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ATTACHMENT C
Studies on the Effects of Utility Cuts

Indirect costs of Utility Placement and Repair Beneath Streets, University of Minnesota, Raymond L. Sterling, Report No. 94-20

The Effect of Utility Cuts on the Service Life of Pavements in San Francisco, Volume I: Study Procedure and Findings, Ghassan Tarakji, PH.D, P.E., Final Report, May 1995

Estimated Pavement Cut Surcharge Fees For the City of Anaheim, California Arterial Highway and Local Streets, IMS Infrastructure Management Services, Inc., December 9, 1994

The Effects of Utility Cut Patching on Pavement Performance in Phoenix, Arizona, Project 499, City of Phoenix, July 18, 1990

Impact of Utility Cuts on Performance of Street Pavements, Final Report, Andrew Bodocsi, Prahlad D. Pant, Ahmet E. Aktan, Rajagopal S. Arudi, Cincinnati Infrastructure Institute, Department of Civil & Environmental Engineering, University of Cincinnati, 1995

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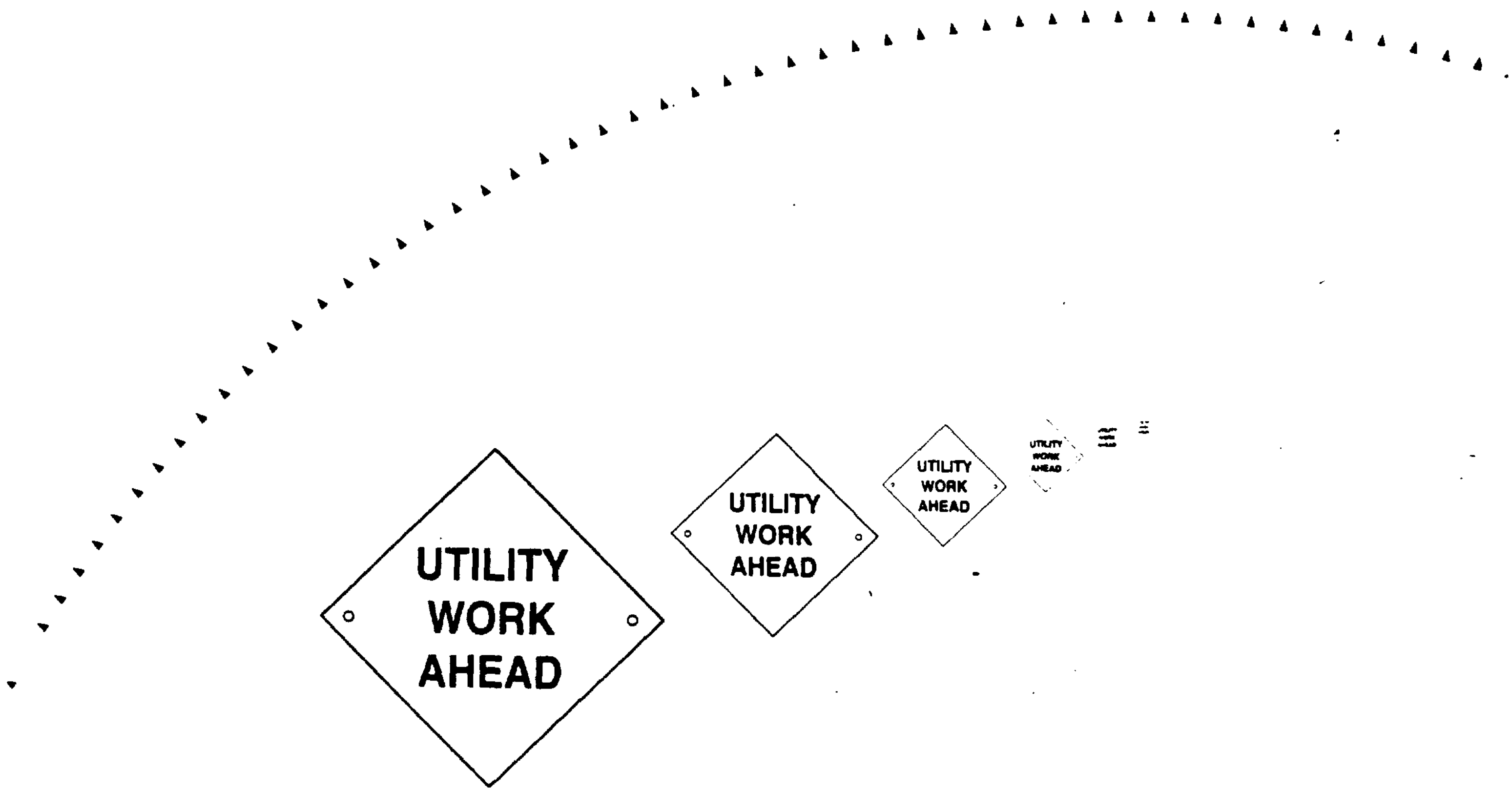

Indirect Costs of Utility Placement and Repair Beneath Streets

MINNESOTA DEPARTMENT OF TRANSPORTATION

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Indirect Costs of Utility Placement and Repair Beneath Streets

FINAL REPORT

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The report examines policy issues related to the placement of utilities beneath public rights-of-way. The principal issues discussed are: recognition of the present and future value of the space beneath public rights-of-way in space allocation decisions, methodologies for assessing the full societal costs of utility work in congested roadways, implementation of contractual practices and fee structures to mitigate conditions involving high societal costs, and the work that would be necessary to attempt to include the impact of utility cuts on life-cycle pavement costs.

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Executive Summary

The report examines policy issues related to the placement of utilities beneath public rights-of-way. The principal issues discussed are: recognition of the present and future value of the space beneath public rights-of-way in space allocation decisions, methodologies for assessing the full societal costs of utility work in congested roadways, implementation of contractual practices and fee structures to mitigate conditions involving high societal costs, and the work that would be necessary to attempt to include the impact of utility cuts on life-cycle pavement costs.

The report establishes the potential importance of including the value of land in both specific project decisions involving the space beneath public-rights-of-way and also in strategic decision-making about future needs for the space as a town or city grows.

The report also summarizes the issues involved and the current state-of-practice of assessing full societal costs in decision-making about utility work in streets and highways. Procedures exist in FHWA guidelines for calculating indirect costs due to several of the factors involved but there remain several issues to be resolved:

- The existing procedures for calculating the indirect costs of time delay, increases in vehicle operating cost and increased accident rates are most readily applied in well defined traffic conditions - for instance, on isolated highways. The procedures are difficult to apply on urban streets because of the difficulty of estimating the time delays caused by utility work due to the multitude of potential alternative traffic routes for avoiding any congestion. For urban streets, the method will be most useful if areas are rated according to their potential for societal impacts caused by utility work. This rating would then affect how the utility projects would be reviewed, the fees assigned for street occupance and/or whether lane rental type fees were included in project bid documents. Specific configurations of work may demand variations in the fees assessed, e.g. work in or near intersections, or partial versus full lane closure.

- Another major issue to be resolved is the creation of a database to answer the question of the impact of utility pavement cuts on the life cycle cost of streets and highways. This issue could not be resolved within the context of this preliminary study.

- The emergence of microtunneling and other "trenchless" technologies as alternatives to the continuous cutting of streets for the installation and repair of utility systems offers a real alternative which is growing rapidly in use and progressively reducing in cost relative to conventional methods. These methods usually can offer lower societal impacts than conventional methods of construction and repair - they are the public works equivalent of microsurgery. It is the contention of this report that, to the extent feasible, societal costs should be included in decisions made about technologies to be used in a project or that the incentives to use methods with the lowest total societal be built into the contract documents for work that is bid.

The future implementation of the findings of this report will require the acceptance of these principles by utility engineers and those responsible for the care and use of streets and highways. More data is needed in some instances to fully apply the methods, e.g. the impact on the life-cycle cost of the pavement, but, in general, the principles and contracting practices necessary to incorporate such factors into decision-making already are established.

Specifically, further work is recommended in three areas:

- The development of a database to answer the question of the impact of utility pavement cuts on the life cycle cost of streets and highways. This issue has been raised with two Transportation Research Board Committees in the form of a research needs statement.

- The development of an expanded methodology from that which currently exists in the guidance from FHWA on user costs. Additional societal cost issues need to be included and a procedure for assessing such costs in an urban area needs to be defined. This work can build on the procedures outlined from the studies conducted in the U.K. Case examples would need to be developed to show how the procedures would be implemented under several typical conditions.

- The development of planning and review procedures to encourage the best utilization of the public underground space resource. The advent of remote-guided microtunneling techniques can solve some of the immediate indirect societal cost problems for utility repair and installation but their use increases the importance of long-range planning because of the reduced constraints on location, and especially depth, afforded by the remote installation techniques. This issue should be addressed now before the tangled maze of utilities now present beneath just beneath our streets extends to much greater depths beneath our urban areas. Since long-term policy and planning issues must be compared to immediate cost implications, case examples of the observed or potential long-range costs impacts for particular cities or towns will be needed to provide definitive examples of the future significance of planning efforts.

> *The maze of interlacing pipes and cables embedded beneath streets has been construed as arising from a total lack of foresight on behalf of city authorities and a lack of good manners on behalf of utilities. The first takes the best place and later users must accommodate to this. Such attitudes may be considered understandable during early development when the extent of future uses was not necessarily contemplated. It is not so today (Duffaut and Labbé, 1992).*

Chapter 1
Introduction

1.1 Background

An urban area requires the provision of many services to businesses, homes and public facilities. These services may include water, sewer, electricity, gas, telephone, other cable services, district heating and district cooling. Most of these services are placed underground and most beneath public streets and highways. Placement of these utilities underground offers the provision of large service networks more or less invisibly across the urban area and provides physical and environmental protection for the services.

Problems with underground services appear when further work is required on the system in order to make new connections, provide a system expansion, or carry out utility repair, replacement or renovation. The need for street access for installation and repair of utilities provides a continuing interplay between the needs for utilities to be installed and maintained and other public interests in:

- the minimization of the total societal costs of utility work
- the effective management of the public space beneath public rights of way
- the mitigation of traffic congestion
- the management of total life-cycle costs of street and highway pavements

This report examines these questions and continues a discussion of whether the overall public "good" is best served by the manner in which decisions are currently made about the placement of utilities beneath public streets and the construction alternatives chosen for installation and repair.

The implicit assumptions which govern the current placement and maintenance of utility systems beneath public rights-of-way are being questioned as the impact of such work increases, public expectations for environment controls rise, and alternative less-intrusive methods of construction and repair become available. In the past, the traffic intensities were lower than today, traffic could more easily be diverted and the public was more accepting of the inconvenience of road works -- with little question as to the relationship of their delay to the manner in which the utilities were laid out or being repaired.

These issues have been raised in many countries in the past ten to fifteen years. For example:

> *During the next decade, construction of new highway facilities will be less intensive than in the recent past. Instead, reconstruction and maintenance activities will increase. As these activities increase, correspondingly higher traffic volumes will be affected. Therefore, improving safety and minimizing negative economic and*

environmental impacts of work zones will be become more critical than ever (FHWA, 1981).

Should the general public be entitled to demand that preventative maintenance, replacement or renovation are carried out with the overall economy in mind and not that of the particular undertaker? In the long run it is the public who pays for the works on the country's infrastructure - either directly through charges/taxes or indirectly(Read and Vickridge, 1990).

A related question, less commonly addressed is that the underground space beneath public rights-of-way is public resource which has value. The tradition of using this space for utility placement on a first-come, first-served basis or on a utility corridor basis can greatly degrade the value of the resource in solving future societal needs. This topic and the issues posed by such considerations are examined in Chapter 2.

1.2 The Size of the Problem

The magnitude of the U.S. investment in underground utility infrastructure is enormous; the approximate mileage of the existing U.S. utility network in 1989 was as follows (Kramer et al, 1992):

Electricity:	595,500 km (370,000 miles) of underground distribution cables
Natural gas:	1,448,400 km (900,000 miles) of distribution mains and 965,600 km (600,000 miles) of distribution services
Sewers:	965,600 km (600,000 miles) of collector sewers with 600,000 lateral connections
Telephone:	418,400 km (260,000 miles) of direct buried cables and 482,800 km (300,000 miles) of cable in conduit
Water:	724,200 km (450,000 miles) of distribution pipe

In the U.K., where much of the research regarding the indirect costs of utility work has been carried out, the length of underground utility mains was estimated in 1983 to be 1.65 million kilometers compared to the length of the road network of 0.34 million kilometers (Dept. of Transport, 1985 in Bristow and Ling, 1989). The U.K. road network carries an estimated 68 vehicles per kilometer of road. The Confederation of British Industries has estimated that the overall cost of traffic congestion in the UK's urban conurbations has reached UK£3 billion per year (approximately US$4.5 billion). It also has been estimated that there are over 2 million road openings a year by utilities in the U.K, representing an average of about 5.6 openings per kilometer of road per year (Vickridge et al., 1992).

In the U.S., the impact of utility work on traffic congestion varies greatly across the country. The most affected sites are those with a road network already at or close to capacity during peak hours and few acceptable alternatives to reroute traffic away from the affected stretch of roadway. Less densely populated cities with wider streets and a grid-pattern street layout (typical of many newer western and mid-western cities tend to be less affected.

1.3 Estimating The Total Societal Costs of Utility Construction and Repair

The total societal costs of construction, maintenance, repair or upgrading of utilities include the indirect as well as the direct costs of such work. The indirect costs include costs of social and economic disruption to road users and neighboring property owners and any additional costs that must be borne by other public works providers or agencies of government because of negative impacts of the work on their facilities or responsibilities.

> *Congestion costs result in substantial economic losses. A report by the Texas Transportation Institute 1989 Roadway Congestion Estimates and Trends estimates that in 1989 the total cost of congestion for 50 urban areas studied was approximately $39.1 billion. Delay accounted for approximately 85 percent of the cost and excess fuel consumption for approximately 15 percent (FHWA 1993).*

> *The public utilities right to break open the highway in order to lay, repair, alter or remove apparatus dates back to a series of nineteenth century acts of parliament...There is now a high level of conflict between the needs of the utilities on one hand and the needs of the road users on the other (Bristow and Ling, 1989).*

The direct costs of utility work are those which are paid for as part of the contract price and other direct costs to the agency or utility for whom the work is being carried -- the costs that would enter into a direct financial analysis of construction or repair alternatives. These costs include those for the excavation and backfilling of the trench, the costs of pipes and pipelaying, the costs of street pavement reinstatement and the direct costs of providing any utility or traffic diversions/control to allow the work to be carried out.

The indirect costs are those which caused by the project but which are not paid directly by the agency or utility for whom the work is being carried out. These costs include those for traffic affected by the utility work, temporary environmental impacts, safety impacts, damage to the street pavement caused by the utility cut and economic losses to neighboring business affected by the utility work. A more complete list is provided in Chapter 3.

Where the above problems have become severe, this has lead to a search for possible alternatives or modifications to the way in which utilities are currently constructed and serviced.

1.4 Issues Raised by the Availability of Trenchless Technologies

The availability of trenchless techniques for repairing and installing utilities with only limited access from the surface provides an important alternative to traditional trenching techniques for installing and maintaining utilities. Often, however, for shallow utilities, these techniques suffer from higher first costs than the alternative technique of trenching from the surface. In order to lower the overall cost to the public of maintaining both utilities and road pavements, it is necessary to have a means of estimating the cost of different levels of street or highway occupance and the statistical impact of a road cut on the life cycle cost of a pavement. When calculated or established, these indirect costs can be applied to utility construction or repair decisions in the same way as congestion costs and accident costs are applied to current highway alignment decisions -- the savings to society are included in the decision-making process for the selection of alternatives even though the costs are not directly paid by the agency making the decision. The procedures for doing such analyses are well established but, for some of the indirect costs, the database currently is insufficient to establish the necessary correlations between differences in construction or repair procedures and specific indirect costs.

In most cases, it can be shown that "trenchless" technologies or microtunneling only provide lower initial costs than trenching for construction or repair if the depth to the utility in question is greater than a certain depth (dependent on local site conditions and termed the "break-even cost depth." Figure 1 illustrates a summary comparison of break-even depth for sewer construction based on 16 contract bids in Northumbria, U.K. between 1970 and 1981 (Norgrove and Reilly, 1990). The break-even depth spans a range of depths depending on site conditions and the diameter of the pipe. Break-even depths varied from 8-16 m for 150 mm sewers through 8-9 m for 1000 mm diameter sewers to 4-7 m for 2130 mm diameter sewers. Below the breakeven depth, trenchless construction is already cheaper than open trenching in direct costs and indirect costs only come into the analysis as far as selecting options of where to provide access shafts for the construction and how to further mitigate construction disruption. Above the break-even depth, however, the direct cost for trenched construction is lower and the question becomes important as to what indirect penalties are involved in choosing this lowest direct cost alternative. Even though the trend over the past several years has been for the break-even depths between trenched and trenchless construction to become shallower as the technology for trenchless construction has been in a period of rapid development, the value of the technology to reduce overall societal costs for utility work is clearly not being fully realized.

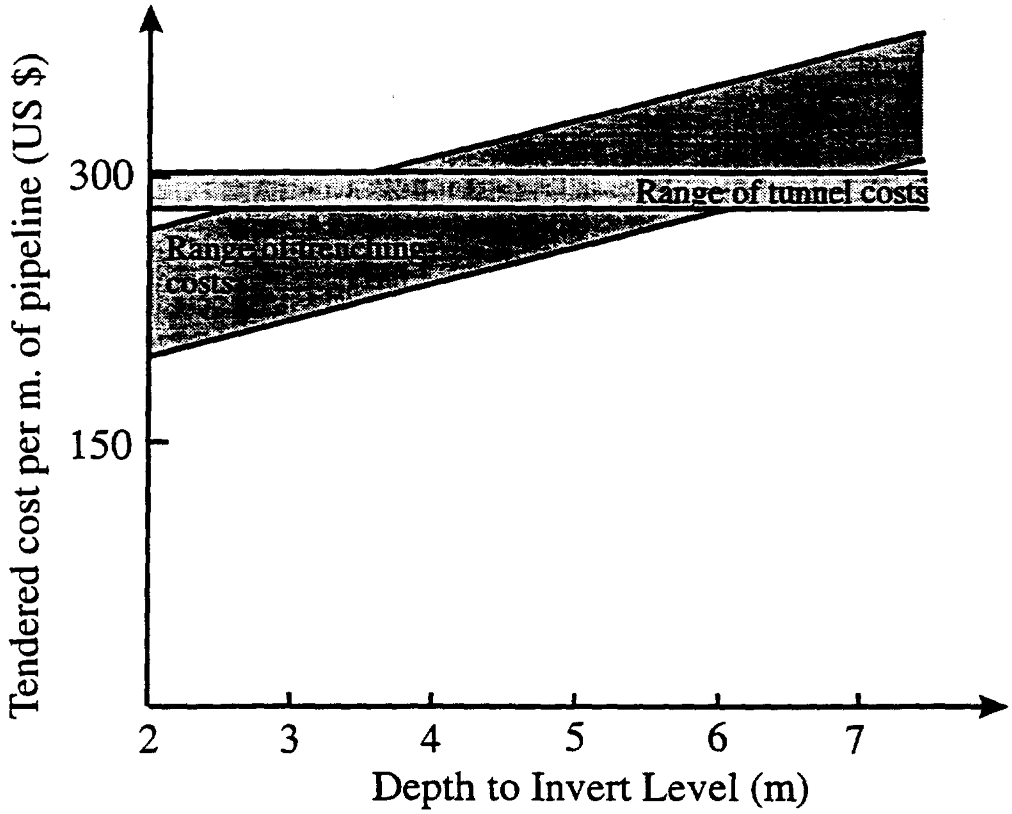

Figure 1 Breakeven Depth for Trenchless Methods in Sewer Construction

Chapter 2
Value of Land Beneath Public Streets

2.1 Background

Land in most countries of the world is available for private ownership. Also, in most countries, ownership of the land surface carries with it ownership of the underground region beneath and ownership of the air space above the specified surface land area. This ownership usually extends downwards to the center of the earth but upwards only as far as reasonable use of the space can be made. The latter restriction on the upward extent of the space reserved by surface land ownership came after the spread of aviation and was introduced to avoid the condition of trespass every time an aeroplane flew over private property (Thomas, 1979). A recent survey of the legal and administrative controls on the use of underground space carried out by the International Tunnelling Association found that, with a few notable exceptions, most countries had similar laws governing the ownership and regulation of underground space (ITA, 1990).

The presence of valuable minerals or fluids in the ground considerably complicates the issues involved. To encourage the recovery of valuable minerals, mineral rights can be sold to another party than the landowner who then has the right to carry out mining to recover the minerals. This has led to many lawsuits about damage to the land surface caused by mining and who might own the underground mined-out space left following mineral recovery. Fluid resources beneath property present even more difficult issues since the resource is not fixed in place and can move across property boundaries during pumping for recovery.

Although such issues surrounding property rights for underground space are of general interest to this study, the principal issue of concern in this report is whether underground space beneath public rights-of-way has its own intrinsic value which should be taken account of in decisions about how such space should be used for the public "good."

The monetary value of most land and other resources in the U.S. are determined by the price at which the resource will trade. The value is affected by the desirability of a particular location, the economic potential of the land or its location and the effect of any government restrictions or incentives which may affect the use of the land. Since the public land used for street and highway right-of-ways is seldom traded, its value is usually not as readily determined.

One can assume, in general, that as the value of tradeable land increases, the intrinsic value of adjacent public or non-tradeable land also increases (this relationship being modified by the extent to which the public land is necessary for access, service or amenity to allow the private land to hold its value). As the price of land has risen rapidly, some major cities of the world (notably in Japan and southeast Asia), interest has been generated in minimizing costs for new facilities or generating additional economic returns by utilizing underground space beneath both public and private land.

A 1978 World Bank paper reports that the issue that the price of land is "too high" or is rising "too fast" is a common complaint in cities with limited land area. The reports states that *"....if one retains the same boundaries of a city and if that city is growing, the assertion that average land prices are increasing rapidly is neither surprising nor very interesting.* ***Such increases are necessary for the efficient allocation of space."*** *(World Bank, 1978, p 67).*

The relationship that price plays in the conservation and efficient allocation of a resource is an important one. As land in a city becomes more expensive and space for new facilities more scarce, the waste of space or land in inefficient allocation carries with it a loss of "opportunity cost." Again, from the World Bank report:

> *"The cost of land plays an important role in many decisions by both governments and private agents. In order to delineate the consequences of decisions to use land for specified purposes, one must measure costs in terms of the output of useful goods and services that would be foregone; this is then the true cost or opportunity cost of the land." (World Bank, 1978, p73)*

> *"The critical attribute of land that distinguishes it from most other resources is that, with minor exceptions, it is non-reproducible. If land is extraordinarily valuable in the center of a city, one cannot devote resources to produce more of that valuable land; amount must be taken as given. The only recourse is to make different uses of the existing stock of land.* ***Hence there is the desiderata that land should be employed in its most valuable use"*** *(World Bank, 1978, p73).*

In a discussion of the interaction of project and land opportunity costs for an imaginary new port in a developing country, the World Bank observes that land in the area of the port which had a low value prior to port construction will sustain a large rise in value when the port is finished. *"Thus, there are two opportunity costs of land -- one without the project and one with the project completed."* The question of whether the port is worthwhile or should be at that location is answered using the without-project opportunity cost of the land. The other question of whether the port has the right amount of land also must be answered because there may be technologies which can trade land for additional capital. In this tradeoff, *"one should make the port compete with other with-project land uses."* The first decision is a decision on a "lumpy" investment. In the second case, a "marginal" investment of additional land versus additional capital cost is being considered. *"In principle, one should find the most efficient configuration of the port before asking whether it is worthwhile to build it."*

The above general comments on utilizing land effectively as a resource and maximizing its opportunity value can now be related to how we make decisions about the utilization of underground space - especially beneath public rights-of-way.

In a study of the value of urban underground land, Pasqual and Riera (1990) state:

> *"A great deal of resources are devoted to implementing a whole variety of projects in subsurface land. Studies are usually undertaken to identify the optimal allocation of thos^ resources. Thus, in the decision making process, public administration takes into account all sorts of costs and benefits in order to achieve the best cost effectiveness of the investment. However, there seems to be one relevant cost constantly ignored in such studies: the price of the underground land consumed by the project."*

Regarding the reasons that the value of subsurface land has been ignored, Pasqual and Riera suggest:

- There is no specific market for subsurface land
- Developers usually ignore the opportunity cost of additional underground development
- Rights to underground land are bought and sold with the rights to surface land area and thus there is no financial link to the use or misuse of subsurface space
- Historically, the expectation of the need for using underground space was small compared to the amount that existed and underground space was thus usually treated as a "free good"
- Utilities were often granted free use of the space beneath public streets on the basis of public good and a lack of competing demands for the space
- Because there is no specific market, the price of underground space is not obvious
- If the price is not obvious, it is difficult to include the value in cost-benefit analyses

If the value of underground space is not considered in cost-benefit analyses involving underground facilities, the analyses may not provide the optimal solution among several alternatives or the correct answer to whether a project has a net benefit or cost. Of particular relevance to utility placement is that more of the resource of underground space may be consumed than is justified when there are competing technologies or configurations available which use less underground space overall or less valuable underground space at greater depths. In the absence of strict planning controls, the treating of underground space as a "free good" can and has resulted in a chaotic use of the underground. In Tokyo, city planners are looking to layers of underground space at depths of 50 m or more to find zones which are clear enough from existing structures to allow substantial new infrastructure facilities to be built. Perhaps, as in all major cities, this need to go deep for new facilities could be mitigated with better long-range planning and better accounting of the value of the resource usurped by earlier structures.

2.2 Value of Land in Public Rights-of-Way

It is perhaps of interest to estimate in broad terms what the total value of the land in public rights-of-way might be in a major city even though that value could never be realized in direct sale because access and services are necessary for the land to have significant economic value. Localized values are important, however, if land in the public-right-of-way is sold or traded with regard to a specific development. In small parcels, the value of the public land should approach the value of the adjacent private land.

Consider a hypothetical downtown city grid - as illustrated in Figure 2. A one-square block area with a block size of 100 m by 100 m (330 ft. by 330 ft.) together with the appropriate portion of 21.4 m (70 ft.) wide rights-of-way which separate the blocks is shown in the shaded portion of Figure 2. This shaded portion is made up of 10,117 m² (108,900 ft²) of block area and 4,747 m² (51,100 ft²) of street right-of-way. If the value of the public right-of-way were assumed to be equal to the adjacent private property, then the value of the public land area would be 47 percent of the value of private land area for the single block. If the value of land in the downtown area is assumed to be $4.65 per m² ($50 per ft²) , [the estimated 1988/89 market values of 7 downtown city blocks in Minneapolis considered for a new Hennepin County Safety Facility were $10.2 million, $12.9 million, $10.7 million, $5.4 million, $15 million, $4.7 million and $6.3 million respectively - all representing higher values than the figure chosen] then the value of the block itself would be $5.45 million and that of the adjacent right-of-way $2.56 million.

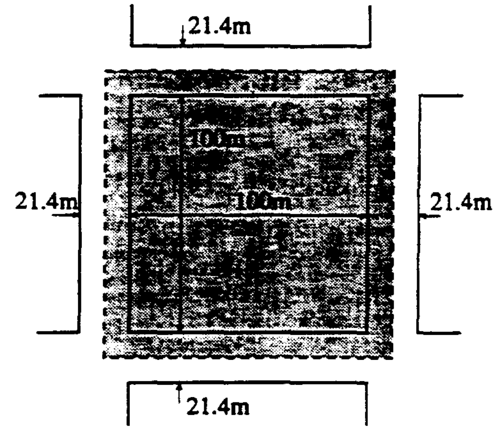

Figure 2 Plan of Downtown City Block

Over a downtown area of 2.59 sq. km (1 sq. mile), the total value of the public right-of-way would be approximately $446 million ($172 million per sq. km.). For residential blocks with an average block size of 152 m by 91 m (500 ft. by 300 ft.) and 15 m (50 ft.) rights-of-way (see Figure 3), the block area is 13,935 m² (150,000 ft²) and the associated right-of-way area is 3,948 m² (42,500 ft²). If an average value of $5 per ft² were taken for residential blocks (equivalent to a lot price of $37,500 for a lot 15 m by 45 m (50 ft. by 150 ft.)), then the above assumptions would lead to value of the public right-of-way in each square kilometer of residential area of $11.89 million ($30.8 million per sq. mile). Taking the City of Minneapolis (152 sq. km. or 37,568 acres in total area - City of Minneapolis, 1981 - see Table 1) as an example for which the above assumptions are reasonable , the total value of public rights-of-way could be said to be as high as $2.2 billion. This figure is derived from taking a downtown area of 2.59 sq. km. at the $4.65 per m² land value, the remaining area of commercial and industrial properties (14.6 sq. km. at $0.93 per m² and all remaining areas (107.6 sq. km.) including residential areas (53.6 sq. km.) but excluding water (9.5 sq. km.) and social-cultural (17.7 sq. km.) at $0.46 per m². Multiplying these areas by the assumed average values for public right-of-way in each square kilometer respectively gives a total value of $2.23 billion.

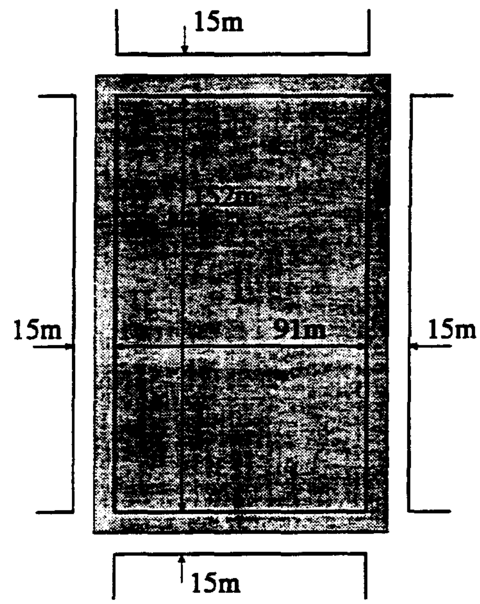

Figure 3 Plan of Residential City Block

Using the area of streets and alleys in the 1981 report (35.9 sq. km.) the figure of \$2.2 billion would imply an average land value for the streets and alleys of \$61 per m^2 or \$5.70 per ft^2.

Table 1 Distribution of Land Utilization in Minneapolis (1981)

	Sq. Km.	Percent of Total
Residential	53.59	35.0
Commercial	9.26	6.0
Industrial	7.93	5.0
Social-Cultural	17.69	11.0
Transportation	4.59	3.0
Streets and Alleys	35.90	23.0
Miscellaneous	0.97	0.6
Utilities	0.21	0.1
Vacant	3.31	2.0
Water	9.47	6.0
Other	9.08	6.0
TOTAL	152.04	

Includes recreation, open space, educational uses and cemeteries
Source: "State of the City 1981, "Minneapolis Planning Department, December 1981.

2.3 Discussion on the Monetary Value of Underground Space

The value of land, of course, varies from country to country, city to city and from city to small town. In some parts of the world, urban land prices have risen so high as to severely curtail the provision of new infrastructure which cannot be accommodated within existing public rights-of-way. Tokyo, as the extreme example, has localized land prices which reached \$500,000 per m^2 (\$50,000 per ft^2) in 1988 (Kuwabara 1988). This should not be considered representative of densely-populated major business centers, however. Hong Kong with much less land area and much higher land use densities had a maximum land value of \$14,000 per m^2 (\$1,400 per ft^2) in 1989 (Vail 1989) and downtown New York had a maximum land value of around \$25,000 per m^2 (\$2,500 per ft^2) in 1989 (Downes 1989).

The cost of land in Tokyo has reached the point where the cost of land required for a new public works project can exceed 95 percent of the total cost of the project. Such high land prices cause a substantial dislocation in the way public agencies think about the provision of new facilities. Legislation has been introduced into the Japanese Diet to alter land ownership under Tokyo. The central element of the legislation would be to make underground space below 50 m (164 ft.) public property and thus avoid the separate condemnation and purchase of easements beneath private land. Also, one finds in Japan many shopping centers and public parking facilities constructed beneath the public streets at major commercial centers. Such construction allows the provision of needed facilities in locations where new surface land is unavailable and where the cost of private land is prohibitive.

Despite the ability to avoid the cost of the purchase of private land, however, the construction of major new facilities beneath streets in heavily-used commercial districts is fraught with many difficulties - disruption to the existing neighborhood during construction, relocation of existing utilities, etc. and damage to streets. These questions will be addressed later in the report but in this chapter, one issue will be focussed on - does the fact that public agencies and utilities do not have to pay for utilizing the public space beneath rights-of-way mean that the space should be administered as if it has no value and no impact on the long-term development of the urban area. In effect, this is what often happens at present - current projects to be placed beneath streets are laid out and constructed on the basis of avoiding existing utilities, maintaining access for future repair, minimizing damage to boulevard trees, and where possible following utility layout corridors which have been set up to reduce future utility conflicts and accidental damage due to unknown location. These issues present difficult problems to resolve, especially in older portions of cities with narrower streets and a longer history of utility development. The nature of the decisions currently made however do not consider substantially alternate uses of the space which may be desirable later in the growth of the urban area.

The alternate uses may include:

- Underground pedestrian connections - these require less change of elevation for pedestrians than skyways across streets, they do not visually interfere with the aesthetics of the existing streetscape and they make a more convenient circulation system for cities with an underground transit system. The reason pedestrian tunnels are not built more often has mainly to do with the expense of relocating the existing utilities to accommodate the tunnel. Other reasons may include poor personal security in uncontrolled pedestrian tunnels and the greater ease of wayfinding in a skyway system.

- Public or private facilities needed in a particular area for which there is no longer any private land available - this is less of a problem in U.S. cities than in Japan or Europe because land costs are lower, there are fewer historical districts which require preservation, and planning restrictions are generally less severe. These needs can result in parking structures and shopping centers beneath streets and plazas in central cities.

The value of underground space beneath private land depends on several factors:

1. Are mineral resources of value involved?
2. Will normal use of the surface land be affected?
3. Will the construction of future structures be limited by any underground use?
4. How accessible is the underground zone?
5. Is it likely that this zone would or could be developed by the current owner?
6. What is the cost of developing the underground zone?
7. Is the actual underground space utilized dependent for its stability on an undisturbed zone of ground around the opening?
8. Is there an psychological impact on land value from partial undermining?

If the issue of mineral resources is neglected, factors 2 through 5 indicate that the value of underground space should tend to decrease with increasing depth and decreasing impact on surface uses. If the land surface is effectively usurped, then one would expect the cost of the underground space to equal the full cost of the surface land required. With decreasing impact on the current and future uses to which the surface land may be put, the loss in land value to the owner of the surface land diminishes. Such a decreasing impact may be expected to occur with increasing depth. Also, the owner is less likely to want to or to be able to develop the underground space at greater depths. For the developer of the underground space, the principal issues are 4 and 6. The underground space is not useful if it is not accessible and the price the developer is willing to pay for the right to the space will be related to the cost to develop the underground zone in question. If other costs are fixed, cheaper construction costs will allow a higher price to be paid for the space. Construction costs generally will tend to increase with depth below ground reinforcing the other factors mentioned above. This will not always be the case, however. In cases where different geological formations provide substantially different costs for excavation and support of underground openings, costs to construct underground space may be less in favorable geological formations at greater depth than in poorer shallow conditions. This lower construction cost may result in an increase in the value of underground space within this favorable zone. An analysis and discussion of the interaction between land cost and the cost/benefit analysis for underground versus aboveground buildings is provided in Carmody and Sterling (1993).

When considering the cost of an easement or land purchase for underground development it is important to take into account any additional ground or land area required for the support of the underground excavation made. Many underground structures are designed based on the interaction of the structure and the surrounding ground and it may not be possible to build a new structure immediately adjacent to the previously constructed facility without extensive strengthening work. This restriction on the future use of the ground surrounding the current use should be included in calculating the value of the easement and it should be clear whether the value assigned is for the actual area occupied below ground or the total area necessary to maintain the stability of the structure.

There also may be cost impacts on the value of surface land due to underground easements which are not as readily determined. When easements are created or underground structures exist beneath a property, there may be an impact on land value due to a fear of loss of support or the added complications in the title to the land. Such concerns are likely to be more prevalent for residential properties than for commercial or public properties.

2.4 Examples of Valuations for Underground Easements

A few examples of the valuation of underground easements exist from countries around the world that have wrestled with this problem are shown in Figure 4. Examples from Belgium, France, and Germany taken from the ITA report (1990) are graphed against depth for comparison.

As can be seen, there is no consensus on the change of value of an underground easement with depth. The differences are more than can be expected due to the different geological conditions (types of soil or rock and level of the groundwater table) which may be present in each area which may inhibit underground construction and thus reduce the value of the underground space. They reflect the inherent difficulty in assessing a value for a commodity for which there is only a limited market and for which the decisions on value are make by public authorities or the courts.

Some countries have used administrative procedures or legal decisions to assign only a nominal value to underground space below a certain depth when usurped for public purposes (Sweden, for example). In most cases, these actions are also aimed at speeding the granting of easements for tunnel or utility projects that must cross many private properties.

If one accepts the premise that space beneath public rights-of-way has value and that there may be future "higher" uses for the shallow underground in urban areas than for a maze of utilities, then it is important to try to understand what, if anything, should be done to change the way in which utility placement is planned and executed to take account of the value of the space which is being occupied.

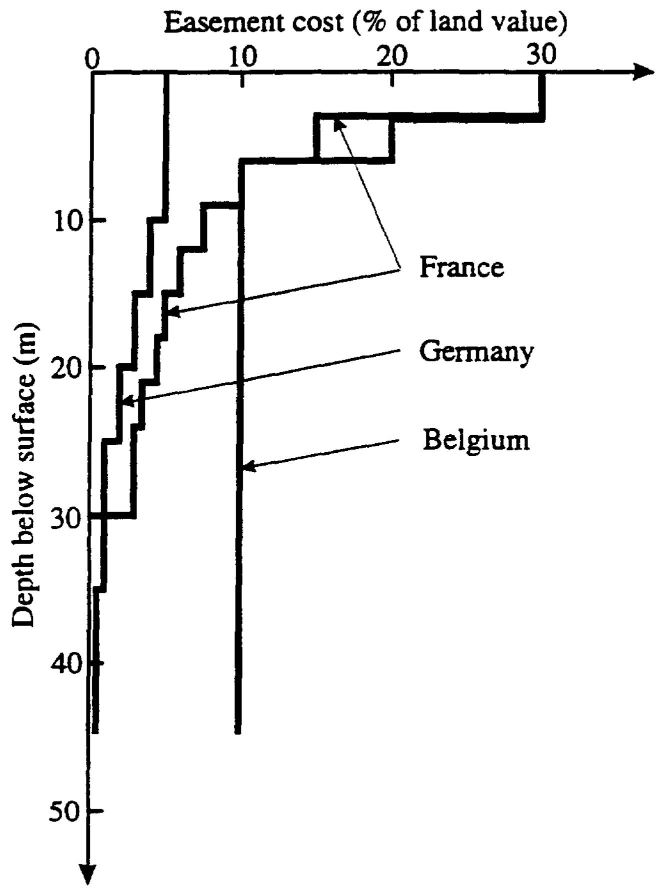

Figure 4 Examples of Easement Valuations

To examine what kind of land value might be assigned to a typical utility, consider the utility shown in Figure 5. Its depth is 2.0 m and its diameter 0.6 m. Other utilities will not be permitted to be placed above this ut'lity or within 0.3 m either side of the utility. The surface projection of the space occupied is thus a strip 1.2 m wide. If a easement value (for this 2 m depth) of 30 percent is applied to the value of the land adjacent to the street (say \$100.00 per m^2) then the cost of the easement per lineal meter of utility would be \$36.00. This compares to a 1994 estimated construction cost for a 0.6 m utility at a 2 m depth of around \$90.00 per lineal meter (i.e, the easement value would represent about 40% of the direct construction cost).

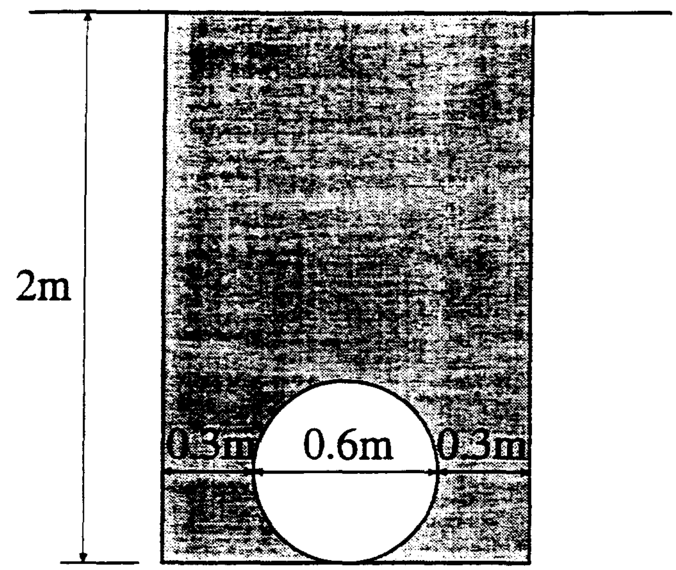

Figure 5 Section of Buried Utility

It is clear from attempting to do simple calculations such as this for the value of the space occupied that the procedures of multiplying the value of the surface land by a percentage based on the depth of the construction do not properly take into account the differences among the space efficiencies of various utility layout approaches. In the example given, the value of the easement would be the same whether the utility allowed another utility to be placed above its service or not. A more useful measure of the value of the space taken would be one based on volume usurped as modified by factors such as depth, impact on current and future uses of the surface, geological conditions, etc. A simple equation for the decrease in value with depth (as suggested in Funes 1988) can be integrated over depth to provide a value for the volume taken but this requires first an estimate of the value if all of the underground space were taken beneath a certain surface area but leaving the surface intact.

2.5 A Specific Approach to Estimating the Financial Value of Underground Space

Pasqual and Riera (1990) provide what they term a first attempt at a means of estimating the value of underground space as follows:

First, the value of underground land is determined from consideration of a hypothetical development which includes both aboveground and underground development. The value of underground land is derived by considering the assigned profit, construction cost and land value to each facet of the development, i.e.

$$u = \frac{p}{1 + b} - c$$

where

u = price of subsurface land
p = price of the portion of the building built underground
b = developer's rate of profit
c = construction cost of the underground portion of the building

This formulation leads to the conclusion that as the construction cost of an underground facility increases, the value of the subsurface "land" should decrease by the same amount. This relationship stems from the fact that the land is assumed to be worth what a developer is willing to pay for it. The developer cannot afford to pay as much for the underground land if the construction costs more and if the same profit margin is to be maintained. The relationship also indicates that the value of underground land will decrease with higher profit requirements on the part of the developer.

The above formulation does not provide information about the change of value with depth. Rewriting the above equation as a function of parcels of underground land at different depths, i, one has (Pasqual and Riera, 1990):

$$u_i = \frac{p_i}{1 + b} - c_i$$

If the price of the underground space is assumed to decrease with depth and the construction cost is assumed to increase with depth, then it follows that the calculated value of underground land will necessarily decrease with depth. (Note: these two assumptions are normally valid but may not be satisfied in geological conditions which allow cheaper underground construction in specific geologic zones at greater depth).

The main problem in applying this more detailed analysis is that it is difficult to assess the price of underground space as it relates to depth below the surface. A second problem is that underground "land" cannot be considered as a commodity defined by its area in a horizontal plane (as is surface land.) The costs and values are necessarily tied to volume rather than area. In Pasqual and Riera's formulation, there is an implicit assumption that the price is based on usable thicknesses of underground space that are related to the value of the land at a particular depth. Thus the value of the underground "land" changes with the changes in construction cost and the price a tenant or purchaser is willing to pay for the space obtained at a particular depth from the surface, i.e. the area of the underground land together with its associated thickness. To avoid confusion, it appears better to treat underground space as a value per unit volume. This is in fact what Pasqual and Riera did when they applied their approach to a case example.

2.6 Case Example for the Evaluation of a Utilidor

Pasqual and Riera used their approach to underground land valuation to investigate the alternatives of a common utility tunnel versus the traditional approach of separate utility locations beneath the roadway for construction of a major ring road project in Barcelona. The value for underground land was determined from the known value of an underground parking space in Barcelona ($p =$ US$25000), the known cost of constructing an underground parking space ($c =$ US$12,000) and an assumed value of the developer's margin ($b = 0.35$). From equation (1), the value of the underground land is US$6519 per m^2 (US$606 per ft^2). This can then be converted to a value per m^3 of underground space by multiplying by the volume of underground space necessary to provide one parking space (including a proportional part of the parking access space, etc.). This volume was estimated to be 57.5 m^2 and hence the value of underground space was calculated to be US$113 per m^3 (US$3.20 per ft^3).

Applying the estimated value of underground space to the ring road utility comparison, yielded a comparison that, since the common utility tunnel would save 7.39 m^3 per linear meter of roadway, the land value savings per meter of roadway would be US$840. Over the 25,735 m of system being considered, the total land value savings were calculated to be US$21.5 million.

The four main variables in the overall comparison were

- Construction costs - greater for the tunnel option
- Maintenance costs - considered for the tunnel option only
- Future utility repair costs - less for the tunnel option
- Underground land costs - less for the tunnel option

The underground land value was the most significant factor in the comparison with savings in repair costs being the next most significant. The discount rate assumed and the period over which the savings in underground land are to be taken were important factors in the calculated magnitude of the savings.

There are many other issues which bear on the general use of common utility tunnels. These issues include (APWA, 1971 and Duffaut and Labbé, 1992):

Benefits

- easy access for maintenance, repairs and extensions
- no street cuts or traffic congestion

Drawbacks

- large early investment required
- administrative concerns among utilities
- security issues for some utilities
- obsolescence of some utility needs
- incompatibility of new needs with space provided

The concept of trying to save underground space in a major new construction is, however, an important one. If this is not done, the difficulty and expense for the provision of later infrastructure of major significance such as transit tunnels, underpasses, etc. will be increased.