OFFICIAL REPORT OF THE
INTERNATIONAL TUNNELLING ASSOCIATION

Planning and Mapping of Underground Space — an Overview

Working Group No. 4, International Tunnelling Association

Abstract—*This report presents the findings of a study undertaken by Working Group 4 (Subsurface Planning) of the International Tunnelling Association. The study compared practices in nine countries—Australia, Czech Republic, Finland, Italy, Japan, Netherlands, Norway, Sweden, and Turkey—concerning the planning and mapping of underground space. [Since the completion of this synopsis, Japan is presently concluding a new law concerning the utilization of deep underground installations.] This overview reviews important issues and presents recommendations for subsurface planning and mapping.*

Foreword

It has been said before, and deserves to be repeated: *Subsurface utilisation is not a "must" in itself.* It is a realistic solution,

- where no space above ground is available (e.g. parking areas, metros);
- where saving the environment is a major issue (road and rail tunnels);
- where costs can be saved (food and energy storage);
- for strategic reasons (communication cables and centres);
- for humanitarian purposes (water supplies);
- and in many other circumstances.

Re-utilisation of abandoned underground installations may well be part of these options. To accomplish this, tools for careful planning and geological mapping are necessary.

This present overview may be seen as a continued effort, focusing on the need for good and professional planning of underground space. By co-ordinating the different interests and needs for building under our cities, and by improving the legislative and administrative routines, development of underground space can be facilitated. It is hoped thereby that in a not too distant future, the implementation of underground facilities will be considered equally as valuable as surface solutions—not least from an environmental point of view.

In my capacity as Animateur, I would like to thank the following national groups of ITA for contributing to this work, thus making a current overview of this topic possible: Australia, Czech Republic, Finland, Italy, Japan, the Netherlands, Norway, Sweden, and Turkey.

I would also like to thank the editor, Gustaf Landahl, for his engagement and work in accomplishing this international synopsis; and the Executive Council of the ITA—in particular, the Tutor of our Working Group, Professor Sebastiano Pelizza—for its support.

For the International Tunnelling Association,
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Background

National legislation and local authorities can either facilitate or restrain the use of underground development. Legislation is often more coherent and clear for surface solutions than is the case for building underground. The lack of clear rules and routines or standards for underground construction may delay the legal procedures, thus delaying or prolonging projects and increasing their costs. The increasing demands for underground solutions emphasise the need for better co-ordination of the utilisation of underground space.

A major obstacle for many underground projects is that a number of different authorities, federal departments and overlapping legislative documents must be consulted before a building permit can be obtained. It is not unusual for these procedures to take more time than is required to construct the facility.

Within the International Tunnelling Association, Working Group 4 ("Subsurface Planning") is responsible for dealing with these topics. In 1990, a first study on legal and administrative issues in underground space use (ITA 1990)

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was accomplished by Ray Sterling, then Director of the Underground Space Center at the University of Minnesota, U.S.A. The animateur and vice-animateur of W.G. 4 at that time were, respectively, Michael Barker and Syver Froise. Since then, with an increasing demand for underground space use, the lack of legislation, administrative routines and knowledge about the particulars of underground space have become more and more evident, thus underscoring the need for better co-ordination of the issues involved. In 1993, at the ITA annual meeting in Amsterdam, W.G. 4 decided to ask member nations to report on the status of planning and mapping of subsurface space in their countries.

Conclusions

Nine member nations presented their reports on the subject. These are of varying length and contents. Some countries presented reports and summaries of extensive research programmes within this field; others presented short summaries on the present state of legislation in their country. [Since the completion of this synopsis, Japan is presently concluding a law concerning the utilization of deep underground installations.] A list of the national contributions is provided at the end of this report. Almost all the contributions dealt with the questions of why the use of underground space is increasing, and what future uses are being developed.

Based on the contributions of the various countries, we can already conclude that during the past few years, some nations have undertaken to make very comprehensive studies. These have been and are being presented to politicians and decision makers in order to focus on the problems, to suggest improvements in legislation, and to introduce a number of possible infrastructural solutions underground. As a result, the planning authorities in some major cities have recognised the potential of underground space to be considered in future developments of the city.

The national contributions also show that common to most countries as regards planning and mapping of underground space is the concern to maintain the groundwater level, to protect the environment and historically valuable ground, and to develop methods to map the presence of existing underground facilities and geological conditions. Figure 1 shows the range of issues dealt with in the national contributions to this report.

This overview can by no means review in detail everything presented in the submitted national contributions, which are referenced at the end of this summary. Instead, our aim has been to summarise the main points stressed in the contributions and to include some of the examples presented in them. In some cases, recommendations for future action have been pointed out. These recommendations are presented in this summary and are trusted to be of value for the ITA community and its future work in this field.

— G. Landahl, Editor

Underground Space Is Becoming More and More Attractive

All of the national contributions stated that use of underground space is becoming more and more attractive for development. The reasons sometimes differ among the countries, but they also have shown much similarity. One general and major point is that use of underground space is a means for achieving quality aspects such as an improved environment.

As stated in the *Australian* report (Dobinson and Bowens 1997*):

> *Underground development is not an end in itself. It must be viewed as a means of achieving strategic objectives of the community and government rather than as an aim of itself.*

In many cases, the choice of an underground solution is a choice between the underground solution and no solution at all. This is because of environmental concerns.

The ITA Working Group 15 ("Underground Works and the Environment") presented a report in 1998 (ITA 1998) which concludes that

> *"... [t]he increasing environmental sensitivity and legislation will have a positive influence on the future development of underground works. Increased legislation and demands for protective measures will increase the costs for underground works. On the other hand, increased environmental concern, i.e. for preserving the city-scape and landscape, will increase the need for siting certain functions underground. This need will surely overweigh the problems caused by the increased sensitivity and legislation."*

As stated in the *Finnish* report (Rönkä et al. 1997):

> *Underground construction, based on the principles of sustainable development, aims to minimise environmental hazards, to save energy, to increase the functional diversity of the urban structure, to reduce the need for local transportation, to make services more easily accessible to residents, and to protect the urban landscape and culture."*

A summary from the Finnish report of some advantages and disadvantages of building underground is given in Table 1.

In some countries, as pointed out in the contributions from *Japan* (Japan Tunnelling Association 1996) and *Italy* (Peila and Pelizza 1997), topographical and geographical conditions are also a main reason why tunnelling is impor-

[*Note to readers: References to the nine national group contributions are cited the first time they are mentioned in the text. Unless otherwise noted, these contributions are the source material for all further references to the respective countries.]

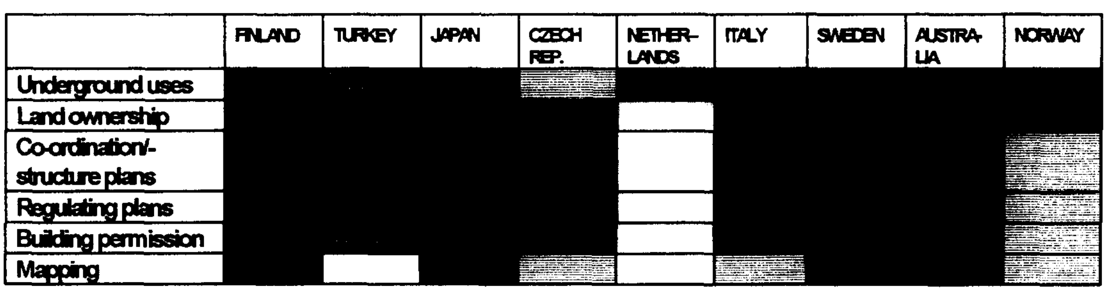

Figure 1. A graphic overview of the issues dealt with in the ITA member nations' contributions to this report.

Table 1. The Finnish report summarises some of the advantages and disadvatnages of building underground (Rönkä et al. 1998).

Aspects	Advatanges	Disadvantages
Economic	• Allows for more compact urban structure • Saves building land from secondary uses (traffic, parking) for recreation, work, housing • The bedrock can be usilized both for heating and cooling	• Surface connections (portals and shafts) may significantly increase the costs of underground construction if the quality of the soil is poor
Technical	• Constructing in rock is cost-effective because of the hard bedrock in Finland	• Surface connections are technically demanding projects in poor-quality soil
Functional	• New streets do not cut across areas • Safety in the urban community	• Connections with the traffic network aboveground may be difficult to arrange
Social	• Taking streets down into tunnels improves the quality of life in city centres	• Lack of external control is one reason for prejudice against underground traffic solutions (tunnels, underground car parks) • Orientation difficult
Environmental	• Tunnel construction helps to protect the natural landscape and saves urban areas • Underground construction does not affect the superficial shape of rocks or the natural conditions of the area • Environmental stress factors (e.g. noise pollution) can be reduced by underground construction • Underground construction helps to protect environmental and cultural values (e.g. townscape)	• Underground construction may lower groundwater table • Job satisfaction in facilities with no windows is generally lower than in facilities aboveground • Location of ramps and other surface connections is difficult

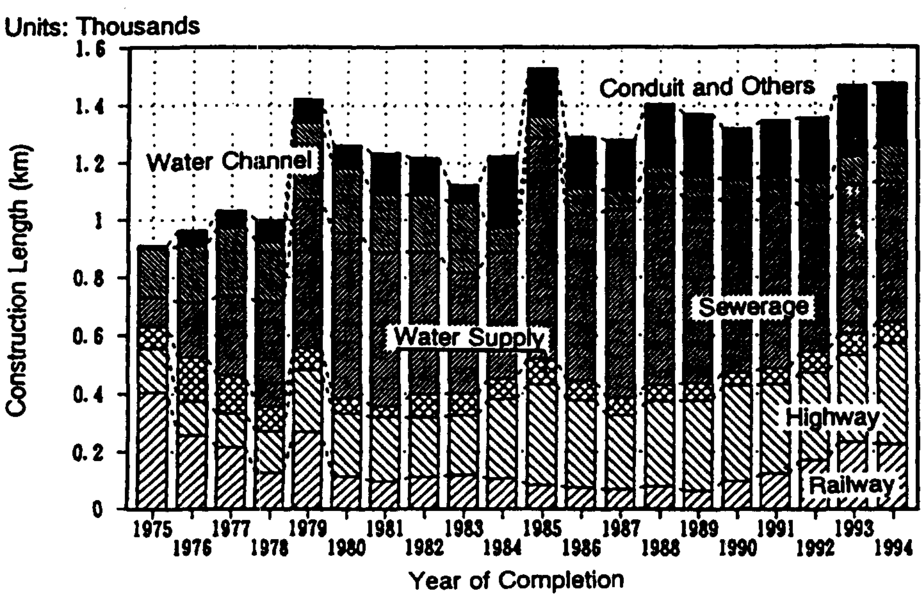

Figure 2. Annual tunnel production in Japan.

Table 2. Possibile impediments related to enabling factors, as described in the Dutch report (Horvat et al. 1998).

Impediments	Nuances/Possible Solutions
I **Legal aspects:** • Unclear legislation and regulation concerning decision-making on (major) projects. • Unclear public and private law provisions concerning underground construction.	• Harmonization and synchronization of legal procedures concerning decision-making on (major) projects is under study. • Legislation and regulation concerning underground construction should be presented transparently and, if necessary, allowed to be amended.
II. **Spatial planning aspects and zoning plan:** • Spatial planning schemes and planning policy are entirely focused on aboveground activities.	• Develop an integrated spatial planning vision on the use of both aboveground and underground space. • Possible solution by amending the Spatial Planning Act.
III. **Lack of a (dynamic) integrated assessment framework:** • Underground options are often not—or not seriously—incorporated into the decision-making procedure. • Lack of a good method for comparing differing underground and aboveground options.	• Development of a (dynamic) integrated assessment framework, to ensure that all the relevant aspects and options are considered at each stage of the assessment process.
IV. **Lack of integrated decision-making procedures:** • Major projects feature an unclear and unmanageable decision-making process, yielding a frequently suboptimal outcome with regard to utilization of underground space.	• Well-designed integrated decision-making procedures can improve the manageability of the assessment process between various options, and can optimize the outcome.
V. **Unfamiliarity with the possibilities of underground construction:** • Utilization of underground space is a relatively new concept in the Netherlands, and many possibilities are yet unknown.	• To ensure optimized utilization of the possibilities of underground construction, certain actors must possess certain know-how; information strategies can be formulated with that objective.

tant. In both countries, mountain ranges complicate the building of rail and road infrastructure. In some cases, tunnels are the only alternative. Especially in Japan, this situation has led to a large number of tunnels (see Fig. 2).

Other reasons for building underground are that

- energy can be conserved by exploiting the constant temperature and humidity of the underground;
- emergency protection can be provided; and
- constant development in design and construction methods have lowered the costs for building underground.

In one case, subsurface use is *not* recommended. The *Finnish* report stresses that underground solutions are not a prime alternative for residential use or for full-time work. In exceptional cases, however, workplaces related to maintenance-overhaul and repair may be located in underground facilities. Additionally, in town centres it is permitted to have control facilities and shops adjacent to underground stations, subways, car parks and other facilities.

What Impedes the Use of Underground Space?

There are a number of possible impediments to the utilisation of underground space. The *Dutch* study (Horvat et al. 1997) analysed these impediments; the results are presented in Table 2.

Costs and Benefits of Building Underground

Some of the reports discuss how to assess the costs and benefits of underground construction. The cost of building on the surface should be compared with the cost of building underground, reduced by the following:

- the "shadow price" of released land on the surface;
- the communities' valuation of the disadvantages of conventional construction in terms of environmental degradation;
- in the case of transportation, also the achieved social and economic savings through reduced surface transport.

For example, transport in city centres is frequently a trade-off between environment and cost. Unfortunately, it is difficult to quantify, in economic terms, the value of many environmental factors.

The *Australian* contribution points out that state governments and the private sector must pursue technological developments aimed at facilitating cheaper and more risk-free underground construction, because cost is a major barrier to greater use of underground infrastructure solutions.

How Can the Use of Underground Space Be Enhanced?

Despite the higher costs, the *Australian* contribution points out that the community is frequently prepared to pay the additional cost for an underground location instead of an aboveground facility. The land value increases, and the release of surface land and air rights for development should be captured and included in the feasibility studies.

One way of stimulating environmentally preferable underground solutions is by means of financial subsidies from the community. The *Australian* report recommends that the commonwealth include underground projects as a new category for financial incentives, since the projects have lower environmental impact.

Strategic Visions for Future Use of Underground Space

One way of enhancing the use of underground space is by presenting visions for future use. The *Australian* contribution stresses that state governments and local authorities must foster visionary, but realistic, design examples that will demonstrate the benefits of the underground through design competitions that focus on the challenges facing Australian cities, and that demonstrate environmental, institutional and economic feasibility.

In the *Netherlands*, a study was carried out cooperatively by the Centre for Underground Construction (COB) and the Delft University of Technology (TUD), in close co-operation with the national Physical Planning Service of the Ministry of Housing, Spatial Planning and the Environment (Horvat et al. 1997). The aim of the study was to develop a strategic vision of utilisation of the underground space in the Netherlands in support of sustainable and functional spatial development, embodying quality.

In four different scenarios, different developments of underground space were assumed (see Fig. 3). One conclusion was that the development of underground space will increase if the following developments occur:

- increasing quality consciousness of safety, living conditions and the environment.
- increasing pressure on the space available.
- rising mobility.
- strong economic growth.
- technological progress.
- an active government with strict policies on spatial development, environmental and safety issues.

Who Owns the Subsurface?

The most common maxim applied to the definition of limits of surface property ownership is from Roman law: *Cujus est solum ejus est usque ad coelum et ad infernos*, ("The owner of the surface also owns to the sky and to the depths"). In the ITA survey "Legal and administrative issues in underground space use" (ITA 1990), four main conditions appeared to exist in relation to the limits of surface property ownership:

1) The surface owner owns the property to the centre of earth.
2) The surface owner owns the property as far as reasonable interest exists.
3) The surface owner owns the property only to a limited depth beneath the land surface (as little as 6 m).
4) Private land ownership is non-existent.

Ownership does not necessarily give the right to use the land or the underground space. The right to use the underground space is often restricted in some way, either through land-use plans or legal praxis. Neither does the ownership of land necessarily give the right to oppose activities of other users under the surface.

In most of the contributions to this overview, the legal framework related to ownership of subsurface space is regarded as a problem.

In *Italy*, the property of the underground is ruled by the civil code which states that the property of the surface is also extended into the underground, with everything it can contain. Some exceptions are regulated by specific national laws (on mineral rights of national interest, on antiques, on

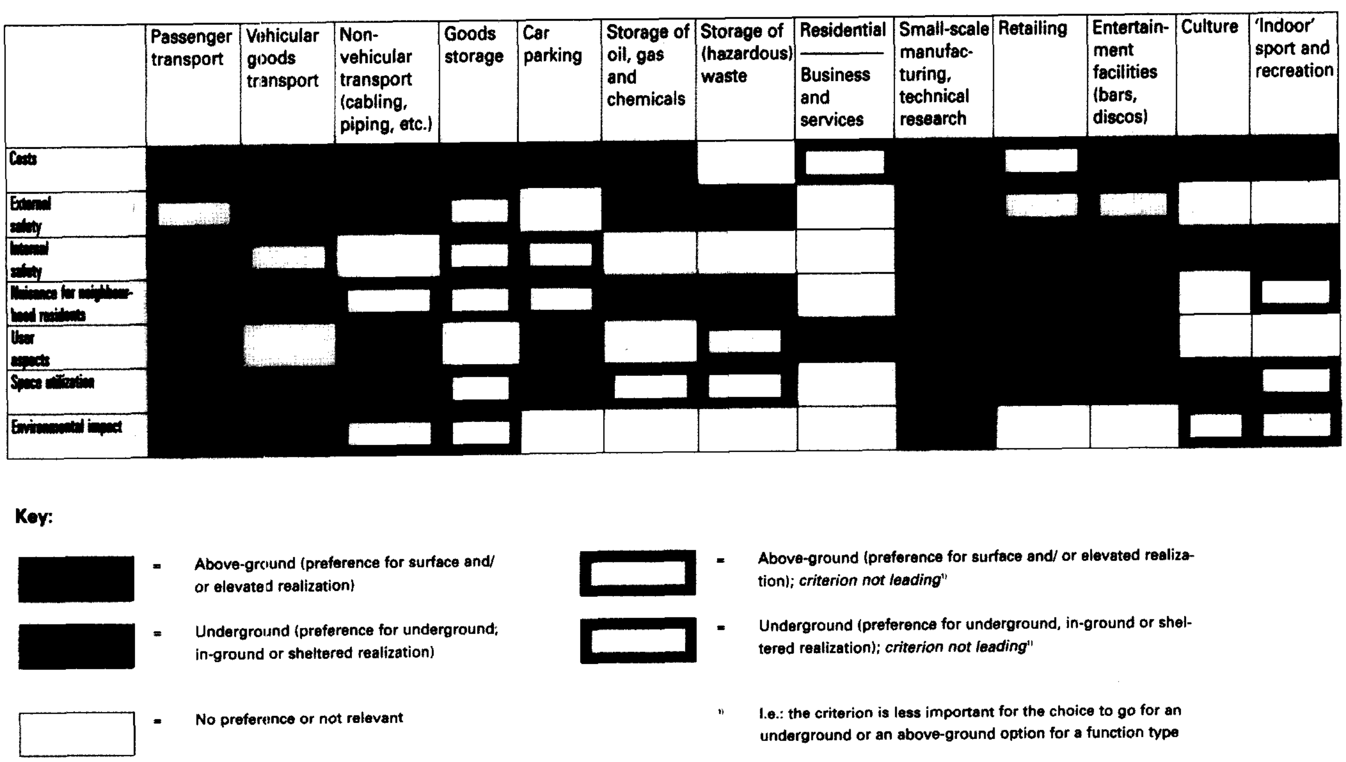

Figure 3. Matrix from the Dutch report showing expected preferences for the construction mode of function types for each location type on the basis of assessment criteria.

water, etc.). It also appears that underground property cannot be separated from the surface property. The legislation therefore allows the owner of the land to make any kind of excavation, provided that it does not cause any damage to neighbours' property. The owner of the land cannot, however, oppose the activities of other persons at a depth at which he has no special interest to exclude.

This is also the case in *Turkey*, where all property starts from the centre of the earth (Akcelik 1997). The legislation does not delimit property in the vertical dimension. Land for road tunnels is acquired through expropriation.

In *Sweden* (Landahl and Nordmark 1996), property also starts at the centre of the earth. Swedish legislation does not deal with the question of a property unit in height and depth, but one commonly accepted view is that property units cannot be three-dimensionally delimited in such a way as to superimpose one property unit on another.

In the *Czech Republic*, private ownership has become the main kind of property ownership (Vales 1997). Although there is no fixed formulation of the landowner's property below the surface, the common law of private property is that it is untouchable. That means that nobody can in any way damage or limit rights of the owner to use his private property. Private property is protected from the technical point of view—i.e. noise, vibration, subsidence, surface damage, environmental pollution. The need now is to formulate the land-owner's rights, restrictions and procedures for obtaining his right of way with respect to underground constructions.

In *Finland*, the landowner's right to underground space is, in principle, unlimited (Rönkä et al. 1997). The prevailing interpretation is that the landowner owns the whole area in his possession to the depth that he can utilise. According to the building code, this normally means one basement story, but the number can be increased in the city plan to two, and, in exceptional cases, even to three or more.

In *The Netherlands*, land is owned to the centre of the earth, but use is restricted, similarly as for mineral rights. Use of the underground owned by others cannot be forestalled without reasonable justification.

In *Australia*, states within the Commonwealth have different definitions of the depth to which the owner of the surface land owns the ground below. For example, the state of Victoria places a depth restriction on land ownership. The Australian contribution recommends that the commonwealth and state governments develop a package of uniform legislation across Australia to rationalise issues of ownership of underground space, with legal responsibilities between owners of underground space and other affected parties clearly defined. The contribution proposes that legislation should limit the depth to which the owner of the surface owns the ground below the surface to the practical depth necessary for ordinary use and enjoyment.

In *Japan*, the use of land and the ownership of land are very strongly connected. Realising projects under private land, such as extensions of the Tokyo subway system, are therefore almost impossible and extremely expensive. In 1995, the "Special Committee for the Utilisation of Deep Underground Space" was formed within the Prime Minister's office, with the objective of dealing rapidly with the relevant legal and administrative problems (Japan Tunnelling Association 2000). One important issue has been to abolish private land ownership under a certain depth, such as 50 m. This "deep underground" is to be in the hands of the public, in order to facilitate the creation of new infrastructure. (Since the completion of this synopsis, Japan has been preparing a new law concerning the utilization of deep underground installations.)

If the Land is Not Owned, How Are Projects Realised?

Because three-dimensional real estate is not yet a possibility, the right to build a tunnel or a cavern must be obtained by other means. The most common way to do this is by obtaining some kind of easement. For example, easements can be established to define security zones protecting a tunnel from other projects that could harm the structure.

In *Italy*, for example, tunnels near the surface public utility works can be achieved by "servitude"— an easement imposing certain restrictions on the land owner to help protect against possible damages caused by the tunnel. These easements can be handled in different ways, depending on whether the surface owner is a public body or a private land owner. In the case of a public body, the easement is granted by means of an agreement. In the case of a private body, an indemnity is due to the land owner.

Even though this possibility exists, there are problems that cannot be solved without making three-dimensional real estate possible.

Make Three-dimensional Real Estate Possible

Some of the contributions propose the idea of creating three-dimensional real estate. For example, by updating land title legislation, the ability to subdivide land into strata could be enhanced. This could be done by defining "land" in the current legislation as being expressly three-dimensional, with ownership defined to include the vertical as well as the horizontal dimension. Legislation should also be amended so that it makes zoning in three dimensions possible.

It must be noted that the liability issues related to subsidence above underground projects and removal of lateral support to adjacent properties may become more complicated when land ownership is subdivided vertically as well as horizontally.

The Need for Planning the Underground

Many of the national contributions focus on the need for better co-ordination and planning of the use of the space below our cities. In many countries, the legal framework for surface construction is clearly formulated. But for underground space, this is not the case. Contributions from some countries stated that state governments and local authorities should institute underground planning efforts in urban areas similar to those for above ground uses.

On the other hand, the contributions also point out that planning, zoning and building code regulations and standard forms of construction contracts do not necessarily properly reflect the nature of underground projects.

As presented in *Japan*'s contribution, in some cities the extensive use of the underground has led to a growing congestion below the surface, similar to the congestion already existing on the surface. This crowding has reached such an extent that in recent years the depth of new underground construction works for rail, road, regulating ponds (underground rivers) and the like have had to be constructed at progressively greater depths. Because of this, various organisations and engineers are currently involved in research and development to find ways to solve the technical problems arising from the greater soil and water pressures, as well as from the increasing construction costs, supporting systems for the pressures, etc., associated with working at increasing depths.

Following the Japanese cabinet's comprehensive policy decision in 1988 to promote more effective land use, widespread interest arose in the development of urban underground space on a scale previously unimaginable. However, the result was not so impressive. To further promote the use of underground space, many matters remain to be dealt with, regarding not just the technical side but also the related laws and administration. The previously mentioned "Special Committee for the Utilisation of Deep Underground Space", established in 1995, is intended to help speed up the resolution of these issues. Hopefully,

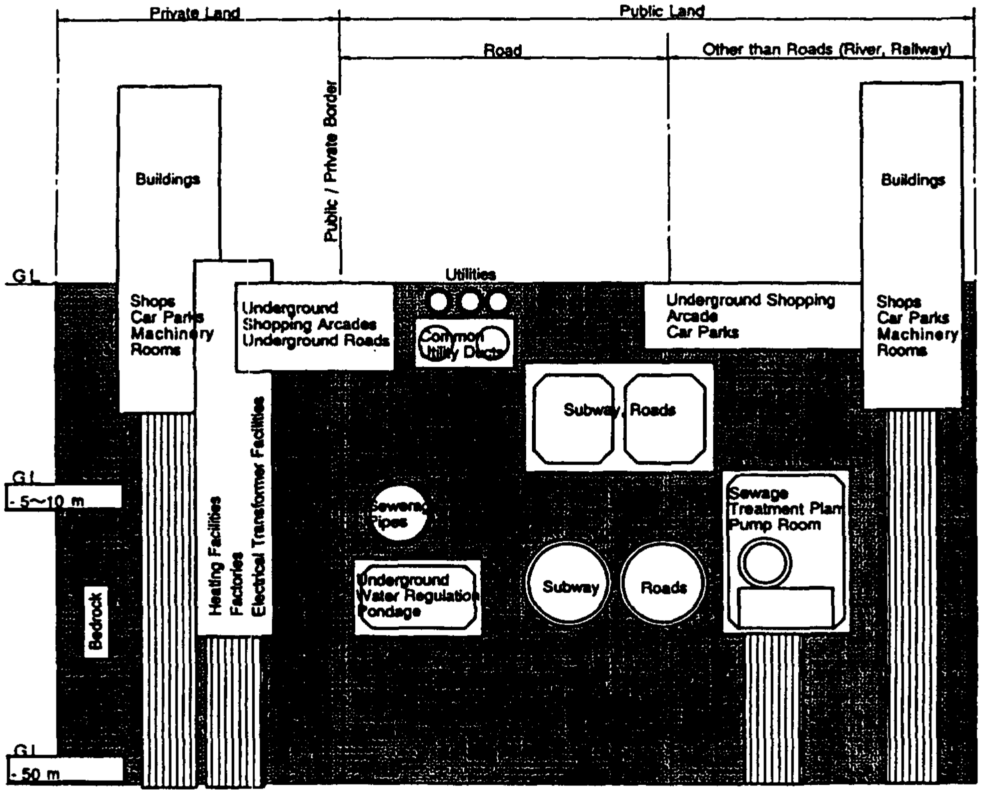

Figure 4. Uses of underground space in Japan in relation to land ownership.

existing legislation will be modified to help overcome the legal and administrative obstacles that today restrain the increased use of underground space in Japan. (Since the completion of this synopsis, we have been informed that a Special Measures Act for Public Use of Deep Underground Space will be implemented in 2001.)

Planning legislation is being reviewed in some other countries as well.

In *Sweden*, planning legislation was altered some years ago. The 1987 Planning and Building Act made it compulsory to acquire a building permit for the construction of tunnels and caverns. This change of legislation requires the local authorities to review the proposed project and coordinate it with other subsurface or surface needs. The need for building permissions has also led to the requirement that all new projects underground mapped. In two studies co-financed by the Swedish Rock Engineering Research – SveBeFo (Egerö et al. 1997, Landahl et al. 1994), the results of this new legislation have been analysed and the needs for further development of the legislation have been pointed out.

The Swedish Planning and Building Act regulates, among other things, the drafting and content of physical plans and what measures require building permission. The law aims to equate construction below the surface with construction above it. An important feature of the law is that building permission is required for tunnels and caverns. This gives the municipalities a possibility to co-ordinate usage of the underground, but also requires the municipalities to acquire knowledge about the underground.

In *Finland*, the Ministry of the Environment appointed a committee in 1988 to review existing planning systems for underground construction. In its report in the spring of 1990, the committee concluded that the current legislation and planning procedures were unsatisfactory. The necessary amendments to the legislation were drafted on the basis of the committee report.

A study on "Underground Space in Land Use Planning" was launched in June 1994 and completed in the summer of 1996. The aims of the study were defined as follows:

- to review the present situation in underground planning and to identify problems and development needs in Finland's largest cities;
- to look at current uses of underground facilities and to explore possible future uses and needs for underground space in the Finnish urban environment;
- to create, for planning purposes, a basic method for the classification of the building potential of rock areas;
- to identify and bring together the various methods currently available for assessing the environmental impacts of underground construction on the basis of the legislation in force (EIA);
- to develop methods for assessing the costs to the urban community for underground space, particularly in comparison with equivalent costs of space above ground; and
- to draft a proposal concerning planning of different level and permit procedures for underground space.

In *Norway*, legislation also has been changed. Previously there were different sector-based planning systems. Now a single plan procedure takes care of building development, traffic problems and the environmental concerns. The parties involved have expressed their satisfaction with this way of simplifying procedures and with the co-operation based on the planning and building regulations. One main reason for this is the benefit of a running dialogue with the citizens and with the politicians. Both factors have contributed to better public acceptance of the projects and to good overall solutions for the community.

The need for better planning procedures is not just a question of co-ordinating different needs for space. In *Italy*, design of a public work must also be submitted for approval to the Cultural Ministry body. If some archaeological artifacts are found during the excavation, the works are stopped and, if possible, the antiques are removed or an alternative design must be adopted.

Common to most countries is the concern to maintain the groundwater level, to protect the environment, to protect historically valuable grounds, and to consider the presence of existing underground facilities and the geological conditions for a sustainable development underground.

Strategic Planning of Underground Space

The Need for Better Co-ordination of Different Uses

Strategic land-use planning (also referred to as *master* or *general planning*) is used in most countries as a way of obtaining a broader perspective and understanding in order to assist in the land-use decision-making process. In some countries, this form of planning is compulsory; in others, it is done on a voluntary basis. In some countries, the master plans are binding for detailed plans; in other countries, they are not. What the strategic land-use plans have in common is that they:

- help establish visions and objectives for the development or conservation of certain areas;
- establish strategies to achieve the visions;
- often are comprehensive, thus taking into account different demands for the use of the land and also addressing issues that reach beyond land-use aspects;
- in many cases, are drawn up incorporating a strong degree of government agency and public participation.

Strategic planning for the use of underground space is not common. In most countries, decisions regarding underground space use have been made on a piecemeal basis, and as long as underground space is only used for a few tunnels in these cities, this is no problem. The difficulties arise when underground space becomes attractive for different needs and when the co-ordination of these needs become evident.

As stated earlier in this report, development of underground space is becoming more and more interesting. Increases in the use of the underground for major transport projects and the rise in the number of private utility providers highlights the importance of underground planning for cities and urban areas. It is obvious that underground space is not an infinite resource and its use must be managed carefully and professionally.

Many of the contributions to this report therefore recommend that strategic planning should be applied to underground space to a greater extent.

According to the *Australian* contribution, state governments and local authorities should investigate the potential for underground space use in major urban areas and upgrade the information on existing underground uses. They must "conceive the use of the underground as reinforcing strategic objectives and enhancing the environmental quality of urban centres and helping maintain its street life not as pulling the urban life below ground" (Dobinson and Bowen 1997). They should also include the possibilities of underground space in cities and major urban areas in their conceptional planning, and they should provide for reservation of this space in their strategic plans. They should reserve corridors for future transport routes, as is done for surface routes.

The *Finnish* contribution points out that general planning may include assessments not only of rock areas but also of the most important points of entry that should be reserved for future use. A general plan of underground space should be drawn up when:

- there are several projects in the same area and the co-ordination of work requires advance planning;
- within a dense urban structure, it is necessary to reserve several alternative points of entry for portals and vertical shafts to underground space;
- there are plans to build extensive city-centre underground carparks for which surface connections need to be reserved.

The *Italian* contribution states that both the tunnels and the surface restraints due to tunnel presence must also be included in the plans.

How Should Strategic Plans for Underground Space Be Drawn Up?

Planning for urban areas should be based on planning goals and existing land use planning, but should also incorporate the geological conditions and their distribution with the anticipated need for future underground facilities. Particular attention should be paid to special geological opportunities in terms of rock/soil type and easy access from the surface to the favourable geological conditions.

Better information is also required if strategic plans are to be drawn up for the subsurface. State governments and local authorities should collect and collate information on underground geological conditions and existing underground structures and should interpret this information for use in short- and long-range urban planning.

Development of underground projects should be undertaken by multidisciplinary teams of engineers, architects, urban planners and professionals from other relevant disciplines, with the same attention to urban design issues that is associated with structures at ground level. Archaeological considerations and implications should not be underestimated.

According to the *Finnish* report, assessments are required of the feasibility of rock areas for construction purposes, detailing the following:

- General feasibility:
  - depth of rock and suitability of soil cover for construction;
  - quality and geomorphology of rock area; and
  - potential for rock engineering in different areas, size and number of spaces.
- Access:
  - portal alternatives and other surface connections; and
  - comparison of different alternatives
- Restrictive factors:
  - built space, reserved space, and safety zones;
  - surface connections, portal options;
  - land ownership and restrictions on land use; and
  - environmental impacts, e.g. groundwater.

At the regional planning level in Finland, the feasibility of rock areas for construction is usually evaluated separately for each project on the basis of geological maps.

At the level of general planning, analysis of the feasibility of rock areas for construction is usually based on an examination of geological bedrock maps and field investigations. At this level, rock areas are not classified in detail because the areas studied are quite extensive and the only limited information is on the nature of the bedrock. Crucial

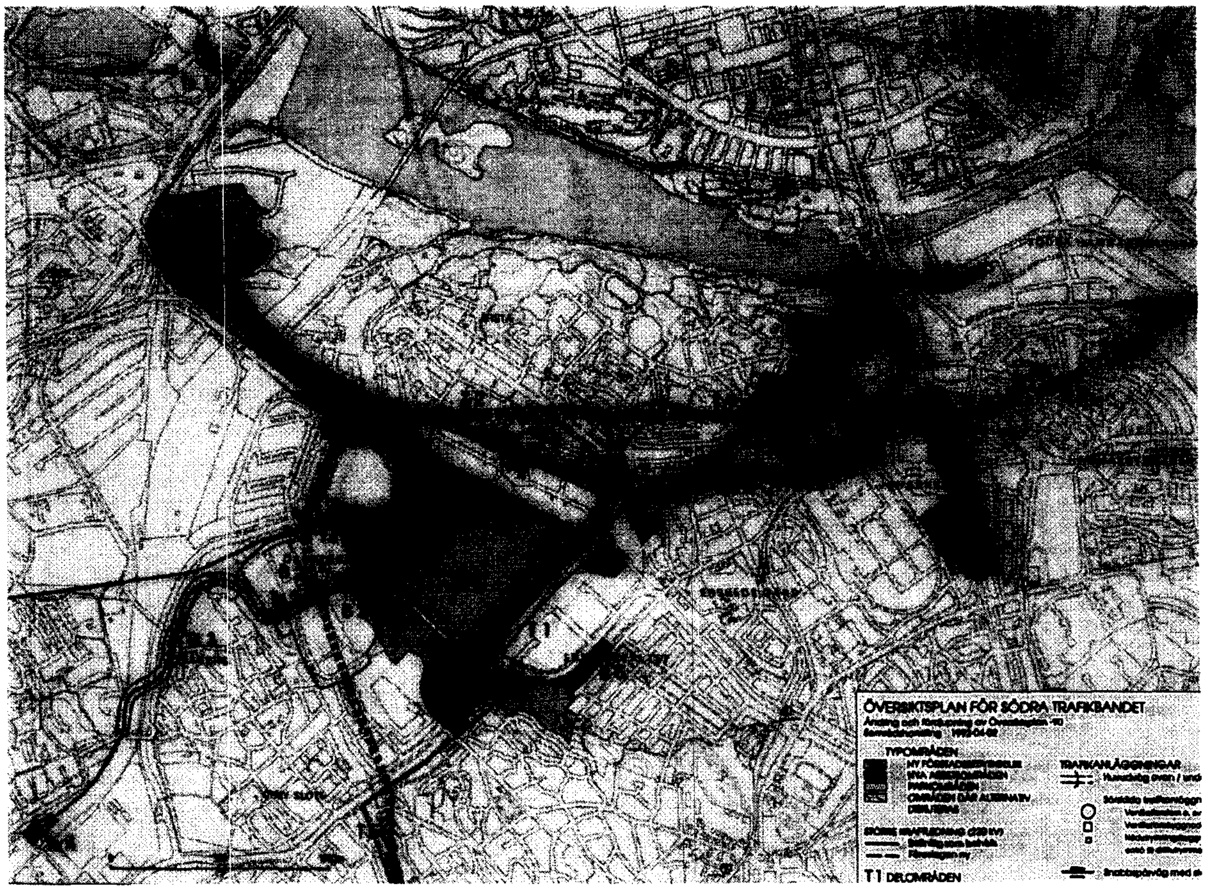

Figure 5. This strategic land-use plan for southern Stockholm includes planning of the Southern Link of Stockholm's ring road, the new light-rail system, and the planned development of the land use.

aspects regarding feasibility include accessibility, i.e. the depth of the rock as well as entry options. Where necessary, the feasibility question can be divided into the following two categories:

1) *Rock areas that can be built normally*: where tunnels and rock caverns require no reinforcement or support and where there are no known obstacles to excavation or the construction to surface connections
2) *Rock areas where construction is difficult:* where topography, geomorphology and the variability of soil cover,as well as zones of fissured rock, increase the cost of constructing the rock caverns, tunnels and surface connections.

According to the Finnish report, underground spaces should be recorded in the regional plan when the project has regional or national significance. They should be recorded in the general plan depending on the extent of the project and the co-ordination of operations. Co-ordination is required if there are several ongoing projects in the same area; this is also necessary in a dense urban structure where several alternatives need to be determined for portals and vertical shafts. Usually underground construction will be noted in the regular general plan map. However, a separate map of underground activities should be attached to the general plan in areas where there are so many underground needs that it is difficult to represent them on the same map with reservations for surface activities.

At the level of general planning, the authorities may decide to adopt a plan for underground space that covers the whole municipality. A separate general plan for underground space may be prepared and submitted for ratification, if necessary in the same way as for other general plans. This will give the plan more legitimacy than a plan that has not been ratified.

What Has Been Done So Far?

It is not uncommon that tunnels are included in the strategic plans for cities. Less common are strategic plans for underground space co-ordinating different needs for future development. A few examples have been identified through this survey.

- The *City of Sydney*'s planning department has initiated a discussion on the preparation of a strategic plan of the city's underground to provide a policy framework for decisions relating to the future uses of this area.
- The *City of Helsinki* has had a space allocation plan for underground activities since 1984. The main purpose of this system is to co-ordinate the underground plans of various municipal authorities and private construction projects.
- The *City of Stockholm's* land-use plan for the southern part of Stockholm includes the planning of the Southern Link of Stockholm's ring road, the new light-rail system, and the planned development of the land use (see Fig. 5).

Detailed Planning

Detailed development plans (sometimes referred to as *zoning plans* or *town plans*) are normally legally binding. The plan consists of a map with regulations concerning the

Table 3. The legal requirements and possibilities vary from country to country. This table summarises the situation in the countries participating in the ITA survey.

Country	Are detailed development plans that deal only with the subsurface possible by law?	Are tunnels and caverns regulated in detailed development plans?
Australia	–	–
Czech Republic	–	–
Finland	No, the regulations apply to both the surface and the underground.	In some cases, especially in Helsinki.
Italy	–	–
Japan	No, the regulations apply to both the surface and the underground.	In some cases.
Netherlands	Plans dealing only with the subsurface do not exist. By law, consequences for the surface have to be included.	Tunnels and underground structures are regulated in development plans.
Norway	No	In some cases.
Sweden	No, the regulations apply to both the surface and the underground.	In some cases, especially in larger cities.
Turkey	No, the regulations apply to both the surface and the underground.	In some cases, especially in larger cities.

use of the land, restrictions and specific requirements on the permitted development. Some countries reported having experience with detailed development plans for tunnels and caverns (see Table 3).

When Are Detailed Development Plans Necessary for Tunnels and Caverns?

Most countries responding to the ITA survey called for increased planning of underground space. According to the *Australian* study, state governments and local authorities should establish systems for planning, zoning, reserving and regulating underground space with codes of best practice for layout of transport and utility infrastructure. The legislation should also be amended so that it makes zoning in three dimensions possible.

In the *Finnish* study, the town plans of eight selected cities were examined. A sample of 24 plans received closer analysis, with the focus on the plan regulations. Most of the plans were of completed projects or work underway, but a few reservations of unbuilt space were also included. In addition, a questionnaire was submitted to the relevant planning authorities in May 1995. The aim of the questionnaire was to explore in detail the current planning systems and procedures for underground construction projects.

Table 4. In Finland, the seven different cases below are used to determine when underground space should be planned with detailed development plans.

Underground space should be specified in the city plan when.

- the project is significant in terms of scope and extent;
- people will be working full-time in the space;
- underground construction will affect local housing, workplace and transport arrangements as well as the rights of the people in the area;
- surface connections to the underground space affect traffic or parking arrangements;
- underground construction has significant consequences with regard to arrangements above ground level;
- underground construction is directly connected with the surface structures;
- underground construction causes significant environmental impacts during the construction stage and during use (e.g. traffic emissions and exhaust gases from sewerage treatment plants).

The basic rule in Finland is that a city plan is required for underground space if the project may be expected to have significant impact on the environment or on land use in the area concerned (see Table 4).

In the *Swedish* contribution, 15 of 30 studied underground constructions were planned with detailed development plans. Two kinds of plans were identified:

1. *New plans*, with zoning regulations applicable for both the surface and to the underground. These plans were often used for single facilities, also regulating their connections to the surface.
2. *Additional regulations to existing plans*. These plans are often used for regulating new infrastructure under built-up areas where changing of existing plans is hardly possible. The problem is that they can only add certain functions to the existing plan, i.e. limiting the deep-level construction rights for the property plans exclusively dealing with the tunnel or cavern.

The *Finnish* report pointed out that different municipalities have different regulations for the planning of underground space. A single set of guidelines and recommendations is called for. The following regulations are the most important ones in Finnish city plans:

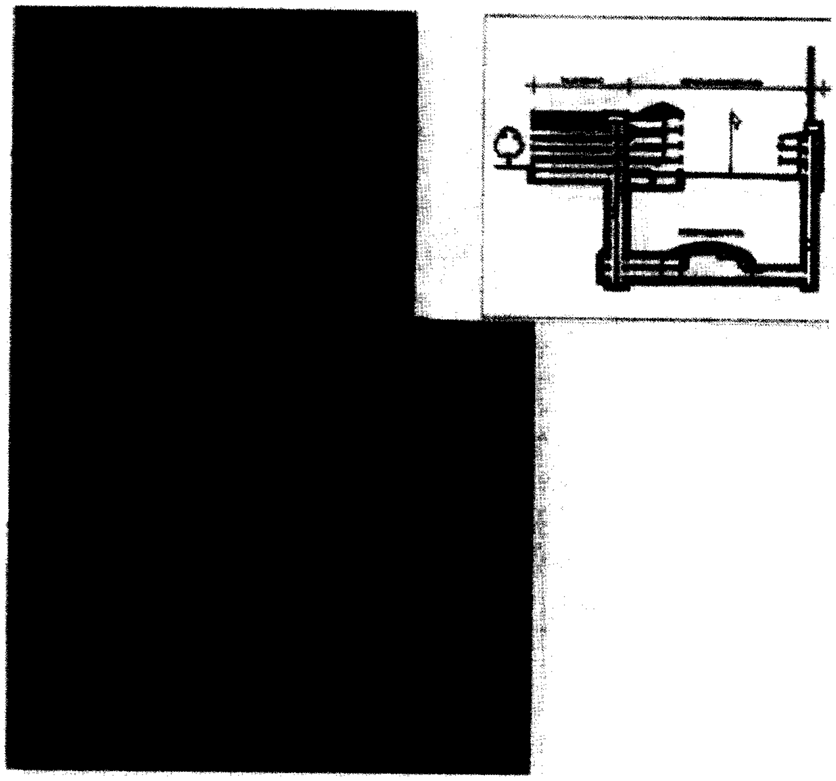

Figure 6. The detailed development plan for a new emergency rescue centre partly under a fire station in Stockholm. The plan restricts the possibility to build under the existing blocks, and by doing so secures space for the underground structure.

1. Regulations related to depth.
2. Functional regulations which concern "underground work spaces."
3. Underground shops and service space.
4. Definition of permitted building volume.
5. Regulations concerning the quality of underground space.
6. Visual and functional aspects of the space.
7. Regulations related to the built environment above ground level.
8. Compatibility with the townscape.
9. Entrances and their location.
10. Vertical shafts and their location.
11. Ventilation ducts and their locations.
12. Regulations concerning environmental impacts.
13. Safety zones.
14. Groundwater table.
15. Noise and vibration.
16. General impacts on the environment.

Stockholm, Sweden, may serve as an example of how regulations in development have adapted to the development of underground construction in Sweden. From the early stages, it was clear that the community's interest in building tunnels was in conflict with the interest of property owners who wanted to extend their basement levels. Thus, in 1958 the City Council decided to limit *Deep-level Construction Rights* in the inner-city by enacting new regulations. These would limit construction deeper than two basement levels underground in order to keep the bedrock free for new tunnels. These regulations were eventually added to the existing plans.

To protect the metro line from damage, a number of *Security Rules* were applied to the new plans. These provided for both a security zone on each side of the metro tunnels and a depth limit on construction for properties above the metro.

The run-off of ground water during the tunnelling and the construction of foundations for new buildings led to damage to existing buildings, streets and surface areas. In the 1970s, there were considerable difficulties in this respect when new metro lines were constructed in bedrock tunnels. Many drainage tunnels through the rock also affected the ground water, giving rise to damage.

A lowest level for *Drainage Operations* was therefore gradually introduced into plans. The bottom of basement floors was not to be below that level. Builders can, however, be granted building permission to build deeper if they can prove that the ground water will not be affected.

Figure 6 shows the development plan for a rescue centre that was built partially underneath a fire station in Stockholm. The plan restricts the possibility to build under the existing blocks, thereby securing space for the underground structure.

Building Permission

In most countries, building permits are required before construction work can start. Table 5 lists the requirements in the countries studied.

When Is Permission Required?

Building permission is required for tunnels and caverns, according to Swedish legislation. Despite this, the *Swedish* study only found a few examples where permission had been granted. Although the legislation is rather new, it also reflects the following problems typically encountered by the municipalities:

1. When is a *tunnel* a *pipe* or a *utility tunnel* and therefore does not require building permission?

Table 5. Requirements for obtaining building permission for tunnels in the countries studied.

Country	Is building permission required by law for tunnels and caverns?
Finland	is required when people are to live or work in the cavern
Turkey	is required
Japan	is required
Czech Rep.	is required
Netherlands	is always required
Italy	is required
Sweden	is required except for mines and metro systems
Australia	–
Norway	is required

2. At what point does a building's *basement* become a *cavern*?

In *Finland*, the results also show variations among different municipalities; different cities have different procedures for the permission procedures. There is a need for a greater consistency. A single set of guidelines and recommendations is called for.

The general requirement in Finland is that underground space is required to have a building permit when people work in that space on a full-time basis and when the construction or use of the space significantly affects the environment or other land-use activities. In the Finnish study, it is proposed that a new clause be added to the Planning and Building Act regarding excavation permits. The purpose of the new clause is to ensure that underground construction is properly supervised and monitored by the relevant authorities.

In some cases, the need for a building permit depends on how the space is defined. For example, in *Italy* there are three different categories of parking construction, each of which requires a different type of permission (see Table 6).

What Do the Permissions Require?

The *Swedish* study noted that the requirements for construction permits often concern safety, escape routes, ground-water issues, noise and vibrations from rail tunnels, etc. The most common questions that have arisen with regard to building permissions concern ground water, safety, and disturbances during and after the construction work.

The conditions set up in the Swedish permissions vary. Sometimes they concern only the routines, e.g. that certain information concerning the building operations must be presented to the municipality. Sometimes the conditions especially concern the fact that the building is located underground. In this case, safety dominates.

Public spaces underground have been especially regulated with regard to fire safety, escape routes and traffic control (if the tunnel is a road tunnel).

Regulations concerning groundwater conditions are also common, i.e. requirements to make the tunnels watertight, and infiltrating the inleaking groundwater so that the groundwater level is not affected.

In *Japan*, building permissions are required, as well as approval from the respective administrative offices. Detailed discussions with the administrations responsible for transport and the utilities are necessary. These discussions relate to how the surface and underground facilities might affect each other. In particular, they consider any negative impacts that the proposed structure might have on the function of existing facilities. In addition they take into account safety, hygiene, disaster prevention, and the environment of the affected area. After presenting countermeasures to help reduce the negative impact, the permission process can proceed and eventually lead to a permission.

How Do the Building Codes Affect Tunnels and Caverns?

In several countries, there seem to be problems applying the building codes for tunnels and caverns.

In *Sweden*, many of the requirements for building above grade, building codes implying fire-walls, etc. are not applicable for underground constructions. The absence of regulations is a problem for those involved in the process.

In *Finland*, the building code regulates the depth of buildings to one basement story, but the number can be increased in the city plan to two and, in exceptional cases, even to three or more.

This is also the case in *Australia*. The Australian contribution recommends that state governments and local authorities should review and modify building codes where appropriate so that they do not unnecessarily inhibit underground use.

Table 6. Examples of license procedures for underground parking construction in Italian cities.

In Italy, three different categories of underground parking construction can be defined:

1. Private parking under private space:
- The permission has no costs
- All the private rights of the neighbourhood must be guaranteed
- Permissions must also be obtained from:
  - the Architectural and Archaeological regional Service
  - the fire department
  - the Unitá Sanitaire Locali (to ensure that all the safety laws are respected)

2. Public construction on public areas (for example, under a street or a square):
- Constructed with public funds or with private funds and with a concession given to the builder for 50-80 years
- All the permissions listed above must be obtained.

3. Private construction under public areas:
- These parking areas are directly linked with the house or office property and cannot be rented. If the house changes ownership, the parking area also must change ownership.

Other needs for amending Australian legislation include the following:

- The building approval legislation and the building code of Australia should also be amended (the building code calls for natural light and ventilation).
- The Workplace Health and Safety laws should continue to be amended, as is being done.

Environmental Assessments

In many countries, an Environmental Impact Assessment (EIA) is required for major projects. In *Finland,* an EIA is required to identify and establish the environmental effects of building of certain types of projects such as motorways, major raw water and waste water tunnels, sewerage treatment plants of a certain size, etc. For certain other projects, an EIA can also be required by the permission granting authority.

The *Czech* submission describes the time required for receiving a permission and the many parties involved in the EIA process. The whole period for getting a permission can take some 155–245 days. The process is described below.

The Czech legislation for environmental impact assessments consists of the following phases:

1. *Publication and discussion of the EIA documentation,* involving both public examination and the State Administrative bodies opinions. The result of this phase is then sent to the competent authority (the Czech Environmental Inspection) within 55 days.
2. *Expert opinion,* ensured by the competent authority. The elaboration period is within 60 days; this period can be extended in reasonable cases, but not for longer than 150 days.
3. *Public discussion and the statement of the competent authority.* Results of the public discussion are included in public minutes. Based on the expert opinion and the minutes of the public discussion, the competent authority issues a statement. Without this, an administrative body cannot issue a permitting decision. This phase is about 40 days.

What Does the EIA include?

The impact of underground space developments on the environment will differ according to the nature and scale of the particular development. Although there are a number of environmental impacts (e.g. blast vibration and archaeological heritage disturbance) and mitigation possibilities (e.g. noise and visual impact) particular to underground development, it is not possible to make a general statement about whether underground development is a "good" or "bad" option in terms of environmental impacts.

According to the *Australian* contribution, all parties involved with environmental assessment should establish from the outside the precautionary principle in the design of underground facilities, by ensuring that *i)* environmental impacts are considered from the outset and *ii)* environmental management practices and safeguards are used to minimise impacts of the project.

General Geotechnical issues

Sufficient and reliable information is required for planning. This is also the case for planning of underground space. Although the geological conditions vary among and within the different countries participating in the working group, all stress the need for good geo-information.

The geo-information available varies widely. In cities, authorities and others have collected more information than is the case in more rural areas. In *Italy,* for example, large cities have collected information from core drillings and underground geological conditions, although a systematic layout of this information has not been adopted all through the nation. Maps of utility tunnels are not compiled as general maps of the tunnels underneath the Italian cities, but rather are held as archives by each utility company.

In *Japan,* three-dimensional soil-structure data systems have been developed by government offices and used in personal computers, and are recently addressed as a part of a GIS (Geographical Information System). The information, primarily intended for specialists in geology, is also used by engineers in charge of ground surveys. The geological survey of Japan (the Ministry of International Trade and Industry) has issued a digital geo-science map composed of a CD-ROM and a printed text.

The Tokyo Metropolitan Government has carried out geological surveys in conjunction with building construction work and urban base improvement undertakings. The extensive information from these surveys is incorporated in a relational data base in a mainframe computer. The system can retrieve and graphically present bore-hole, deep-well, and groundwater data.

In *Sweden,* planning authorities require access to information about the properties of bedrock, soil and groundwater in order to make correct decisions. In the major cities, information about existing tunnels, groundwater levels and quality, foundations of buildings, etc. is maintained by the local authorities.

In *Finland,* the geo-information is provided by soil and bedrock maps, as well as by the topographical maps provided by the Geological Survey of Finland and local authorities. The Geological Survey of Finland has also produced aeronautic low-fly measurements which cover the whole country. The results of these measurements are used in compiling local soil and bedrock maps (see Fig. 7). In some cases, the information is now available in digital formats, thus enabling combination with other information (Vähäaho 1998).

In *Australia,* as is probably the case everywhere, the level of geo-technical investigation is often not adjusted adequately to match the local geological variability and geotechnical risk.

Better Structure for Geo-Information Is Needed

The *Australian* contribution makes some recommendations that probably can be applied internationally. It recommends that state governments and local authorities should collect and collate information on underground geological conditions and existing underground structures, and should interpret this information for use in short- and long-range urban planning.

The further development of information systems for "seeing through the ground" requires the integration of discrete databases and modelling technologies so that user-friendly, three-dimensional underground maps can become a reality. Such maps should include highly detailed 3-D rendering of the geological conditioning in the uppermost 30–60 m beneath an entire urban area. Such development will involve:

- database development, data interchange and identifying minimum data sets for modelling;
- incentives for parties to contribute data and protection against liability for data inaccuracies;
- managing data variation over time on a Geographic Information System (GIS) and with appropriate visualisation.

Recommendations for Subsurface Planning and Mapping

According to this survey, it has been established that the legal framework for the planning of subsurface space is, in many nations, insufficient or even non-existent. It can also be agreed that underground development must be viewed as a means of achieving strategic objectives of a community

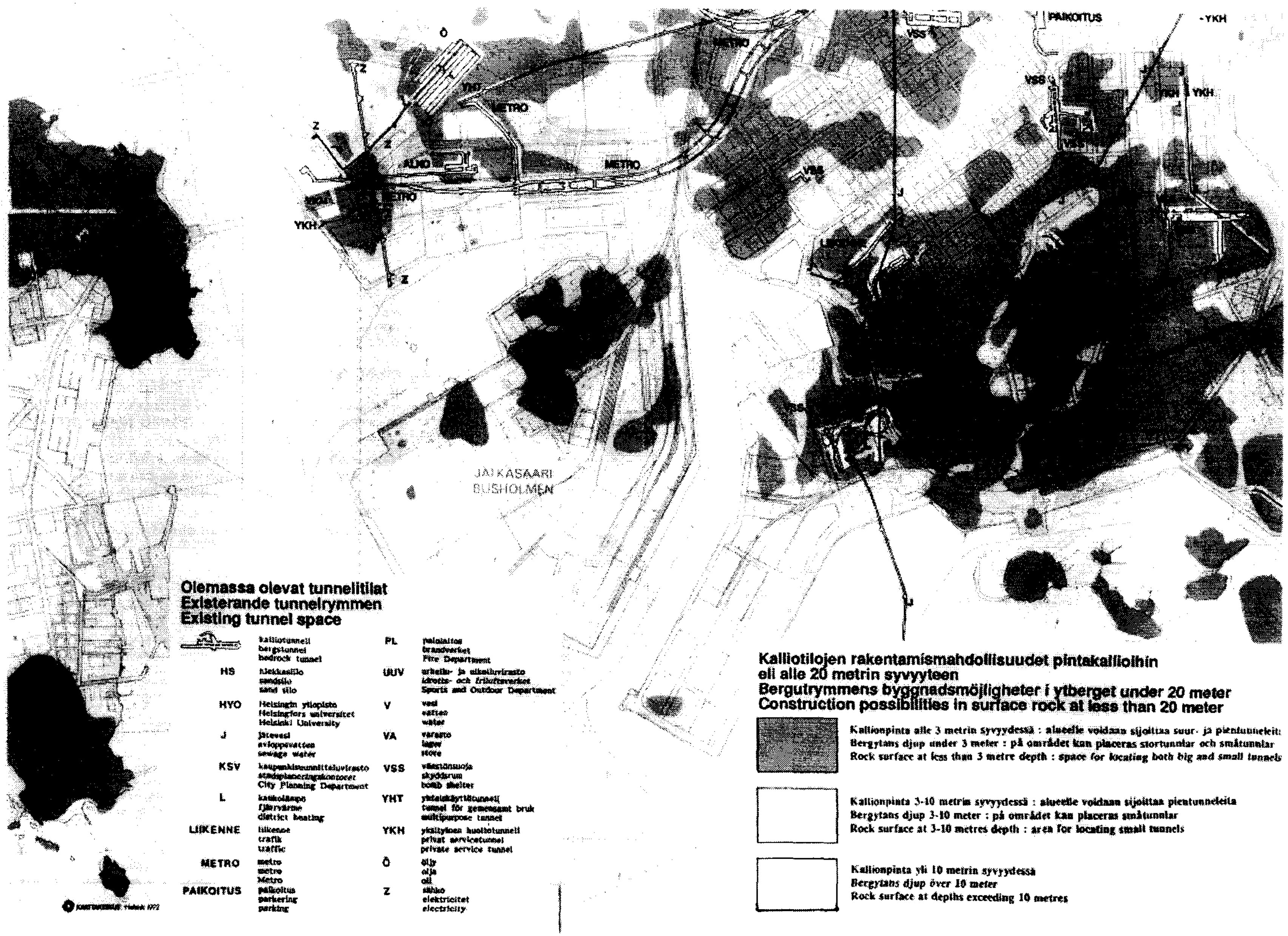

Figure 7. The Finnish capital of Helsinki has special maps describing geotechnical information, tunnels, subsurface structures and groundwater levels for the whole city. This map is a rock resource map of the inner city.

and/or government. In order to accomplish this, the following basic requirements may be suggested for the planning and mapping of underground installations.

National and State Governments

Ownership of subsurface space

It is important that national governments look over the legal framework related to ownership of subsurface space so that the legal responsibilities of owners of underground space and other affected parties are clearly defined. This can be done either by making three-dimensional property possible or by other amendments of existing legislation, so that development of urban underground infrastructure is facilitated.

National support for subsurface solutions

State governments should look at underground space use in major urban areas as a way of reinforcing strategic objectives and enhancing the environmental quality of urban centres and helping maintain its street life—not as "pulling the urban life below ground". There are many ways of stimulating the use of underground space, including the following:

- State governments may foster visions exemplifying the benefits of the underground including reports on environmental, institutional and economical feasibility.
- Because cost is a major barrier to greater use of underground infrastructure solutions, state governments and the private sector should pursue technological development aimed at facilitating cheaper and more risk-free underground construction.

Reform legislation concerning underground planning

The contributions from some countries recommended that state governments should regulate the legal framework for underground construction. Most of the reports from the countries involved in the ITA survey called for increased planning of underground space. The main reason for this is the need for better coordination among the different needs in urban areas. For example, municipalities should reserve corridors for future transport tunnels as done for surface routes. They should also include the possibilities of underground space in cities and major urban areas in their conceptional planning and provide for reservation of this space in their strategic plans. Systems for planning, zoning, reserving and regulating underground space should be developed as well as codes of best practice for layout of transport and utility infrastructure.

It has also been pointed out that state governments should review and modify building codes, where appropriate, so that they do not unnecessarily inhibit underground use.

It is recommended that general national rules or recommendations be established for the protection of the environment, maintenance of groundwater levels etc. In sensitive areas (e.g. of archeological importance), special directions would be called for.

Local Authorities (Cities, Communities, Municipalities)

Many of the national contributions focused on the need for better coordination and planning of the use of the space below our cities. In some cities, the extensive use of the underground has led to a growing congestion below the surface, similar to the congestion already existing on the surface.

As stated earlier in this report, development of underground space is becoming more and more interesting. Increases in the use of the underground for major transport projects and the rise in the number of private utility providers highlights the importance of underground planning for cities and urban areas. It is obvious that underground space is not an infinite resource, and its use must be managed carefully and professionally. Local authorities should therefore better coordinate the different uses and needs of underground space, by viewing it as a means to improve the infrastructure in a long-term planning.

Local authorities may adopt a plan for underground space that covers the whole municipality—i.e. a strategic plan of the underground—to provide a policy framework for decisions relating to the future subsurface uses of the area.

Local authorities should collect and collate information on underground geological conditions, existing underground structures and available underground space. They should interpret this information for use in short- and long-range urban planning, and should consult it when new underground installations in the area are being discussed.

Different cities have different procedures for the permission procedures. There is a need for a greater consistency. A single, nationwide set of guidelines and recommendations is called for.

Specific aspects of planning an underground installation

Particularly in a major underground project, decision-making may often be divided among many "hands" (public/local authorities, clients, owners etc). To achieve harmonization and synchronization of legal procedures concerning decision-making, it is recommended that a detailed *organization scheme* be developed at the early phase of the project with representatives from all of the concerned parties. This would result in shorter "communication-ways" for a decision and, if necessary, would facilitate any amendments that are called for in the regulations for the implementation of the project.

At all times of planning an underground installation, national legislation must be consulted concerning the rights of ownership, water legislation, environmental protection, and other related national legislation.

National Groups of the ITA

National groups of the International Tunnelling Association should actively inform their governments and local authorities about the potential of underground space in infrastructural planning, in particular in densely populated areas. They should also work to reform existing legislation so that the planning of underground space is both facilitated and executed in such a way that the various subsurface uses are well coordinated. This may be done through visits and seminars and should give reference to reports compiled by the Working Groups of the ITA.

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