP, EIS...[1]) are the ones that have a greater influence on underground works. To a lesser extent, regulations on safety and health, wastes generation, noise and vibrations, and water are also relevant.

Environmental legislation has both positive and negative consequences on the different agents that operate in the underground world. The most outstanding effects are on one hand, new market opportunities, but on the other hand, and increase of production costs and a major responsibility demand of the economical agents.

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[1]EIA: Environmental Impact Assessment
EIEP: Environmental Impact Evaluation Procedure
EIS: Environmental Impact Statement

As environmental legislation becomes more and more strict, underground works will take advantage of their advanced position compared to superficial ones. The tunnelling associations of the countries participating in this survey hold varying opinions about the interrelations between underground works and the environment, although the totality consider that the increasing environmental sensitivity and legislation are going to have a positive influence on the development of underground works[2].

2.2 The European Union

2.2.1 Legal aspects of environmental framework

The Treaty of the European Union states that "The Community shall have the task of promoting, through the establishment of a common market and an economic and monetary union and through the performance of common policies and actions... a harmonious balance development of economic activities in the Community as a whole, sustainable, non-inflationist growth respecting the environment... the raising of the level an quality of life..."[3]. Moreover, the main topics of environmental legislation on civil works contributes toward the preservation, protection and improvement of the quality of the environment while simultaneously using natural resources prudently and rationally.

As a conclusion about European environmental legislative framework we should focus our attention on the guidelines for a policy and strategy for protecting the environment and natural resources while carrying out sustainable development. The main legislative framework indicates that the integration of environmental evaluations in a large scale planning process will strengthen environmental protection, and will contribute to a correct underground works management and to levelling out disparities in international and interregional competition for new development projects which currently arise due to discrepancies in the environmental evaluation practices of member countries.

Most of the consulting companies, organisations of underground works management and machinery companies think that the legal aspects of environmental protection in Europe will contribute to create new market opportunities and compensate the drawbacks. On the other hand, the majority of the construction companies think that the new market opportunities created by the legislative framework will not compensate the disadvantages.[4]

[2]For instance, Brazil's answer to the questionnaire states that "By enforcing higher standards on environmental preservations, companies can benefit from a higher demand of their services"

[3]Treaty of the European Union. February 1992. Art.#2.

[4]Related to the question "In what way could the new market opportunities compensate the inconvenients of the environmental legislation?" the answer from Spain may be representative of European way of thinking: The 75% of the consulting companies think that the new market opportunities will compensate the inconvenients. The majority of the construction companies think the opposite. The 100% of the companies or organizations of underground works

2.2.2 Environmental Impact Evaluation Procedure. (EIEP).5

The legal instrument controlling environmental underground works is the Environmental Impact Evaluation Procedure (EIEP). This procedure is established by the European Union Council Directive 85/337/CH, within the framework presented in point 1.2.1

The European Union established the need to subject certain underground projects to a regulated EIEP prior to their approval an execution. This required environmental study must include the following items:

- Project description
- Alternative solutions and a proposal justification
- Environmental elements likely to be altered
- Impact description
- Description of corrective measures

Within this context, the member countries of the European Union have develop their own domestic legal codes and have established the necessary procedures and methods for conducting environmental impact studies.

2.3 The United States

2.3.1 Legal aspects of environmental framework

Institutional and policy related legislative framework in the United States establishes, for all U.S. federal agencies, a basic national charter for protection of the environment. Federal legislation states that "... it is the continuing policy of the Federal government, in co-operation with State and local governments, and other concerned public and private organisations to use all practicable means... to create and maintain conditions under which man and nature can exist in productive harmony and fulfil the social, economic and other requirements of present and future generations of Americans"[6]. In response to these legislative guidelines from the U.S. Congress, federal agencies and municipal governments develop policy guidance and regulations describing how the goals of environmental legislative framework are to be implemented and applied in underground projects.

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management and machinery and products companies think that there will be a compensation from new market opportunities.

[5]Based on info. from *Pilot Study on the Effects of Public Works Projects on the Environment*. North Atlantic Treaty Organization. July 1995.

[6]National Environment Policy Act (NEPA). 1970.

2.3.2 Environmental Impact Statement. (EIS).[7]

Consistent with the Congress environmental legislation appears the requirement to produce an Environmental Impact Statement (EIS) for all major U.S. underground works.

The EIS has five fundamental features:

- A description of the environmental impacts of the proposed action

- A description of any adverse effects which cannot be avoided should the proposal be implemented.

- A description of the alternatives to the proposed action.

- The relationship between local short-term uses of man's environment and the maintenance of enhancement of long term productivity.

- Any irreversible and irretrievable commitments of resources that would be involved if the proposed action were implemented.

The IES has become the principal means for U.S. federal agencies to describe the environmental impacts arising from their activities, for describing measures that will minimise or eliminate the impacts, and for explaining how they will comply with the various other environmental requirements established under U.S. environmental underground statutes.

2.4 Guidelines for world-wide future environmental legislative framework

As a conclusion and guideline for the development of an environmental underground legislation for any social-economic country we have made up a brief summary of points to be incorporated to legislation based upon the European Union / United States directives:

- Legislative directives similar to those developed by The European Union and The U.S. Congress.

- Guidelines based upon economic and environmental equilibrium.

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[7] Based on information from *Pilot Study on the Effects of Public Works Projects on the Environment*. North Atlantic Treaty Organization. July 1995.

- Importance of the concept "sustainable development" applied to underground work and its environmental responsibility.

- Protection of the environment and natural resources according to correct underground works management.

- Effort to levelling out differences dealing with national and domestic legislation in order to unify regulations and legal codes.

- Co-operation between public and private organisations in order to create awareness of the environmental importance and level out co-operation problems.[8]

- Effort to foster greater public dialogue and develop educational materials concerning underground works and their influence in environmental factors.

- Regulation of underground environmental aspects according to Environmental Impact Evaluation Procedure (EIEP - European Union), Environmental Impact Statement (EIS - United States) or similar local procedures that will contribute to generate competitive solutions.[9]

The social awareness of environmental issues points out a trend towards a new tightening of future environmental regulations concerning underground works no matter how important the expected economic and social utility of a project may be. The legal procedures will reinforce controlling methods not only during the construction phase but throughout the planning, construction and operating phases in order to reduce, or even avoid, environmental disturbances by developing a technical, legislative, and management solution for a modern and environmentally friendly way of undertaking underground works.

2.5 Characteristics of environmental legislation for underground works in the surveyed countries members of ITA

The information presented in this chapter is based upon the answers received from 17 countries members of ITA out of a total of 42 surveyed countries to whom the questionnaire was sent. It means a 40% answering ratio. In addition to this information, 13 cases study from 7 countries (Spain, The Netherlands, Sweden, Brazil, Egypt, Japan and Finland) concerning different underground works have been studied.

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[8] Japan's answers to the questionnaire point out the idea that technology developments and tenacious negotiation with inhabitants are the way to compensate the inconvenients of the environmental legislation.

[9] Finland's opinion about environmental legislation emphasizes the idea that "*In the EIA process alternative solutions are compared, and the underground solution is in many cases very competitive, for instance in road tunnels*".

According to these answers from the surveyed countries members of ITA, concerning with different underground works, the international opinion about environmental legislation can be summarised as follows.

Opinion about regulation framework being clear and accurate is perfectly fifty/fifty divided among the surveyed countries. Most of the answers agree with the fact that environmental authorities are dispersed and regulation framework is strictly applied by the authorities and on the other hand about three parts out of four think that there is not a specific regulation framework for underground projects.

The order of importance of regulations on different areas is the following according to the answers to the questionnaire: most of the surveyed countries think that regulations on EIA (Planning and project phase) and regulation on safety and health mean the biggest relative importance[10]. On the other hand, regulation on materials and machinery[11], protection of fauna, flora and special areas and regulation on noise are not considered to have relative importance. Dealing with urban traffic safety and noise disturbances, it is important to take into account the case study "Brazil, Sao Paulo Underground" as an example of relative importance for regulations on safety and noise generation due to its location. It is a project to add four new stations to the existing subway system under several busy streets like Avenida Paulista and Dr. Arnaldo, which means that in order to avoid noise disturbances related to open-cut construction methods as well as traffic problems, the underground solution added a perfect working method to fulfil the traffic and noise regulations. Regulations on waste/dumps generation, vibrations, and water concerned codes occupy the middle of the relative importance classification level even though in some special cases such as urban underground transport infrastructures (Sao Paulo Underground and Pasillo Verde) regulations on waste/dumps generation become important due to the high volume of dumps that have to be evacuated from the working mouths and transport to a long-distance place out of the cities (Sao Paulo and Madrid). This removing of big quantities of soil had to be planned and undertaken with maximum care in order to avoid the affection of the foundations of the buildings on the surface as well as any damage to the numerous existing underground networks of public utility. In non urban areas these problems usually neither exist nor have such a great importance.

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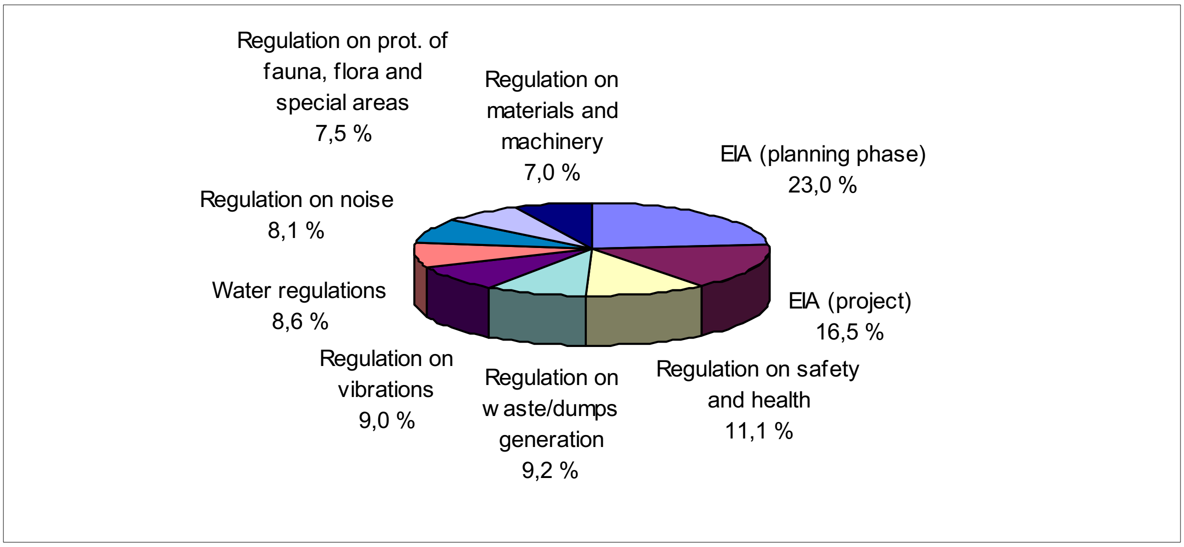
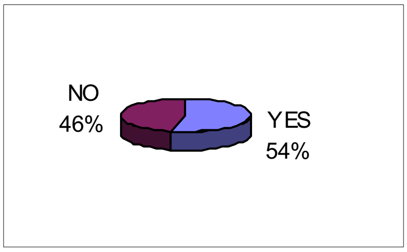
[10]Sweden's answer to the questionnaire states that "*extended planning and design time will be necessary in order to compensate the inconvenience of the environmental legislation*".

[11]Sweden thinks that the new legislative framework will cause a new market for machinery due to an increase of demand for these products.

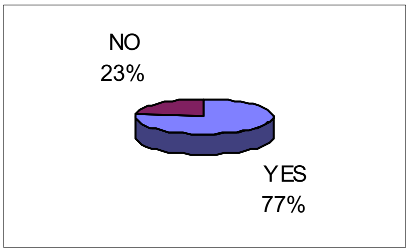


The attached graphics reveal the international opinion about their environmental legislation.

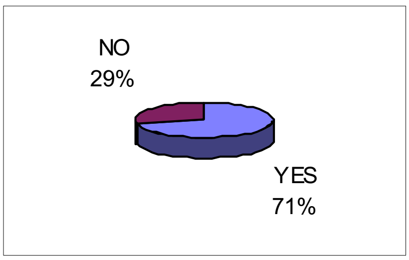
→ Regulation framework is clear and accurate:



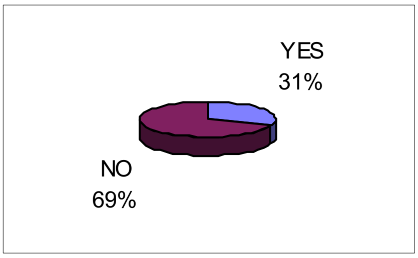
→ Environmental authorities are dispersed:



→ Regulation framework is strictly applied by the authorities:



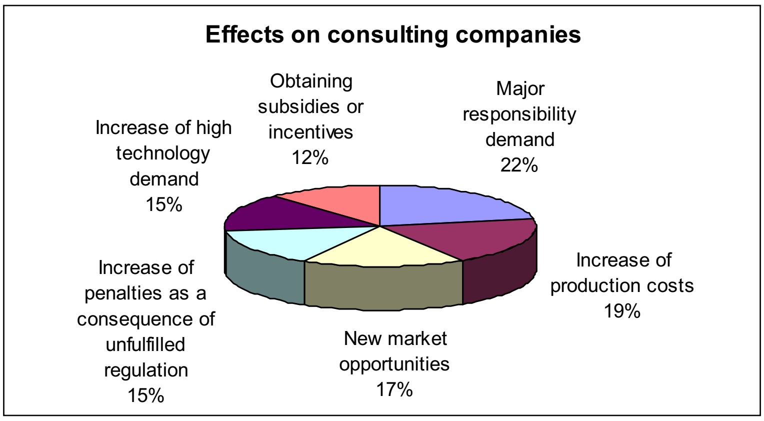
→ There is a specific regulation framework for underground projects:



2.6 Effects of the environmental legislation on different agents

2.6.1 Effects on consulting companies (Planning & Project design)

According to the survey, the effects considered as direct consequence of environmental legislation, in order of importance are major responsibility demand, increase of production costs and new market opportunities. For most of the surveyed countries members of ITA, obtaining subsidies or incentives and increase of high technology demand are the effects with the least relative importance on consulting companies.[12]

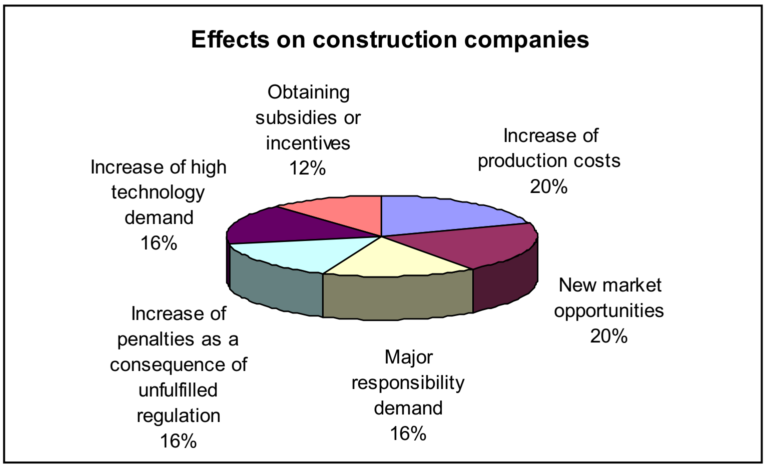


[12] Based on the new legislative framework, the answer of Egypt to the questionnaire accepts the idea that "*The resulting profits of new market opportunities could provide a compensation for the inconvenients of this legislation*",. On the other hand Hungary believes that "*More money should be recircled from tax incomes to environmental investments in order to compensate the inconvenients of the new environmental legislation*".

2.6.2 Effects on construction companies

The most important effects on construction companies considered as a direct consequence of environmental legislation, according to the opinions of the surveyed ITA members are the increase of production costs, and new market opportunities[13]. As a fact, during the excavation of the Sao Paulo Underground concerning the four new stations and lines (Brigadeiro, Trianon, Consolaçao and Clínicas) to be added to the existing subway system had to face a considerable increase of cost due to the removing of big quantities of soil that had to be planned and undertaken with maximum care in order to avoid the affection, and fulfill the urban environmental regulations, regarding the fundaments of the buildings on the surface as well as any damage to the numerous existing underground networks of public importance, and the noise, dust, and traffic problems due to this transport.

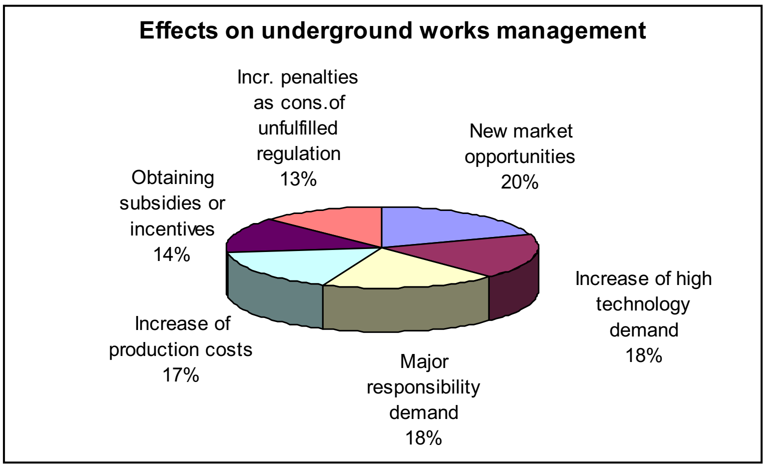
Most of the surveyed countries think that obtaining subsidies or incentives is not an important consequence. Major responsibility demand, increase of penalties as a consequence of unfulfilled regulation, and increase of high technology demand are situated in the average level of importance as consequences on construction companies.



[13] Turkey's opinion supports the idea that "*construction companies will have to investigate (increase of cost) and evaluate the environmental legislation of each new market in order to compensate the legal aspects of environmental policies*".

2.6.3 *Effects on underground works management (companies or organisations)*

According to the survey, the principal effects on these companies or organisations are, in order of importance, new market opportunities, increase of high technology demand, and major responsibility demand. Most of the surveyed countries members of ITA do not consider an important effect on underground works management neither the increase of penalties as a consequence of unfulfilled regulation nor obtaining subsidies or incentives.



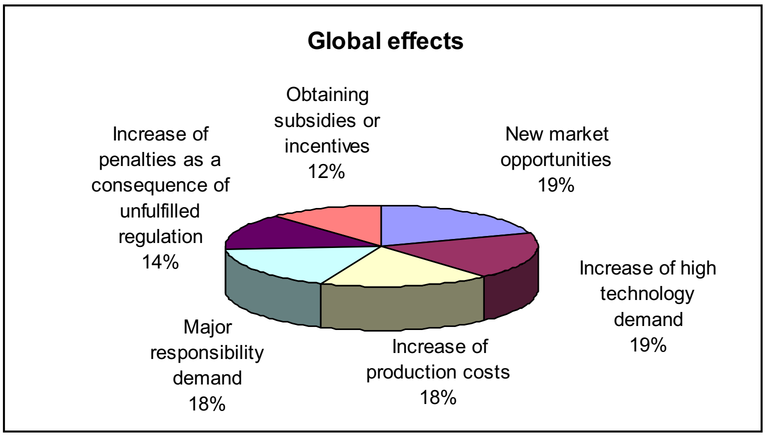
2.6.4 *Effects on machinery and products companies*

The principal consequences of environmental regulations on machinery and products companies are in order of importance are increase of high technology demand and new market opportunities. Anyway, it is important to take into account the fact that countries such as Brazil, with an abundant and not very expensive labor force have a high proportion of less high-technology methods as included in case study "Sao Paulo Underground due to the economic benefits. The answering surveyed countries think that obtaining subsidies or incentives and increase of penalties as a consequence of unfulfilled regulation should not be considered as important effects on machinery and product companies.

2.6.5 Global effects

Taking into account the global results of the survey, the principal impacts on the offer of underground works as consequence of environmental regulations are in order of importance:

- New market opportunities (20%)
- Increase of high technology demand (18.5%)
- Increase of production costs (18%)
- Major responsibility demand (17.5%)
- Increase of penalties as a consequence of unfulfilled regulation (14%)
- Obtaining subsidies or incentives (12%)



2.6.6 Advantages and disadvantages of environmental legislative framework

According to the answers of the questionnaire most of the countries believe that the high standards on environment preservation included in environmental legislative framework will mean benefits for the companies due to a higher demand of their services[14]. By enforcing these codes, more money should be recycled from tax income, as environment projects which will provide a higher profit opportunities as states by Hungary's answer to the questionnaire ("More money should be recycled from tax incomes to environmental investments"), dealing with new market opportunities and inconvenience of the environmental legislation.

Regulations of obligatory environmental impact evaluation procedures will provide a comparative way of working and a competitive underground solution which will increase the possibility for a broaden demand of these underground works.

[14] As an example, Sweden states that "*the new legislative framework will create an increasing demand of various projects in order to compensate the inconvenients of the new legislation*".

Most of the consulting ITA members companies, think that new market opportunities will compensate the inconveniences, but the majority of the construction companies think the opposite, as an example, the need to fulfill regulations on safety, traffic operation, dust, noise, and safety during the construction of the new four stations in Sao Paulo meant an increase of cost due to the high-level planning and undertaken of the works and specifically the removing of great quantities of soil out of the city. Companies or organisations of underground works management and machinery and products companies think that there will be a compensation from new market opportunities.

Overall the totality of the countries that have answered the questionnaire think that the demand of underground works could be increased for environmental reasons.

3 INVENTARY OF ENVIRONMENTAL ASPECTS[15]

3.1 Summary

This chapter develops a series of concepts and relationships related to environment and underground work aspects. The group of impacts and influences that human activities cause to the environment must be study from inert, biotic and human perspective in order to understand the separate impacts and take the correct corrective measures in order to level out the negative consequences caused to these three media.

In this chapter we try to present a brief description or inventory of the main environmental aspects divided into inert, biotic and human media. As inert media we have considered climate, atmosphere, geology and hydrology as the most important features. Biotic media will be studied as soil, flora, fauna and landscape.

Based upon the answers to the questionnaire, and the information received from 13 case studies of underground projects carried out in seven different countries (Spain, Brazil, Sweden, The Netherlands, Egypt and Finland), which widely accept that underground works causes effects on the environment, the surveyed countries add a group of corrective measures in order to avoid these negative effects by proper planning or proper active restoration of natural systems and responsible use of natural resources.

Today, in sharp contrast with the past, underground works development is increasingly subjected to a mandatory examination of its environmental consequences. The goal of sustainable development is to create environmentally sound projects that will serve present and future citizens by providing a better quality of life. It means the integration of economic prosperity and inert, biotic and human environmental health.

The list of effects on the inert media included in the questionnaire sent to the ITA members are alteration of geology and geotechnical properties of the land, hydrological and hydrogeological alterations, alteration of aquifer conditions and quality of water, effects on foundations of pre-existing buildings, alteration of climate, atmospheric pollution, alteration of existing geological, geomorphologic and paleontological wealth, and pollutant discharge on underground and surface courses. The same way, the list of effects on the biotic media attached to the questionnaire sent are visual intrusion, acoustic intrusion, alteration of surface flora and fauna, changes in the landscape, noise generation, emission of pollutant gases, dumps generation, alteration of underground flora and fauna, production of detritus from wash loads caused by surges, and generation of solid and liquid wastes. Concerning with the human media, the effects are alteration of surface land uses, increase of communications possibilities, reduction of occupied

[15] See *"Impacto Ambiental"* by Ignacio Español. Cátedra de Ingenieria Sanitaria y Ambiental. ETSI Caminos, Canales y Puertos, MADRID. 1995.

surface area, impacts on public opinion and social interests, alteration of pre-existing underground infrastructures, alterations of the archaeological and cultural heritage, alteration of demographic patterns, alteration of socio-economic patterns, damage on quality of life and increase of public transport demand.

At the end of the chapter, a series of corrective measures based on the most important effects pointed out by the surveyed countries members of ITA is added. These corrective measures deal with protection of the geotechnical properties of the land, reduction of hydrological and hydrogeological alterations, reduction of subsidence, reduction of atmospheric pollution, correction of noise impact, protection of fauna, archaeology, pre-existing underground infrastructures, and landscape, and corrective measures for wastes generation.

3.2 Effects of underground works on the inert media

3.2.1 Introduction

This chapter focuses on the study of inert media through features such as geology, hydrology, surface, geomorphology and atmosphere. Although there is an inseparable linkage between the inert and biological media, to facilitate the analysis, they are dealt with in separate chapters.

First of all the main effects related to inert media and caused by underground works are introduced, and after this, based upon the answers of the surveyed countries members of ITA, a study of the influence of each phase of project[16] is presented.

3.2.2 Alteration of geology and geotechnical properties of the land[17]

Underground works have specific impacts on important components of the land including aspect, potential soil erosion and runoff, soil moisture content, slope stability, potential vegetative cover, physical disruption of the land due to surface mining and excavation, movement of surface water, drainage system... but the most important aspect is the change of geotechnical properties of the land as consequence of excavations.

Around any excavation, the soil is loosened during the construction processes, and its properties are deteriorated. Besides, underground works limit future uses of surface and subsurface.

During the excavation of the "Metropolitan Expressway Central Circular Route in Tokyo", below the tunnel, at a distance of only 4 meters, passes a subway line. Therefore, the geotecnical conditions of the soil changed and special measures such as grouting against groundwater infiltration, high pressure grout forepiling and others were taken during construction.

[16] Referred to Planning phase, construction phase and operation phase.

[17] See "*Geology and foundations*" by José Antonio Jimenez Salas. Ed. Rueda. MADRID

In a similar way, during the construction of the expanded zone for the new Royal Library in Stockholm, due to the fact that the work was carried out in the middle of Stockholm city, in an area composed of unstable ground conditions and many old buildings, the risk of subsidence forced to develop extensive surveys and highly sensitive vibration meters were installed through the entire area prior to blasting and draining the area. In addition, fixed benchmarks were established to ensure that none of the surrounding roads or buildings would be affected.

3.2.3 Hydrological and hydrogeological alterations[18]

It is important to consider water as an essential part of all life forms, and therefore it should be seriously considered in every environmental essay dealing with underground works. Degradation of the quality of water may occur in either of the two basic water systems: surface water and underground water.

Hydrogeology is an important factor to analyse in underground projects and a crucial factor for any underground work especially those adjacent to bodies of water (both coastal and interior), and those that include water bodies within the project boundaries (lakes, rivers, streams, wetlands). The influence must be studied in order to evaluate changes in volume and direction of surface and groundwater flow, modifications to channels due to increases or decreases in sediment load, damage to adjacent aquatic ecosystems, and possible water quality contamination.

It is important to study the influence of vast volumes of water used in agriculture as irrigation. Al-Salam Siphon beneath the Suez Canal (Egypt) sets up an ambitious plan that aims at conveying 2.300.000 m3/year of wastewater to Sinai region in addition to some water from the eastern branch of the Nile at Damietta. The goal of developing agriculture in Northern Sinai by transferring this volume of water will change the drainage to the sea from the farmlands.

The protection of the groundwater aquifer system is important because of the difficulty in restoring aquifer quality and quantity.

When a tunnel is constructed, there is an interaction with the hydrogeological system of the land. Not only hydrogeology affects the tunnel, but also the tunnel affects hydrogeology. Lowering the groundwater table is the principal impact produced when a cavity is opened below its level. As a consequence, natural springs might be dried up and water may disappear from wells. There is a direct link between surface and underground water systems. Impacts on the surface hydrology could be of a great importance, since water is essential for human communities and for natural ecosystems.

During the exploration of the rock mass, drills are done in order to get samples and obtain a structural model. These drills may function as ways of drainage of aquifers layers drying wells

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[18]See "*Dynamic, ecological, social, and cultural implications of surface and underground water*" by José Francisco Martín Duque. Ed. Caja Segovia.

and springs located over the underground work. If the drill is in the itinerary of the future tunnel, it will probably allow water to flow into the tunnel.

Drainage problems depend on the constructive method. If the excavation is made by blasting, cracking will appear around the cavity. As well as geotechnical problem, this seamy rock will mean an increase of the water flow, not only towards, but also parallel to the tunnel. When the work is made by mechanic methods there will be a minor affection to the surrounding land. But mechanic methods are used in less competent land and therefore generally permeable, so there can still appear drainage problems.

As an illustration of hydrological changes control, during the construction phase of the Royal Library in Stockholm, subsoil water levels in existing holes were measures each day, both before and after blasting in order to control all the variations and keep safety related to old buildings in the surrounded area.

3.2.4 Pollutant discharge on underground and surface course

Due to the importance of water, features such as stream channel morphology (cross and longitudinal sections), water quality, hydraulic factors (flow velocity, fluctuations of water level, sediment load, increase or reduction of capacities), proximity to wetlands, depth to groundwater aquifer and key aquifer characteristics (porosity, conductivity and transmissivity) must be broadly examined in order to determine the impacts.

Other effect to pay attention to is the pollution of groundwater. This is especially delicate when cavities are opened above the groundwater table. Pollution of aquifers layers is irreversible in many cases, which is very serious taking into account the increasing use of underground water for urban uses. Preventive measures should be taken, like waterproofing and effective sewage systems.

The case study "Cairo wastewater scheme" is an illustrative example of tunnels running below the existing sewers and part of the Metro system, below the groundwater table. It is an essentially environmental project that aims at improving the sanitary conditions in Cairo with a minimum disturbance to the water quality in the city of Cairo.

3.2.5 Effects on foundations of pre-existing buildings[19]

The progressive increase of underground works at small depth in urban area has a great influence on existing buildings and structures placed in the proximity of the work. Underground works modifies the original situation of the ground, generating movements in the proximity in order to re-establish the stress balance of the soil. This has been proved in several occasions by measuring the superficial settlings originated by excavations, varying from few millimetres to 20 centimetres.

This superficial deformation due to the alteration of the internal balance of the soil and not to applied superficial overloads is known as subsidence.

In fact, the case study "Sao Paulo Underground" finds the existing buildings foundations impact one of the main planning features of the project. The city of Sao Paulo is one of the world's biggest with around approximately 18 million people living in its metropolitan area, and the itinerary passes under several very busy streets with high buildings. In order to avoid the affection of these foundations of the nearby buildings on the surface, the removing of big quantities of soil had to be planned with maximum care.

Urban underground projects in the middle of cities such as Cairo, Sao Paulo, Delft, Madrid, Stockholm, Tokyo and Helsinki are analyzed in their cases study in order to avoid disturbances to nearby foundations of buildings.

3.2.6 Alteration of existing geological, geomorphologic and paleontological wealth

Referring to alteration of existing geological, geomorphologic and paleontological wealth, underground works have a positive influence by preserving the surface geological formations and by allowing the knowledge and study of underground formations, which otherwise would be inaccessible.

3.2.7 Atmospheric pollution

The quantity of dust generated by an underground work is highly less than that able to create a potential impact of significant dust concentrations including microclimatic changes, direct effects on vegetation and soil, respiratory diseases, allergies and irritations, hazards arising from poor visibility, damage to machinery and buildings.

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[19] See *"Geotecnia y cimientos I, II y III. Cimentaciones, excavaciones y aplicaciones de la geotecnia"* by José Antonio Jimenez Salas, Cañizo, Escario...

Atmospheric pollution due to tunnels consists of two types of emissions: dust, mainly produced in the construction stage, and smoke containing polluting substances, emitted by vehicles during operation.

Atmospheric pollution gets a relative importance in urban areas such as Sao Paulo Underground. In order to avoid dust pollution and interference with the habitants of Avenida Paulista and Dr. Arnaldo, the four new stations (Brigadeiro, Trianon, Consolaçao and Clínicas) had to be planned taken into account these impacts. This was and advantage for the underground solution over the surface one. In a similar way occurs with Madrid, Cairo, Tokyo, Stockholm, Delft and Helsinki where urban concentration of population forces strict dust emissions controls as included in the particular urban cases study.

Compared to the surface alternative, the underground work reduces remarkably emissions. The way the emissions inside a road tunnel affect the external atmosphere depends on the ventilation system and on the location of the expulsion points. In normal conditions atmospheric pollution due to tunnels is no significant, since there are severe limits for the inside concentration of pollutants, and besides this concentration is reduced outside by spreading.

3.2.8 International experience

This chapter includes the list of effects on the inert media according to the different phases of the underground project and based upon the information from the surveyed ITA member countries, and the 13 cases study from Spain, The Netherlands, Egypt, Sweden, Finland, Japan and Brazil which try to cover all kinds of underground projects: transport infrastructures, utilities infrastructures, public underground space use, storage infrastructure and underground industrial activities.

Planning phase

During the planning phase, the effects on the inert media that are taken into account in most of the countries for all kind of projects are hydrological and hydrogeological alterations, alteration of aquifer conditions and quality, and possible affectation to foundations of pre-existing buildings. The Sao Paulo Underground is an example of interference between underground excavations and the foundations of pre-existing buildings as develops in the case study "Sao Paulo Underground. Brazil".

These effects are generally considered unfavourable for underground works choice, except in singular cases, like waterway or storage projects where Finland and Iceland consider them favourable.

Construction phase

During construction, the inert media (climate, atmosphere, geology, hydrology) seems to be much more affected by underground works than the biotic or the human media. Considering all type of projects, the effects that have a higher influence on budget increase, as the survey shows, are in order of importance: hydrological and hydrogeological alterations, (as presented for Al-

Salam Siphon beneath the Suez Canal), possible settling of existing buildings (as indicated for the Sao Paulo Underground, Tokyo Metropolitan Expressway and all the urban areas underground works cases study), and alteration of geology and the geological properties of the land.

However, in the construction of industrial and storage underground facilities, there is an important affectation to the budget produced by alteration of aquifer conditions and quality and pollutant discharge on underground and surface courses.

Operation phase

Referring to operation, effects on the inert media are the ones that have greater possibilities of producing additional works like repairing, maintenance, environmental restoration... according to the surveyed countries.

Alteration of hydrology and hydrogeology is the most conflictive effect considering all kinds of projects. Effects on pre-existing buildings produce extra works especially in waterway[20], road and railway[21] infrastructures. Protection of aquifer conditions and quality of water[22] cause repairing works, both internal and external to the infrastructure, during operation of waterways, roads, railways and hydrous.

3.3 Effects of underground works on the biotic media[23]

3.3.1 Introduction

The integration of biological community components that may be impacted or displaced by construction or that may be benefited by habitat restoration, rehabilitation, creation, protection, or enhancement along with the features of the underground project must be taken to study in the environmental impact evaluation procedure.

Biotic media is considered as the addition of soil, fauna, flora, and landscape qualities and features.

[20] Case study: urban utilities infrastructure, Cairo waste water scheme in Egypt.

[21] See urban areas railway case studies (Sao Paulo Underground, Case Deft railway in The Netherlands, and Pasillo Verde railway in Madrid-Spain).

[22] See "*Saneamiento y alcantarillado*" by Dr. Ing. Aurelio Hernández Muñoz. Servicio de publicaciones de la ETSI Caminos, Canales y Puertos. MADRID.

[23] See "Impacto ambiental" by Ignacio Español. ETSI Caminos, Canales y Puertos. MADRID-SPAIN, and "Manual de túneles y obras subterráneas" by López Jimeno, Carlos. MADRID-SPAIN.

This chapter focuses on the study of biotic media through features such as visual and acoustic intrusion, generation of noise and vibrations, alteration of surface and underground fauna and flora, changes in the landscape, generation of solid and liquid waste and dumps, and production of detritus from wash loads caused by surges. Even though there is a close linkage between inert and biotic media, this chapter focuses on the biotic perspective of these features.

First of all the main effects related to the biotic media and caused by underground works are introduced, and after this, based upon the answers of the surveyed countries members of ITA, a study of the influence of each phase of the project[24] is presented.

3.3.2 Visual intrusion

Underground works are positive in relation to visual intrusion. They are perfectly integrated in the environment, and eliminate the construction of embankments which produce a very negative visual impact. This is especially interesting in landscapes of a high value, which are frequently located in mountainous zones.

3.3.3 Acoustic intrusion

During construction and operation of transport infrastructures, important emissions of noise are produced. Noise causes annoyance to people and affects the environment, so it should be studied, controlled and avoided if possible.

In road or railway tunnels, circulation of vehicles or trains produces noise problems. Outside the tunnel, in the proximity of its mouths, acoustic intrusion would exist even if the tunnel was not constructed. Inside of it, noise is perceived by users in a high intensity, lowering their comfort.

This was one of the advantages of the Sao Paulo Underground, planning four new underground stations and, in this manner, the environmental impact "acoustic intrusion" related to urban problems due to a large open cut excavation for surface solution could be avoided and noise disturbances mainly reduced. Another important acoustic intrusion reduce was possible thanks to the "Paillo Verde" underground solution in Madrid, and in a similar way the Case Delft railway in The Netherlands, Case Sophia railway, Vallvidrera Road tunnel, and Metropolitan Expressway in Tokyo mean friendly solution compared to the surface work as far as environmental noise disturbances reduction is concerned.

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[24] Referred to Planning phase, construction phase and operation phase.

3.3.4 Generation of noise and vibrations

There is an increasing interest in noise and vibrations originated by trains and underground especially when they cross tunnels located in urban areas.

Rolling on rail generates noise and vibrations that affect the habitants of nearby buildings. This alteration affects as far as 50 metres in both sides of the tunnel. The trains frequency and schedule (day or night trains) are important factors to consider in the evaluation of the level of annoyance in the receptor. This is an important feature of transport infrastructures built in urban areas such as Pasillo Verde in Madrid (Spain) and Sao Paulo Underground (Brazil). Even though these kind of urban trains generate vibrations the fact that these underground railway tunnels reduce the emission of noise compared to the surface solutions points out the overall advantage of underground transport methods.

3.3.5 Alteration of surface fauna and flora

Underground works, compared to the surface alternative, minimise the negative impact caused to the surface fauna and flora. There is only an indirect affectation to these elements. The construction of tunnels in mountainous zones, which are usually isolated, facilitates the access to visitors to these fragile areas, with the possibility of producing negative impacts.

Occupation of land in the proximity of the mouths will destroy the existing vegetation, with negative consequences on fauna.

During operation ventilation systems will emit polluted air, and if there is a constantly dominant direction of the wind, this emission will affect continuously in the same area whose flora will be deteriorated.

In order to understand the extend of the environmental advantages of the underground solution, (impacts are proportional to the occupied surface area) it is enough to take into account the large surface that railway and road tunnels such as the ones presented in the cases study (Pasillo Verde, Sophia railway, and Vallvidrera road tunnels) save from disturbances if the surface solution would have been chosen.

3.3.6 Alteration of underground fauna and flora

Depression of the groundwater table due to the excavation may result in destruction of the underground fauna and flora located in the dry band.

3.3.7 Changes in the landscape

This effect is locally reduced to the tunnel's mouth and chimneys. An appropriate design of these elements will minimise the effect. For instance, in order to improve its appearance and prevent from erosion it is very advisable to treat the slopes planting vegetal species suitable to the local climate. In fact, the case study "Pasillo Verde" in Madrid, Spain, contributes to a high-value environmental solution easily translated into a benefit for the urban landscape and green spaces.

3.3.8 Generation of solid and liquid waste

Construction and operation of underground works generate solid and liquid wastes[25], which must be necessarily controlled.

During construction there are basically two kinds of wastes: those typical of any public work and those resulting from the excavation. The first ones consist of spilt oils and greases, diverse materials, mud and polluted water. These wastes will cause several management problems. The best solution in this case is to make good use of these materials in embankments located close to the work.

During operation of a road tunnel, solid and liquid wastes are of a less importance. They consist of rubbish thrown by users, pieces of load fallen from lorries, pieces of material coming from accidents and sewage water.

3.3.9 Generation of dumps[26]

When it is not possible to make good use in nearby slopes of the wastes generated in the excavation, there in nothing left to do but dumps. This is an urban areas underground works related problem such as Brazil Sao Paulo Underground where the removing of big quantities of soil had to be perfectly planned and an increase of cost due to the transport was necessary.

Dumps carry problems of stability, safety and integration in the environment. The emplacement of a dump in conditioned by technic-economical, environmental and social factors. The type or material will depend on the type of soil or rock, and its sieve test on the constructive method.

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[25] See "*Depuración de aguas residuales*" by Prof. Ing. Aurelio Hernández Muñoz. Servicio de Publicaciones de la ETSI Caminos, Canales y Puertos. MADRID.

[26] See "*Catalogación del impacto ambiental de vertederos de los principales municipios de la provincia de Segovia*". Martín Duque, Díez Herrero, Lorenzo Lobo... Caja de SEGOVIA.

3.3.10 Production of detritus from wash loads caused by surges

When the ceiling, walls and floor of and underground work are not isolated, water enters the excavation through rock fractures or permeable zones of the soil, carrying mud. This may produce cavities around the infrastructure resulting in structural problems and repercussions on the surface area. Besides, the mud carried inside mean an increase of the wastes generated by the work and may contribute to damage the sewage system. The effect can be avoided by an adequate waterproofing.

3.3.11 International experience

The list of effects on the biotic media[27] attached to the questionnaire sent to the ITA members and related to each phase of project is introduced in this chapter.

Planning phase

Referring to the affectation of the biotic media, effects of underground works are remarkably favourable for the election of this alternative instead of the surface solution. The biotic media compared to the inert or human media is the one that takes more advantage of underground works.

The most positive contribution of underground works in the biotic media for all types of projects is the non-alteration of the landscape. Alteration of surface flora and fauna as well as visual intrusion are also avoided by the construction of a tunnel compared to the surface alternative. Even the underground solution may be used in cooperation with fauna, flora, and landscape benefits as referred in case study "Pasillo Verde. Madrid" where green spaces are maintained thanks to the underground solution.

Generation of solid and liquid wastes is considered in a reduced number of countries a negative point for underground works. However, these wastes are also produced when choosing a surface project, so it is not relevant for the exclusion of tunnels.

Construction phase

The answer to the questionnaire show that in the construction of underground works there are not important deviations in the predicted budget due to alterations on the biotic media. The factors that might produce alterations in the budget are:

- dumps generation especially when it is difficult to find a location close to the work.

[27] Biotic media is understood as the addition of soil, fauna, flora, and landscape features.

- changes in the landscape.

- noise effects.

Operation phase

The necessity of additional works during the life of an underground infrastructure is usually caused by effects on the inert media more than effects on the biotic media.

The factors more likely to produce additional works related to the biotic media are noise generation, emission of pollutant gases and changes in the landscape. The generation of solid and liquid wastes produces important additional works in storage infrastructures.

3.4 Effects of underground works on the human media

3.4.1 Introduction

The underground works includes a group of impacts on human media which must be analysed from a complicated perspective. First of all the alteration of inert and biotic media itself, and then the consequences of these changes from a human frame of reference (communication[28], public opinion, infrastructures[29], quality of life...). Most of these features of human media are subjected to relative opinions; this fact complicates the study of the effect of underground works.

The integration of human community components that may be impacted or displaced by construction or that may be benefited by habitat restoration, rehabilitation, creation, protection, or enhancement along with the features of the underground project must be taken to study in the environmental impact evaluation procedure.

This chapter focuses on the study of human media through features such as alteration of surface land uses, increase of communication possibilities, occupied surface land[30], public opinion and social interests, pre-existing underground infrastructures, archaeological and cultural heritage, socio-economic patterns, effects on quality of life and public transport demand. This chapter focuses on the human media perspective of these features.

[28] Transport infrastructures such as Sao Paulo Underground (Brazil), Case Delf Railway (The Netherlands), or Pasillo Verde Railway in Madrid (Spain) in an urban area and Ferrovia do Aco Railway (Brazil), Case Sophia Line Section Railway (The Netherlands), and Vallvidrera Road tunnel (Spain) in non-urban have been studied as examples of communication underground advantages.

[29] See as an example of water infraestructure "*Abastecimiento y distribución de aguas*" by Prof. Dr. Ing. Aurelio Hernández Muñoz. Servicio de publicaciones de la ETSI Caminos, Canales y Puertos. MADRID.

[30] The Royal Library in Stockholm (Expansion of Sweden National Library) is a representative example of public underground space usage in order to get advantages of the pre-existing surface land uses.

First of all the main effects related to human media and caused by underground works are introduced, and after this, based upon the answers of the surveyed countries members of ITA, a study of the influence of each phase of project[31] is presented.

3.4.2 Alteration of surface land uses

Underground works minimise the alteration of surface land uses and surface infrastructure and building uses. This is especially interesting in urban zones but it is also important in rural zones. Changes in the land uses can affect socio-economic issues, housing, industries, agricultural labours and estates of high ecological value.

3.4.3 Increase of communication possibilities[32]

In mountainous areas where morphology makes difficult the construction of communication networks, tunnels are the best solution and promote the development of depressed rural zones.

And in urban zones such as Sao Paulo (Brazil), Metropolitan Expressway in Tokyo, and Madrid (Spain) the underground railway tunnels increase the city internal communications system as presented in their cases study "Sao Paulo Underground", "Metropolitan Expressway Central Circular Route", and "Pasillo Verde".

3.4.4 Reduction of occupied surface area

During the execution of any civil work a piece of land is occupied, with the consequent costs of acquisition and effects on landscape and land uses. Occupation of land is only necessary in the tunnel entrances and external facilities like ventilation chimneys.

There are two kinds of occupation: permanent and temporal. The former takes place during the operation of the infrastructure, and the later during construction.

In a road tunnel, for example, the permanent occupation would consist of roadway, shoulders, ditch, slopes, mouths and chimneys[33]. The cut-and-cover system has the advantage of reducing considerably the permanently affected area. This system consists of excavating the tunnel on the open air and covering it afterwards.

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[31] Referred to Planning phase, construction phase and operation phase.

[32] Case study: Case Sophia line railway and Vallvidrera road tunnel.

[33] See any of the transport infrastructures case studies: Pasillo Verde, Sao Paulo Underground, Case Delft railway, Case Sophia Line Section and Vallvidrera road tunnel.

Temporal occupation takes place only during construction. It means a bigger surface of land than the permanent occupation. This is an important feature of urban underground works such as Sao Paulo Underground, Pasillo Verde and Case Delft railway due to the few spaces available for new building construction in the big cities and the need to increase communications according to the city growth.

3.4.5 Impacts on public opinion and social interests

Public opinion is generally in favour of underground works. These type of works are considered much more acceptable from an environmental point of view than superficial works. They are also supported for their efficiency and safety.
Taking into account social interests, it is important not to forget that the construction of a tunnel may carry some changes in the population's ways of life. In rural and mountainous places the presence of foreigners affects local costumes. A very positive reason for choosing the underground option is the elimination of biological barriers which would exist if constructing the surface alternative.

3.4.6 Alteration of pre-existing underground infrastructures

There are underground areas that are overcrowded, especially in urban zones. Any excavation in these areas could damage urban facilities such as water supply conductions, sewage[34], electric cables... This interaction can also exist in rural areas.

In order to minimise this impact, every underground infrastructure or excavation must be authorised, registered, and clearly documented. As examples of underground infrastructures interaction "Al-Salam Siphon" passes underneath the Suez Canal at a maximum depth below surface of about 45 meters and most of the urban underground projects as included in the cases study: "Sao Paolo Underground", "Case Delft Railway", "Pasillo Verde", "Cairo Waste Water Scheme", "Royal Library in Stockholm" and "Viikinmäki Waste Water Treatment Plant in Helsinki" have to be carefully planned and constructed in order not to interfere with other underground works, foundations of pre-existing buildings, water supply networks...

3.4.7 Alterations of the archaeological and cultural heritage

Effects on the archaeological heritage could be minimised by making boring tests supervised by expert archaeologists. Anyway, tunnels are preferred to surface works considering this issue.

[34]See "*Abastecimiento y distribución de aguas*" and "Saneamiento y alcantarillado" by Hernández Muñoz, Aurelio. Servicio de Publicaciones de la ETSI Caminos, Canales y Puertos de MADRID.

3.4.8 Alteration of demographic patterns

During construction tunnels affect the population pyramid of nearby villages, adding the presence of mainly young workers who demand lodge and other services.

Referring to the spatial distribution of the population, tunnel so not change land properties and therefore do not affect the spatial distribution.

During the operating phase, railway tunnels such as Sophia Line Section case study and Vallvidrera Road Tunnel in Spain make it easy for the population to travel and connection amongst areas is increased changing demographic patterns and customs.

3.4.9 Alteration of socio-economic patterns[35]

During construction, the flow of workers to nearby villages increases the demand of services, resulting in an increase of the number of jobs. The better accessibility of the areas connected by the tunnel will produce benefits on the industrial sector because of an easier freight transport[36].

3.4.10 Effects on quality of life[37]

In urban areas the construction of underground ways for vehicles favours the development of pedestrian zones and reduces traffic congestion problems. Besides, underground car parks allow other uses in big surface areas. This means a better quality of life for the inhabitants of the cities.

Urban railway tunnels such as Sao Paulo Underground, Case Delft railway and Pasillo Verde in Spain mean a good solution for traffic while reducing interference with the inhabitants daily activities, noise disturbances, dust emissions and an overall positive effect on quality of life.

In rural areas tunnels result in a better accessibility of the zone, improving the quality of life of people from small villages who found it very difficult to travel before the construction of the tunnel.

Execution of drills inside an underground work results in hygienic and safety problems for the workers. The level of dangerousness depends on the size of the particles and the silica concentration. Many countries have severity regulations in this issue. In inside works, water is usually used as a sweeping fluid. In outside works both dry and humid methods are use.

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[35] See: "*Manual de túneles y obras subterráneas*". Entorno Grafico S.L. By López Jimeno, Carlos. MADRID.

[36] Case study: Vallvidrera Road Tunnel, Spain. It is an example of non-urban transport infraestructure.

[37] See "*Pasillo Verde. Madrid*". Case studies. Transport infrastructures, urban area, railway.

3.4.11 Increase of public transport demand

Underground works produce an improvement of the public transport systems and an increase of the public transport demand in big cities. They have allowed the establishment of suburban railway networks improving the mobility of the population such as Sao Paulo Underground new stations, Pasillo Verde in Madrid and The Netherlands railway (case study Delft).

3.4.12 International experience

This chapter focuses on the list of effects on the human media[38] according to the information obtained from the questionnaire sent to the ITA members, and related to each phase of project.

Planning phase

Taking into account effects on the human media, underground works are generally preferred to surface works resulting in numerous and important social benefits.

This is especially appreciable in road and railway tunnels, where this type of effects are the decisive ones for the choice of an underground work. Referring to urban Undergrounds, Sao Paulo and Madrid cases study mean avoiding traffic disruption, interference with habitants, noise disturbances and dust amongst several other underground benefits over the surface solution as presented in their respective cases study "Sao Paulo Underground" and "Pasillo Verde".

According to the answers to the questionnaire, the factor chosen by a grater number of countries for all kind of projects is the reduction of occupied surface area. After this one, other benefits produced by tunnels and underground works are the increase of communication possibilities, and the non-alteration of surface land uses. Besides, public opinion is in favour of this sort of works.

Construction phase

According to the survey, and referred to the 13 cases study from Spain, The Netherlands, Egypt, Finland, Brazil and Sweden the effect more likely to have some influence on budget deviations is the impacts on public opinion and social interests, followed by the alteration of pre-existing underground infrastructures. Other factor considered by the interviewed countries is the damage on quality of life (contamination impacts, safety...). This aspect affects builders, whose working conditions are worse than in surface works. A budget increase may be produced by the implementation of protective measures for the workers.

[38] Biotic media is understood as the adition of soil, fauna, flora, and landscape features.

Operation phase

During operation, effects on the human media do not produce new works on the own infrastructure or externally to it (soil recuperation...). Effects on the inert media are the principal cause of this extra works.

3.5 Corrective measures.

3.5.1 Introduction

Protection of the geotechnical properties of the land

When an excavation is done, the ground is loosened and its geotechnical properties deteriorated. Landslide around the tunnel mouth is a big danger. A good corrective and preventive measure is jet-grouting around the excavated area.

After an excavation land is decompressed. If a concrete lining is done before this decompression, it stops the land from deforming, but consequently will have to support a high stress. Shotcreting before the definitive concrete lining allows a small deformation of the land. After this relief, the definitive lining is executed. This method is positive from a structural point of view, but might result in damages to pre-existing buildings.

Reduction of hydrological and hydrogeological alterations

In order to minimise impacts on hydrogeology, it is necessary to study as accurately as possible the following issues:

- Hydrological detailed model of the area.
- Inventory of wells, springs, and damp or flooded zones.
- Temporal distribution of flows.
- Precipitation data of the area.
- Levels of water.

To avoid the problems caused by water the solution is the impermeabilization by injection of cement or resins. This method improve the geotechnical properties of the land and fill the seams and pores reducing the water transmission. Other solution is to cover the work with impermeable materials.

These solutions are not expected to achieve a total impermeabilization because it is more economic to install a drainage system.

Reduction of subsidence

Subsidence is a general consequence of mining, even in the case when works are filled back. This may produce settling of pre-existing buildings especially in urban zones and it is very dangerous in the limits of the subsidence area, where tilt may damage the existing infrastructures.

Although it is more usual to pay attention to superficial movements for its repercussion in superficial foundations, it is important not to forget that there are also considerable underground movements that can affect deep foundations.

There are different measures to reduce the effects of settlings:

- Reinforcement of the foundations of nearby structures, underpinning with micropiles elongated up to an area where movements are not foreseen. This system has been sometimes applied after, once the damage is done.
- Execution of continuous protection walls placed between the affected building and the excavation. These elements must be rigid enough to reduce the movements.
- Reinforcement of the soil by injections in the proximity of the vault (jet-grouting, etc.)
- Injection of a high viscosity mortar which pushes the ground and compensates the settlings.
- Choosing an adequate constructive process: injecting holes between covering and ground, shortening the period when galleries are open, reducing as much as possible the digging area, etc.

Reduction of atmospheric pollution

A system to reduce the pollutant concentration of emissions is installing filters in the local chimneys of the underground work. These measures require a proper maintenance (removing the filter material). The most efficient type is the active coal filters which use the adhering properties of the coal eliminating very small particles. Other filters are fabric filters which retain pollutant particles in the fabric and electrostatic filters where particles are stuck by electric attraction. These filters are usually provided by vibrators to make the adhered particles fall from the filter.

Regarding dust emissions there are four kinds of actions:

- Prevention: avoiding activities that generate dust. A correct work planning can reduce the levels of dust generation.
- Control: preventing solid particles from floating in the air by dry or humid ways.
- Dilution: mixing dusty air with clean air by ventilation, reducing its concentration. This is not an advisable system because it only covers the problem, but it should be used when it is not possible to choose other options. In inside works it is the only solution.
- Isolation: avoiding the propagation of dust. In order to this it is necessary to protect the dusty areas from wind. This usually occurs in the slopes of the tunnel mouth and in places where loading and unloading of material take place. In slopes the best measure is

to plant vegetation which also produces other environmental benefits. It is important to point out that underground works reduce remarkably dust emissions compared to surface works.

Correction of noise impact

During construction and operation of underground works important emissions of noise are generated. Noise is cause of bothering on people and affects natural space, so it should be studied, controlled and prevented.

The measures that must be taken to minimise the acoustic impact provoked by underground works are:

- Study the acoustic situation of the area previous to the works.
- Foretell the acoustic impact of construction and operation on the environment.
- Stabilise a risk level for each element of the affected area.
- Suggest and analyse different alternatives to reduce the impact.
- Introduce corrective measures to reduce or eliminate the acoustic impact.

The corrective measures to acoustic impact are of three types:

- Actuation on the emitting source.
- Actuation on the propagation.
- Actuation on the receptor.

Actions on the emitting source, as well as a physic isolation of the emission, include the restriction of the most pollutant activities to periods of a less sensitivity. These activities are forbidden in fragile periods or areas: resting areas, schools, hospitals, at night or at weekends, during reproduction and breeding periods for fauna, etc. In order to reduce noise emissions it is very important to choose not very noisy machinery, and to make a strict upkeep of the equipment. The use of rubber materials in the works reduces noise generated by impacts.

Actuation on the propagation consists of incising in the sound waves movement, enlarging their way towards the receptor. Inside the tunnel a good solution is to cover it with noise absorbent materials, especially near its exits. Sounder screens are installed between the emitting source and the receptor in order to absorb the noise and enlarge its itinerary to the affected area. These screens can be prefabricated, with different sizes and materials. It is necessary to achieve its integration in the landscape. Another type of sounder screens are hills covered with vegetation, which can be made of materials from the excavation. The reduction of the level of noise by vegetation depends on characteristics as its height, thickness and extension. Sounder screens of vegetation are preferred to the prefabricated ones, for they reduce visual impact and flora alteration.

Actions on the receptor are basically based on its isolation. There are labour regulations that force the use of helmets in specific sonorous atmospheres. When the corrective measures on the emissary or on the propagation are not sufficient to achieve an acceptable level of noise, it is necessary to isolate the fronts of the affected buildings.

Protection of fauna

There are different devices installed in roads to prevent the entrance of animals and to facilitate its way out of the road. This is necessary in the proximity of the tunnel. One of the most frequent impact on fauna is the barrier effect. There are basically two ways of improving the situation: with transverse subways or with flyovers adequately designed for animals.

Corrective measures for the landscape

In tunnels and other underground works the principal corrective measure for the landscape is the revegetation of slopes, in order to stop the erosion and achieve an environmental recuperation. Revegetating treatments require a good use of the vegetal soil removed in the beginning of the works. This fertile soil must be kept in small stocks with a regular watering to keep its biological, physical and chemical properties.

Corrective measures for wastes generation

It is necessary to distinguish two phases of generation of wastes: construction phase and operation phase.

During construction there are spilt oils and greases, spare or irregular constructing materials, plastics, mud and polluted water. The collection and transport of these wastes to controlled dumps must be planned. If the underground work is important, the best solution is to make good use of these materials in embankments located close to the work.

During operation, the production of wastes is reduced to rubbish thrown by the users, detachment of load from lorries and sewage water. This water carries substances spilt by vehicles, rich in plumb and other heavy metals, soot settled in walls and pavement prominent from smokes, and sodium chloride spread on the platform in cold weather areas to prevent from frost. In order to minimise the dangerousness of this water, the pollutant substances can be settled in small chests placed in the external channels of the tunnel.

Protection of the archaeology

There are preventive and corrective measures to avoid the appearance of archaeological remains during the works, guaranteeing the conservation of the discovery and the viability of the project. These measures are the following:

- First of all, all official information about archaeology in the affected area should be collected.
- According to the characteristics of occupation of the different civilisations that were settled in the area, it is advisable to study the risks of finding archaeological remains in the zone.
- Specialists should visit the affected area and make a superficial observation.

- When the previous measures detect high risks of discoveries, excavations and borings should be done to analyse in detail the existence of remains avoiding further works.

The discovery of archaeological remains can be a result of the construction of an underground line. In some cases, these discoveries can be observed in their exact location. For example in the construction of a new line on Mexico underground the Echécatl-Quetzalcóatl pyramid was found and it is exposed to the public at the Pino Suárez station.

Protection of pre-existing underground infrastructures

There are underground areas that are overcrowded, especially in urban zones. Any excavation in these areas could damage urban facilities such as water supply conduction, sewage, electric cables, etc.

In order to minimise this impact, every underground infrastructure or excavation must be authorised, registered, and clearly documented. Previously to the works, an inventory of the facilities that can be affected must be done, and since the first stages of the project technical measures must be provided to eliminate this affection. These measures can mean a high cost that must be conveniently estimated.

When the underground work affects existing infrastructures, sometimes it is possible to change the location of those infrastructures but when this is impossible, the only solution is to choose an alternative itinerary for the tunnel.

3.5.2 International experience

In order to homogenise the answers, data for each measure showed below were calculated by adding the punctuation of each country and dividing it by the number of answers corresponding to that measure. The following table shows the average priority given to each corrective measure (1=highest, 6=lowest).

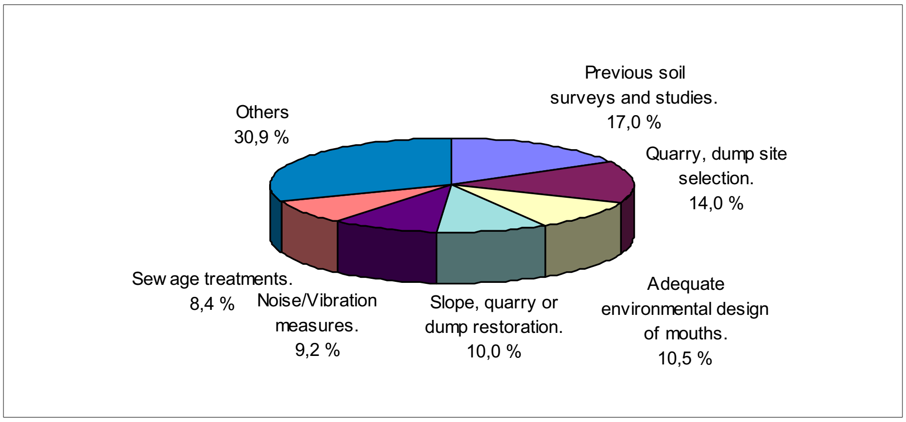
CORRECTIVE MEASURES	PRIORITY
Slope, quarry, dump restoration	2.9
Quarry, dump site selection	2.1
Adequate design to environment of mouths	2.8
Previous soil surveys and studies	1.7
Noise/vibrations measures	3.2
Sewage treatments	3.5
Pollutant emissions control	3.9

CORRECTIVE MEASURES	PRIORITY
Using of subproducts as raw material	5.4
Adequate planning of machinery movements	5.8
Precaution against water table level alteration	4.3
Work planning	5.1

Therefore, the measures more usually derived from underground works are, in order of importance:

Measures: Relative importance (%):

1) Previous soil surveys and studies. 17
2) Quarry, dump site selection. 14
3) Adequate environmental design of mouths. 10,5
4) Slope, quarry or dump restoration. 10
5) Noise/Vibration measures. 9,2
6) Sewage treatments. 8,4
7) Pollutant emissions control. 7,5
8) Precaution against water table level alteration. 7
9) Work planning. 6
10) Use of subproducts as raw material. 5,4
11) Adequate planning of machinery movements. 5



4 ENVIRONMENTAL BENEFITS OF UNDERGROUND WORKS[39]

This chapter deals with three different points related to environmental benefits of underground works: reasons for the selection of the underground solution, new technologies for the construction of underground works that will mean the reduction of construction impacts, and future demand of underground projects.

The first part introduces and describes the principal factors that determine the underground work as a better solution over the surface option based on environmental impact reasons.

The second part focuses on the study of new technologies both engineering and structural management related that have meant a reduction of construction impacts. The development of the multiboom track-mounted drill jumbo and the modern data drill method greatly reduce impacts and can be combined with environmentally friendly explosives but it is particularly the improvements in positioning technology, which incorporates laser technology and the global positioning system the principal advance towards reducing environmental underground working methods[40]. It is a fact that machine automation and computer control have improved efficiency, precision and safety of excavation work. All these new techniques mean that the proportional cost of underground works has fallen and protection of the environment may be improved without an increment of budget.

The last part introduces the trends of future underground projects investigated amongst ITA members and the following results were found. This chapter focuses on the future underground works pointing out railways, water, human protection, recreational and necessary facilities, business community, parking lots, metro stations and routing plans, traffic and communication solutions, municipal services, materials storage and nuclear wastes. An additional part dealing with future demand and its relation to legislative framework is added.

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[39] See *"La Obra Subterránea y el Medio Ambiente"*. Written by ENVIRONMENT, TRANSPORT & PLANNING. November 1994.

[40] See *"The fourth wave of rock construction"*. Environmentally responsible underground design, engineering, and applications. Editors: Kimmo Rönkä and Jouko Ritola. Technical Research Centre of Finland.

4.1 Reasons for the selection of the underground solution

4.1.1 Summary

The reasons pointing towards the underground solution must be understood as benefits over the surface solution. In most of the real situations the comparison between surface and underground solutions becomes an important part of the environmental impact evaluation procedure.
The features of a project taken into exam in order to decide a solution make up an endless list: economy, politics, quality of life, risks, environment, equipment, materials, facilities, legal aspects, profit and benefits, physical studies... The broad group of factors that have a specific importance makes the decision extremely variable according to the relative interpretation of each factor. Regardless of all this, there are an objective group of environmental benefits offered by the underground solution.

This chapter introduces and describes the main factors that determine the underground work as a better solution over the surface option based on environmental impact reasons.

4.1.2 Avoiding Planting project

If choosing the surface solution planting and plant materials should be studied by the project team prior to completing the project design, then take care to select the most dominant and useful native species to use on the restoration project and ensure adaptability, food and stability for the fauna and flora. This procedure means time, and the help of a number of public and commercial nursery sources which means expensive budgets. The underground solution minimises the surface and therefore saves money.

Avoiding planting is especially important in non-urban areas transport infrastructures such as study cases "The Netherlands Case Sophia Line Section Railway" and "Vallvidrera Road Tunnel in Spain" because of the long distance and the proportional high landscape surface the surface solution would have involved.

4.1.3 Uses of surface and subsurface

Underground works rarely limit the use of surface land. It means that the use of surface land may be dedicated to the same activity that before the execution of the project. In some cases specific action must be developed in order to allow the same use but the properties of land and soil rarely change compared to the disadvantages of surface solution. This should be pointed out in highly congested urban zones such as Madrid and Sao Paulo where the underground railway solutions (Sao Paulo Underground and Pasillo Verde study cases) do not interfere with the different uses of surface. Concerning Sao Paulo Underground, it is important to point out that this four new stations and tunnel avoided disruption of traffic, relocation of land uses, construction noise and visual impact on a very busy city street.

Even though the geotechnical properties of the land change as consequence of excavation, and the soil is loosed during the construction processes, the properties of land, as far as agriculture, tourism, travelling... and similar activities is concerned, remain without important alterations.

4.1.4 Geological, geomorphologic and paleontological wealth

Underground works respect the surface geological formations and allow the knowledge and study of underground formations which otherwise would be inaccessible.

4.1.5 Soil erosion and runoff

Geomorphic elements include slope gradient. The change of surface slope gradient may cause soil erosion if the surface solution is chosen. Changes in soil moisture content, slope stability, potential local vegetative cover and other site characteristics may result in erosion and negative impacts. The underground solution becomes advisable under these conditions.

As included in the non-urban zone study cases concerning road or railway tunnels such as Sophia Line Railway (it is a section of 7 km. The planned double track freight rail link between the port of Rotterdam and the Hinterland and Germany crosses two very busy motorways, and River de Noord, which is a major motorway as well as others smaller roads and waterways. An Integral Evaluation Study was carried, similar to the one for Case Delft), or Vallvidrera Road Tunnels, the surface option would occupy an extend area, and the slope gradient changes of these zones could cause soil erosion and runoffs unless a proportional quantity of money were input into corrective measures.

4.1.6 Dust and gaseous emissions

Atmospheric pollution due to tunnels is reduced to the emission of dust in the mouth an chimney zones of the underground works. Compared to the surface alternative, the underground work reduces remarkably emissions. The way the emissions inside a road tunnel affect the external atmosphere depends on the ventilation system and on the location of the expulsion points. In normal conditions atmospheric pollution due to tunnels is not significant, since there are sever limits for the inside concentration of pollutants, and besides this concentration is reduced outside by spreading.

The intensity of the impact produced by the emission of dust into the atmosphere is meaningless as far as include microclimatic changes, direct effects on vegetation and soil, respiratory diseases, allergies or irritations and damage to machinery or buildings.
It is important to underline the fact that in urban zones the dust and gaseous emissions must be

reduced in order to protect urban population. "Sao Paulo Underground", "Case Delft Railway", "Pasillo Verde Railway" and "Metropolitan Expressway in Tokyo" underground works highly reduce the risk of dust and other gaseous emissions to the people living in these cities during the construction phase.

4.1.7 Noise reduction

The reduction of noise is a great advantage of underground solution since noise is a cause for concern due to the serious nuisance it may cause and its potential long-term effects on public health an possible effects on animal behaviour.

A number of factors influence the propagation of noise between the source and receptor: distance, the presence of obstacles, meteorological conditions, phenomena of refraction and reflections, and the absorption and reflection characteristics of the intervening ground. The underground solution is highly recommended over the surface one based upon these factors.

Urban transport infrastructures such as Sao Paulo underground or Pasillo Verde in Madrid highly reduce the noise even though vibrations produced by the trains may cause little local disturbances to the nearby buildings.

4.1.8 Avoiding surface preparation

Establish desired topography is necessary for the surface solution. Because soils are susceptible to erosion during grading and shaping activities, those activities should be scheduled and included in the budget during periods of study. By choosing the underground solution a number of impacts disappears such as establishing vegetation on the soil, shaping and grading, standard site stabilisation, restoration measures following several basic conservation principles, replacing or redistributing topsoil... This advantages is particularly important when dealing with non-urban linear transport infrastructures such as Case Sophia Line (Railway), Vallvidrera Road Tunnels and even Metropolitan Expressway in Tokyo.

4.1.9 Stockpiling soil[41]

Underground works avoid the need to collect, stockpile and treating topsoil.

Also, if soil is to be stockpiled for more than 3 months it should be temporarily seeded to prevent erosion and compaction, to compensate for the loss of organic matter and to provide a biotic base to protect and encourage original microfauna, microflora and invertebrates. Following completion of construction, topsoil should be redistributed and seeded promptly to prevent from

[41] See "*Pilot Study on the Effects of Public Works Projects on the Environmet*". Chapter III. North Atlantic Treaty Organisation. July 1995.

flowing water. Stockpiling soil has been avoided thanks to the underground solution in The Netherlands Sophia Line and Spanish Vallvidrera tunnels.

4.1.10 Visual intrusion[42]

Underground works are positive in relation to visual intrusion. They are perfectly integrated in the environment, and eliminate the construction of embankments which produce a very negative visual impact. This is especially interesting in landscapes of a high value, which are frequently located in mountainous zones, such as Vallvidrera Road tunnels, a group of tunnels that allows the maintenance of natural landscape.

4.1.11 Alteration of surface fauna and flora

By choosing the underground solution the occupation and consequent alteration of surface would be reduced to the proximity of the mouths. These would reduce the negative consequences caused by the surface solution. As well as other advantages of the underground solution, the alteration of surface fauna and flora depends upon the occupied surface, and therefore the big transport infrastructures in high ecologically rich areas will accept the tunneling as an environmentally respectful solution. This corresponds with the non-urban areas underground works in Vallvidrera road tunnels as indicated in the study case "Vallvidrera Road Tunnel. Spain".

4.1.12 Non-alteration of the landscape

This effect is locally reduced to the tunnel's mouths and chimneys. An appropriate design of these elements would minimise the effect. It is advisable to treat the slopes with vegetal species suitable to the local climate.

The same reasoning process used for protection of fauna and flora could be translated to the conservation of the landscape for the Vallvidrera study case. Even "Pasillo Verde" study case in Madrid would be a good illustration for non-alteration of the "cityscape" and even the opportunity to create green spaces to rise the environmental features. In a similar urban non-alteration of cityscape The Royal Library in Stockholm, expansion of Sweden National Library retaining its original outer appearance with two rock chambers, each measuring 150x15x19 meters (lxwxh) , with their floor at 40meters below ground level, becomes a good illustration as shown in its study case.

[42] See "Environmental Impact" by Ignacio Español. ETSI Caminos, Canales y Puertos. MADRID-SPAIN.

4.1.13 Operation phase additional works

The necessity of additional works during the life of an underground infrastructure is reduced to the effects on the inert media more than biotic media. The only factors concerning these additional works are related to noise generation and changes in the landscape close to the mouths.

Other works could be related to the use of the underground work facilities such as nuclear waste controlling activities in the Äspö Hard Rock Laboratory (nuclear waste storage for the final disposal of spent fuel 500 meters down in the bedrock), the treatment of waste water in Viikinmäki plant in Helsinki (1.000.000 m3 rock cavern built under a few future residential area saves valuable building land and eliminates the malodorous drawback of sewage treatment in surface plants. Treats the waste water effluent of about 700.000 local resident and industry) , the maintenance of the Cairo waste water scheme (tunnels run below the existing sewage and part of the Metro system, below the ground water table. It is a essentially environmental project that aims at improving the sanitary conditions in Cairo with a minimum disturbance to the city), and the usage of the Al-Salam siphon under the Suez Canal (siphon for transferring water from the Nilo to Sinai through four 5.1 meters internal diameter tunnels) may be considered as operational phase additional works. Anyway, they do not add any exclusively underground related disturbance but the natural consequence of these operating facilities.

4.1.14 Non-necessary mulching

Mulches are well-used when choosing surface solutions to temporarily stabilise soil surfaces and modify the deeded environment to enhance vegetation establishment. They provide benefits such as conservation of moisture available for newly established seedlings, reduction of soil temperatures during summer months, prevention of alternative freezing and thawing of soil in the winter, reduction or water erosion... but they suppose an increase of the work.

As related to the non-urban transport infrastructures (Case Sophia Line Railway, Vallvidrera Road Tunnels, Metropolitan Expressway in Tokyo...) the necessary mulching caused by surface solution would mean a great increase of budget.

4.1.15 Alterations of socio-economic and housing uses

Underground works minimise the alteration of surface land and infrastructure-building uses. This is especially interesting in urban zones where changes in the land uses can affect socio-economic issues, housing, industries...[43]

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[43] Case studies: Cairo waste water scheme, Royal Library in Stockholm and viikinmäki waste water treatment plant in Helsinki are urban related underground projects concerning with industrial and public space activities.

4.1.16 Increase of communication

In mountainous areas where morphology makes difficult the construction of communication networks, tunnels are the best solution and promote the development of depressed rural zones.[44]

And concerning with urban zones, Sao Paulo Underground , The Netherlands Delft railway, Metropolitan Expressways in Tokyo, and Pasillo Verde in Spain have improved urban communication while avoiding road traffic disruption and interference with the inhabitants daily activities.

4.1.17 Public opinion

Public opinion usually accepts the underground solution, according to the answers to the questionnaire, based upon safety and efficiency reasons and taking into account the increasing environmental public sensibility that is easily translated into a stronger environmental respect.

4.1.18 Socio-economic local reasons

Underground solutions are preferred because of the economic benefits that an easy transport of materials and products means, and the environmental benefits related to human media it means.

It produces an improvement of the public transport systems and an increase of the public level of mobility which means an increasing economic conditions. As an example, the Vallvidrera Road Tunnel in Spain will allow the road communication of the western part of Barcelona and the interchanges of the city with its commercial and industrial hinterland.. The establishment of suburban railway networks improves the mobility of the urban population[45].

4.1.19 Development of pedestrian zones

In urban zones where the traffic congestion are hard to avoid, the underground solution generates a fluent traffic and the development of pedestrian zones[46]. It means levelling out safety problems as traffic accidents and an improvement of quality of life. Pasillo Verde in Spain has become a representative project to show the importance of environmental construction of urban railway planning that fully respects green pedestrian zones.

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[44]Case study: Vallvidrera Road Tunnel in Spain. non-urban transport infrastructure.

[45]Case studies: Sao Paolo Underground, Case Delft railway and Pasillo Verde in Spain.

[46]Case study: Pasillo Verde in Madrid; railway; urban area; transport infrastructure.

4.2 New technologies for the construction of underground works that will mean the reduction of construction impacts

4.2.1 Summary

Nowadays the importance of construction impacts is considerably serious and, therefore, new technologies, both engineering and structural management, for the construction of underground works have appeared in order to reduce these negative impacts and draw attention to the environmental advantages of rock engineering solutions.

Many successfully accomplished underground projects based upon new technologies demonstrate that subsurface construction is a good alternative from the environmental perspective.

The present chapter focuses on the study of new technologies both engineering and structural management related that have meant a reduction of construction impacts. The development of the multiboom track-mounted drill jumbo and the modern data drill method greatly reduce impacts and can be combined with environmentally friendly explosives but it is particularly the improvements in positioning technology, which incorporates laser technology and the global positioning system the principal advance towards reducing environmental underground working methods. It is a fact that machine automation and computer control have improved efficiency, precision and safety of excavation work. All these new techniques mean that the proportional cost of underground works has fallen and protection of the environment may be improved without an increment of budget.

4.2.2 New engineering technology

The main feature of environmental-based new technologies is the fact that construction should be done in harmony with the environment and the use of the underground space should not have any impact on the environment. Materials that give rise to environmental impacts during their production processes should not be used in underground construction.

New technologies must propose the possibility to excavate large rock caverns. Most of the old traditional methods such as cooling and heating of the bedrock are nowadays part of the past history of underground works due to their time and high budget demands. Gunpowder gradually took their place in rock and came into regular use since the last century as the drills necessary for hard rock drilling were developed into the actual high-technology drills.

The activities done in the drill-and-blast method to excavate are: pre-grouting, drilling, charging, blasting, ventilation, hauling of blasted rock, scaling and work-stage reinforcement[47]. Of course, as the excavations progresses reinforcements are done.

One of the most important drills types is the multiboom track-mounted drill jumbo, which has recently been used with outstanding outcomes in Finland. The development of the tunnelling technology started out with the jack-jammed with air leg which has ended up into the modern data jumbo. With this procedure it has been possible to save more rock surface than previously and therefore the environmental impacts are greatly reduced.

The Data Drill method is based on the movements of the programmed boom so that the drill moves from one hole to the next automatically. All the other drill controls are computerised as well. In this method the role of the drill operator is to supervise the movements of the booms and to make adjustments when and if necessary. This way we get control of tunnel over-break, optimisation of the drilling pattern and security with high velocity. This method may be combined with environmentally friendly explosives which reduce the harmful effects in either the water from excavation or in the gaseous emissions of blasting work.

In order to reduce the visible and obvious environmental effects of on-site crushing (dust and noise) enclosing principal sources in sound damping material and maintaining the plant between constructed banks of overburden may be taken into account.

As far as hydrological and hydrogeological alterations are concerned, drainage problems depend on the constructive method. If the excavation is made by blasting, cracking will appear around the cavity. As well as a geotechnical problem, this seamy rock will mean an increase of the water flow, not only towards, but also parallel to the tunnel. When the work is made by mechanic methods there will be a minor affection to the surrounding land. But mechanic methods are used in less competent land and therefore generally permeable, so there can still exist drainage problems. It proves that sometimes, high-technology may be replaced by traditional mechanic methods even though it may mean an increment of time. The perfect use of the correct excavation method should be part of the correct project in order to maximise results and use high technology correctly.

The principal new technology for underground works construction that means reduction of construction impacts is the improvements in positioning technology, which now incorporates laser technology and the global positioning system.

Machine automation and increasingly widespread computer control have improved the efficiency, precision and safety of excavation work. This means a major efficiency, safety, lower energy consumption, less disturbance and fewer harmful emissions.

Reducing the pollution of groundwater is other important negative impact to pay attention to. Pollution of aquifers layers is irreversible in many cases, which is very serious taking into account the increasing use of underground water for urban uses. Preventive measures should be

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[47] *"Manual de túneles y obras subterráneas"* by López Jimeno, Carlos. MADRID 1996.

taken, like waterproofing and effective sewage systems in order to mean a reduction of impacts.

The important of all these new techniques relays on the fact that the proportional cost of excavation has fallen considerably compared to the traditional projects while protection of the environment has improved.

4.2.3 New structural management technologies

In order to reduce environmental impacts new technologies in project management tools must be designed. In all underground works project a multi-disciplinary technical team should be used to assure that engineering features and requirements are compatible with environmental aspects and considerations. These teams should be made up of engineers and scientists from appropriate fields, including ecologists, biologists, soils specialists, hydrologists, socio-economic specialists, and any other project-specific discipline needed. The use of these multi-disciplinary teams will enable the construction of underground works according to the environment and improve quality of life.

Future structural management technologies may add "Integral Evaluation Studies" in order to submit and compare several options. This kind of studies have been taken into account in "Case Deft Railway" in The Netherlands dealing with a extension of the existing rail corridor which traverses the city of Delft, where the study was made in order to compare four different options as a pilot case, because such studies had never been done before. The IES must cover several factors involved in a project such as capital investment, operational costs, construction time, hinder to the affected area, technical risks of construction and operating phases, environmental impacts on land, water, ecology, air quality, noise, vibrations, living environment, safety, agriculture, recreation and on residential and business uses of the area. Other issues to be studied in the IES are economical impact on employment, cost of traffic congestion and time and effort to conduct all the necessary procedures to obtain the permits. These aspects are quantified in terms of money and the different solutions are compared in order to make a choice.

Monitoring of the underground work project is an important component of new management technology for purposes of both engineering integrity and environmental respect. Monitoring consists of either short-term or long-term efforts, and requires pre-, during, and post-project data collection. Monitoring provides baseline data, documents chronology and specifics of project development, and provides information that can be used to develop similar environmental projects in the future. The monitoring process include a maintenance control as part of the environmental management.

The traditional monitoring process provides details for physical and engineering monitoring. The new concept of total monitoring system must add ecological evaluation concerning colonisation, survival, growth, and reproduction of the biota (fauna, flora, and even micro-organisms is needed) that occur on the underground work project. It is necessary to determine what is expected to be displaced or destroyed in order to take the correct measures to reduce the negative impact. As the rest of the monitoring system, ecological monitoring should be conducted from the pre-construction phase through post-construction phase to the operation of the project. Along permanent transact lines, wildlife, vegetation, and soil features data collections and working procedures in order to avoid negative impacts, a number of ecological monitoring models have been developed that allow for a quick evaluation of impacts.[48]

4.3 Future demand of underground projects

4.3.1 Summary

Underground works find their origins in later caverns, which served as shelter from the weather and natural dangers and protection from wild animals. Then, tunnels were used to house different types of technical services (sewers[49], metro tunnels, municipal engineering facilities, military defence structures, power plant technology...) as society discovered the benefits of underground construction in connection with urbanisation. Thirdly, underground spaces began to be used for human activities, and nowadays, greater environmental awareness has led to the increasingly widespread construction of underground spaces for human activities such as sports halls, swimming pools, ice hockey rinks, recreational and cultural applications or churches. Even the business community also brought underground pedestrian precincts, parking and other facilities to city centres.

All these "waves" of underground engineering follow and complement one another. The next step up to take by underground works may be a modern alternative to traditional surface construction.

In fact, the slow and difficult excavation methods traditionally used in hard bedrock made it economically impossible the use of underground spaces. Nowadays, high-technology development turns this hard rock obstacle into a factor favouring the underground use of spaces because bedrock allows wider spans and stands up to fast and efficient excavation.

The trends of future underground projects have been investigated amongst ITA members and the following results were found. This chapter focuses on the future underground works pointing out railways, water, human protection, recreational and necessary facilities, business community, parking lots, metro stations and routing plans, traffic and communication solutions, municipal services, materials storage and nuclear wastes. An additional part dealing with future demand and its relation to legislative framework is added.

[48] See: "*Impacto ambiental*" by Ignacio Español, Cátedra de Ingeniería Sanitaria y Ambiental. ETSI Caminos, Canales y Puertos. SPAIN-MADRID.

[49] See "Saneamiento y alcantarillado" by Hernández Muñoz, Aurelio. Servicio de Publicaciones de la ETSI Caminos, Canales y Puertos de MADRID.

4.3.2 Future underground works

Railway[50]

Unlike roads, railway do not have the flexibility to draw its planning project, otherwise it has to adjust to the land and therefore underground tunnels become an economic alternative. Planners simply do not have any other alternative to tunnelling when confronted by hills. This fact assures a good future for railway underground routing.

Sao Paulo Underground stations and tunnel avoided disruption of traffic, relocation of land uses, construction noise and visual impact on a very busy city street and, therefore, practically the only physical interference of the entire work with the movements taking place on the surface occurred at the two mouths of the new tunnel system. This achievement was of vital importance because the Paulista Line lays under some very busy city streets that would very badly support any disturbance of the habitual traffic of vehicles and pedestrians.

Delft railway, in The Netherlands, is an example of a rail corridor consisting of a double track viaduct of approximately 3 km. length where the high traffic demand requires an extension with two more tracks traversing the city of Delft. The high levels of transport in the urban zones may create a future demand of underground railways with new lines based on old simple lines.

The Sophia Line Section study case is another type of modern double track freight rail link between the Port of Rotterdam and the hinterland of Germany. This kind of underground works which have to cross different types of obstacles such as motorways, highways, rivers and other kinds of small roads may change the areas lying along into a residential and business area in the future.

Water[51]

The new concept of water infrastructure began at the beginning of the present century with the excavation of water main tunnels. This was followed by raw water tunnels, waste water treatment plants and in increasingly in recent decades, caverns and tunnels for a variety of water engineering applications. For instance, the Päijänne water tunnel in Finland has become the solution for the evident inadequate water reserves in the Helsinqui region regarding quantity and quality. This underground work meant the security for water supply for the area in accordance with the legal plans; in order to minimize the harmful effects to the ecological balance the projects includes certain attentions to the groundwater situation in the area near the tunnel line as explained in its study case.

In fact most of the surveys countries think that tunnels play a vital environmental role by

[50]See Case studies: Case Delft, Sao Paulo Underground, Pasillo Verde, and Case Sophia Line Section.

[51]See "*Abastecimiento y distribución de aguas*" by Hernández Muñoz, Aurelio. Servicio de Publicaciones de la ETSI Caminos, Canales y Puertos de MADRID.

delivering clean water to urban areas and collecting waste water. But refereeing to "Water collection systems and conduits will be required in increasing quantities. Underground reservoirs and tunnels decrease the loss of water by evaporation" and "Rain water can be collected in tunnels and underground reservoirs, separating it from domestic sewage in order to prevent sewage treatment plants from overwhelming in rainy cities" the answers are divided equally.

As a representative example of waste water treatment plant, Viikinmäki plant in Helsinki cooperates in wastewater treatment as an integrated sewerage system of sewers lines, wastewater pumping stations, sewer tunnels, treatment plant and an effluent outfall to the sea. This way, the land which for years had been taken up by several small surface treatment plants has now become available to build housing for several thousand people. As far as environmental issues is concerned, the underground solution will make for a major reduction in the odor and noise problems commonly associated with wastewater treatment. For farther information see "Viinkinmäki Wastewater Treatment Plant in Helsinki".

"Cairo Wastewater Scheme" study case should be taken into account in order to illustrate future tunnels running below urban underground infrastructures in future works. In this case, the underground tunnels run below the existing sewers and part of the Metro system, below the groundwater table. It is a essentially environmental project that aims at improving the sanitary conditions in Cairo with a minimum disturbance to the city. These kind of projects will increase as most of the important cities in the developed countries have overloaded sewers systems as population increases. Reusing the waste water for agriculture is one of the important environmental points of this scheme.

Al-Salam Siphon under the Suez Canal which serves for transferring water from the Nile to Sinai through tunnels, is an environmental solution that, according to the limited water resources available to Egypt, aims at conveying 2.300.000 m3/year of wastewater under the Suez Canal to Sinai agricultural areas. The main propose is to develop agriculture by offering irrigation by transferring large volumes of water and wastewater.

Human protection

Underground caverns have been used as refuge against wild animals, temperature changing, natural catastrophes... and nowadays military security has used caverns and underground constructions as air defence shelters, population protection, radioactivity or biological weapons.

Nowadays, Cairo wastewater scheme has become a great improvement towards figuring out a solution to all the discharges caused hazards to health. It is an essentially protective underground work that aims at improving sanitary conditions in Cairo.

Recreational and necessary facilities[52]

According to the growth of popularity, underground recreational, hospital, sports, cultural and multi-purpose facilities will be built. The integration of the underground spaces into surface townscape has been a trend of development that has just began.

All the surveyed countries answered as important-very important the fact that congestion in urban areas has been dramatically reduced by the use of underground works.

The Royal Library in Stockholm, Sweden, was designed to accommodate a certain number of volumes and offer work places. Eventhough the library has been expanded in several it has overgrown itself and underground works have been considered to be the solution for the new expansion in order to meet the present and future needs. The historically and culturally important building of the Royal Library should remain its original appearance, therefore the new chambers should be placed underground.

Business community

Underground works present technical facilities for the business community. Cities do not have enough surface space to build office and business buildings and in order to keep a city compact, and preserve the cityscape, underground works are the solution. This undersurface use of land will allowed a pedestrian and traffic-reduced city.

According to the answers to the survey, most of the countries think that it is indifferent-important the fact that underground space is being increasingly used for industrial, office and even residential facilities[53].

Most of the urban works cause a group of disturbances to the business community due to the disruptions to the commercial areas, maximizing traffic problems, and reducing surface area to develop business projects. On the other hand, underground urban projects such us "Cairo Waste Water Treatment Plan", "Sao Paulo Underground", "The Royal Library in Stockholm" and "Viikinm·äki Waste Water Treatment Plant in Helsinki" respect the uses of surface land, avoid disruptions to the commercial areas and therefore offer a new modern cityspace for the business community.

Parking lots

Parking often presents problems in designing residential areas. Cars take up a lot of space parked at ground level, which is valued more highly by residents if used for living space and greenery. The future demand of car parks will be increased due to the more effective use of land

[52] Case study: The Royal Library in Stockholm.

[53] Case studies: *The Royal Library in Stockholm.*

and less damage to the cityscape.

Most of the surveyed countries think that it is important the sentence "The usable space of a lot can be almost doubled in some cases by adding underground building or storage"

Metro stations and routing plans[54]

Metro trains have been running in the most important world cities as it becomes a comfortable, fast, environmental, and economic way of transport. Lines are design according to underground works projects connecting surface/subsurface stations. The aim will be to keep the line underground wherever possible in order to respect built-up areas.
According to the answers to the questionnaire most of the countries consider important-very important the fact that in the future, private vehicles should be replaced wherever possible by efficient public transportation systems such as underground. And as a representative examples "Sao Paulo Underground", "Delft railway" and "Pasillo Verde" put underground railway system into one of the most environmental ways of urban transportation as indicated in their study cases.

Traffic and communication solution

Underground solution is usually accepted as environmentally respectful compared to the surface solution. They are used to penetrate hills and mountains both in small-scale tunnels and major traffic tunnel projects.

The underground solution serves the need of the environment: natural conditions, user requirements and the views of local residents are all taken into consideration when building traffic tunnels all over the world. "Pasillo verde", in Madrid has become an example as environmentally friendly solution for urban railway underground solutions and at the same time adds the opportunity to improve the cityscape with ecologically accepted green spaces aiming at a better local residents level of life.

Traffic tunnels will become a better alternative as the importance of environment preservation grows. Tunnels can reduce negative impacts such as traffic noise, emissions, and the annoying effect that a road causes.

According to the answers to the questionnaire, most of the surveyed countries agree with the thesis that tunnels provide safe, ecological and fast transportation systems for people from all walks of life in both developed and developing countries. Referring to the question "Rapid systems and a better use of underground space in metropolitan centres should be implemented in the future, in order to protect, maintain and develop agricultural rural areas in sustainable regions, that will require the use of great surfaces of land", the answers are divided between indifferent, important and very important.

"Delft Railway" study case is considered to be a pilot case, because such studies on existing

[54] Transport infrastructure Case studies in urban and non-urban areas in Brazil, The Netherlands and Spain.

corridors which traverse cities had not been done before. The improvement of communications according to an Integral Evaluation Study was based on economic, environmental, safety, impacts on land, water and ecology, traffic needs, comparative solutions... as explained in this study case.
In a similar way, Vallvidrera Road Tunnel in Spain is part of a new road axis that will substantially improve the westward road connections of city of Barcelona, (this Spanish city is an important maritime port with a logical important area, submitted to a dynamic expansion process and at the same time hindered by natural barriers made up of mountain chains). Underground solution is the best compared to the surface one in order to break this mountain barrier just like in most of the high-mountain zones.

Municipal services[55]

Energy cannot be distributed to industries and householders without qualified infrastructure. In order to ensure the reliable distribution of services the underground solution is fast, economic and environmentally accepted.

Water mains, sewage pipes, heating pipes, electric cables, communication lines... will be installed in multi-purpose tunnels as a comfortable solution. This way, it is possible to save construction costs and reduce environmental impacts.

Kazunogawa pumped storage power plant in Japan in an underground power plant tries to compensate the significant fluctuation of power demand between the night time of-peak and the day time peak maintaining the quality of electric service, and at the same time saves the beautiful mountains and canyons close to the well-known Fuji region.

Most of the surveyed countries consider important-very important the ideas "Tunnels and other underground works will have their greatest application in future mega cities if there are sufficient funds and other barriers are eliminated" and "A better urban planning and an increasing use of underground infrastructures may help to improve the situation of decayed central cities".

Fuel, food and gas storage

Underground fuel storage greatly minimises risks and maintains emergency fuel reserves in order to improve the needs of a city. Oil, petroleum, liquids and gases can be stored as an alternative to surface tanks and facilities.

Around 75% of the surveys countries think that underground space for bulk storage of food, liquids and gas has gained increasing acceptance in several places in the world. Most of the countries consider important the fact that in some cases, the cavities created by mining can be used for other purposes such as underground storage.

[55] Case study: Underground industrial activities such as Viikinmäki waste water treatment plant in Helsinki, and utilities infrastructures such as the Cairo waste water scheme, Al-Salam siphon under the Suez Canal and Päijänne water tunnel in Finland.

As a matter of fact, storage has found its way in underground solutions such as "Kazunogawa Pumped Storage Power Plant" study case in Japan. This underground plant tries to compensate the significant fluctuation of power demand between the night time off-peak and the day time peak. It is located in the area of the cities of Otsuki and Enzan in the Yamanashi Prefecture, close to a mountainous topography with a great environmental value which means that the construction had to be designed as non intrusive as possible. The underground solution perfectly matched with this condition.

Nuclear wastes

The various radioactive wastes produced in nuclear power stations can be hazardous to the environment for very long periods of time. The underground solution to store this substances is one of the safest and cheapest. Studies and tests have been conducted in order to ensure that the final disposal of spent nuclear fuels is stored without any detrimental effects on the environment or public health.

The constant conditions prevailing deep beneath the surface, and the long-term strength and durability of rock as a material are part of the advantages of storage in deep rock caverns. The radioactive materials will be sealed and left until they become harmless as time goes by[56].

Underground storage of nuclear wastes in "The Äspö Hard Rock Laboratory" is a responsible method for ensuring that Sweden's radioactive waste from nuclear power, medical care, industry and research is disposed in a safe manner and a way to guarantee the absence of environmental damage caused by the disposal of radioactive material. Information about investigations and technical characteristics of the project can be found in its included study case.

Indeed, the vast majority of the surveyed countries think that underground is the only safe location for storage of nuclear wastes and other hazardous or undesirable materials.

4.3.3 Future demand and legislative framework

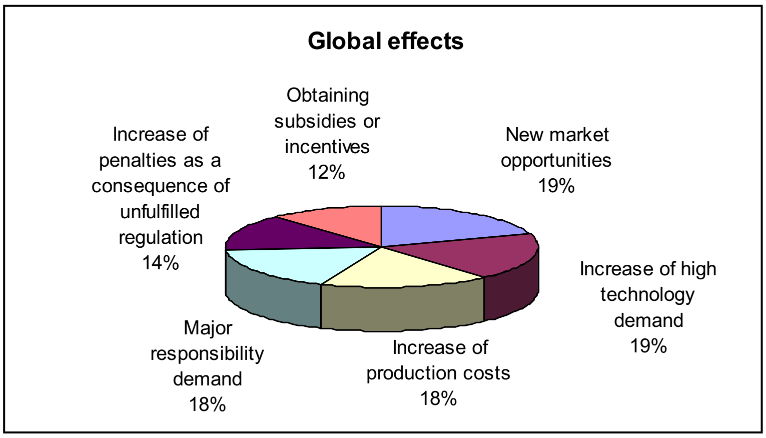
The environmental regulations connected with Evaluation Impact Assessment are the ones that have a greater influence on underground works. To a lesser extent, regulations on safety and health, wastes generation, noise and vibrations, and water are also relevant.

Environmental legislation has both positive and negative consequences on the different agents that operate in the underground world. The most outstanding effects are on one hand new market opportunities, but on the other hand, an increase of production costs and a major responsibility demand of the economical agents.

[56]See Case study: *The Äspö Hard Rock Laboratory*. Nuclear waste storage.

As environmental legislation becomes more and more strict, underground works will take advantage of their advanced position compared to superficial ones. The tunnelling associations of the countries participating in this survey hold varying opinions about the interrelations between underground works and the environment, although the totality consider that the increasing environmental sensitivity and legislation are going to have a positive influence on the development of underground works.

As a matter of fact, nowadays most consulting and underground works management companies have developed their own environmental department according to the legislative framework and all of the surveyed ITA members countries think that the environmental departments on this type of consulting and underground works management companies or organisations will be increased in the future until all of these companies have an specific environmental department. In a similar way, the surveyed countries agree with the fact that almost half of the construction and machinery companies lack a developed environmental department but most of the countries believe that, in the future, about 80% of these construction and machinery companies will have an environmental department.



5 OPPORTUNITIES AND THREATS OF UNDERGROUND WORKS IN RELATIONSHIP TO ENVIRONMENT

5.1 Summary

This chapter tries to include a study of the opportunities and threats of underground works in relationship to environment. In order to accomplish this goal, the first part of the chapter includes several ideas related to sustainable development, underground works and environment. A second part emphasises the incidence of underground works on the environment according to the information from the surveyed ITA member countries in the planning, construction, and operation phase. The last part presents a study of the future opportunities due to environmental implications including an introduction about past and present demand of underground works.

5.2 Sustainable development, underground works and environment

According to the advanced countries trends, awareness of environmental issues concerning construction projects will be the key to understand and develop future works. The principles of sustainable development will drive construction based upon quality and environmental responsibility as competitive factors for the construction industry. Environmentally responsible construction based on the principles of sustainable development means not only a lasting in result of high quality but also one that is easy to repair and maintain.

In order to maintain a balanced equilibrium between progress and environmental responsibility as assumed by sustainable development, underground solutions will gain points compared to surface ones. Even the technical development for underground constructions will be influenced. The machines of the future will perform excavation quicker, more efficiently and cause less harm to the environment. Manual work will lose importance and information technology and roles of supervision and planning will occupy most of the budgets.

Sustainable development reinforces the idea of responsible care for the environment. Underground related companies have to accept the challenge of assuming environmental responsibility and sustainable development. Development of underground construction must follow the handling of environmental issues.

Underground works conserve the natural surface and landscape helping to unite environmental respect and development.

The idea is a change of working frame of reference from economic approaches to socio-economic-environmental approaches of construction projects.

5.3 Incidence of underground works on the environment[57]

Underground works are generally identified as a means to minimise environmental impacts. Tunnels are the alternative to equivalent superficial works. Choosing one or other option depends on different kinds of considerations: social, financial, politic... and in many cases environmental. According to the specific type of tunnel (railway, corridor, road, urban/non urban...) there are features and characteristics that point out the underground solution as the friendly environmentally respectful as indicated in the different study cases: Sao Paulo Underground, Delft Railway, Pasillo Verde, Sophia Line Railway and Vallvidrera Road Tunnel.

When environmental criteria are taken into account, underground works are usually preferred to superficial works. This assertion stems from data obtained through bibliographical sources, and the opinion of specialists in subterranean works, representatives of the surveyed countries.

The environmental effects of underground works that are mainly taken into account during the planning phase of a project are:

		Positive / negative impact
-	Reduction of occupied land	+
-	Alteration of surface land uses	+
-	Visual intrusion	+
-	Alteration of surface flora and fauna	+
-	Hydrological and hydrogeological alterations	-
-	Alteration of aquifer conditions and quality[58]	-

Only two of the mentioned effects are negative. However, these effects are only relevant at the planning stage when dealing with a especially protected area. Even in this case, it could be possible to palliate these impacts with adequate preventive and corrective measures.

[57] See "*Manual de Túneles y Obras Subterráneas*". López Jimeno, Carlos. MADRID 1997.

[58] See "*Abastecimiento y distribución de aguas*" by Hernández Muñoz, Aurelio. Servicio de Publicaciones de la ETSI Caminos, Canales y Puertos de MADRID.

During construction of an underground work, the most significant effects are:

		Positive / negative impact
-	Hydrological and hydrogeological alterations	-
-	Alteration of aquifer conditions and quality	-
-	Alteration of geology and geotechnical properties of the land	-
-	Effects on foundations of pre-existing buildings	-

Underground works, as any other public works, produce negative impacts during construction. Depending on the location of the project, the principal effects will vary. For instance, in urban areas effects on foundations of pre-existing buildings will be especially delicate[59], while in other areas hydrological alterations[60] will be the ones to worry about.

During operation phase, underground works are likely to require corrective measures for solving problems related to hydrological and hydrogeological alterations. In urban areas foundations of pre-existing buildings can be affected in the long run due to settlings. A good auscultation system since the beginning of the construction can be very useful to foresee and apply preventive measures in time. The principal environmental benefits produced during operation of subterranean projects are the elimination of visual intrusion, the preservation of the landscape and the reduction of occupied land.

5.4 New opportunities due to environmental implications

5.4.1 Past and present demand of underground works

Previously to analysing the future opportunities for underground works due to environment, it is important to summarise past and present uses of these works.

Through the history, tunnels have been assuming different functions. The Eighteenth Century corresponded to the Channels Era, and the Nineteenth Century to the Railway Era. But it was in 1863 when the history of tunnels acquired a special rhythm, with the appearance of the Underground. The Underground not only became a quick, safe, ecological and efficient public transport system, but also encouraged the development of a subterranean town planning in many cities. This transportation system has solved many environmental problems by reducing traffic

[59]See "*Geología y Cimientos. Cimentaciones, excavaciones y aplicaciones de la Geotecnia*". Jimenez Salas, Antonio. MADRID.

[60]See "*Abastecimiento y distribución de aguas*" by Hernández Muñoz, Aurelio. Servicio de Publicaciones de la ETSI Caminos, Canales y Puertos de MADRID.

congestion in the surface.

Among the most representative Undergrounds, the Moscow Underground stands out as a real subterranean palace for the people[61]. Some of its entrances are monumental buildings that correspond to the same philosophy as its interior, with great spaces, vaults, pillars and vestibules, without mentioning the noble materials employed like marbles, luxury lamps, mosaics, sculptures and other ornamental elements.

Other outstanding Underground is located in Stockholm, and it is known as "the longest art gallery in the world". The Järva line stations are grottoes that show the excavation as it is, with only a shotcreting cover.

5.4.2 Future demands of underground works

There is no doubt that the social concern about the environment is increasing. This, added to the more and more restrictive environmental regulation, plays a very positive role in the future demand of underground works.

In the future, all the agents that operate in the underground world (consulting companies, construction companies, underground works management companies or organisations, and machinery and products companies) will have an environmental department. On one hand, their production costs will increase, but on the other hand they will gave greater demand of work.

In urban areas, the types of underground projects that will have a greater increase in their demand are those related to transport: car parking, as well as road, suburban railway, and Underground tunnels[62].

In non urban areas, roads, railways and waterways will be the most demanded projects. Since railway is less aggressive with the environment than road, policies for transferring traffic to railway should be implemented in order to protect the environment, with a consequent growth of the demand of this projects.[63]

In the election of tunnels versus cuttings in linear projects there are two principal aspects to take into account: economical and environmental aspects. The first question is from which depth it is

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[61] See as representative examples of Underground transport infrastructures the case studies: Sao Paolo Underground, Case Delft Railway, Case Sophia Line Railway, Pasillo Verde in Spain.

[62] See as urban areas examples the case studies: Sao Paolo Underground, Case Delft Railway, Cairo Waste Water Scheme, The Royal Library in Stockholm, Viikinmäki Waste Water Treatment Plant in Helsinki, and Pasillo Verde in Spain.

[63] See as non-urban types of underground projects the case studies: Case Sophia Line, Ferrovia do Aco in Brazil, Vallvidrera Road, Al-Salam Siphon under the Suez Canal in Egypt, Päijänne Water Tunnel in Finland, and The Äspö Hard Rock Laboratory of Nuclear Waste Storage.

worth to choose the subterranean solution. The preservation of the landscape is having a greater and greater influence in this decision. This, added to the increasing mechanisation in the construction of tunnels and the progressive technological advances, makes the tunnels gain position from both environmental and economical points of view.
One of the most representative examples of the environmental advantages of underground works is the storage of nuclear wastes. Underground is the safest location for nuclear wastes and other hazardous or undesirable materials[64]. This use of underground works will increase in the future.[65]

Other recent use of underground cavities is the storage of liquid and gaseous fuels. This is technically economic in the following circumstances:

- Countries of a high industrialisation, that have an increasing demand of this energetic products.

- When a secure supply is required in the long run.

Future innovations will be sea water desalting plants, which are currently in study, as well as underground power stations.

Microtunnelling is a modern tunnelling technique that is having more and more acceptance in urban works, especially in the installation of pipes and sewage networks. The principal reasons for the success of microtunnelling are its technical advantages and its less environmental incidence compared to the classical ditch method.

The progressive technical innovations in underground works will improve their technical and economical competitively. Moreover, the development of constructive methods friendly with the environment will also encourage the future demand of these works.

5.5 Conclusions

The fact that society has developed an increased awareness of the environmental impacts and the need to minimised their natural consequences have created an attractive possibility for underground works solution due to the lower rates of environmental impacts compared to the surface solutions.

The minimisation of environmental problems have provided an impetus for respectful solutions able to guarantee nature conservation, the desire to protect old urban environments from

[64]"*Chernobil, the most dangerous nuclear accident in the world*". Nigel Hawkes and other members of "The Observer". Planeta, Spain.

[65]Case study: Sweden, The Äspö Hard Rock Laboratory (Nuclear Waste Storage).

redevelopment, and the need to fulfil the stricter legislation requirements.

The growing trend towards ecological alternatives, such as the renaissance of rock and stone constructions[66], the excavation of genuine caverns to build railway and traffic tunnels respectful with nature, the tendency to appreciate surface natural open spaces..., are some of the actual environmental frames of reference that indicate the positive situation of underground works.

All this means that the opportunities of underground works due to environmental reasons seem to grow up.

[66] "*The Fourth Wave of Rock Construction*". Kimmo Rönkä & Jouko Ritola. Editorial Board. Technical Research Centre of Finland.

6 SOCIO-ECONOMIC CONTEXT: COMPARATIVE CROSS-CULTURAL STUDY.[67]

6.1 Summary

As the result of the questionnaire sent to the ITA members countries in the world and the collected experience with various underground related programs, a comparative cross-cultural study dealing with economy, social structures, underground works projects and level of development would classify the countries into two different groups. The first group would be the high-technology countries and the rest would be part of the underdeveloped ones.

Most of the principal reasons that force the construction of a big engineering project deal with social, economic, politic, and environmental reasons. Therefore, either the underground or the surface solution will have to be taken into study according to these four frames of reference. There is no doubt that the social-economic context of the different countries will determine the type and specific features of the project and the opinion of people about the construction of the infrastructure and the added value it means.

6.2 Demography

The effects that underground works, and especially road and railway tunnels, cause to demography, depend on the increasing possibilities of communication that the construction generates. Clear examples could be the new Metropolitan Expressway in Tokyo, that will improve the driving times for the people living/working in Tokyo and its surrounded towns. Also the Vallvidrera road tunnels in Spain that will allow the communication of Barcelona with its commercial and industrial hinterland (Tarrasa, Sabadell, San Cougat...), and the rapid mobility that the new Sao Paulo Underground stations will improve amongst Brigadeiro, Trianon, Consolaçao and Clínicas.

During the construction phase, a certain quantity of workers (usually young people) will live in the towns close to the underground works. It means that there will be an increase of young people and a little variation of local demography as far as age and sex distribution is concerned. Once the underground work is over and the operating phase starts to work, the influence of the tunnel will depend on the social distribution of population. In the first kind of developed country, the tunnel will mean a faster communication between two points of population and business will get the benefits of reducing travelling and transport costs, but the tunnel will not cause new settlements or towns, since the urban points are already defined. Concerning with the sub-developed countries, were urban cities are not big enough and rural population is not concentrated, a tunnel will facilitate the construction of new urban towns around the new

[67] See "*Manual de túneles y obras subterráneas*". Chapter 28. By López Jimeno, Carlos. MADRID 1996.

communicated parts.

This new settlements will cause an attraction of population towards then, and may be the beginning of a future urban city, which means that a change in the distribution of population will take place.

Sophia Line (Railway) is an example of non-urban future transport infrastructures based on underground works. The adopted solution consists of 2 km. of cut and cover tunnel; further 4 km. of twin bored tunnels and 1km. of depressed railway. As far as demography is concerned, this solution includes the free use of the land next to the railway line and above it for residential and other developments allowing a fast way of transportation.

The Metropolitan Expressway network in Tokyo, has allowed the development of social and economic activities in the city sphere of influence. At the present, consisting of several radial routes, and one ring route, it plays the role of mayor arterial roads in the capital and due to the actual traffic congestion The Central Circular Route will become the second ring expressway and will spread to a radius of 8 km. from the city center, linking up with existing radial roads to form a new road network, and will contribute to ease the heavy traffic congestion. All these features will contribute to save driving time and a new offering group of traffic alternative routes, that will facilitate the demographic spreading process of the city.

6.3 Business and industry

During the construction phase, the workers of the underground construction will have the same importance regardless of the grade of development and socio-economic circumstances of the country.

During the operating phase, the new tunnel will mean an increase in the level of communication and it will reduce the cost of transport as far as urban railways such as Sao Paulo Underground, Pasillo Verde in Madrid, Metropolitan Expressway Central Circular Route in Tokio, and Delft railway in The Netherlands and non urban areas such as Sophia Railway and Vallvidrera Road Tunnels.

In the case of a high-technology country, the construction will mean an increment of benefits but the distribution of industries will remain the same. On the other hand a new tunnel that communicates two isolated places will mean a new market and business opportunity in a sub-developed nation. It will cause a change in the traditional industry and the new communication network will provide the positive conditions for a migration from rural ways of life to modern socio-economic structures. The economic changes will have a tremendous weight in the country.

6.4 Socio-cultural factors

It is one of the clearest examples concerning the different effects of an underground work in either a developed or sub-developed countries.

During the construction phase, the new workers will cause an influence in the rural population of a sub-developed zone. The different customs, way of life and even socio-cultural concepts will generate an influence and change the traditional way of life of local people. And once the new tunnel starts its operating phase, the possibility to travel and easily visit other cities will provide the rural zones a tool to achieve new socio-cultural features. The influence in this kind of zones is total.

On the other hand, the influence in a developed country will not mean a socio-cultural change since most of the population share similar points of view and ways of life. But it will improve the quality of socio-cultural activities, º and facilitate the opportunity to enjoy facilities such as the Royal Library in Stockholm (the present expansion provide it with 90.000 meters of shelf space), that must has outgrown itself and, in order to retain its original appearance, the new chambers should be placed underground.

6.5 Environmental characteristics

According to the data collected from the surveyed countries and the consulted material, the environmental awareness of people and levels of legal responsibility varies a lot according to the socio-economic and cultural context.

Most of the sub-developed countries do not pay attention to environmental concepts and therefore their legislative framework is not strict at all. This is an important reason that will influence the underground work project. Quality controls, environmental features, design and construction methods... are not forced to respect any kind of legal instruments and therefore the impacts of public underground works projects grow up as the quality is lower.

Besides, people living in sub-developed areas do not appreciate the construction of a tunnel in the same way as people in developed countries. In the first case, people see the tunnel as a great improvement in their life, that will mean new working opportunities, enormous time savings, and people is delighted with the new facility, and is not probably that they regret the environmental impact that the tunnel is causing.

On the other hand, well-developed countries share modern environmental legislative frameworks and programs that usually include:

- The need to institute the evaluation/assessment procedures earlier in the planning process.
- The need to utilise multi-disciplinary teams
- The need to include socio-economic aspects of the project in the environmental impact statement.
- The need to develop all reasonable alternatives during the planning phase .
- The need to incorporate up-to-date scientific and technical information into their techniques for impact identification, appraisal and ranking.
- The need to develop corrective measures (mitigation) at the proper scale and integrate them as part of the project proposal prior to approval.
- The need to have monitoring programs as an integral part of any project proposal.
- Procedures for the management of public underground works and their environment restoration, sanitary features, and environmental impact liability responsibility associated with the construction, operation and abandon of the work.

The construction of a tunnel in these developed countries generally do not mean an important change in the lifestyle of people, and of course do not mean new works opportunities for people nor enormous time savings, since in these countries other infrastructures are always available. Therefore people in these areas do not value the tunnel in the same way to those in sub-developed ones, since real benefits are considerably lesser for people.

6.6 Conclusions

Parallel to the development grade accomplished by a country, the awareness and need to preserve the environment increases. Nowadays the environmental tendency to protect and take care of the natural resources and landscapes is accepted in most of the modern underground environmental legislative frameworks.

The planning, design, construction, and use of underground spaces depend upon the socio-economic level of a country. The more developed a zone is, the stricter its environmental legislation becomes, and the allowed impacts decrease both quantity and quality speaking.

In a similar way, the more industrialised and developed a country is, it will demand more complicated underground facilities, such as road and railway tunnels, food and material storage caverns, municipal facilities, underground hospitals, water needs, sewage, sports buildings, Underground lines and stations... in order to improve its level of life.

Regardless of the particular conditions of each nation, it could be accepted that the level of advanced sustainable development of a country is directly proportional to the quantity and quality of underground works.

7 CONCLUSIONS

The general conclusions have been classified according to the different aspects studied. The findings are related to the relation between underground works and the environment, focusing in the advantages of underground construction compared to the cutting solution, and the role of social, economical and legislative framework.

Environmental Legislative Framework

Environmental legislation has both positive and negative consequences on the different agents that operate in the underground world. The most outstanding effects are on one hand new market opportunities, but on the other hand, an increase in production costs and a major responsibility demand of the economical agents.

As environmental legislation becomes more and more strict, underground works will take advantage of their advanced position compared to the superficial ones. The tunnelling associations of the countries participating in the survey hold varying opinions about the interrelations between underground works and the environment, although the totality consider that the increasing environmental sensitivity and legislation will have a positive influence on the future development of underground works.

In the future, legislation will not be only applied in the construction phase, but also in the planning and operation phases.

When taking into account the environment protection by public administrations in particular, and by technicians in general, it is necessary to consider it since previous stages of the project design. The current legislation by itself is not enough for widely minimisation of the negative effects / impacts of the work, the really important question is that people involved in the design and implementation of underground projects have an adequate implication and compromise with the environment.

Environmental Aspects

In contrast with the past, nowadays, making underground works needs an exhaustive exam of environmental aspects and impacts, and a proposal of corrective measures. This way of action must be progressively enhanced and improved, and must be extended to underdeveloped countries.

The level of effectiveness of environmental corrective measures for an underground work is in direct relation to the beginning of the life cycle of the civil work. That is, if the feasibility study is not done under environmental considerations (criteria), the design and implementation of later corrective measures can be a mere aesthetic operation.

The whole set of existing measures to improve the aesthetic, comfort and safety of tunnels and underground works are neither a luxury nor a caprice. The future of the tunnels and its use are considered under the high priority of the aesthetic aspects requirements, the environment integration, the comfort of its use, and the safety.

Environmental Benefits of Underground Works

The underground work is a better solution than the surface option when dealing with environmental issues. The main benefits of this option are for example, non limit in the use of surface land, avoiding soil erosion and runoff, less dust and gaseous emissions, noise reduction in construction phase, and overall, the underground solution minimises the visual intrusion, the damage to the landscape and the alteration of fauna and flora.

From the point of view of the new technologies, many successfully accomplished underground projects based upon new technologies demonstrate that subsurface construction is a good alternative from the environmental perspective.

Opportunities and Threats of Underground Works in Relationship to the Environment

There is no doubt that the concern about the environment is increasing. This, added to the more and more restrictive environmental regulation, plays a very positive role in the future demand of underground works. Therefore, when environmental criteria are taken into account, underground works are preferred to superficial works. The preservation of the landscape is having a greater and greater influence in this decision.

Besides, the increasing mechanisation and technical innovations, in the construction of tunnels and the progressive technological advances, make the tunnels gain position from environmental points of view. This will encourage the future demand of underground works.

From the economic point of view, the underground solution is gaining position since the increasing mechanisation and technical innovations yet mentioned, makes the tunnels cheaper.

Besides, since the price of square metre of surface soil is increasing and the price of cubic metre of underground excavation is decreasing, the future of underground works is assured.

However, we still have to consider the great existing differences between rich and sub-developed countries. In the first case, the costs per Kilometre of tunnel are considerably higher than in the last one. The main consequence of this difference are dangerous working conditions, lesser wages to the workers, and the non consideration of the environmental aspect.

Finally, in the future, all the agents that operate in the underground world (consulting companies, construction companies, underground works management companies or organisations, and machinery and products companies) will have an environmental department. On one hand, their production costs will increase, but on the other hand they will have a greater demand of work.

The major significance of future underground projects are located in urban areas. The types of underground projects that will have a greater increase in their demand are those related to transport: car parkings, as well as road, suburban railway, and Underground tunnels.

Socio-Economical Context: Comparative Cross-Cultural Study

Social issues have also a great influence in the election of the underground solution. Both in urban and non-urban areas, public opinion is in favour of underground works for transport, utilities, storage and industrial projects. However, the use of underground space for public facilities (shop centre, library, etc.) is less admired by public opinion.

There is no doubt that the social-economic context of the different countries will determine the type and specific features of the project and the opinion of people about the construction of the infrastructure and the added value it means.

For example, a new tunnel that communicates two isolated places will mean a new market and business opportunity in a underdeveloped nation because it will cause a change in the traditional industry and the new communication network will provide the positive conditions for a migration from rural ways of life to modern socio-economic structures. Therefore people have a great opinion about the tunnel and they are not concerned about environmental impacts or safety and health problems during construction phase. On the contrary, in developed countries, social opinion about new infrastructure is quite different, and therefore the added value that the construction of a new tunnel means in a developed area is lesser, because the improvements that the new infrastructure will cause are not related to new working opportunities, nor changes in industry and demography. Probably in a developed area, the new tunnel only will mean time savings and more comfortable communications, and these benefits are not enough to most of people if environment and health are in risk.

In non urban areas, roads, railways and waterways will be the most demanded projects. Since railways are less aggressive with the environment than road, policies for transferring traffic to railways should be implemented in order to protect the environment, with a consequent growth of the demand of these projects, that implies a bigger percentage of tunnels.

As we have mentioned yet, the progressive technical innovations in underground works will improve their technical and economical competitively. Moreover, the development of constructive methods friendly with the environment will also encourage the future demand of these works.

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Topic

UNDERGROUND AND ENVIRONMENT

Title

"Underground Works and the Environment" - Annex I

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Résumé: -

Remarks: In order to develop the tasks proposed within the Working Group 15 framework, a questionnaire was sent to all the ITA members (42 countries), having a percentage of answers of the 40% (17 countries). Although we miss the contribution of several countries that for their special linkage to underground works would have enriched the study, we consider that the sample has a good size and variety.

ANNEX I: QUESTIONNAIRE

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A.I.-

1 Summary

In order to develop the tasks proposed within the Working Group 15 framework, a questionnaire was sent to all the ITA members (42 countries), having a percentage of answers of the 40% (17 countries). Although we miss the contribution of several countries that for their special linkage to underground works would have enriched the study, we consider that the sample has a good size and variety. The countries that have filled the questionnaire and the contact person are the following:

Country	Name	Company
Brazil	Roberto Kochen	Bureau de Projetos e Consultoria LTDA
Czech Republic	Richard Snupárek	Institute of Geomechanics Academy of Sciences of Czech Republic
Egypt	A. Amr Darrag	Dar Al-Handasah Consultants
Finland	Jouko Ritola	Communities and Infrastructure Rock and Environmental Engineering
France	Pierre Duffaut	Pierre DUFAUT
Hungary	Pal Kocsonaya	Fömterv-Civil Engineering Consulting Corporation
Iceland	Hrein Haraldsson	Public Roads Administration
Italy	Bruno Pigorimi	Snamprogetti
Japan	G. Fukuchi	Japan Tunelling Association
Mexico	P.A. Ortega	Asociación Mexicana de Ingeniería de Túneles y Obras Subterráneas.
Netherlands	Eelco Negen	Directoraat-Generaal Rijkswaterstaat
Norway	Aslak Ravlo	Norsk Foreining for Fjellsprengningsteknikk
Spain	Elías García	Asociación Española de Túneles y Obras Subterraneas
Sweden	Per Högard	Skanska
	Göran Husebey	Municipal Serviceo of Environment, Gothenburg
	Annica Nordmark	Swedish Rock Construction Commitee
	Tomas Hokmström	Nationa Swedish Road Administration
	Pavel Huzevka	Scndiaconsult
Thailand	Chanin Areepitak	Electricity Generating Authority of Thailand
	Noppadol Phien-wej	School of Civil Engineering.
Turkey	Yücel Erdem	Turkish Road Association
USA	Susan Nelson	American Underground Construction Association

This annex shows the questionnaire form itself and the main results that can be extracted from the answers received in the different countries.

2 Questionnaire Form

Questionnaire Number:____________
(please leave blank)

Please complete this form and return it to:-

Julia Pérez-Cerezo
Environment, Transport & Planning
c/ General Pardiñas, 112 bis, 11A
28006 MADRID
SPAIN

Some of the questions on this questionnaire require answers which may be difficult to provide. If you are not able to provide all the information requested please send back the partially completed form, as this will be more use, than no information at all.

1 Country: ______________

2 Details of person completing form

Name	
Position	
Organization	
Address	
Postcode	
Country	
Telephone (international)	
Fax	
E-mail (if available)	

FRAMEWORK OF UNDERGROUND WORKS / ENVIRONMENT IN YOUR COUNTRY

1.1 Construction Investment in Tunnels and Underground Space

Please indicate the total approaching amount of tunnel and underground construction works under contract by national construction industry for each type of project and year if possible.

Currency: _____________

TYPE OF PROJECT	1980	1985	1990	1995
WATERWAY				
ROAD				
RAILWAY				
CABLE, HYDRO				
UNDERGROUND INDUSTRIAL ACTIVITIES				
PUBLIC UNDERGROUND SPACE, SHOP MALL				
STORAGE				
OTHERS (please specify)				
TOTAL				

1.2 In general, how time is dedicated in each phase of an underground work life cycle?
Please provide an estimated timing, in years, for a general type of underground work on each type.

TYPE OF PROJECT	PLANNING	DESIGN	CONSTRUCTION	OPERATION & MAINTENANCE
WATERWAY				
ROAD				
RAILWAY				
CABLE, HYDRO				
UNDERGROUND INDUSTRIAL ACTIVITIES				
PUBLIC UNDERGROUND SPACE, SHOP MALL				
STORAGE				
OTHERS (please specify)				

GENERAL INVENTORY OF EFFECTS/IMPACTS IN ALL THE ENVIRONMENTAL MEDIA (GIE)

The following list shows general effects detected in environmental media for underground works. If you consider for answering next questions some other effects, please add these effects to the list.

1. INERT MEDIA (climate, atmosphere, geology, hydrology)

- *1.1 Alteration of the geology and geotechnical properties of the land.*
- *1.2 Hydrological and hydrogeological alterations*
- *1.3 Alteration of aquifer conditions and quality properties*
- *1.4 Possible foundations of preexisting buildings.*
- *1.5 Alteration of climate*
- *1.6 Atmospheric pollution*
- *1.7 Alteration of existing geological, geomorpholocical and paleontological wealth*
- *1.8 Pollutant discharge on underground and surface course*
- *1.9 Other (please specify):______________________________*
- *1.10 ____*

2. BIOTIC MEDIA (soil, flora, fauna, landscape)

- *2.1 Visual intrusion*
- *2.2 Acoustic intrusion*
- *2.3 Alteration to surface fauna and vegetation*
- *2.4 Change in the landscape*
- *2.5 Noise generation*
- *2.6 Emission of pollutant gases*
- *2.7 Dumps generation*
- *2.8 Alteration of underground flora and fauna*
- *2.9 Production of detritus from wash loads caused by surges*
- *2.10 Generation of solid and liquid waste*
- *2.11 Other (please specify):______________________________*
- *2.12 ____*

3. HUMAN MEDIA

- *3.1 Alteration of surface land uses*
- *3.2 Increase in communications possibilities (transport facilities include)*
- *3.3 Reduction of occupied surface area*
- *3.4 Impacts on public opinion and social interests*
- *3.5 Alteration of preexisting underground infrastructures*
- *3.6 Alterations of the archeological and cultural heritage*
- *3.7 Alteration of demographic patterns*
- *3.8 Alteration of socioeconomic patterns*
- *3.9 Damage on quality of life (contamination impacts, safety)*
- *3.10 Other (please specify):_______________________________*
- *3.11 ____*

1.3 **On planning phase (considered as previous studies and evaluation of alternative solutions), which effects of the list (GIE) are usually taken into account for underground work solution selection?**
Please provide for each generic type of project and kind of area the "*number of effect*" following by brackets (). Select inside brackets one of these marks: ++,+,-,--.

++ if effect is extremely favorable for underground selection
+ if effect is favorable
- if effect is unfavorable
-- if effect is extremely unfavorable

TYPE OF PROJECT	**URBAN**	**NON-URBAN**
WATERWAY		
ROAD		
RAILWAY		
CABLE, HYDRO		
UNDERGROUND INDUSTRIAL ACTIVITIES		
PUBLIC UNDERGROUND SPACE, SHOP MALL		
STORAGE		
OTHERS (please specify)		

1.4 During construction phase which effects of the list (GIA) can usually put up the predicted budget of?
Please select the effects and their influence on budget deviation inside brackets:

+++ if effect has high influence on budget deviation
++ if effect has important influence
+ if effect has some influence

TYPE OF PROJECT	**URBAN**	**NON-URBAN**
WATERWAY		
ROAD		
RAILWAY		
CABLE, HYDRO		
UNDERGROUND INDUSTRIAL ACTIVITIES		
PUBLIC UNDERGROUND SPACE, SHOP MALL		
STORAGE		
OTHERS (please specify)		

1.5 During operation of the underground infrastructure, which effects of the list (GIA) have a major possibilities to produce additional works on repairing, maintenance, environmental restoration or optimizing?

Please select the effect and put in brackets:

I, if effect affects new works on own infrastructure
E, if effect affects other kind of works (external, soil recuperation,...)

TYPE OF PROJECT	**URBAN**	**NON-URBAN**
WATERWAY		
ROAD		
RAILWAY		
CABLE, HYDRO		
UNDERGROUND INDUSTRIAL ACTIVITIES		
PUBLIC UNDERGROUND SPACE, SHOP MALL		
STORAGE		
OTHERS (please specify)		

REGULATION REGARDING TUNNELLING/UNDERGROUND WORKS AND THE ENVIRONMENT

2.1. Characteristics of environmental legislation for underground works in your country.
Please indicate the estimated appreciation for all type of underground projects (yes/no).

Regulation Framework is clear and accurate	
The environment authorities are dispersed	
Regulation framework is applied strictly by authorities	
There is a specific regulation framework for underground projects	

2.2 Which environmental legislation is more strict on underground works?
Please number (up to) the highest priorities in order of importance (Ordered 1-n , 1= highest), by selecting the appropiate cell for those that you consider.

Regulations	**Priority**	**Law**	**Guideline**	**Standard**	**Other (please specify)**
Environment Impact Evaluation (planning phase)					
Environment Impact Evaluation (project design)					
Regulation on noise					
Regulation on vibrations					
Regulation on materials and machinery					
Regulation on safety and health					
Regulation on protection of fauna, flora and special areas					
Regulation on waste/dumps generation					
Water regulations					
Others: please specify					

2.3 Is significant the contribution of underground works for reducing environment impacts?
Please answer *yes/no*

____

2.5 Can underground works produce less impact to environment that surface equivalent ones?
Please answer *yes/no*

____

2.6 Which of the following measures to reduce negative impacts/effects are usually derived from underground works?
Please number (up to) the highest priorities in order of importance (Ordered 1-n , 1= highest) from those that you consider.

CORRECTIVE MEASURES	PRIORITY
Slope, quarry, dump restoration	
Quarry, dump site selection	
Adequate design to environment of mouths	
Previous soil surveys and studies	
Noise/vibrations measures	
Sewage treatments	
Pollutant emissions control	
Using of subproducts as raw material	
Adequate planning of machinery movements	
Precaution against freatic level alteration	
Work planning	
Other (please specify):	

2.7 Which of the following effects are a direct consequence of the Environmental Legislation?
Please select the effect and number (up to) the highest priorities in order of importance (Ordered 1-n , 1= highest) for each kind of agent.

EFFECTS	**CONSULTING Co. (planning & project design)**	**CONSTRUCTION Co.**	**UNDERGROUND WORKS MANAGEMENT (Co. or Organizations)**	**MACHINERY AND PRODUCTS Co.**
Major responsibility demand				
Increasing production costs				
New market opportunities				
Increasing penalties related unfulfilled regulation				
Obtaining subsidies or incentives				
Increasing of high tech. demand				
Others (please specify)				

2.8 In what way the new market opportunities could compensate the inconvenience of the environmental legislation?
Please give a brief response
____
____
____

2.9 Could be increased the demand of underground works for environmental reasons?
Please answer *yes/no*

____

2.10 Environmental Departments on underground work market agents.
Please indicate *yes/no* if these departments are in operation today on each kind of agent and your opinion for the future.

AGENTS	**TODAY**	**FUTURE**
CONSULTING Co. (planning & project design)		
CONSTRUCTION Co.		
UNDERGROUND WORKS MANAGEMENT (Co. or Organizations)		
MACHINERY AND PRODUCTS Co.		
OTHERS (Please specify)		

NEW OPPORTUNITIES FOR UNDERGROUND WORKS

3.1 Types of underground projects that will increase their demand according to the environmental implications.

Please select the type of project you consider and number (up to) the highest priorities in order of importance (Ordered 1-n , 1= highest) for each kind of area.

TYPE OF PROJECT	URBAN AREA	NON URBAN AREA
WATERWAY		
ROAD		
RAILWAY		
CABLE, HYDRO		
UNDERGROUND INDUSTRIAL ACTIVITIES		
PUBLIC UNDERGROUND (SPACE, SHOP MALL)		
STORAGE		
PARKING		
OTHERS (Please specify)		

3.2 Regarding the use of space and sustainable development, which of the following items could increase underground works in the future?

Please select ++, very important
+ , important
0 , indifferent

_____ Tunnels play a vital environmental role by covering clean water to urban areas and by covering waste water out.

_____ The usable space of a parcel of land can, in some cases, be almost doubled by adding floor space or bulk storage below the ground surface.

_____ If urban planners want an important lifeline to survive an earthquake they should go out of their way to use tunnels.

_____ The underground is the only safe location for storage of nuclear waste and other hazardous of undesirable materials.

_____ In transit systems, tunnels provide safe, environmentally sound, very fast, and unobtrusive transportation for people in all walks of life in both developed and developing countries.

_____ Underground space is being used increasingly for industrial, office and even residential facilities.

_____ Underground space for bulk storage of food, liquids, and gas has gained increasing acceptance in various areas of the world.

_____ Congestion in urban areas has been dramatically reduced by the use of the underground.

_____ Rapid transit systems and better use of underground space in metropolitan centers should be mandated in the future to protect, maintain and redevelop rural agricultural areas in sustainable regions that will require maximum use of available agricultural land.

_____ Water collection systems and conduits will be required in increasing quantities. Underground reservoirs and tunnels decrease water loss through evaporation.

_____ Storm water can be collected in tunnels and underground reservoirs to separate shorn flows from domestic sewers and to prevent overwhelming sewage treatment plants for those cities subjected to high storm flows.

_____ In some cases mining operations can be conducted so that the cavities created can be used for other purposes such as underground storage and other purposes.

_____ With time, individual vehicles should be replaced wherever possible with efficient mass transportation such as railroads and underground transit systems.

_____ The future use of tunnels and underground construction will have its greatest application in future mega cities if sufficient funds are made available and other barriers removed.

_____ Waste water treatment plants are increasingly being constructed in underground cavities in rock.

_____ Tunnels and underground construction may provide one of the keys to reclaiming farm lands damaged by poor land management and soil erosion.

_____ Better urban planning and increased use of underground infrastructure may also help to stimulate revival and renewal of decayed central cities.

_____ Others (please specify)

3 General Inventory Of Effects In All The Environmental Media

The inventory of effects included in the questionnaire sent to the ITA members is the following:

1. INERT MEDIA (climate, atmosphere, geology, hydrology)

    1.1 Alteration of the geology and geotechnical properties of the land.
    1.2 Hydrological and hydrogeological alterations
    1.3 Alteration of aquifer conditions and quality properties
    1.4 Possible foundations of preexisting buildings.
    1.5 Alteration of climate
    1.6 Atmospheric pollution
    1.7 Alteration of existing geological, geomorphological and paleontological wealth
    1.8 Pollutant discharge on underground and surface course

2. BIOTIC MEDIA (soil, flora, fauna, landscape)

    2.1 Visual intrusion
    2.2 Acoustic intrusion
    2.3 Alteration to surface fauna and vegetation
    2.4 Change in the landscape
    2.5 Noise generation
    2.6 Emission of pollutant gases
    2.7 Dumps generation
    2.8 Alteration of underground flora and fauna
    2.9 Production of detritus from wash loads caused by surges
    2.10 Generation of solid and liquid waste

3. HUMAN MEDIA

    3.1 Alteration of surface land uses
    3.2 Increase in communications possibilities (transport facilities include)
    3.3 Reduction of occupied surface area
    3.4 Impacts on public opinion and social interests
    3.5 Alteration of preexisting underground infrastructures
    3.6 Alterations of the archeological and cultural heritage
    3.7 Alteration of demographic patterns
    3.8 Alteration of socioeconomic patterns
    3.9 Damage on quality of life (contamination impacts, safety)
    3.10 Increase in public transport demand.

4 Effects In Planning Phase (Answers To Question 1.3)

The following tables show the answers from different countries to the question: “Which effects of the list are usually taken into account for the choice of an underground work?”

++ if effect is extremely favorable for underground selection
\+ if effect is favorable
\- if effect is unfavorable
-- if effect is extremely unfavorable

EFFECTS IN PLANNING PHASE TYPE OF PROJECT: WATERWAY		
COUNTRY	**URBAN**	**NON-URBAN**
Brazil	1.3(+), 1.4(-), 2.1(+), 2.3(+), 2.4(+), 3.3(++), 3.4(+), 3.5(-)	1.7(-), 2.1(+), 2.3(+), 2.4(+), 3.1(+)
Czech Republic	1.2(+), 1.3(+), 2.10(-)	1.2(+), 1.3(+), 2.10(-)
Egypt		2.1(++), 2.2(++), 2.3(++), 2.4(++), 2.5(++), 2.6(++), 2.7(++), 2.8(++), 2.9(++), 2.10(++)
Finland	1.2(+), 1.3(+), 1.4(+), 3.1(+), 3.2(++), 3.3(++)	1.2(+), 2.3(++), 3.1(++), 3.2(++), 3.3(++)
Iceland		1.2(+), 2.1(+), 3.1(+)
Spain	1.2(-), 1.3(-), 1.4(-), 1.7(-), 2.3(+), 3.3(++)	1.2(-), 1.3(-)
Sweden		1.1(+), 1.2(-), 1.3(+), 1.4(-), 1.5(+), 1.6(+), 1.7(+), 1.8(+), 2.1(+), 2.2(+), 2.3(+), 2.4(+), 2.5(+), 2.6(+), 2.7(-), 2.8(+), 2.9(+), 2.10(+), 3.4(+)
Thailand		1.1(-), 1.2(-), 1.3(-), 2.1(-), 2.5(-), 2.10(-)

EFFECTS IN PLANNING PHASE TYPE OF PROJECT: ROAD		
COUNTRY	**URBAN**	**NON-URBAN**
Brazil	1.3(+), 1.4(-), 2.1(+), 2.3(+), 2.4(+), 3.3(++), 3.4(+), 3.5(-)	1.7(-), 2.1(+), 2.3(+), 2.4(+), 3.1(+)
Czech Republic	2.1(+), 2.4(+), 2.5(++), 2.10(-), 3.2(+), 3.3(+)	2.1(+), 2.4(+), 2.10(-)
Finland	1.3(-), 1.4(-), 2.3(++), 2.4(++), 3.1(++), 3.2(++), 3.3(+)	1.3(-), 2.3(++), 2.4(++), 3.1(++), 3.2(++), 3.3(++)
Iceland	2.5(+), 2.6(+), 3.2(++)	3.2(++)
The Netherlands	2.1(++), 2.2(+), 2.4(+), 2.5(++), 3.3(++), 3.4(++), 3.5(+)	2.1(++), 2.2(+), 2.4(+), 2.5(+), 3.3(+), 3.4(++), 3.5(+)
Spain	1.2(-), 1.4(-), 1.6(++), 1.7(-), 2.3(+), 2.4(+), 2.6(++), 3.1(++), 3.3(++)	1.2(-), 1.6(+), 1.7(-), 2.3(++), 2.4(++), 2.6(+), 3.1(++), 3.3(+)
Sweden	1.1(++), 1.2(-), 1.3(-), 1.4(-), 1.5(++), 1.6(+), 1.7(++), 1.8(++), 2.1(++), 2.2(++), 2.3(++), 2.4(++), 2.5(++), 2.6(++), 2.7(-), 2.8(++), 2.9(++), 2.10(++), 3.1(++), 3.2(++), 3.3(++), 3.8(++)	1.3(++), 2.3(++), 2.4(++), 3.2(++), 3.3(++), 3.7(+)
Turkey	1.1(--), 1.2(--), 1.3(--), 1.4(--), 1.8(--), 2.1(-), 2.3(-), 2.4(-), 2.6(--), 2.7(-), 3.1(-), 3.2(++), 3.3(++), 3.4(++), 3.5(--), 3.6(--), 3.7(+), 3.8(+), 3.9(-)	1.1(--), 1.2(-), 1.3(-), 1.4(-), 1.8(-), 2.1(-), 2.3(-), 2.4(-), 2.6(--), 2.7(-), 3.1(-), 3.2(++), 3.3(+), 3.4(++), 3.5(-), 3.6(--), 3.7(+), 3.8(+), 3.9(-)

EFFECTS IN PLANNING PHASE TYPE OF PROJECT: RAILWAY		
COUNTRY	**URBAN**	**NON-URBAN**
Brazil	1.3(-), 1.4(-), 2.1(+), 2.2(+), 2.4(+), 2.5(+), 2.6(+), 3.1(+), 3.2(+), 3.3(++), 3.4(+), 3.8(+)	1.2(-), 1.7(+), 2.1(+), 2.3(+), 2.4(+), 3.2(++), 3.4(+), 3.8(++)
Czech Republic	2.1(+), 2.4(+), 2.5(++), 2.10(-), 3.2(+), 3.3(+)	2.1(+), 2.4(+), 2.10(-)
Egypt	1.1(+), 1.2(+), 1.3(+), 1.4(+), 1.5(+)1.6(+), 1.7(+), 1.8(+), 2.1(+), 2.2(+), 2.3(+), 2.4(+), 2.5(+), 2.6(+), 2.7(+), 2.8(+), 2.9(+), 2.10(+), 3.1(++), 3.2(++), 3.3(++), 3.4(++), 3.5(++), 3.6(++), 3.7(++), 3.8(++), 3.9(++), 3.10(++)	
Finland	1.3(-), 1.4(-), 2.3(++), 2.4(++), 3.1(+), 3.2(+)	2.3(++), 2.4(++), 3.1(++), 3.2(++), 3.3(++)
Hungary	1.2(-), 1.6(+), 2.5(+), 3.2(++), 3.3(+), 3.5(+/-), 3.6(+/-)	
The Netherlands	2.1(++), 2.2(+), 2.4(+), 2.5(++), 3.3(++), 3.4(++), 3.5(+)	2.1(++), 2.2(+), 2.4(+), 2.5(+), 3.3(+), 3.4(++), 3.5(+)
Spain	1.2(-), 1.4(-), 1.7(-), 2.3(+), 2.4(+), 3.1(++), 3.3(++)	1.2(-), 1.7(-), 2.3(++), 2.4(++), 3.1(++), 3.3(+)
Sweden	1.1(++), 1.2(-), 1.3(-), 1.4(-), 1.5(++), 1.6(+), 1.7(++), 1.8(++), 2.1(++), 2.2(++), 2.3(++), 2.4(++), 2.5(++), 2.6(++), 2.7(-), 2.8(++), 2.9(++), 2.10(++), 3.1(++), 3.2(++), 3.3(++), 3.8(++)	1.3(++), 2.3(++), 2.4(++), 3.2(++), 3.3(++), 3.7(+)

EFFECTS IN PLANNING PHASE TYPE OF PROJECT: CABLE, HYDRO		
COUNTRY	**URBAN**	**NON-URBAN**
Brazil	1.2(-), 1.3(-), 1.4(-), 2.1(+), 2.9(+), 3.3(+), 3.5(+), 3.9(-)	1.2(-), 1.7(-), 2.1(+), 2.3(+), 2.4(+), 3.3(+)
Czech Republic	2.10(-), 3.2(+), 3.3(+)	
Finland	2.3(+), 2.4(++), 3.1(++), 3.3(++)	2.3(+), 2.4(+), 3.1(++), 3.2(+), 3.3(+)
Spain	1.2(-), 1.4(-), 1.7(-), 3.3(++)	1.2(-), 2.3(+)
Sweden	1.1(++), 1.2(-), 1.3(++), 1.4(-), 1.5(++), 1.6(++), 1.7(++), 1.8(++), 2.1(++), 2.2(++), 2.3(++), 2.4(++), 2.5(++), 2.6(++), 2.7(-), 2.8(++), 2.9(++), 2.10(++), 3.9(+)	2.1(+)
Thailand		1.1(-), 1.2(-), 1.3(-), 2.1(-), 2.5(-), 2.10(-)

EFFECTS IN PLANNING PHASE TYPE OF PROJECT: UNDERGROUND INDUSTRIAL ACTIVITIES		
COUNTRY	**URBAN**	**NON-URBAN**
Brazil	1.1(-), 1.2(-), 1.3(-), 1.4(-), 2.1(+), 2.2(+), 2.4(+), 2.5(+), 2.6(+), 2.7(+), 2.9(+), 3.1(+), 3.2(+), 3.3(+), 3.4(+), 3.5(-), 3.8(+), 3.9(+)	1.1(-), 1.2(-), 1.3(-), 2.1(+), 2.3(+), 2.4(+), 3.1(+), 3.3(+), 3.4(+)
Finland	1.2(-), 1.3(-), 1.4(-), 2.3(+), 3.1(+), 3.3(++)	1.2(-), 1.3(-), 2.3(+), 2.4(+), 3.1(+), 3.3(+)
Spain	1.2(-), 1.4(-), 1.7(-), 2.4(+), 3.3(++)	1.2(-), 2.3(++), 2.4(++)
Sweden	1.1(+), 1.2(-), 1.3(+), 1.4(-), 1.5(+), 1.6(+), 1.7(+), 1.8(+), 2.1(+), 2.2(+), 2.3(+), 2.4(+), 2.5(+), 2.6(+), 2.7(-), 2.8(+), 2.9(+), 2.10(+), 3.1(+), 3.2(+), 3.3(+), 3.4(+), 3.5(+), 3.6(+), 3.7(+), 3.8(+), 3.9(+)	

EFFECTS IN PLANNING PHASE TYPE OF PROJECT: PUBLIC UNDERGROUND SPACE, SHOP MALL		
COUNTRY	**URBAN**	**NON-URBAN**
Brazil	1.1(-), 1.2(-), 1.3(-), 1.4(-), 2.1(+), 2.2(+), 2.4(+), 2.5(+), 3.1(+), 3.3(+), 3.4(+), 3.5(+), 3.8(+)	
Czech Republic	2.1(+), 2.4(+), 2.5(++), 2.10(-), 3.2(+), 3.3(+)	
Finland	1.2(-), 1.3(-), 1.4(-), 2.3(+), 2.4(++), 3.1(+), 3.2(+), 3.3(+)	1.2(-), 1.3(-), 2.3(+), 2.4(++), 3.1(+)
Hungary	1.2(-), 1.4(+), 1.6(+), 2.6(+), 3.1(+), 3.3(++)	
Spain	1.2(-), 1.4(-), 1.7(-), 3.3(++)	1.2(-), 2.3(++), 2.4(+)
Sweden	1.1(+), 1.2(+), 1.3(+), 1.4(-), 1.5(+), 1.6(+), 1.7(+), 1.8(+), 2.1(+), 2.2(+), 2.3(+), 2.4(+), 2.5(+), 2.6(+), 2.7(+), 2.8(+), 2.9(+), 2.10(+), 3.1(+), 3.2(+), 3.3(+), 3.4(+), 3.5(+), 3.6(+), 3.7(+), 3.8(+), 3.9(+)	1.1(-), 1.2(-), 1.3(-), 1.4(-), 1.5(-), 1.6(-), 1.7(-), 1.8(-), 2.1(-), 2.2(+), 2.3(-), 2.4(-), 2.5(-), 2.6(-), 2.7(-), 2.8(-), 2.9(-), 2.10(-), 3.1(-), 3.2(-), 3.3(-), 3.4(-), 3.5(-), 3.6(-), 3.7(-), 3.8(-), 3.9(-)

EFFECTS IN PLANNING PHASE TYPE OF PROJECT: STORAGE		
COUNTRY	**URBAN**	**NON-URBAN**
Brazil	1.1(-), 1.2(-), 1.3(-), 1.4(-), 2.1(+), 2.2(+), 2.4(+), 2.5(+), 3.1(+), 3.3(+), 3.4(+), 3.5(+)	1.1(-), 1.2(-), 2.1(+), 2.3(+), 2.4(+), 3.1(+)
Czech Republic	1.2(++), 1.3(+), 2.4(+), 2.6(+), 2.10(-), 3.3(+), 3.4(+)	1.2(++), 1.3(+), 2.4(+), 2.6(+), 2.10(-), 3.3(+), 3.4(+)
Finland	1.2(-), 1.3(-), 2.3(+), 3.3(+)	1.2(-), 2.3(+), 2.4(++), 3.1(+)
Spain	1.2(-), 1.3(-), 1.4(-), 1.7(-), 2.4(++), 3.3(++)	1.2(-), 1.3(-), 1.7(-), 2.3(++), 2.4(++), 3.3(+)
Sweden	1.1(++), 1.2(++), 1.3(++), 1.4(-), 1.5(++), 1.6(++), 1.7(++), 1.8(++), 2.1(++), 2.2(++), 2.3(++), 2.4(++), 2.5(++), 2.6(++), 2.7(++), 2.8(++), 2.9(++), 2.10(++), 3.1(++), 3.2(++), 3.3(++), 3.4(++), 3.5(++), 3.6(++), 3.7(++), 3.8(++), 3.9(++)	1.1(+), 1.2(+), 1.3(+), 1.4(+), 1.5(+), 1.6(+), 1.7(+), 1.8(+), 2.1(+), 2.2(+), 2.3(+), 2.4(+), 2.5(+), 2.6(+), 2.7(+), 2.8(+), 2.9(+), 2.10(+), 3.1(+), 3.2(+), 3.3(+), 3.4(+), 3.5(+), 3.6(+), 3.7(+), 3.8(+), 3.9(+)

5 Effects In Construction Phase (Answers To Question 1.4)

The following tables show the answers to the question: "During construction phase which effects of the list can usually increase the predicted budget?"

+++ if the effect has high influence in budget deviation
++ if the effect has important influence
+ if the effect has some influence

EFFECTS IN CONSTRUCTION PHASE TYPE OF PROJECT: WATERWAY		
COUNTRY	**URBAN**	**NON-URBAN**
Brazil	1.2(++), 1.4(++), 2.10(++), 3.4(++), 3.5(++), 3.9(+)	2.4(+), 3.4(+), 3.9(+)
Czech Republic	1.1(+++), 1.2(++), 1.4(+)	1.1(+++), 1.2(++)
Egypt		1.1(+++), 1.2(+++), 1.3(+++), 1.4(+++), 1.5(+++), 1.6(+++), 1.7(+++), 1.8(+++)
Finland	1.1(++), 1.2(++), 1.3(++), 1.4(+++), 2.4(++), 2.5(+)	1.1(+), 1.2(+), 1.3(+), 1.4(++), 2.4(+)
Iceland		1.1(+++), 1.2(++)
Spain	1.2(++), 1.4(+++), 1.7(++), 3.5(+++), 3.6(++)	1.2(++), 1.3(+), 1.7(+), 1.8(++)
Sweden		1.2(++), 1.4(++), 2.1(+)

EFFECTS IN CONSTRUCTION PHASE TYPE OF PROJECT: ROAD		
COUNTRY	**URBAN**	**NON-URBAN**
Brazil	1.4(++), 1.8(++), 2.7(+), 2.10(+), 3.4(+), 3.5(+), 3.9(++)	1.8(+), 2.7(+), 3.4(+), 3.9(+)
Czech Republic	1.1(+++), 1.2(++), 1.4(+)	1.1(+++), 1.2(+)
Finland	1.2(+), 1.3(++), 1.4(++), 2.5(++)	1.2(+), 1.3(+), 1.4(++)
Iceland	1.1(+++), 1.2(++), 1.4(+), 3.4(+)	1.1(+++), 1.2(++)
The Netherlands	1.2(+), 2.5(+), 2.10(++), 3.4(+)	2.5(+), 2.10(++), 3.4(++)
Spain	1.1(+), 1.2(++), 1.3(++), 1.4(++), 1.6(++), 2.7(+), 3.5(+++), 3.6(++)	1.2(++), 1.6(+), 1.7(+), 2.4(+), 3.4(++)

Sweden	1.1(++), 1.2(++), 1.3(++), 1.4(++), 1.5(++), 1.6(++), 1.7(++), 1.8(++), 2.1(+), 2.2(+), 2.3(+), 2.4(+), 2.5(+), 2.6(+), 2.7(+), 2.8(+), 2.9(+), 2.10(+), 3.4(+), 3.5(+), 3.6(+), 3.9(+)	1.1(++), 1.2(++), 1.3(++), 1.4(++), 1.5(++), 1.6(++), 1.7(++), 1.8(++), 2.1(+), 2.2(+), 2.3(+), 2.4(+), 2.5(+), 2.6(+), 2.7(+), 2.8(+), 2.9(+), 2.10(+)
Turkey	1.1(+++), 1.2(+++), 1.3(+++), 1.4(+++), 1.8(++), 2.1(++), 2.3(++), 2.4(++), 3.1(+++), 3.2(+), 3.3(++), 3.5(+++), 3.6(+++), 3.9(++)	1.1(++), 1.2(++), 1.3(++), 1.4(+), 1.8(+), 2.1(+), 2.3(+), 2.4(+), 3.1(+), 3.2(+), 3.3(+), 3.5(+), 3.6(+), 3.9(+)

EFFECTS IN CONSTRUCTION PHASE TYPE OF PROJECT: RAILWAY		
COUNTRY	**URBAN**	**NON-URBAN**
Brazil	1.4(++), 1.8(++), 2.7(+), 2.10(+), 3.4(+), 3.5(+), 3.9(++)	1.8(+), 2.7(+), 3.4(+), 3.9(+)
Czech Republic	1.1(+++), 1.2(+), 1.4(+)	1.1(+++), 1.2(+)
Egypt	1.1(+++), 1.2(+++), 1.3(+++), 1.4(+++), 1.5(+++), 1.6(+++), 1.7(+++), 1.8(+++), 2.1(+), 2.2(+), 2.3(+), 2.4(+), 2.5(+), 2.6(+), 2.7(+), 2.8(+), 2.9(+), 2.10(+), 3.1(++), 3.2(++), 3.3(++), 3.4(++), 3.5(++), 3.6(++), 3.7(++), 3.8(++), 3.9(++)	
Finland	1.2(+), 1.3(+), 1.4(+), 2.5(++)	1.2(+), 1.3(+)
Hungary	1.2(+), 3.3(++)	
The Netherlands	1.2(+), 2.5(+), 2.10(++), 3.4(+)	2.5(+), 2.10(++), 3.4(++)
Spain	1.1(+), 1.2(++), 1.3(++), 1.4(++), 1.6(++), 2.7(+), 3.5(+++), 3.6(++)	1.2(++), 1.6(+), 1.7(+), 2.4(+)
Sweden	1.1(++), 1.2(++), 1.3(++), 1.4(++), 1.5(++), 1.6(++), 1.7(++), 1.8(++), 2.1(+), 2.2(+), 2.3(+), 2.4(+), 2.5(+), 2.6(+), 2.7(+), 2.8(+), 2.9(+), 2.10(+), 3.4(+), 3.5(+), 3.6(+), 3.9(+)	1.1(++), 1.2(++), 1.3(++), 1.4(++), 1.5(++), 1.6(++), 1.7(++), 1.8(++), 2.1(+), 2.2(+), 2.3(+), 2.4(+), 2.5(+), 2.6(+), 2.7(+), 2.8(+), 2.9(+), 2.10(+)

EFFECTS IN CONSTRUCTION PHASE TYPE OF PROJECT: CABLE, HYDRO		
COUNTRY	**URBAN**	**NON-URBAN**
Brazil	1.2(++), 1.4(++), 2.7(+), 2.10(+), 3.4(+), 3.5(+), 3.9(+)	1.2(+), 2.7(+), 3.4(+), 3.9(+)
Czech Republic	1.1(+++), 1.2(+), 1.4(+)	1.1(+++), 1.2(+)
Finland	1.3(+), 1.4(+)	1.3(+), 1.4(+)
Spain	1.7(+), 1.4(++), 3.5(++)	1.2(+), 1.8(+)
Sweden	1.1(++), 1.2(++), 1.3(++), 1.4(++), 1.5(++), 1.6(++), 1.7(++), 1.8(++), 2.1(+), 2.2(+), 2.3(+), 2.4(+), 2.5(+), 2.6(+), 2.7(+), 2.8(+), 2.9(+), 2.10(+), 3.4(+), 3.5(+), 3.6(+), 3.9(+)	1.1(++), 1.2(++), 1.3(++), 1.4(++), 1.5(++), 1.6(++), 1.7(++), 1.8(++), 2.1(+), 2.2(+), 2.3(+), 2.4(+), 2.5(+), 2.6(+), 2.7(+), 2.8(+), 2.9(+), 2.10(+)

EFFECTS IN CONSTRUCTION PHASE TYPE OF PROJECT: UNDERGROUND INDUSTRIAL ACTIVITIES		
COUNTRY	**URBAN**	**NON-URBAN**
Brazil	1.4(++), 1.8(++), 2.7(++), 2.10(++), 3.4(+), 3.5(+), 3.9(+)	1.8(++), 2.7(++), 2.10(++), 3.4(+), 3.9(+)
Finland	1.3(++), 1.4(+), 2.5(++)	1.3(++), 1.4(+)
Spain	1.2(+), 1.3(+), 1.4(+++), 2.3(+), 3.5(++)	1.2(+), 1.3(++)
Sweden	1.1(++), 1.2(++), 1.3(++), 1.4(++), 1.5(++), 1.6(++), 1.7(++), 1.8(++), 2.1(+), 2.2(+), 2.3(+), 2.4(+), 2.5(+), 2.6(+), 2.7(+), 2.8(+), 2.9(+), 2.10(+), 3.4(+), 3.5(+), 3.6(+), 3.9(+)	1.1(++), 1.2(++), 1.3(++), 1.4(++), 1.5(++), 1.6(++), 1.7(++), 1.8(++), 2.1(+), 2.2(+), 2.3(+), 2.4(+), 2.5(+), 2.6(+), 2.7(+), 2.8(+), 2.9(+), 2.10(+)

EFFECTS IN CONSTRUCTION PHASE TYPE OF PROJECT: PUBLIC UNDERGROUND SPACE, SHOP MALL		
COUNTRY	**URBAN**	**NON-URBAN**
Brazil	1.1(+), 1.3(+), 1.4(+), 2.5(+), 2.6(+), 2.7(+), 2.9(+), 3.4(+), 3.5(+)	
Czech Republic	1.1(+++), 1.2(++), 1.4(+)	1.1(+++), 1.2(+)
Finland	1.3(++), 1.4(++), 2.5(++)	1.3(++), 1.4(+)
Hungary	1.2(+), 3.3(++)	
Spain	1.1(++), 1.2(++), 1.3(++), 1.4(++), 1.6(++), 1.7(+++), 3.5(+++)	1.1(++), 1.2(++), 1.3(++), 1.6(+), 1.7(+), 1.8(++)
Sweden	1.1(++), 1.2(++), 1.3(++), 1.4(++), 1.5(++), 1.6(++), 1.7(++), 1.8(++), 2.1(+), 2.2(+), 2.3(+), 2.4(+), 2.5(+), 2.6(+), 2.7(+), 2.8(+), 2.9(+), 2.10(+), 3.4(+), 3.5(+), 3.6(+), 3.9(+)	1.1(++), 1.2(++), 1.3(++), 1.4(++), 1.5(++), 1.6(++), 1.7(++), 1.8(++), 2.1(+), 2.2(+), 2.3(+), 2.4(+), 2.5(+), 2.6(+), 2.7(+), 2.8(+), 2.9(+), 2.10(+)

EFFECTS IN CONSTRUCTION PHASE TYPE OF PROJECT: STORAGE		
COUNTRY	**URBAN**	**NON-URBAN**
Brazil	1.3(+), 1.4(+), 2.4(+), 2.7(+), 2.9(+), 3.1(+), 3.4(+), 3.9(+)	1.3(+), 2.4(+), 2.7(+), 3.4(+), 3.9(+)
Czech Republic	1.1(+++), 1.2(++), 1.4(+)	1.1(+++), 1.2(++)
Finland	1.3(++), 1.4(++), 2.5(++)	1.3(++), 1.4(+)
Spain	1.3(+++), 1.4(++), 1.7(+++), 1.8(+++), 2.3(++), 3.4(++)	1.3(+++), 1.7(+), 1.8(+++), 2.3(++), 2.4(++), 3.4(++)
Sweden	1.1(++), 1.2(++), 1.3(++), 1.4(++), 1.5(++), 1.6(++), 1.7(++), 1.8(++), 2.1(+), 2.2(+), 2.3(+), 2.4(+), 2.5(+), 2.6(+), 2.7(+), 2.8(+), 2.9(+), 2.10(+), 3.4(+), 3.5(+), 3.6(+), 3.9(+)	1.1(++), 1.2(++), 1.3(++), 1.4(++), 1.5(++), 1.6(++), 1.7(++), 1.8(++), 2.1(+), 2.2(+), 2.3(+), 2.4(+), 2.5(+), 2.6(+), 2.7(+), 2.8(+), 2.9(+), 2.10(+)

6 Effects During Operation (Answers To Question 1.5)

The following tables show the answers to the question: "Which effects have more possibilities of producing additional works (repairing, maintenance, environmental restoration...) during the operation of an underground infrastructure?"

I if the effect produces new works on the own infrastructure.
E if the effect produces external works (soil recuperation,...).

EFFECTS DURING OPERATION TYPE OF PROJECT: WATERWAY		
COUNTRY	**URBAN**	**NON-URBAN**
Brazil	1.3(I), 1.8(I), 2.8(I), 3.9(I)	1.8(I), 2.8(I), 3.9(I)
Czech Republic	1.2(E), 2.5(E), 2.6(E)	1.2(E)
Egypt		1.1(I), 1.2(I), 1.3(I), 1.4(I), 1.5(I), 1.6(I), 1.7(I), 1.8(I)
Finland	1.1(E), 1.4(E)	1.1(E), 1.4(E)
Iceland		1.2(I)
Spain	1.2(E)	1.2(E)
Sweden		1.2(I), 1.3(I), 1.4(I)

EFFECTS DURING OPERATION TYPE OF PROJECT: ROAD		
COUNTRY	**URBAN**	**NON-URBAN**
Brazil	1.7(E), 2.4(E), 2.5(I), 3.1(E), 3.9(I)	1.7(E), 2.4(E), 3.9(I)
Czech Republic	1.2(I/E), 2.5(E), 2.6(E)	1.2(E)
Finland	1.2(I/E), 1.3(E), 1.4(E)	1.2(I), 1.3(E), 1.4(E)
Iceland	1.2(I), 2.6(I)	1.2(I), 2.6(I)
Spain	1.4(I), 1.6(I), 1.7(E), 3.4(I)	1.6(I), 3.4(I/E)
Sweden	1.2(I), 1.3(I), 1.4(I), 2.5(E), 2.6(E)	1.2(I), 1.3(I), 1.4(I), 2.5(E), 2.6(E)
Turkey	1.6(I), 1.8(I), 2.1(E), 2.3(E), 2.4(E), 2.5(I)	1.1(I), 1.8(I), 2.1(E), 2.3(E), 2.4(E), 2.5(I)

EFFECTS DURING OPERATION TYPE OF PROJECT: RAILWAY		
COUNTRY	**URBAN**	**NON-URBAN**
Brazil	1.7(E), 2.4(E), 2.5(I), 3.1(E), 3.9(I)	1.7(E), 2.4(E), 3.9(I)
Czech Republic	1.2(E), 2.5(E), 2.6(E)	1.2(E)
Finland	1.2(I/E), 1.3(I/E), 1.4(E)	1.2(I), 1.3(I)
Hungary	1.2(I/E), 1.7(E), 3.5(E)	
Spain	1.4(I), 1.7(E), 3.4(I)	3.4(I)
Sweden	1.2(I), 1.3(I), 1.4(I), 2.5(E), 2.6(E)	1.2(I), 1.3(I), 1.4(I), 2.5(E), 2.6(E)

EFFECTS DURING OPERATION TYPE OF PROJECT: CABLE, HYDRO		
COUNTRY	**URBAN**	**NON-URBAN**
Brazil	1.3(I), 2.8(I), 3.9(I)	1.3(I), 3.9(I)
Czech Republic	1.2(E), 2.5(E), 2.6(E)	1.2(E)
Finland	1.2(I), 1.3(I)	1.2(I), 1.3(I)
Spain	1.2(E), 1.4(I), 1.7(E)	1.2(E)
Sweden	1.2(I), 1.3(I)	1.2(I), 1.3(I)

EFFECTS DURING OPERATION TYPE OF PROJECT: UNDERGROUND INDUSTRIAL ACTIVITIES		
COUNTRY	**URBAN**	**NON-URBAN**
Brazil	1.2(I), 1.3(I), 1.7(E), 2.4(E), 2.6(I), 2.10(I), 3.1(E), 3.9(I)	1.7(E), 2.4(E), 2.10(I), 3.9(I)
Finland	1.2(I/E), 1.3(I/E), 1.8(E), 2.5(I/E), 2.6(E), 2.10(E)	1.2(I/E), 1.3(I/E), 1.8(E), 2.5(I), 2.6(E), 2.7(E), 2.10(E)
Spain	1.2(E), 1.4(I)	1.2(E)
Sweden	1.2(I), 1.3(I), 1.4(I), 2.5(E), 2.6(E)	1.2(I), 1.3(I), 1.4(I), 2.5(E), 2.6(E)

EFFECTS DURING OPERATION TYPE OF PROJECT: PUBLIC UNDERGROUND SPACE, SHOP MALL		
COUNTRY	**URBAN**	**NON-URBAN**
Brazil	1.2(I), 1.3(I), 1.7(E), 2.4(E), 2.10(I), 3.1(E), 3.9(I)	
Czech Republic	1.2(E), 2.5(E), 2.6(E)	1.2(E)
Finland	1.2(I/E), 1.3(I/E), 1.4(E), 2.5(E)	1.2(I), 1.3(I), 1.4(E)
Hungary	1.2(E)	
Spain	1.2(E), 1.4(I)	1.2(E)
Sweden	1.2(I), 1.3(I), 3.4(I)	

EFFECTS DURING OPERATION TYPE OF PROJECT: STORAGE		
COUNTRY	**URBAN**	**NON-URBAN**
Brazil	1.2(I), 1.3(I), 1.7(E), 2.4(E), 2.10(I), 3.1(E), 3.9(I)	1.2(I), 1.7(E), 2.10(I), 3.9(I)
Czech Republic	1.2(E), 2.5(E), 2.6(E)	1.2(E)
Finland	1.2(I/E), 1.3(E), 1.4(E), 2.5(E)	1.2(E), 1.3(E), 1.4(E)
Spain	1.2(E), 1.3(E)	1.2(E), 1.3(E)
Sweden	1.2(I), 1.3(I), 1.4(I), 3.4(I)	1.2(I), 1.3(I)

7 Corrective Measures (Answers To Question 2.6)

The following table collects the answers to the question:
"Which of the following measures to reduce negative impacts/effects are usually derived from underground works?
Please number (up to) the highest priorities in order of importance (From 1 to n , 1= the highest , n= the lowest) for those that you consider."

CORRECTIVE MEASURES	Braz.	Czech Rep.	Egy.	Fin.	Hung.	Ice.	Jap.	Neth.	Spain	Swed.	Thai.	Tur.
Slope, quarry, dump restoration	2		2	7	4	2		2	8	3	4	1
Quarry, dump site selection	1		2	6	3	1		2	7	3	3	1
Adequate environmental design of mouths	7	1		4	6	3			1	1	1	2
Previous soil surveys and studies	3	1	1	2	1			2	2	2	2	1
Noise/Vibration measures	6	2	1	1	6		1	4	4	1	7	2
Sewage treatments	4	1	2	6	4			2	5	2	6	3
Control of pollutant emissions	8	2	1	8	2	4	3	2	3	3	9	2
Use of subproducts as raw material	9		3	5	5			4	9	2	10	2
Adequate planning of machinery movements	10		4	9	3			5	10	2	8	1
Precaution against freatic level alteration	5		1				4	3	4		11	2
Work planning	11		2	3	3		6	3	11		5	2
Minimizing surface settling							2					

In order to homogenise the answers, data for each corrective measure showed below were calculated by adding the punctuation of each country and dividing it by the number of answers corresponding to that measure.

CORRECTIVE MEASURES	**PRIORITY**
Slope, quarry, dump restoration	2.9
Quarry, dump site selection	2.1
Adequate design to environment of mouths	2.8
Previous soil surveys and studies	1.7
Noise/vibrations measures	3.2
Sewage treatments	3.5
Pollutant emissions control	3.9
Using of subproducts as raw material	5.4
Adequate planning of machinery movements	5.8
Precaution against freatic level alteration	4.3
Work planning	5.1

8 Effects Of Environmental Legislation On Different Agents (Answers To Question 2.7)

The following tables show the answers to the question:
"Which of the following effects are direct consequences of the Environmental Legislation? Please select the effect and number (up to) the highest priorities in order of importance (Ordered from 1 to n , 1= highest, n= lowest) for each kind of agent."

EFFECTS ON CONSULTING CO. (PLANNING & PROJECT DESIGN)	Braz.	Egy.	Fin.	Hung.	Ice.	Jap.	Neth.	Spain	Swed.	Thai.	Tur.
Major responsibility demand	2	2	2	1	2	3	4	1	3	3	1
Increase of production costs	6	4	4	2	2	1	3	2	5	1	2
New market opportunities	3	2	1	5	2		4	3	4	2	2
Increase of penalties due to unfulfilled regulation	1	4	6	4			3	4	1		2
Obtaining subsidies or incentives	4	5	3	5			5	5			2
Increase of high technology demand	5	2	5	3	2	2	2	6			1

EFFECTS ON CONSTRUCTION CO.	Braz.	Czech Rep.	Egy.	Fin.	Hung.	Ice.	Jap.	Neth.	Spain	Swed.	Thai.	Tur.
Major responsibility demand	2		2	2	3	3	3	4	2	3	5	1
Increase of production costs	1	1	1	3	4	1	1	3	1	4	4	2
New market opportunities	4		1	1	1	3		4	3	1	3	1
Increase of penalties due to unfulfilled regulation	3		2	6	2			3		2	2	1
Obtaining subsidies or incentives	5		3	5	2			5	4			2
Increase of high technology demand	6		1	4	3	4	2	2			1	1

EFFECTS ON UNDERGR.WORKS MANAGEMENT	Braz.	Egy.	Fin.	Hung.	Ice.	Jap.	Neth.	Spain	Swed.	Thai.	Tur.
Major responsibility demand	5	2	1	2	1	1	4	3	3	4	1
Increase of production costs	6	1	3	1	3	2	3	2	3		1
New market opportunities	1	2	2	4	1		4	1	2	1	3
Increase of penalties due to unfulfilled regulation	4	3	5	5			3		2	3	1
Obtaining subsidies or incentives	2	1	6	3			5				1
Increase of high technology demand	3	1	4	3	1	3	2			2	2

EFFECTS ON MACHINERY AND PRODUCTS CO.	Brazil	Czech Rep.	Egypt	Fin.	Ice.	Neth.	Spain	Swed.	Thai.	Tur.
Major responsibility demand	4			1	4	4	3	2	4	2
Increase of production costs	5			3	4	3	2	2	3	2
New market opportunities	2		1	2	4	4	1	2	2	1
Increase of penalties due to unfulfilled regulation	6			4		3		2		
Obtaining subsidies or incentives	3		2	6		5				
Increase of high technology demand	1	1	1	5	3	2			1	1

9 Time Spent In Each Phase Of An Underground Work Life Cycle (Answers To Question 1.2)

The answers to question 1.2 from the questionnaire.

DURATION OF PLANNING PHASE	Bra	Czech Rep.	Egy.	Fin	Fran	Hun.	Ice.	Neth	Nor.	Spain	Swed	Thai	Tur	USA
WATERWAY	2	3-4	3-5	5-10	5		3		2	5-15	10	1		25
ROAD	1	3-4	10	3-10	5		2	10	3-8	3-8	3		0,5	25
RAILWAY	1	1-2	10	2-5	5	8-10		10	1-7	3-15	3-4	1	1	25
CABLE, HYDRO	0,5	1			1				4-10		1	1		10
UNDERGROUND INDUSTRIAL ACTIVITIES	2			2-5	2				1-2	2-5	2			5
PUBLIC UNDERGROUND SPACE, SHOP MALL	2	2		3-5	5	1,5			1-2	1-5	3-4		1,5	2
STORAGE	2	3-4		1-2	1				1-2	1-2	2-3			2

DURATION OF DESIGN PHASE	Bra	Czech Rep.	Egy	Fin	Fran	Hun.	Ice.	Neth	Nor.	Spain	Swed	Thai	Tur	USA
WATERWAY	0,5	1-2	2	3-5	3		2		1	2-3	2-5	2		5
ROAD	0,5	1-2	2	1-3	2		1	3	2	2-3	2-3		1	5
RAILWAY	0,5	1	2	1-2	3	5-6		3	2	1-3	2-3	1	1	5
CABLE, HYDRO	1	1		1-3	1				2	2-3	0,5-1	2		2
UNDERGROUND INDUSTRIAL ACTIVITIES	1			1-2	2				0-1	2-3	2			1
PUBLIC UNDERGROUND SPACE, SHOP MALL	1-1,5	1		1-2	2	0,5			0-1	1-3	2		1,5	1
STORAGE	2	1-2		1-2	1				0-1	0-1	2			1

DURATION OF CONSTRUCTION	Bra	Czech Rep.	Egy	Fin	Fran	Hun.	Ice.	Neth	Nor.	Spain	Swed	Thai	Tur	USA
WATERWAY	2	4-6	3-5	3-10	4		4		2	2-3	2-5	2-3	7-20	7
ROAD	1-2	2-3	3-5	2-3	3		3	3	2-3	2-4	3-4		1-6	4
RAILWAY	1-2	1-3	3-5	2-3	4	15		3	2-3	2-8	4	1-2	1-6	4
CABLE, HYDRO	1-4	2-3		1-3	1				2-5	2-3	1-2	2-3	16	2
UNDERGROUND INDUSTRIAL ACTIVITIES	2-4			1,5-3	3				2	2-3	2-3			2
PUBLIC UNDERGROUND SPACE, SHOP MALL	2-3	2-3		2-3	3	1-1,5			2	2-3	2-3		2-8	2
STORAGE	2	4-6		1,5	3				1-2	<1	2-3			1

DURATION OF OPERATION & MAINTENANCE	Bra	Fin	Fran	Hun.	Ice.	Neth	Nor.	Spain	Swed	Thai	USA
WATERWAY	15-30	50-100	>100		>50		40	100	100	50	50
ROAD	20-30	50-100	>100		>50	100	50	100	100		25
RAILWAY	20-30	50-100	>100	6-20		100	100	100	100	50	25
CABLE, HYDRO	20-40	20-50	50-100				60	100	100	50	25
UNDERGROUND INDUSTRIAL ACTIVITIES	30-50	10-30	50				30-60	50-100	100		20
PUBLIC UNDERGROUND SPACE, SHOP MALL	15-20	30-50	50				20-50	50-100	100		15
STORAGE	30	20-50	>50				20-50	20	50		20

The average times for each phase obtained from the previous tables are:

TYPE OF PROJECT	PLANNING	DESIGN	CONSTRUCTION	OPERATION & MAINTENANCE
WATERWAY	6,6	2,5	4,7	65
ROAD	6,4	2,1	3	69
RAILWAY	6,4	2,3	4	69
CABLE, HYDRO	3	1,6	3,6	59
UNDERGROUND INDUSTRIAL ACTIVITIES	2,8	1,5	2,5	50
PUBLIC UNDERGROUND SPACE, SHOP MALL	2,6	1,3	2,5	47
STORAGE	1,9	1,2	2,2	34

10 Types Of Underground Projects That Will Increase Their Demand According To Environmental Implications (Answers To Question 3.1)

URBAN AREA	Bra	Czech Rep.	Egy	Fin	Fran	Hun	Ice.	Jap	Neth	Nor.	Spain	Swed	Thai	Tur	USA
WATERWAY	5	3	2	6				1		9	5		4	1	4
ROAD	1	2	1	3	4	1	1	3	1	1	2	2	1	1	1
RAILWAY	6	3	1	5	2			1	1	6	3	3	5	1	2
CABLE, HYDRO	7	2	1	4	1			1		7	6	4	3	1	5
UNDERGROUND INDUSTRIAL ACTIVITIES	8			8				2		5	7	5	7	1	6
PUBLIC UNDERGROUND SPACE, SHOP MALL	4	2		2	5	3		2	1	4	8	4	6	1	7
STORAGE	3	1	2	7				2	1	3	4	2	8	1	8
PARKING	2	2	1	1	3	2	2	1	1	2	1	1	2	1	3

NON URBAN AREA	Bra	Egy.	Fin	Fran	Hun.	Ice.	Ja p	Neth	Nor.	Spain	Swe d	Thai	Tur	USA
WATERWAY	3		4			1	1		9	5		4	1	4
ROAD	1		2		2	2		1	1	2	2	1	1	1
RAILWAY	2		1				2	1	6	3	3	5	1	2
CABLE, HYDRO	4	3	3						7	6	4	3	1	5
UNDERGROUND INDUSTRIAL ACTIVITIES	7	4	5	1	3				5	7	5	7	1	6
PUBLIC UNDERGROUND SPACE, SHOP MALL		2	6						4	8	4	6	1	7
STORAGE	5		7	2	1		1		3	4	2	8	1	8
PARKING	6		8		2				2	1	1	2	1	3

Topic

UNDERGROUND AND ENVIRONMENT

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Remarks: In this chapter the aim is to present 13 case studies of underground projects carried out in seven different countries (Brazil, Egypt, Finland, Spain, Sweden, and The Netherlands), that show the range of different possibilities of underground works. Therefore the case studies have been selected trying to choose the more interesting ones according to their environmental implications, as well as intending to show several different types of modern underground works.

The information used for the description of the case studies has been obtained by a request directed to the respective authorities in charge of the planning of the works. The demanded information included the most important technical aspects of each project as well as a report about the environmental relevant features.

The final selection of the case studies presented in this chapter had to take into account the quantity and quality of the documents sent in return of the request. Not in all cases did the information received contain the same amount of useful information concerning the environmental aspects of the project.

ANNEX II: CASE STUDIES

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A.II.-

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1. Introduction

In this chapter the aim is to present 13 case studies of underground projects carried out in seven different countries (Brazil, Egypt, Finland, Spain, Sweden, and The Netherlands), that show the range of different possibilities of underground works. Therefore the case studies have been selected trying to choose the more interesting ones according to their environmental implications, as well as intending to show several different types of modern underground works.

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The following matrix shows the selected cases:

CASE STUDIES		TYPE OF PROJECT				
		Transport Infrastructures	**Utilities Infrastructures**	**Storage Infrastructures**	**Public Underground Space**	**Underground Industrial Activities**
AREA	**Urban**	BRAZIL: Sao Paulo Underground	EGYPT: Cairo Waste Water Scheme		SWEDEN: The Royal Library in Stockholm (Expansion of Sweden National Library)	FINLAND: Viikinmäki Waste Water Treatment Plant in Helsinki
		THE NETHERLANDS: Case Delft (Railway)				
		JAPAN: Metropolitan Wxpressway Central Circular Route, Tokyo.				
		SPAIN: Pasillo Verde Madrid (Railway)				
	Non-Urban	THE NETHERLANDS: Case Sophia Line Section (Railway)	EGYPT: Al-Salam Siphon under the Suez Canal	SWEDEN: The Äspö Hard Rock Laboratory (Nuclear Waste Storage)		JAPAN: Kazunogawa Pumped Storage Plan.
		SPAIN: Vallvidrera Road Tunnel	FINLAND: Päijänne Water Tunnel			

Looking at concrete cases in different countries, has shown that environmental problems should more and more be considered not only as additional difficulties for a project from a technical point of view, but as a fundamental aspect that has to be integrated in the three phases of underground works: planning, construction, and operation.

This attitude is fundamental regarding the expected tightening of future environmental regulations concerning underground works as well as the dwindling public acceptance of projects causing relevant environmental damage, no matter how important the expected economic and social utility of a project may be.

Therefore it should be a central aim at every planned project to underline the efforts made in order to limit, or even avoid, environmental disturbances by developing technical solutions for a modern, environmental friendly way of undertaking underground works.

Specially in the densely populated urban areas the undertaking of important underground works has to face problems that are not limited to mere technical challenges. It must be taken into account that in urban areas the number of persons that may be directly affected by the construction works is higher than in rural areas, and therefore the weight of public opinion when undertaking this kind of projects may become very important.

Under this premises, it is of vital significance to minimise the disturbances and negative impacts on the environment not only during the construction phase, in order to guarantee the wide acceptance of the whole project.

2. Case Study: Sao Paulo Underground (Paulista Line), Brazil

2.1 Summary

Underground stations and tunnel avoided disruption of traffic, relocation of land uses, construction noise and visual impact on a very busy city street.

2.2 Introduction

The city of Sao Paulo is one of the world biggest cities, with around approximately 18 million people living in its metropolitan area.

The project to add four new stations to the existing subway system had to face the fact that the foreseen itinerary passed under several very busy streets like the Avenidas Paulista and Dr. Arnaldo, supporting very high volumes of traffic. In order to avoid severe traffic disturbances open-cut construction method had to be laid aside.

2.3 Technical Characteristics of the project

The Paulista Line is the most recent extension of the Sao Paulo Subway System. The line consists of four new stations Brigadeiro, Trianon, Consolaçao and Clínicas.

The new stations show the following technical features:

Brigadeiro and Trianon: ended 1989, soil cover 4 to 7,4 metres, length 150 m; excavated soil of porous clay (SPT blow count 6 to 23); no groundwater; excavation method NATM full section; lining shotcrete and steel sets (45 cm thick, primary plus secondary); lateral tunnels excavated first and central tunnels supported by lateral tunnels; lateral tunnels with 7,4 m of equivalent diameter; completed excavation with 160 m2 of area.

Consolacao: ended 1990, soil cover 12 m, length 140 m /both tunnels); excavated soil of porous clay (SPT blow count 8 to 17); groundwater level 4 m above tunnel´s roof; excavation method NATM full section; primary lining unreinforced cast-in-place concrete (550 cm thick); both tunnels excavated independently and then connected by transversal tunnels; equivalent diameter 10 m for each tunnel.

Clinicas: ended 1990, soil cover 11 m, length 300 m (each tunnel); excavated soil of porous clay (SPT blow count 13 to 45); groundwater level 2 m above tunnel´s roof; excavation method NATM (pilot tunnel with lateral enlargements, twin tunnels with common wall, etc.); lining shotcrete and steel sets (45 cm - primary plus secondary); equivalent diameter 10 m for each tunnel.

2.4 Construction

Construction began in 1988 and the works finished three years later, in 1991.

The construction of the underground stations followed different proceedings:

The Brigadeiro and Trianon underground stations, length 150m each, were built excavating first two lateral single track tunnels, used to support the main chamber primary lining. After casting the concrete structure, lateral tunnel walls were demolished.

Consolaçao station, length 140m (both tunnels), was built by excavating two lateral tunnels with large cross sections, each containing the track plus the platform. The tunnels were finally connected by transversal tunnels of small diameter (4m).

Cínicas underground station, length 300m (each tunnel), was built by excavating first a pilot tunnel, casting a concrete pillar inside it, and excavating the enlargements, supported on one side by the previously casted concrete pillar.

The connecting tunnels between stations were built using open face shield machines (with unbolted precast concrete segments) and NATM (New Austrian Tunnelling Method) where possible. The criteria for choosing between shield and NATM were dictsted mainly by time frames available for construction completion. Shield machines were able to excavate an average of 30 meters of tunnel per day, and NATM an average of 6 to 9 meters per day at single track tunnels.

The excavated soil consisted mainly of porous clay. The excavation laid a minimum of 2m under the groundwater level.

2.5 Environmental aspects

The building of a new underground tunnel under the surface of a big city isn't usually an easy task. Some technical and environmental problems that do not appear in non urban areas have to be considered when undertaking underground works in a densely populated area.

The removing of big quantities of soil had to be planned and undertaken with maximum care in order to avoid the affection of the fundaments of the buildings on the surface as well as any damage to the numerous existing underground networks of public utility. In non-urban areas these problems usually don't exist or are of much less importance.

The whole subway line was designed to be built underground. In this manner the environmental urban problems due to large open cut excavations could be avoided:

- Traffic disruption
- Interference with the inhabitants daily activities
- Noise disturbances

- Dust
- And the disposal of a large volume of excavated soil.

So practically the only physical interference of the entire work with the movements taking place on the surface occurred at the two endings of the new tunnel system.

This achievement was of vital importance because the Paulista Line lies under some very busy city streets (Avenidas Paulista e Dr. Arnaldo) that would very badly support any disturbance of the habitual traffic of vehicles and pedestrians.

And finally it has to be underlined too, that the high proportion of underground works, which is usually demand less mechanised, fitted well with the fact that in Brazil is labour force is abundant and not very costly

3. Case Study: Cairo Wastewater Scheme, Egypt

3.1 Summary

Tunnels run below the existing sewers and part of the Metro system, below the groundwater table. It is an essentially environmental project that aims at improving the sanitary conditions in Cairo with a minimum disturbance to the city.

3.2 Introduction

The preliminary investigations revealed that the sewer systems on both banks of the Nile were heavily overloaded. The population had increased out of all proportion (1950-1975) and the sewage disposal had deteriorated to a great extent. In the 1970s it became evident that major reconstruction works would be necessary to rectify the situation.

In 1978 a master plan for the Cairo Wastewater Scheme aimed at removing the waste water from the city in a sanitary manner while making maximum use of existing facilities as well as treating the wastewater for re-use in agriculture.

3.3 Technical Characteristics of the Project

The preliminary design involved a major investigation into the condition of the existing sewerage system, the predicted growth and distribution of the population and the water consumption and resulting wastewater production. This investigation revealed that settled grit and other deleterious matter substantially reduced the capacity of the old sewerage system.

The new system was designed to prevent such problems providing a minimum mean velocity of 0,6 m/s at the minimum average estimated flows with a minimum sediment transport capability of 200 mg/litre.

These criteria resulted in minimum gradients of 1:950 and 1:1090 for sewers of 1,2 m and 5 m internal diameter respectively. This gradients compare with that of 1:2500 found for the first main collector of 1,6 m internal diameter constructed in 1913.

The combination of sewer sizes and depths to invert of between 18 m and 22 m made it necessary to construct the new system by tunnelling techniques.

The tunnels were driven under the city of Cairo using the bentonite tunnelling technique through very hazardous ground conditions highly charged with water.

Site investigations revealed that all of the tunnels would be well below ground-water level, and most would pass through medium to coarse sands containing layers and lenses of clay or silt with occasionally layers of gravel and cobbles. The most southerly tunnel under Fostat would be in moderately strong to weak fissured rock charged with water.

The combination of fine granular materials and high groundwater levels produces extremely difficult shaft sinking and tunnelling conditions making it necessary to adopt special design considerations regarding tunnel routes and the form and method of construction.

In the highly congested environment of Cairo the need to minimise settlement effects was fundamental, and wherever possible the tunnels were routed under streets. In addition to the beneficial settlement effects this minimised property purchase and associated legal problems. Routing the tunnels under streets resulted in the majority of tunnel lengths being curved under access shafts.

3.4 Shafts and Tunnels

A standard design of access and working shafts was developed comprising an upper reinforced concrete circular structure sunk as a caisson and a lower segmental lining section installed by underspinnin techniques and subsequently line d with reinforced concrete. The shafts were designed to be constructed using compressed air to resist the inflow of groundwater and to stabilise the granular soil.

Generally shaft diameters were standardised, except were angles of deviation and low level branch connections dictated special hydraulic consideration and configurations to suit.

Frond treatment in conjunction with compressed air was specified for breaking out of the shafts for the hand construction of the tunnelling machine launching and reception chambers, and also for constructing the blind chambers provided for future tunnelled connections.

A bolted segmental form of pre-cast reinforced concrete ring was designed for the primary lining to the tunnels. The segmental rings for the 5 m and 4 m internal diameter sewers on the main trunk tunnel from Fostat to Ameria were tapered 2,5 cm across their horizontal faces to allow the tunnels to be driven around curves without special packing.

Both shaft and tunnel are lined with special acid resistant bricks pointed with acid resistant epoxy mortar to resist corrosion. The soffits of shaft roof slabs and access landing slabs are PVC faced for the same purpose.

3.5 Environmental Aspects

The inadequacy of the existing system to cope with the discharges caused hazards to health, commerce and tourism.

The Cairo Watewater Scheme Project is essentially an environmental project that aims at improving the sanitary conditions in Cairo with a minimum of disturbance to the city.

Tunnelling minimises disruption to the commercial and residential life of central Cairo, which would otherwise occur with trench construction and the associated diversion of the numerous obstructing services.

The designed tunnels were watertight and constructed accurately to line and level with the minimum of surface effects and disruption of the public at large.

Finally, it has to be mentioned that access shafts were located at strategic points along the new system for construction purposes, connections to the existing system, and minimising disruption to traffic.

4. Case Study: El-Salam Siphon beneath the Suez Canal, Egypt.

4.1 Summary

The El-Salam Siphon beneath the Suez Canal serves for transferring water from the Nile to Sinai through four 5,1 metres internal diameter tunnels.

4.2 Introduction

Owing to the limited water resources available to Egypt, the Ministry of Public Works and Water Resources of the Arab Republic of Egypt has a general policy to re-use as much possible of 7.000.000.000 m3 / year of agricultural wastewater which presently drains to the sea from the farmlands.

This policy is being applied by the North Sinai Development Organisation in their scheme for irrigating agricultural areas in the North Sinai.

The Ministry has set up an ambitious plans that aims at conveying 2.300.000 m3/ year of this wastewater to Sinai in addition to some water from the eastern branch of the Nile at Damietta.

During its journey, the water will travel across the Suez Canal through four 5.1 m finished internal diameter tunnels.

El-Salam Syphon under the Suez Canal is part of a the El-Salam Canal Project, which was first conceived in the late 1970s and that consists of three main elements:

1. El-Salam Canal, west of the Suez Canal
2. Syphon under the Suez Canal
3. El-Sheikh Gaber Canal, in Northern Sinai

The main goal of this ambitious project is to develop agriculture by offering irrigation to 400.000 feddans in Northern Sinai by transferring large volumes of water (160 m3 / s), wastewater and some water of the eastern branch of the Nile, from the existing El-Salam Canal to the new canal system on the east bank.

4.3 Technical Characteristics of the Project

El-Salam Syphon Project under the Suez Canal consists of four identical tunnels of 6,56 m excavated diameter (5,1 m internal diameter) and 775 m length. The tunnels pass under the Suez Canal at a maximum depth below ground surface of about 45 m. The tunnels were constructed using closed face betonite slurry machine (mixed shield).

The alignments of the tunnels were chosen taking into account the future deepening and widening of the Suez Canal, minimum surface settlement to the Port Said - Ismailia railways under which they pass and avoidance of Port Said - Ismailia highway.

The inclined sections form each bank have a gradient of 1 in 5 with a 1-200 gradient beneath the Suez Canal to a low point on the east side. These straight gradients are connected by 500 m vertical curves. At the inlet and outlet structures, the tunnels are at 12 m centres and then they diverge for most of their length.

The tunnels have been constructed through water bearing ground conditions and in an aggressive environment. The groundwater is high saline and particular attention has been paid to the durability of the tunnel lining and the long-term life of the tunnel.

The tunnel's lining is a two-phase lining system and comprises primary and secondary lining.

The primary lining consists of precast reinforced concrete segments (30 cm thick). It has 7 segments and a key segment forming each ring. The primary lining has been designed to withstand 75 % of overburden and 100 % hydrostatic pressure at the maximum depth to axis of approximately 45 meters. A function of the primary lining is however, to enable the uninforces secondary lining to be constructed in a safe and substantially dry environment.

The secondary lining consists of a waterproof unreinforced concrete cast in-situ to a final internal diameter of 5,1 m. It has been designed to withstand the full overburden and hydrostatic pressures.

4.4 Geology of the Project Site

The soil formation at El-Salam Syphon Project is a typical Northeast Delta geological condition.

Ground conditions are predominantly silty clays and sands with a maximum water pressure of 4,5 bars. The clays within this area are considered as lagoon deposits with thickness ranging between 4 to 50 m. The typical Northeast Delta clays are generally cover by “Sabkha”, a very salty dark grey silty clay with very low consistencies. The sensitivity of these clays is medium and ranges around 2.

The upper portion of the inclined section of the four tunnels runs through clay formations with consistency varying from very soft to stiff. At a depth of about 30 m, the tunnel alignment penetrates into a sand layer under artesian water pressure. The permeability of this sand is high at about 10-1m/s.

The primary lining was chosen to be a circular bolted segmental lining, while the secondary lining was chosen to be an in-situ concrete lining. Construction was carried out using a mixed shield designed tunnel boring machine.

4.5 Hydraulic design

The hydraulic design formed an important part of the design of the siphon. The maximum design flow is 160 cubic meters per second, but there is a wide variation in the monthly design flows, as it is shown in the table below.

The minimum flow of 42 m3/s is in October and the peak flows in June and July. The minimum velocity in the tunnel siphon will be 1 m/s and the maximum velocity 2 m/s. The design head loss in the siphon is 0,9 meters.

Monthly flows

	M3/s		m3/s
January	64	July	160
February	84	August 148	
March	82	September	117
April	86	October	42
May	82	November	94
June	160	December	108

4.6 Environmental Aspects

The choice of a tunnel solution caters for environmental requirements of the project such as the aesthetics of the water crossing structure as well as the pollution that may be caused during construction.

The (four) tunnels are constructed under important transportation and utility lines; namely: Suez Canal, Port Said-Ismailia Freeway and railway lines, and Port Said Fresh Water Canal. Therefore, controlling the ground displacements associated with tunnel construction has been considered as an essential requirement.

The future development of agriculture in the irrigated areas will provide new economic opportunities for more than 400.000 people in the Northern Sinai.

5. Case Study: Case Delft (The Netherlands)

5.1 Summary

Extension of the existing rail corridor which traverse the city of Delft. A study was made in 1993 of an "Integral Evaluation" of four different options. Case Delft was used as a pilot case, because such studies had not been done before.

5.2 Description of the Project

A rail corridor consisting of a double track viaduct of approximately 3 km length traverses the city of Delft. The high traffic demand requires an extension with two more tracks.

The technical options that have been considered for the planned extension are the following:

1. An additional viaduct parallel to the existing viaduct.
2. Two new underground tracks by cut and cover construction and a length of 3,75 km, with the existing viaduct remaining in operation.
3. Two single tracks bored tunnels of a length of 4,00 km. Here too, the existing viaduct remains in operation.
4. Four new tracks by cut and cover construction method and removal of the existing viaduct.

In 1993 these four options where submitted to an "Integral Evaluation Study". This kind of studies had not been done before, so that Case Delft was used as a pilot case for this new procedure.

The Integral Evaluation Study must cover all actors that are involved by a project:

1. Capital investment and operation costs.
2. Aspects concerning construction time and hinder to the affected area.
3. Technical risks of the construction and technical risks of the operating stage.
4. Environmental impact on land, on water and ecology, air quality, noise, vibrations, impact on the living environment, on safety, on agriculture, on recreation, and on residential and business use in the area.
5. Economical impact on employment, the cost of traffic congestion and the contribution to BNP.
6. Time and effort to conduct all the necessary procedure matters to obtain the permits.

Where it was possible, these aspects were quantified in terms of money.

It appears that the difference of an integrally weighed cost between a viaduct and a bored tunnel solution is much less in an urban area than in a rural area.
It is also clear that an Integral Evaluation Study does not lead to an objective conclusion of a

preferred solution, but it is a strong support during the planning stage and subsequent public procedures to enable the taking of the final decision.

6. Case Study: Sophia Line Section, The Netherlands

The Sophia Line Section is a 7 km long section of the planned new double track freight rail link between the Port of Rotterdam and the hinterland of Germany.

In this section there have to be crossed two very busy motorways, a mayor waterway, the River de Noord, as well as some other smaller waterways and roads.

The area lying along most of the line section is presently rural, but will predictably develop to a residential and business area in the future.

As it had been done for Case Delft, an Integral Evaluation Study was carried out for the Sophia Line Section. The technical options to be considered were:

1. A bored tunnel of 7km length.
2. The construction of a depressed railway with submerged tunnels under the waterways.
3. A depressed railway with bridges to cross the waterways.

The project is presently (April 1997) in the final design.

The adopted solution consists of 2 km of cut and cover tunnel; further 4 km of twin bored tunnels, and 1 km of depressed railway. A very important aspect of this solution is that it includes the free use of the land next to the railway line and above it for residential and other developments.

7. Case Study: Metropolitan Expressway Central Circular Route, Tokyo, Japan

7.1 Introduction

Since its first section was opened just before the Tokyo Olympic Games in 1964, the Metropolitan Expressway network has grown in line with the development of social and economic activities in Tokyo. At present, Metropolitan Expressways, consisting of several radial routes and one ring route, play the role of mayor arterial roads in the capital, carrying an average of almost 1,2 millions vehicles each weekday.

However, with the development of roads converging on the city centre, the Inner Circular Route, the sole ring expressway in Tokyo, bears a terrific load which has led to a situation of chronic traffic congestion. Presently there is no choice but to use the ring route to pass through the city centre to reach another radial route.

The Central Circular Route will be the second ring expressway. It will spread to a radius of 8 km from the city centre, linking up with existing radial roads to form a new road network.

Once opened, it will contribute to ease the heavy traffic congestion and will cut driving time, while offering a wider selection of routes to satisfy drivers needs.

7.2 Description of the project

The project consists of two parts, the Shinjuku Route with a length of 11 km, and the Oji Route, with 6,2 km of length. The entire Route passes through a high-density residential and Business area.

The Shinjuku Route mostly passes beneath the Yamate Street and thus consists of underground structures: cut and cover tunnels, shield tunnels, several ventilation plants, and entrances and exists to and from existing streets and other expressway routes.

Since the route has two lanes for each direction, the diameter of shield tunnels will be 13,6 m. The route intersects many existing structures such as a railroad, and for this reason special measures such as pipe roofing and underpinig works are necessary.

As it does not exist a similar long urban underground expressway in Japan, comprehensive safety measures will be implemented, including exhaustive emergency facilities and an effective traffic control system.

The Oji Route consists mainly of a double deck viaduct, whilst a tunnel structure by the New Austrian Tunnelling Method (NATM) is partly adapted.

The tunnel itself consists of two twin 2-lane tunnels which are separated by a central pillar, with a total width of approximately 23 m. The tunnel passes beneath a notable park with a low overburden of 1o to 20 m.

The ground of the construction side presents altered layers of Pleistocene sand, silt, and gravel with a STP value of 7 to 50, some of which are aquifer.

Below the tunnel, at a distance of only 4 m, passes a subway line. Therefore, a bunch of special measures such as grouting against groundwater infiltration, high-pressure grout forepiling and others, have been taken during construction

7.3 Environmental aspects of the project

For the Shinjuku Route, the plan that goes underground instead of viaducts is adopted because the route passes through a highly populated residential and office area. Therefore environmental impacts such as air pollution and sunlight obstruction had to be minimised.

For Oji Route, NATM tunnelling at Asukayama area has been adopted because within this area there is a notable park for cherry blossoms in spring and ancient remains.

For the entire project the harmony with the surrounding environment had to be considered carefully. The project includes not only building new expressways, but also improving the existing arterial roads and local streets to create a conformable environment.

7.4 Time schedule of planning, design, and construction

Both routes are now (March 1997) under construction. The date of completion is not fixed at this point.

8. Case Study: Kazunogawa Pumped Storage Plan, Japan

8.1 Introduction

The Tokyo Electric Power Company (TEPCO) is the company that supplies the electricity to the Tokyo Metropolitan Area. TEPCO has planned the pumped storage power plant project in the pursuit of energy efficiency, intending to compensate the significant fluctuation of power demand between the night time off-peak and the day time peak.

The Kazunogawa Pumped Storage Power Plant in an underground power plant and it is located in the area of the cities of Otsuki and Enzan in the Yamanashi Prefecture.

8.2 Technical characteristics of the project

The general data of the project are the following:

1. Reservoirs

Reservoir areas	Upper reservoir	0,51 km2
	Lower reservoir	0,43 km2
Gross storage capacity	Upper reservoir	11.200.000 m3
	Lower reservoir	11.500.000 m3
High water level	Upper reservoir	E.L. 1.481 m
	Lower reservoir	E.L. 744 m

2. Power Plant

Installed capacity	1.600 MW (400 MW x 4)
Discharge for generation	280 m3 / sec
Effective head	714 m

3. Main Structures

Upper dam	Rockfill dam with centre core Height 87 m, crest length 494 m, volume 4.060.000m3
Lower dam	Concrete gravity dam Height 105 m, crest length 264 m, volume 620.000 m3
Headrace tunnel	Inner diameter 8,2 m, length 3.166 m
Penstock	Inner diameter 8,2 m - 2,1 m, length 1.978 m
Power Plant	Underground type Width 35,5 m, height 56,5 m, length 224 m, overburden 500 m Geology: mesozoic sandstone and mudstone; average UCS 108 Mpa
Tailrace tunnel	Inner diameter 4,2 m - 8,2 m, length 3.201 m

8.3 Environmental Aspects

The project area is marked by a mountainous topography of an intense scenic beauty. The area is dominated by the awesome heights of Mount Daibosatsurei and the Koganezawa Canyon. The project area faces the well-known Mount Fuji region that is located on the opposite side of the Sasago River.

To make the construction as non intrusive as possible, in an mountainous nature with a splendours animal and plant wildlife to be preserved, TEPCO has assumed its environmental responsibility by a form of project execution that will not scar the landscape. Efforts are being made to minimise any changes to the landsurface that will be required for reforming, to replant excavation sites and to restore exposed soil to wildlife supporting fertility.

8.4 Time schedule of planning, design, and construction

The construction works including the upper and lower dams commenced in January 1993. The excavation of the cavern started in August 1994 and was completed in May 1996. The first phase of operation will start in July 1999.

9. Case Study: The Royal Library in Stockholm, Sweden

9.1 Introduction

The Royal Library in Stockholm was originally inaugurated in 1878. At that time the building was designed to accommodate 200.000 volumes and offered ten work places. Today, the library contains 3.000.000 volumes and has 250 employees.

Since it beginnings in 1878 the library has been expanded in two different stages. The first was in the 1920s and the second 30 years later, when the annex to the main building was added. However, by 1970 the library had once again outgrown itself.

The present expansion provides the Royal Library with 90.000 metres of shelf space, which will be sufficient to meet, needs well into the next century.

Technical Characteristics of the Project

Type of project:	Rock chambers in an inner-city environment
Customer :	Statens Fastighetsverk
Form of contract:	General contract
Contract value:	25 MSEK
Construction period:	1992 - 1993
Volume blasted:	105.00 tfm3
Rock chambers:	Two chambers, each measuring 150 m x 15 m x 19 m (length x width x height) at 40 m below ground level
Waterproofing requirement:	2 liters per minute and 100 m of tunnel
Injection grouting:	130.000 bore meters
Special methods:	Continuos pre-injection grouting in a vibration-sensitive environment

9.2 The Construction Phase

Following the installation of temporary work-site accommodation and offices, the first stage of the project was the construction of a 5,5 meter high access tunnel.

An open cut was blasted vertically to achieve a 6 meter high load bearing rock cap. The access road was blasted with continuous charges in a line parallel with the library towards the point selected for the rock chambers. The work continued with a 90 degree curve in towards the library and up to the rock chambers.

Throughout the entire blasting stage, seepage was contained before and after blasts by means of cement grouting, under 20 bar pressure, in hopper-shaped shields drilled parallel to the tunnel. A new shield was drilled each ninth meter along the route.

The rock chambers and their access points were located on each side of the final section of the tunnel. The blasting of the chambers started with the ceiling and thereafter gradually continued downwards in sections.

At the peak of this phase, 15 trucks worked in a shuttle system to haul away a full road of gravel every second minute. When the rock chambers were ready, all that remained was to permanently reinforce the rock walls with rock bolts and cover the walls with gunite.

NCC left the rock chambers completely ready for the next phase, which was the construction of the actual storage facilities.

9.3 Environmental aspects

The historically and culturally important building of the Royal Library should retain its original appearance; therefore the new chambers should be placed underground.

The work was carried out in the middle of Stockholm City, in an area composed of unstable ground conditions and many old buildings, whose foundations have not been piled down into the bedrock. This meant that there was a mayor risk of subsidence. Similarly, there was also a danger of subsoil water levels declining, which would lead to old piles beginning to rot.

Prior to blasting and draining the area, extensive surveys were conducted and highly sensitive vibration meters were installed throughout the entire area. In addition, fixed benchmarks were established to ensure that none of the surrounding roads or buildings would be affected.

Subsoil water levels in existing holes were measured each day, both before and after blasting.

Finally, the rubble produced by excavation was transported away at surface level in small 12-ton-trucks to comply with traffic regulations in the inner-city area of Stockholm.

10. Case Study: The Äspö Hard Rock Laboratory (Äspö HRL), Sweden

10.1 Introduction

The Swedish Nuclear Fuel and Waste Management Company, SKB (Svensk Kärnbränslehantering AB) is responsible for ensuring that Sweden's radioactive waste from nuclear power, medical care, industry and research is disposed in a safe manner.

SKB has been conducting research on final disposal of radioactive waste since the mid-70s, collaborating with universities, engineering colleges, research institutes and other experts, both in Sweden and all over the world.

During the 1990s SKB has started investigations to site the deep repostery. After general studies of the whole country and feasibility studies in several municipalities, site investigations were conducted on a couple of candidate sites.

Extensive pre-investigations of the bedrock in the Äspö district were initiated in 1986. On Äspö the bedrock has been exposed in several trenches to permit further field studies. And to obtain more information on the geological structure of the bedrock and the geological processes that have acted on the Äspö bedrock since it was formed more than 1.700 million years ago.

Eight organisations from seven countries (Canada, Finland, France, Great Britain, Japan, Switzerland the USA) have participated in a joint research project at the Äspö HRL.So the Äspö HRL is a natural continuation of the development work that began in the mid 70s by an international research program in the abandoned Stripa iron mine in Bergslagen.

The agreements that have been concluded bring broad international expertise to bear on the project. In this way, the Swedish research programme can benefit from the knowledge and experience gained from important work in other countries. Furthermore, Äspö provides continued opportunities for development work in a realistic and undisturbed rock environment down to a depth equivalent to that at which the final disposal of the Swedish nuclear fuel will take place.

10.2 Technical characteristics of the project

The facility consists of a tunnel 3.600 m in length down to a depth of 450 meters. The tunnel was excavated using conventional drill-and-blast methods down to a depth of 400 meters. From 400 to 450 meters the tunnel was bored with a tunnel-boring machine (TBM). This method creates a tunnel with a circular cross section, smooth walls and a diameter of 5 meters. At Äspö the tunnel is connected to the ground surface via shafts for elevators, ventilation etc.

There is also a research village on Äspö.

10.3 Time schedule

The rock construction work was started in the autumn of 1990 and was concluded in the spring of 1995. The investigations and experiments needed for construction of the deep repostery will continue after that. The research village was concluded in 1994.

10.4 Costs

The total cost from 1986 to the spring of 1995, when the facility was completed, was about 500 million SEK. About half of this sum represents the cost of the facility itself.

10.5 Goals of the investigation in Äspö HRL

There are three main goals for the activities carried out in Äspö HRL:

4. To test which methods are most appropriate for investigating the bedrock.
5. To refine and to demonstrate methods for adapting the deep repository to the local properties of the rock in connection with design, planning and construction.
6. The collection of material and data of importance for analysing the safety of the deep repository.

The knowledge and skills gained from these investigations will then be used to start construction of a deep repository a few years after the turn of the century.

The Äspö HRL provides an opportunity for research technical development and demonstration in a realistic setting. The laboratory also provides an opportunity for practical testing of different aspects of the design of a deep repository. Extensive field studies of the interaction between the engineered barriers and the surrounding rock can be conducted before the deep repository is built.

The purpose of this work is to demonstrate and summarise methods for investigating the rock. The investigations are being conducted in many different ways, using from satellite photos to microscopes used to obtain the data.

An other aspect of the research that takes place in Äspö concerns the surface investigations. The first step is to perform a general survey of large ground areas. Satellite photos and measurements conducted from aeroplanes provide a rough but good picture of rock type variations and reveal the location of large fracture zones. Measurements are also performed from the ground surface to obtain a more detailed picture of the bedrock.

With this information obtained, the first simple models are made of the appearance of the rock at depth and of the formation and movements on the groundwater, for example where the water flows up out of the bedrock and where it flows in.

To refine these models, a number of boreholes of a length up to 1.000 meters have been drilled.

The drill cores that are retrieved show which rock types occur along the bore hole, as well as fractures and their directions. The fracture zones are studied in rather detail using a small television camera lowered into the hole. To date the origin of the fractures geologists examine the minerals on the fracture surfaces.

The natural groundwater pattern is altered when the tunnel is constructed. The data collected can be used to develop methods that allow the prediction of these changes. The pressure head and chemistry of the groundwater are measured in many boreholes.

10.6 Environmental aspects

The research project itself will guarantee the absence of environmental damage caused by the disposal of radioactive spent fuel. Furthermore the investigations that will be carried out in the laboratory will produce useful results for the state of the art of technically sophisticated underground works.

The safety assessments prior to construction had to operate with large margins.

The chemistry and pattern of formation and movement of the groundwater are two of the key fields being studied at the Äspö HRL. Such studies yield facts that are used in calculations of the safety of a deep repository.

Material is being gathered that will enable estimates to be made of canister life, how the fuel will be affected, and how far and at what rate any dissolved radionuclides will be carried away with the water. It is only via groundwater that has been in direct contact with the radioactive materials in the repostery that someone in the future could possible be harmed.

The laboratory is situated on the coast of the Baltic Sea on an uninhabited island providing undisturbed conditions in the bedrock for summarising, evaluation and demonstration of the knowledge existing within these areas. The sitting of the laboratory near the Oskarshamm Nuclear Power Station reduces the need for additional roads, power lines and other facilities, while permitting available services at the station to be utilised.

11. Case Study: Päijänne water tunnel, Finland

11.1 Introduction

As early as the 1960s it was evident that the water reserves in the Helsinki region would eventually become inadequate regarding quality as well as quantity. The National Board of Public Roads and Waterways drafted a general plan for water supply at the request of the municipalities in the region. The plan, completed in 1968, provided for a tunnel to supply water from Lake Páijänne to the Helsinki region with water treatment in the user area.

The municipalities in the Helsinki region decided jointly to secure the water supply for the area in accordance with the Päijänne plan, and in 1972 set up the Helsinki Metropolitan Area Water Company to carry out the project.

The tunnel was designed and built by the new created company. All the users of water from the tunnel are shareholders in the company: Helsinki, Espoo, Vantaa, Porvoo Rural District, Hyvinkää, Kirkkonummi, Kauniainen, Nurmijärvi, Tuusula District Waterworks and Oy Alko Ab. The Tuusula District Waterworks is an intermunicipal corporation, which supplies water from the tunnel to Tuusula, Kerava, Järvenpää and Sipoo.

After the completion of the tunnel in 1982, the Helsinki Metropolitan Area Water Company has taken care of tunnel operation in co-operation with the cities of Helsinki and Hyvinkää and the Tuusula District Waterworks.

Presently, the tunnel conveys about 70 million m3 of water a year to over one million residents in the Helsinki metropolitan area and neighbouring municipalities.

11.2 Technical Characteristics of the Project

The Päijänne water tunnel transports raw water from Lake Päijänne to the grater Helsinki area over a distance of more than 120 km.

The tunnel starts from Asikkala at the southern end of Lake Päijänne, and ends in a vertical shaft near Pit käkoski water treatment plant in Helsinki. The Vanhankaupunki and Pit käkoski treatment plants take in their raw water from the shaft. A branch tunnel to the Silvola equalising reservoir connects the Päijänne tunnel.

The flow of water to the greater Helsinki area is “slowed down” by the Kalliomäkipower pants pump house. The electricity generated by the power plant is fed into the local power line in Hyvinkää.

The main technical features of the Päijänne tunnel are the following:

Location	from Lake Päijänne to greater Helsinki metropolitan area
Characteristics of the area	
	The Päijänne raw water tunnel is excavated at a depth of 30 - 199 meters in the crystalline bedrock. The area is partly a high density urban area, and partly rural area.
Time schedule	Design: 1970 - 1972
	Construction: 1973 - 1982
	Beginning of water supply: 1979
Technical specifications	
	Length: 120 km. This makes the Päijänne tunnel the longest continuous rock tunnel in the world. Cross-sectional area: 13,5 - 18 m3 Volume: 2 million m3 Water-carrying capacity: by gravity 10 m3 / s By pumping20 m3 / s Water abstraction rate: 25 m3 / s Water intake: 2,7 m3 / s Utilisation rate: 25 % Available difference in elevation: 36 m Power plant capacity: 830 kW Cost, at 1981 cost level: FIM 530 million
Water intake	Asikkalanselkä intake station
Water distribution points	
	Kalliomäki power plant and pumping station Korpimäki pumping station Pitkäkoski intake station

11.3 Construction

The Päijänne tunnel was constructed during the years 1973 - 1982. It was excavated in three phases: Phase I, length 35 km, in 1973 - 1976, Phase II (59 km) in 1975 - 1979, and Phase III (26 km) in 1979 - 1982.

At the beginning of tunnel construction access tunnels, each 500 m long, were excavated at 5 km intervals. The quarried rock that was used for various construction purposes was transported to the surface along these tunnels.

11.4 Special Structures

Apart of the tunnel itself, the project consists of several other infrastructures. The most relevant are the following:

4. Asikkalanselka Intake Station

There are two intake cribs of the intake station located on the lakeshore at Asikkalanselkä:

The point for continuous intake is at a distance of 215 m from the shore and at a depth of about 17 m. The water entering the tunnel has a fairly low temperature throughout the year. from 3 to 12 C. The reserve intake is 50 m from the shore at a depth of 5 m.

The water flow from the lake into the tunnel is measured with electromagnetic flow meters in the pipelines. The cribs are fitted with screens with a mesh size of 30 mm. Another set of screens in the intake building has a mesh size of 15 mm. Before entering the tunnel, the water flows through basket -type chain creeks with a mesh size of 0,57 mm.

5. Kalliomäki Power Plant and Pumping Station

At Kalliomäki in Haus järvi a power plant and a distribution pumping station are located in a rock cavern 80 m below ground level. The turbine in Kalliomäki regulates the flow of water from Lake Päijinne into the tunnel. The power plant generates electricity using the the 32-meter head in the tunnel. With a water intake of 3.o cu.m/s the plant has an annual output of some 6,5 million kWh.

There are two sets of pumps in the cavern, one for pumping water to the Porvoo Rural District (max. output 1.100 l/s) and the other to Hyvinkää (max. output 140 l/s).

6. Korpimäki Pumping Station

The Korpimäki Pumping Station in Nur mijärvi is located next to the main tunnel, some 56 m below ground level. The cavern houses the pumps of the Tuusula District Waterworks with an output of 180 l/s. Space is also reserved for a later installation of pumps to Nurmijäri and Oy Alko Ab.

A reserve water outlet for Helsinki into the Vantaa River is also located in Korpimäki.

7. Ylästö Valve Station

Two pipelines running through the Ylästö Valve Station carry water to the tunnel leading to the Helsinki water treatment plants. One of the pipelines branches off to the tunnel leading into the Silvola Reservoir.

The electromagnetic flowmeters in the pipelines measure the amount of water taken by the treatment plants operated by the City of Helsinki Water and Sewage Authority. This volume also includes the water from Lake Päijänne taken by Espoo, Vantaa, Kauniainen and Kirkkonummi as treated water through the Helsinki treatment plants.

11.5 Environmental aspects

The permit to built the Päijänne tunnel is based on rulings by the Finland water court in 1973. To minimise the anticipated harmful effects to the ecological balance the permit includes certain rulings that pay particular attention to the groundwater situation in the area near the tunnel line.

To chart the situation before the beginning of the construction work, the wells, spring, and the Water intake stations were registered and filled and continuously observed. The width of the observation area was 400 - 2000 m containing approximately 850 wells.

The groundwater situation was monitored during the construction period (1973-1982).

The quality of the water in the nearby wells was examined. The company provided water supply for the 250 wells that dried up during construction from 1973 to 1980.

Landscaping was taken into account in the planning phase by placing the shaft openings and pilings areas in forested areas where the trees block the views of the site.

The Water Court permits terms do not include a clause for surface waters. However, the builder is under obligation to prevent subsequent damage or to minimise it.

Furthermore the tunnel is continuously monitored and regulated by the Helsinki water treatment plants and the main control centre.

Safely submerged at a depth of 26 m and at a distance of 350 m from the shore, the intake stations makes the water pass through bar screens and microfilters.

Finally it has to be noted that the tunnel taps only one per cent of the annual discharge from Lake Päijänne, a fact that assures the long term sustainability of the Päijänne tunnel project.

12. Case Study: Viikinmäki Waste Water Treatment Plant in Helsinki, Finland

12.1 Introduction

Helsinki and the adjoining municipalities have co-operated in wastewater treatment since the 1960s. On the basis of agreements, Helsinki has treated the wastewater of Kerava, Tuusula and Järvenpää and most of the wastewater of the city of Vantaa.

Nevertheless, in the 1970s effluent was still discharged into coastal waters. Phosphorus removal was in the early stages and the recipient areas became eutrophic.

Plans for a central treatment plant got under way in 1983. A suitable location for treating all of Helsinki´s wastewater was found in the rocky terrain at Viikinmäki. In 1986 agreements on financing the Viikinmäki plant were concluded with Vantaa and the and the Central Uusimaa Municipal Association for Water Pollution Control. The municipality of Sipoo joined the agreement in 1991.

Once the Viikinmäki plant was finished, Helsinki disposed of an integrated sewerage system with over 1.700 km of sewers, about 120 wastewater pumping stations, about 60 km of sewer tunnels, the Viikinmäki treatment plant, a composting area of about 20 ha, and an 18 km effluent outfall to the sea.

Concentration of treatment at one site makes for more reliable operation and lower costs. In addition, the land which for years had been taken up by up to eleven small treatment plants has now become available to build housing for several thousand people.

12.2 Technical Characteristics of the Project

Location
: The Viikimäki plant lies alongside the Lahti motorway, some six kilometres from the centre of Helsinki. The site, including underground facilities, covers 15 hectares, of which some 5 hectares are taken up by surface buildings and equipment.

Characteristics of the area
: Viikinmäki is typical of the hilly topography in southern Finland with its soil layers and hard, crystalline bedrock. The area consists predominantly of granite and mica gneiss combined to form migmatite, which covers most of the area. Rock quality is uniformly good with weakness zones clearly linked to dips in the surface.

Characteristics of the project

The Viikinmäki plant is located mainly underground and has a total of seven parallel lines. In addition to the process lines, facilities for pre-treatment, sludge treatment, machinery and equipment have also been excavated in rock. The total volume of the excavated space is roughly 1,1 million m3. Most of the process facilities are above sea level.
The present treatment capacity of 120 million m3 guarantees wastewater treatment for 700.000 local residents and industry.

Time schedule	Planning and design	1983-
	Site investigations	1985 - 1988
	Excavation work	1988 - 1992

Operation

The first two process lines came on stream in early May 1994. By September, all wastewater from the old plants had been rerouted to Viikinmäki.

Cost and financing

Total cost at 1994 price level was FIM 1.070 million. The project was divided into a main contract and several subcontracts. The plant was financed by loans from the city's central administration. The loan installments and interests will be paid out of income from wastewater treatment charges. The effect of the extra costs on charges in Helsinki is at most about FIM 2/m3.

The cost incurred by the utility is covered by water and wastewater charges levied on customers. Any profit made is turned over to the owner, the City of Helsinki.

12.3 Construction

The very last technology was adopted in the rock construction. The amount of blasted rock was enormous, amounting to 1 million m3, which roughly corresponds with the total volume of the excavated space. The rock was crushed at Viikinmäki and used at construction sides in the Helsinki area.

Thanks to the good quality of Finnish rock, the costs of rock construction are relatively low. It also gives greater freedom regarding the use of space than conventional methods. This meant, that the wastewater treatment basins could be made wider and deeper than usual, thus improving effluent quality.

The ceilings of the underground facilities are 20 m thick on average and are reinforced by bolting and shotcreting. The basins are of concrete, but the surrounding rock has been used in structural solutions whenever possible. The total volume of concrete was 76.000 m3.

12.4 Environmental Aspects

In terms of water protection, the Viikinmäki wastewater treatment plant is important and will have far-reaching effects. In the whole Helsinki area there are now only two effluent outfall points, both of them well beyond the archipelago were the open sea begins. Efficient treatment ensures that the 40 km wide coastal and archipelago zone retains its amenity for recreation for the entire Helsinki metropolitan area (population around 700.000) and is the contribution of the City of Helsinki to the conservation of the Baltic Sea.

Furthermore, the Viikinmäki plant will make for a major reduction in the odour and noise problems commonly associated with wastewater treatment. And since all heavy traffic is concentrated in one location and directed to the main roads leading out of the city, traffic serving the plant will cause fewer problems.

Nitrogen removal will be very effective at the Viikinmäki plant. One of the seven-wastewater treatment lines is an experimental line designed to find the optimal nitrogen removal method with the present plant construction. If nitrogen removal requirements become more stringent, the plant will have to be enlarged.

Viikinmäki employs the activated sludge process. The plant has been designed to produce effluent with a BOD of less than 10 mg/l and a total phosphorus concentration of less than 0,5 mg/l. Every day some 200 metric tonnes of sludge are removed, conditioned by digestion and dewatered in centrifuges. Total solids content is 30 - 35 %, considerably higher than at the old plants. The total volume of dewatered sludge has decreased.

At the mechanical treatment stage, coarse solids are removed by bar screens and grit and more fine grained soils by sedimentation. This removes half of the solids and one third of the organic matter and phosphorus nutrients.

In the biological treatment process, microbes feeding on organic matter form a standing crop, which are settled, at the bottom of the sedimentation basis for removal. This leaves less than 5% of the original solids and oxygen-consuming matter in the wastewater.

The composting area is surfaced with watertight rubberised bitumen asphalt. Seepage and runoff waters are channelled through sewers to the Viikinmäki plant to ensure that the further processing of sludge will not contaminate groundwater or otherwise harm the environment.

Chemical treatment, or phosphorus removal, prevents entrophication in the receiving bodies of water. Phosphorus is precipitated during biological treatment and removed with sludge (efficency=95%). The nitrogen removal level achieved is roughly 35%.

The plant itself uses the digester gas produced during sludge processing. The amount of energy produced annually using gas is nearly 50.000.000 kWh. The gas is used mainly by gas operated generators. The plant produces all its own heating energy and some 40% of its electricity.

Exhaust air (130 m3/s) is led through a stack to roughly 80 m above sea level. There is no smokestack releasing noxious fumes into the environment, and heavy traffic carrying dewatered sludge can be kept to a minimum.

Helsinki is an active participant in the efforts of the coastal cities of the Gulf of Finland to improve their wastewater management.

The history of wastewater treatment in Helsinki dates back to the turn of the century and have now culminated in the rock-encased Viikinmäki plant, an internationally significant and momentous environmental installation. Now there is enough sewerage capacity in Helsinki to cover the needs of the metropolitan area far into the future.

13. Case Study: Vallvidrera Road Tunnel, Spain

13.1 Summary

Construction of a road tunnel as part of a new road axis that will substiantally improve the westward road connections of the city of Barcelona

13.2 Introduction

Barcelona is situated on the Spanish Mediterranean coast between the river deltas of the Llobregat and the Besós. To the west the urban area is limited by a mountain chain, the Sierra de Collserola.

Being an important maritime port, the city has had a long tradition as a busy commercial center. Since the nineteenth century Barcelona has been the most important industrial area in Spain and a metropolitan area submitted to a dynamic expansion process.

The main access routes to the city have traditionally followed the north - south axis along the coast, crossing the river deltas.

The old roads traversing the Sierra de Collserola to the region called Vallés proved insufficient as soon as the industrialisation process gained importance. This circumstance severely hindered the interchanges of the city with its commercial and industrial hinterland: Terrassa, Sabadell, San Cougat etc.. In consequence a number of projects have been developed since the nineteenth century to "break" the natural barrier of the Collserola mountain chain.

Since 1916 an electric railway has crossed the Sierra de Collserola connecting Barcelona with San Cougat, Sabadell, and Terrassa through four tunnels, the longest with a length of 1.625 m. The axis of this railway coincides largely with the route of the new road and the Vallvidrera tunnel.

The present project had its precedents in several initiatives born in the 1960s. In 1971 contruction work had actually begun, but was interrupted three years later leaving behind a service tunnel of 2.300 m length.

13.3 Technical Characteristics of the Project

The Vallvidrera Axis is a four lane (two lanes in each direction) toll road of 12,5 km length that connects the city of Barcelona with the motorway Rubí - Terrassa in the west. The tunnel of Vallvidrera is the most eastern tunnel of the four tunnels on the Axis. The works, which were finished in 1992, before the Barcelona olympics, made it possible to cross the Collserola mountain chain offering a safe and time saving road infrastructure.

The expected traffic intensity on the new road foresaw a daily average number of 16.000 vehicles. This figure meant an important reduction of the congestion suffered by the still existing old road of Vallvidrera as well as of the A-2 and A-7 motorways.

13.4 Environmental Aspects

In the first stages of the project two exhaustive environmental studies were carrried out in order to gain the best possible information about the characteristics of the region to be crossed and the possible environmental harm caused by construction and subsequent operation of the new infrastructure.

The first study concerned the flora and fauna and the second aimed at foreseeing the effects on air pollution and noise disturbances. Both studies were carried out in 1986 by specialized university departments.

The study of the flora and fauna showed that the new road was to cross an area of important ecological value in the Sierra de Collserola. The weight of this circumstance was reinforced by the fact that the nearby valleys in the area had already suffered important environmental disturbances.

One the other hand it must be taken into account that the planned route follows an already intensively occupied natural communication axis supporting a road, a double track railway and several urban areas.

The results obtained from the study concerning the expected air pollution revealed that only at peak hours, and on days with practically non-existent atmospheric dispersion features, serious concentrations of pollution will have to be expected.

Due to calculations, the expected noise level will exceed 72 dB(A) only at a few points of the itinerary, such as the tunnels´entrances. At these points the placement of plant barriers or, in severe cases, of noise absorbing barriers made of porous concrete and soil has been considered.

Nevertheless, the University of Bellaterra has been charged with the monitoring of the construction works in order to detect environmental problems not considered in previous studies.

One the other hand, a series of investigations have been carried out to establish the expected interactions between the project and the human- and natural environment. During six months an intensive campaign was conducted to get the most reliable information about the characteristics of the area to be crossed by the new road and of the nearby lying areas. These investigations included three main activities:

a. bibliographic search of historical data
b. analysis of soil and water
c. establishment of personal contacts with naturalists who had previously carried out works in the area, and with local experts on diverse environmental aspects.

13.5 Study of Flora and Fauna

The affected area presented an important botanic heterogenity, with 34 different species of trees and 40 different species of bush and other minor plants. This mixture was the result of the conincidence of central European, Mediterranean and North African flora in the Sierra Collserola.

The major part of the surface affected by the works was covered with pine tree woods and different types of oak groves. The latter, less in numbers and in a process of slow recovery, were specially worth preserving.

Regarding the number of represented animal species, the fauna of Collserola could be considered very rich. Field reseach detected the existence of 4 species of fish and 10 species of amphibians in the only stream affected by the works. Particularly the existence of so many varieties of amphibians indicated an exceptional water quality in this stretch of the stream, a circumstance not easily found in these days. Furthermore the presence of 15 species of reptiles, 41 species of mammals, and 241 species of birds (including those with a seasonal presence in the area) had been registered.

In spite of the absence of any extremely rare or endangered species, it was its wealth of animal life as a whole that had to be preserved.

13.6 Restoration of the Environment

Deforestation works had to be accomplished only along 4.012 m (39,1 % of total route length), due to the existence of the four tunnels, as well as to the circumstance of agricultural use of the final stretches of the course, and the crossing of several other parts already exploited by human activities.

In order to limit the harm caused, preventive and regenerative measures were taken to prevent damage on the existing flora in the areas affected.

The surface that had to be deforested was marked with great precision by ribbons. The same procedure was applied to limit the places were earth movements had to be undertaken.

The most important part of the restoration works was the replanting of the affected areas with more than 70.000 trees and bushes. These works were executed according to the following criteria:

1. using of previously extracted vegetal soil previously treated to maintain or even improve its original quality;
2. replanting of only autochthonous species, except for an increase of the relative presence of some easily adaptable varieties; the disposal of a sufficient quantity of these plants previously guaranteed by taken respective logistic measures, in view of their absence in the habitual commercial circuits; furthermore, securing by this procedure asured the

mainteinance of the previously existing genetic pool;

3. planting of trees up to 3 m high where plant barriers had to be erected in order to avoid visual and acoustic impacts;
4. guarantee of the surface soil stability against erosion through the planting of herbaceous plants.

13.7 Altering of the landscape

The construction of the route demanded the deforestation of more than 20 acres of land, and a total volume of earth movement of 2.000.000 m3 of excavation and 1.400.000 m3 of embankment. These figures clearly show the intensity of change of landscape.

Logically, the montainous areas covered by woods were more severely affected than the stretch of the route in the more densely populated valley of Vallés. The correcting measures taken were the following:

5. replanting of all slopes;
6. strategic placement of plant barriers to limit the visual impact;
7. erection of rugged walls to allow an easy and quick covering with algae, mushrooms, lichen, moss and creepers.

13.8 Altering of Riverbeds and Barrier Effect

The deplorable situation of most of our rivers, streams, and torrents causes the isolation of many animal populations on those streches of river-basin that are less polluted. This is the case of the Riera de Vallvidrera.

The majority of torrents are crossed by viaducts. Where it is not so, underpasses have been constructed. That means, without syphons and with braces permitting the accumulation of water, sediments, and moss as on the natural riverbed. The final goal was to hinder access to the highway platform and to facilitate the movements of amphibians along the river.

On the othr hand, the barrier effect on mammals is not significant. Wild bores and foxes, which are the most commonly affected species, are used to dodge human made obstacles on their nocturnal wanderings.

The lack of open air stretches longer than 1.500 m, together with the construction of fences and adequate underpasses, make the negative impact negligible.

13.9 Environmental Aspects

In the first stages of the project two exhaustive environmental studies were carried out in order to gain the best possible information about the characteristics of the region to be crossed and the possible environmental harm caused by construction and subsequent operation of the new infrastructure.

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Nevertheless, the University of Bellaterra has been charged with the monitoring of the construction works in order to detect environmental problems not considered in previous studies.

14. Case Study: Pasillo Verde (Railway Corridor), Madrid, Spain

14.1 Summary

The project consisted in removing the barrier formed by railway tracks and related installations in the west and south of Madrid, and in recovering these areas for urban use including the construction of an underground railway.

14.2 Introduction

In April 1989 the consortium "Consorcio Urbanístico Pasillo Verde Ferroviario" was formally established in Madrid. The Consortium consisted of two equal partners: the City of Madrid and the Spanish railway company, RENFE. The goal was to manage and to carry out a series of works which would largely modify an ancient railway corridor in the south and east of Madrid in order to recuperate these areas for urban use. The partnership included the cession of urban ground and the execution of works on urban and railway infrastructure, as well as the construction of all urban facilities and installations considered necessary. The project was named "Pasillo Verde Ferroviario", which means "Green Railway Corridor". In 1996, the works related to the project were successfully finished.

The area object of transformation laid in the southern part of central Madrid, between the Manzanares River, the city highway M-30, the inner road belt Las Rondas, and Méndez Alvaro Street. A total of 1,5 million square meters have been recuperated, of which more than two thirds are green areas, installations or transport infrastructure. Furthermore an important number of the new housing facilities have been constructed, as well as 8,5 km of subterranean railway tracks and three new underground stations.

It has to be mentioned too, that the project was carried out with a high-level performance in spite of having been to a great extent undertaken during the period of economic recession that affected the country since 1992. It was thanks to the joint efforts of all political forces represented in Madrid´s City Council that works could be brought to an end accomplishing the goals marked at the starting of the project.

14.3 Historical records

In the nineteenth century a railway track had been constructed crossing the now recovered area. The attraction effect due to the new railway caused an important transformation of the affected quarters.

One one hand the railway track represented an important physical barrier. One the other hand, the installation of industry, storage facilities, and coal deposits produced a severe degradation of the adjoining areas, damaging their adequacy for residence due to the absence of urban facilities and a high level of atmospheric and acoustic pollution. All these factors provoked the isolation and deterioration of this part of the city that was situated not far from the city centre.

14.4 The Project

The project “Pasillo Verde Ferroviario” consisted of the following basic elements:

- Construction of a double-track subterranean railway permitting the completion of the suburban railway network;
- Upfilling with housing and service facilities of the area that remained out of use due to the existence of the railway track;
- Design of the new edification, installations, and equipment in accordance to modern urban criteria, limiting height and density of buildings, and improving the development potentialities of the area;
- Amelioration of the road network and general communication facilities permitting the connection of previously isolated areas.

The project divided the existing railway corridor into four sections according to the actions that had to be taken:

Section 1 Parque del Oeste (West-Park) and Príncipe Pío Station

Parque del Oeste

- Creation of a linear park (Parque de la Bombilla, 115.000 m2) parallel to the Avenida de Valladolid. This park was to be connected with the Parque del Oeste by a green platform. Enlargement of the Parque del Oeste.
- Enlargement of the area assigned to schools.
- Preparation of surfaces for sport facilities.
- Creation of a subterranean parking for residents and a public parking on the surface.

Príncipe Pío Station

-
- Restructuring and modernisation of the entire railway network by separating the long distance lines from suburban lines. A plant barrier has separated the two tracks. The works further include the construction of a new terminal connecting the San Vicente Square and the Metro.
- Transforming the surface formerly occupied by railway installations (106.000 m2) in an area for commercial activities, business, and tertiary services. This proceeding included the creation of a park of 106.000 m2, several smaller green areas or gardens, and a fountain.
- Construction of a parking for buses serving long distance lines and construction of bus - stops for urban buses, connecting both facilities with the new railway and Metro stations.

- Construction of a public parking on surface, and a subterranean parking for nearby residents.

Section 2 Ronda de Segovia (Segovia Ring) and Imperial Station

Ronda de Segovia

- Moving of the now lowered railway track to the axis of the ring. This allowed building on the liberated surface, including the construction of sidewalks on which trees could be planted. A part of this recovered surface was assigned to industrial use. A former existing street could be widened and split. The area lying between both roads was filled with a slope covered with vegetation.

Imperial Station

- Construction of one of the biggest areas in Madrid dedicated to sport facilities, contributing this way to balancing the equal distribution of those types of equipment in the city.
- Construction of a siding for railway related services.
- Construction of linear buildings in an area destined to tertiary services surrounding the area occupied by the railway. These actions include the building of an auditorium, and a centre for cultural activities.
- Building of housing facilities enlarging the existing residential area.
- Construction of a public parking in the underground.

Section 3 Francisco Morano-Ortega Munilla Square and Pirámides Square

Morano - Munilla Square

- Building of a new avenue crossing Toledo Street.
- Construction of a railway tunnel.

Pirámides Square

- Correction of the existing front line of buildings.
  Ortega-Munilla Square - Peñuelas Station
- Lowering the road stretch between Ortega Munilla and Peñuelas Station, and urban amelioration of the street by constructing new buildings on both sides of it The existing industrial facilities were not affected by this measures, but they provided the avenue with a more adequate front than the former existing walls of the industrial buildings.
- Transformation of the former railway platform into a park (Parque de Peñuelas, 28.000 m2) connecting the adjoining quarters with the River Manzanares. At the west side of the park, facilities like a school and a centre for vocational training have been opened, and on its eastern side several equipment have been installed for sport activities as well as a public open air swimming pool. On the southern border the previously existing residential area has been enlarged, whilst the northern area was assigned to tertiary services.
- Construction an old people’s home.

- Construction a subterranean parking.

Section 4 Delicias Station

- Construction of a large avenue for pedestrians with an elevated crossing facility over the railway track.
- Use of the even surfaces of the new station for installations belonging to the Railway Museum and to the Museum of Science and Technology.
- Construction of a new residential area on the southern border of the pedestrian precinct is connecting with residential areas adjoining to Delicias Avenue.
- Restoration of several nineteenth-century buildings, which were particularly interesting as examples for industrial architecture.
- Creation of two parks: Parque del Bronce (29.200 m2), and Parque de las Delicias, (34.000 m2), the latter occupying the former railway station.
- Construction an elevated crossing facility for pedestrians.
- Creation of a three-level elevated viewpoint.
- Enlargement of the Parque Tierno Galván.
- Closure in the near future of the industrial area of Embajadores thus connecting the park Tierno Galván with the most densely populated part of the district.

The enlisted works, which represent only the major works carried out on the former existing railway corridor, have gone accompanied by countless smaller measures, and have been complemented by the construction of the Metro station Méndez Alvaro, and the opening of a new terminal for long distance bus lines, the Estación Sur de Autobuses.

14.5 Environmental Aspects

Regarding the project Pasillo Verde Ferroviario from an environmental point of view, underlines its value as a huge urban project destined to ameliorate the quality of life not only for people living in the recovered area and its surroundings, but in general of people living in the city of Madrid, which now have all access to the use of new transport and recreation facilities.

All equipment and facilities created have been well suited with green areas, and other architectonic measures intending to improve the quality of life for its users. The needs of handicapped people have also strongly been taken into account.

The Pasillo Verde has been designed to transform an ancient architectonic and urban barrier into an area that should become a link for all kind of activities taken place in the city. The creation of new parks connecting with each other and with previously existing green areas, may have some kind of symbolic character in this respect.

Topic

UNDERGROUND AND ENVIRONMENT

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ANNEX III: GLOSSARY

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ANNEX III: GLOSSARY

This annex compiles words that are related to underground works and the environment.

A

“A” line: External limit of the cross section of a tunnel.

Access: Slope to reach the tunnel mouth.

Acoustic intrusion: Negative alteration of noise levels.

Active span: Space or trunk between the lining of a tunnel and the excavation point that does not produce dangerous landslides.

Afterdamp: Gaseous mixture that occupies a mine after a firedamp.

Aggregates: materials, which when bound together into a conglomerated mass by a matrix, form concrete, mastic, mortar, plaster, etc.

Airlift drilling: Boring by mean of compressed air.

Air shaft: Drill that has the function of ventilating the tunnel.

Alluvial cone: Fan-shaped deposits caused by torrential streams.

Alternative solutions: Different proposals studied in the project phase.

Ammonia Dynamite: Type of explosive made from a mixture of ammonium nitrate and nitro-glycerine.

Angle of repose: Maximum angle of a slope in which loose materials remain stable.

Angle of slide: Angle measured from the horizontal line that implies the slide of a material over a surface.

Apparent water table: Free water table of limited dimensions, found at a higher level than the continuous phreatic level, usually involving a perched aquifer.

Aquiclude: A geological formation or layer that for practical purposes obstructs the flow of ground water.

Aquifer: Permeable stratum over an impermeable layer that is saturated of water.

Aquitard: A geological formation or layer that transmits water at a very slow rate compared to the aquifer.

Artesian aquifer: An aquifer under sufficient head to cause the ground water to rise above the surface of the earth, if opportunity were afforded to do so.

Atmospheric pollution: Air pollution.

B

Back: Upper part of the cross section of a tunnel.

Back fill: Material that is placed over an area that has been excavated previously.

Bank: The mouth or entrance of a drill.

Bearing capacity: The capability of a structure of supporting a load.

Bed: Layer, stratum.

Benching: Excavation producing benches or columns of soil.

Bentonite mud: Mixture of bentonite and water used to refrigerate, lubricate, and stabilise the walls of an excavation.

Biotic media: Belonging to alive nature.

Black smoke: Smoke composed by carbon particles in suspension, proceeding of diesel engines.

Blasting: Tunnel construction method by mean of explosions.

Blasted rock: Rubbish rock produced by explosions.

Blind shaft: Well that has been closed and is not usable.

Blocky rock: Rock that is fragmented in pieces separated by joints.

Blow out: Sudden escape of air in a tunnel excavated with overpressure.

Bootleg: Explosion that has failed.

Bulkhead: A wall built to resist side pressure from soil or water.

Bulking: Increase of volume of a material.

Bodies of water: Water pocket between two impermeable layers.

Boring tests: Test that is made by mean of drills in order to know the characteristics of the rocks.

C

Caisson: A box used during underwater construction into which water cannot flow.

Calk: To cover or refill cracks and fissures.

Carbon Monoxide: One of the most pollutant elements produced by fuel engines.

Cast: Formed by pouring into a mold.

Catchment area (of an aquifer): infiltration area from where water eventually reaches an aquifer.

Causeway: *Embankment*.

Caving: Collapse of the rock.

Cavity: Natural cave.

Chemical grouting: Injection of chemical products in order to cover fractures.

Chimney: Ventilation well.

CO limit: Maximum admissible limit of pollution produced by Carbon Monoxide.

Cofferdam: Temporal dam built in order to protect a working area against water flow.

Cohesion: The mutual attraction of soil particles.

Column: A vertical supporting member/structure.

Compaction: Any procedure that implies a decrease in the pores volume and an increase in the density.

Competent: Rocks or terrain that are more resistant to strain than others around.

Compressibility: The possibility of making the soil denser by various mechanical means.

Conductivity: The capacity of allowing the flow of electric current.

Confined aquifer: An *aquifer* that is overlain by a formation or layer of less permeable or impermeable material.

Consolidation: Reduction of volume and increase of the density of a soil caused by an enhancement of compression stresses.

Construction phase: Period in which the tunnel is being constructed.

Contamination: Introduction into water of any undesirable substance not normally present.

Corrective measures: Group of measures adopted in order to restore environmental damages caused in the construction.

Cut-and-cover: Type of tunnelling construction that implies the excavation of a trench, the construction of the tunnel structure open air (with no soil above) and at the end, the covering of the tunnel.

D

Dead air: The air expelled through the ventilation fans.

Debris: Rubbish, pieces of rock.

Decanting basins: Basins used for decanting of drilling bentonite mud.

Desanding plant: Equipment used for treating and eliminating sand of bentonite mud.

Dewatering: Decrease of the *water table* in order to make easier the tunnel construction in water saturated terrain.

Diesel smoke: Carbon particles in suspension, main pollutant element of diesel engines.

Differential settlement: *Settlement* that has not the same magnitude in all the areas.

Discharge pipe: Pipe used to eliminate rubbish inside the tunnel.

Draft: Air current or stream.

Drag: A force that resists motion.

Drain pipe: Pipeline used to eliminate water.

Drainage system: Collection of elements that allow the elimination of water in the tunnel.

Drawdown: Lowering of the *ground water table* caused by pumping or other means of withdrawal.

Dredging: Pumping silt or sand usually from the bottom of a body of water such as a river or a harbour.

Drill: Hole made in the rock.

Dump: Place to throw depots and material from the tunnel construction.

Dust exhaust system: Equipment designed to allow the elimination of dust in air.

E

Ecosystem: Community of alive beings that have a relationship.

Elastic: Capable of returning to its original size and shape.

Embankments: Sloped terrain made from granular materials.

Emissions: Quantity of a substance that is thrown to the air.

Environmental aspect: Activity or action that could cause an *impact* on the environment.

Environmental elements: Parts or elements of the environment that could be modified by the construction activities.

Environmental impact: Damage on the environment caused by an activity.

Environmental Impact Assessment: Group of procedures carried to determine the magnitude of a construction on the environment.

Environmental Impact Evaluation Procedure (EIEP): Particular type of Environmental Impact Assessment carried out in the European Union.

Environmental Impact Statement (EIS): Particular type of Environmental Impact Assessment carried out in The United States.

Exhaust: Gases from engines, pollutant emissions.

Exhaust scrubber: Equipment installed in all diesel vehicles working in underground works. It depurates gases from engines.

Expansive clays: Type of clay that produces great volume variations by addition or loss of water.

F

Face collapse sensor: Sensor installed in the top of some pressured tunnelling boring machines that warns when a collapse is going to appear.

Failure: Collapse of a material that has been received stresses greater than its resistant capability.

Fan: Machine that allows to remove the polluted air of the tunnel.

Filling: Embankment, material that has been put to cover something.

Filter cartridge: Filter elements to eliminate dust particles in engines and vehicles.

Fire damp: Explosive gas that appears in mines and tunnels.

Fire proof design: It is related to equipment able to resist fires.

Fissility: Easy break along parallel wake planes.

Fissure: A fracture with a component of displacement normal to the fracture surface.

Flood Flow: Theoretical flow used to make the calculations in a project.

Flowing ground: Terrain that moves and flows down.

Foundation: Lowest part of a construction that supports all the structure and that is generally placed underground.

Freezing: Constructive procedure that implies the artificial freezing of the ground before the excavation. It is used under the water table.

Fume: Smoke produced in the construction site.

G

Gas pocket: Cavity in the rock full of gas.

Geomorphology: Part of the geology that studies the surface of the earth.

Gradient: Percentage of elevation or decrease by horizontal distance.

Groundwater: Water that occupies the holes and pores of the terrain. Subsurface water on the zone of saturation.

Groundwater artery: A more or less tubular body of permeable material encased in less permeable material and saturated with water.

Groundwater storeys: Superimposed water-bearing strata, separated by layers of less permeable or impermeable material.

Groundwater table: Level of water that is placed over an impermeable layer.

Gunite: Type of mortar made from sand, cement and water, that is projected with pressure air gun over the walls of the tunnel.

H

Harmful gases: Dangerous gases produced by engines.

Hauling shaft: Shaft or well made to allow the extraction of materials, equipment, etc.

Heading: Face of the tunnel. The point from which work progresses on a tunnel.

Healthful work environment: Word that is relative to health working conditions inside the tunnel.

High voltage: Electric current greater than 1000 volts.

Hoisting shaft: Shaft or well made to allow the extraction of materials, equipment, etc.

Hot spot: Elements of the equipment which accumulate hot and are dangerous when working with explosive gases.

Hydrology: The science dealing with terrestrial waters, their occurence, circulation and distribution, their physical and chemical properties and their interaction with the physical and biological environment, including the effects of the activity of man.

Hydrologeology: Part of the geology that studies *hydrology*. Science that deals with the geological aspects of subsurface waters and water-containing rocks and with these waters as a geological agent.

Hydrostatic pressure: Pressure that is produced by the weight of a column of water.

I

Impact rate: Frequency of impacts produced by percussion drilling machines. It is expressed in herzios.

Impervious ground: Impermeable terrain.

Incompetent ground: Terrain that is unable to support stresses.

Induced stresses: Stresses different from “in situ” stresses that are caused by the execution of an excavation.

Infiltration: The downward movement of water from the surface into the soil.

Intake area: see *catchment area*.

Internal friction: The resistence to sliding offered by a soil mass.

Inert media: Belonging to non living media.

J

Jacking station: Building were jacks are installed. Used in construction of pipe jacking tunnels.

Jet fan: Machine that allows to remove the polluted air of the tunnel.

Joint set: Group or family of diaclases and fractures.

K

Karst: Group of natural drills, caverns and wells, produced by the action of underground water on carbonated rocks.

L

Landslides: Movements and falls of stones and ground by the action of gravity on a slope.

Launch chamber: Place to assembly the equipment that is going to be used in the tunnel construction.

Leakage: Water flowing through pores or fractures.

Lining: Permanent protection in order to support underground excavations.

Liquid limit: Quantity of water of a soil that is between plastic and liquid states.

Liquid waste: Liquid polluted products.

Loose area: Area affected by the excavation of the tunnel that is not under stress.

Loose blocks: Rock blocks which are not joined to the walls.

Loudness: Acoustic intensity.

Low voltage: Electric current between 50 and 1000 volts.

Luminescence: Property of producing light. It is measured in Lumens.

M

Manhole: A well that allows the entry of a man inside of it.

Mechanic methods: Excavation by means of non manual machines.

Mesh: Steel bars joined in a square shape.

Mill: Well for the rubbish.

Mining: Mine exploitation.

Mole: Tunnelling Boring Machine. A tunnelling machine that can bore through hard rock.

Mouth: The entrance to the tunnel.

Muck: Soil and rocks that have been excavated and that have to be removed from the tunnel.

Muck hole: Well used to throw *muck* from the tunnel.

Mud: Bentonitic mud used in wells, drills, etc.

N

Nappe: Big rock mass that has moved over other rocks through a slide surface.

Natural cavern: Big hole in the rock from natural origin.

Noxious fumes: Pollutant and dangerous smoke produced in the construction site.

O

Off-road truck: Truck that is not authorised to circulate in ordinary roads because of its weight, size or other reasons.

Offset: Detour.

Oil mist: Type of pollution caused by air with oil particles.

Opencut: Excavation.

Open hole: Well that is not covered with a lid.

Opening: Excavation, mine, drill.

Out take: Ventilation well.

Over excavation: Excavation that is made out of the project limits.

Overburden: Thickness of rocks and ground that is over the tunnel.

Operation phase: Period that begins when the tunnel construction is finished. It corresponds to the utilisation of the tunnel.

P

Patching: Works made to fix up a lining.

Perched aquifer: Limited ground-water body resting on a layer of less permeable material; it is shallower than and without contact with the phreatic water table.

Permeable zone: Area of soil that allows the flow of water through its pores, holes, etc.

Pervious ground: Permeable ground.

Phreatic level: Level where the pressure in the ground water is atmospheric.

Pilot drift: A small exploratory tunnel bored in advance of a tunnel project along the same route. It provides geological information, as well as ventilation.

Pit: Well, mine, drill.

Pneumatic drill: A compressed air machine that is used to make holes in rock.

Popping: Fallen of rocks in deep tunnels. Similar to *rock burst*.

Pore: A small opening in a material through which fluid may pass.

Porosity: Quality of the soil of having pores.

Probe hole: Boring made to recognise the rock.

Preventive measures: Measures that are undertaken in order to avoid an environmental impact.

Q

Quarry: Place were rock is extracted for construction causes.

Quicksand: Sand and water mixed in such a way that the upward seepage of water equals the weight of the sand.

R

Raise: To excavate a well upwards.

Ravelling: General fallen of rocks and ground.

Reception pit: Well constructed in order to disassembly a tunnelling machine that has finished its work.

Regulation on materials and machinery: Group of laws that manage materials and machinery and their uses in construction sites

Regulation on noise: Group of laws that manage noise pollution in construction sites.

Regulation on safety and health: Group of laws that manage safety and health in construction sites.

Regulation on waste/dumps generation: Group of laws that manage wastes in construction sites.

Regulation on vibrations: Group of laws that manage vibration in construction sites.

Regulation on water: Group of laws that manage water and its uses in construction site.

Reek: Gas produced in explosions.

Residual soil: Soil polluted or altered after a procedure.

Retaining wall: A wall built to hold a bank of soil in place.

Rifle effect: Suddenly gas exit through the mouth of a drill when the explosion is not enough to break the rock.

Rock haulage: Transportation of excavation rocks and other wastes.

Running ground: Non cohesive soil placed over the water table, that moves towards any cavity until they reach the rest angle.

S

Safety measures: Group of actions undertaken in order to avoid accidents.

Sampling: Action of taking samples by means of drills.

Scaling: Excavation of rocks and blocks that has danger of falling after a blasting.

Seamy rock: Rock that has layers of another mineral inside of it.

Sediment load: Width of ground proceeding from sedimentary origin. Generally composed by gravel, sand, mud.

Seepage: The movement of liquid through small openings in a material.

Settlement: Lowering of the foundations of a structure in order to move to a more stable position.

Sewage water: Polluted water after its use in the construction.

Shaft: Well, pit. In tunnel construction it is used for vertical wells.

Shafthauling hole: Drill made to allow the transportation of the rocks and wastes from the tunnel to the external area.

Shear: The tendency of one layer of soil to slide across another.

Shoulders: Part of the cross section of a tunnel between the top and the sidewalls.

Solid waste: Solid products useless that have to be eliminated.

Slope stability: Capability of a slope to remain stable without movement.

Spilt oils: Related to all kind of oils and liquids of engines that can pollute the soil.

Streams: Flows of water. Very dangerous in tunnelling construction.

Structural model: Idealisation of the structure of the rock mass in order to calculate the tunnel.

Subsidence: Gradual lowering of overlying strata due to extraction of mined material or to compaction of the underlying sediment.

Subsurface: Part of the soil that is immediately below of the surface.

Sump: Sewer, hole that allow the water to be eliminated from the tunnel.

Sustainable development: Capability to continue with the development of an area without causing damage to the environment.

Sympathetic detonation: Explosion caused because of the proximity of another one.

T

Tail water: Water that leaves the back part of a tunnel.

Tamp: To apply a great force to a soil in order to compress it.

Tar: Coal. Very used in tunnelling construction, it is also very pollutant.

Test pit: Little well in order to remove superficial soil and study inferior layers.

Threshold limit value: Highest concentration of pollution that does not mean a risk over the health of a worker.

Trank sewer: Main pipe in a drainage system.

Tunnelling shield: A large cylinder with a cutting edge that can be moved forward by jacks. It is used when tunnelling through clay or soft rock.

U

Underground water: Water that flows through the wells, holes and fractures in a rock system.

Underground work: Type of construction works made in tunnels. It supposes some added difficulties like ventilation, lighting, drainage, etc.

Underprofile: Excavation that does not reach the limits defined in the project.

Unlined tunnel: Tunnel that does not need lined because the rock in which it has been excavated is very stable.

V

Value engineering: Improvements in the design or in the construction proposed by the contractor to the client after the sign of the contract.

Vegetative cover:

Ventilation duct: Pipeline used to ventilate the tunnel, eliminating polluted air.

Visual impact: Damage over the environment caused by the degradation of the landscape or the loos of visual conditions.

Visual intrusion: *Visual impact.*

Void: Hole, pore, cavity.

W

Wall: In tunnelling construction it is one of the vertical sides in the excavation.

Washing: When water drag little particles like sand and slime from the soil.

Waste rock: Rocks produced in the excavation that have to be eliminated because they have not got constructive value.

Waste water: Polluted water that has to be eliminated through the drainage system.

Water table: *Phreatic level*, as observed in observation wells.

Waterproof: An impermeable element that can work in very wet places or in contact with water.

Water quality: Criteria and specifications of chemical, physical and bacterial constituents of water supply, depending on its use for domestic, industrial or agricultural purposes; determination of organic and inorganic constituents, acidity, specific electrical conductance, temperature, colour, turbidity, odour, taste, coliform organisms.

Well: 1. Artificial, open excavation of more or less permanent nature to produce ground water or to carry out observations.
2. A borehold.

Workplatform: Place of the construction site were workings are taking place.

X

Xenoblast: Terms applied to cristals that have grown during metamorphisms without developing their cristal faces.

Y

Yard: Place for precasting and machinery workings.

Yield: Energy radiation from an explosion expressed in terms of equivalent, Kilotons or Megatons of TNT explosive.

Yield Safe: The maximum permanent withdrawal that can be made from and aquifer continuously, including dry periods without producing undesired result.