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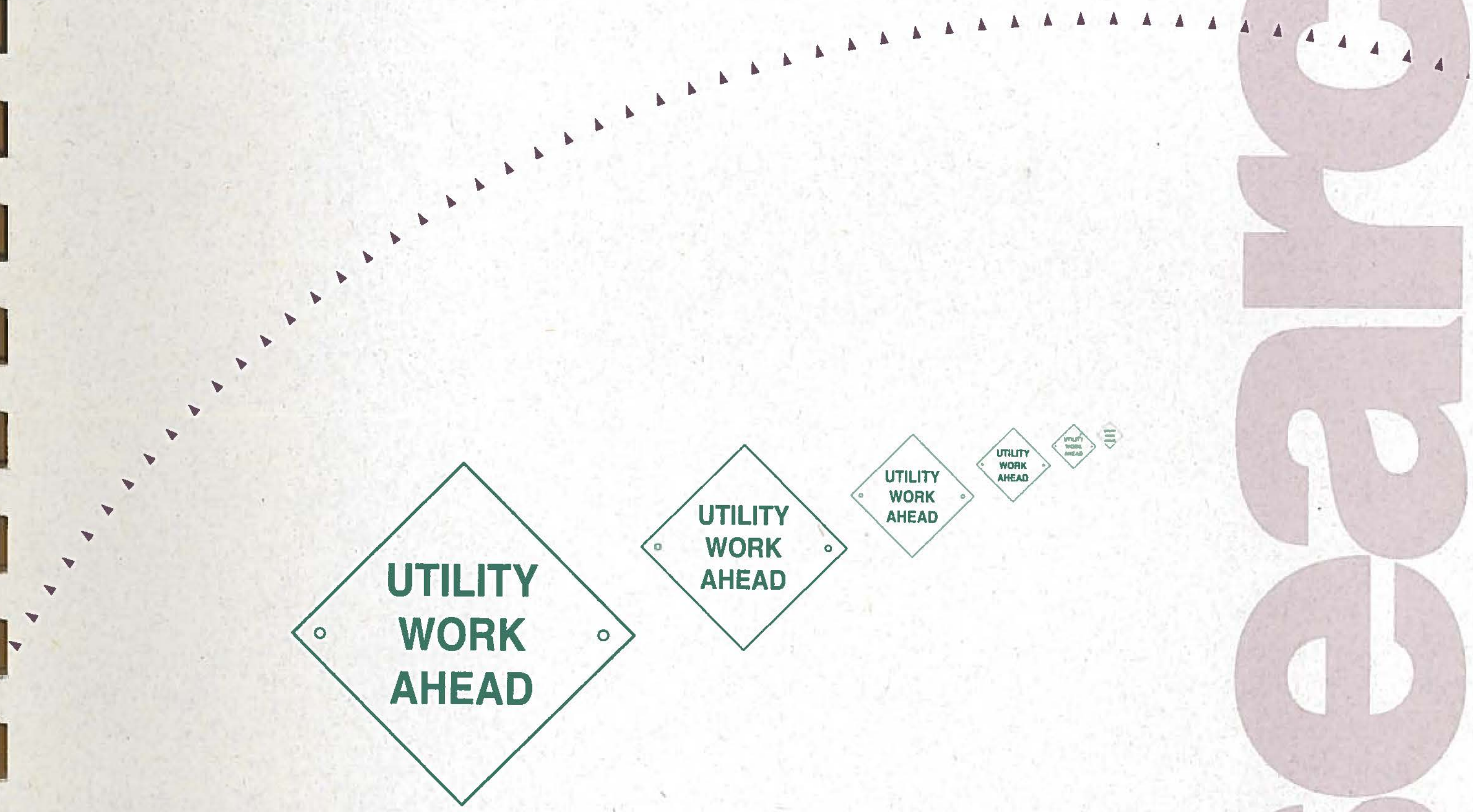

Indirect Costs of Utility Placement and Repair Beneath Streets

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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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Indirect Costs of Utility Placement and Repair Beneath Streets

FINAL REPORT

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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.

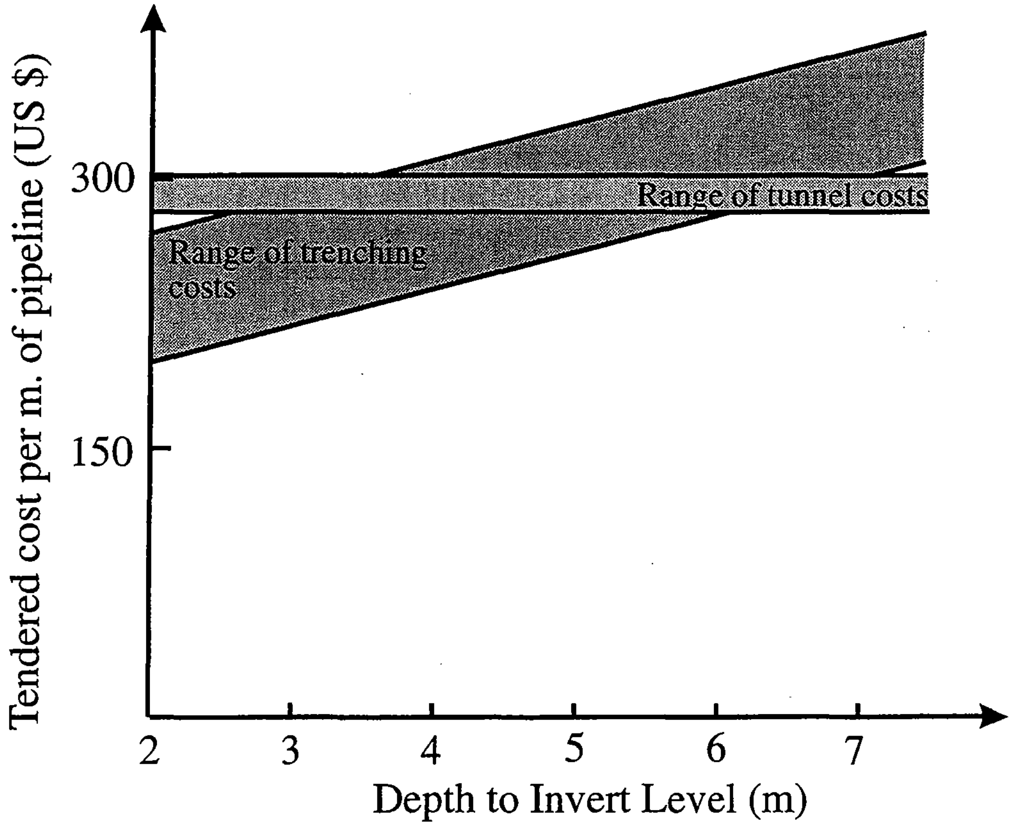

Figure 1 Breakeven Depth for Trenchless Methods in Sewer Construction

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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 those 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 m^2 (108,900 ft^2) of block area and 4,747 m^2 (51,100 ft^2) 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 m^2 (\$50 per ft^2), [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.

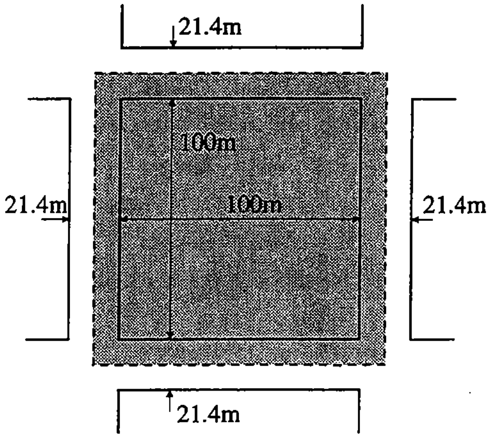

Figure 2 Plan of Downtown City Block

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 m^2 (150,000 ft^2) and the associated right-of-way area is 3,948 m^2 (42,500 ft^2). If an average value of \$5 per ft^2 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 m^2 land value, the remaining area of commercial and industrial properties (14.6 sq. km. at \$0.93 per m^2 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 m^2. 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.

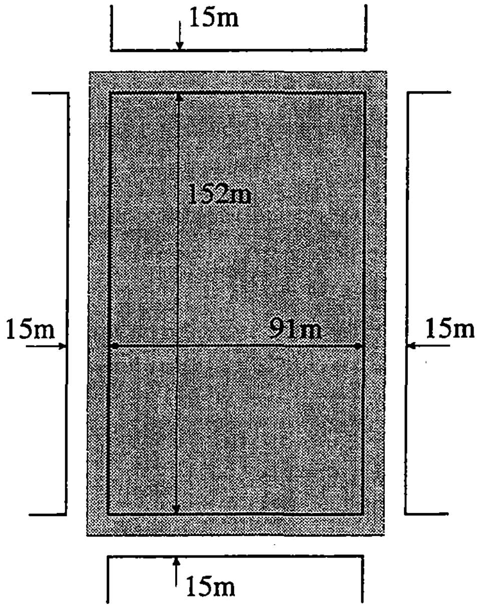

Figure 3 Plan of Residential City Block

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.

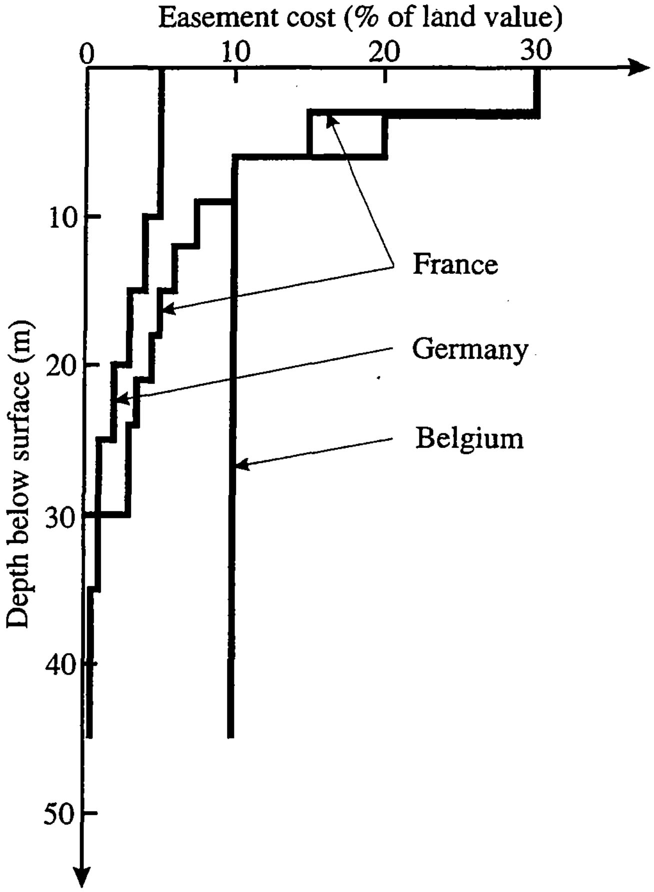

Figure 4 Examples of Easement Valuations

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 utility 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).

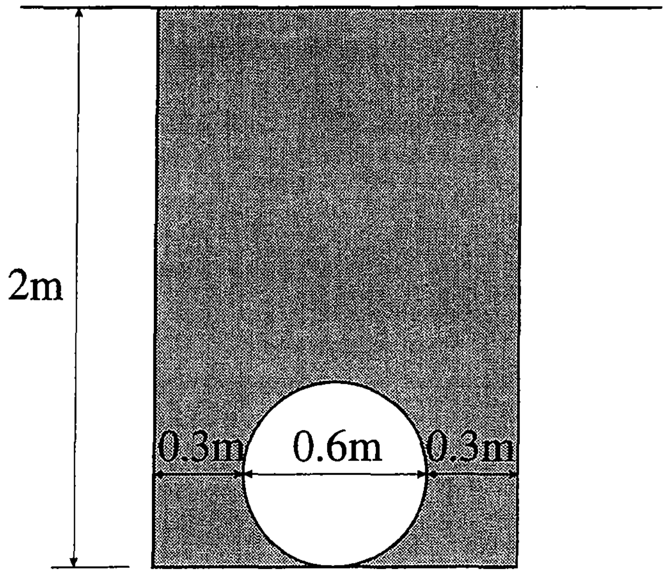

Figure 5 Section of Buried Utility

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.

Chapter 3
Indirect Costs of Utility Work

3.1 Background

As explained in the introduction, the purpose of an analysis of indirect cost of utility work is to minimize the total economic costs to the community as a whole. In a situation where the indirect costs are significant, the method of work which is most cost-effective for the community as a whole may not be the method with the lowest first cost. Basing the choice of the speed of working and the selection of construction technique on both direct and indirect costs does not increase the total cost to the community of the project. Instead, it avoids one segment of the community being unfairly penalized with the imposition of the social costs while another group pays less than the true cost of the work.

3.2 Costs to be Considered

The costs to be considered will vary from situation to situation depending on which factors are important in terms of the potentially significant indirect costs. The listing of possible costs given below is taken from the work of the University of Manchester Institute of Science and Technology (UMIST) in the U.K. The direct costs of utility work include:

- Excavation and backfill
- Pipe and pipelaying
- Pavement reinstatement
- Temporary utility service diversions
- Traffic diversions and traffic control

The indirect costs of utility work include:

Traffic
- Traffic diversions and delays ✓
- Increases in vehicle operating cost ✓
- Loss of accessibility and parking spaces
- Delays to public transport ✓

Environmental
- Increased noise ✓
- Increased air pollution
- Increased construction mess
- Increased visual intrusion

Safety

- Decreased safety for motorists ✓
- Decreased safety for pedestrians ✓

Economics

- Loss of trade to local businesses
- Damage to other utilities
- Damage to street pavement
- Increased workload on other government agencies or utilities

The cost of public transport disruption can be further broken down as:

- Additional route mileage
- Delay-time costs
- Shuttle/relief
- Extra walk time
- Information and inspectors time
- Loss of revenue
- Impact of bus traffic on diversion routes

In cities with heavy bus usage on critical routes, the costs of public transport disruption can be very significant. In one analyzed case in the U.K, a major sewer collapse resulted in an 18 month road closure requiring a route diversion of 7 km and 20 minute delays during peak periods. The estimated costs to London Transport and passengers amounted to UK£3 million (Probert, Holmes and Flemons, 1982 in Bristow and Ling, 1989).

A flowchart for the inclusion of societal costs in construction method selection (including whether such an analysis is necessary) has been prepared by Vickridge et. al. (1992) and is shown in Figure 6.

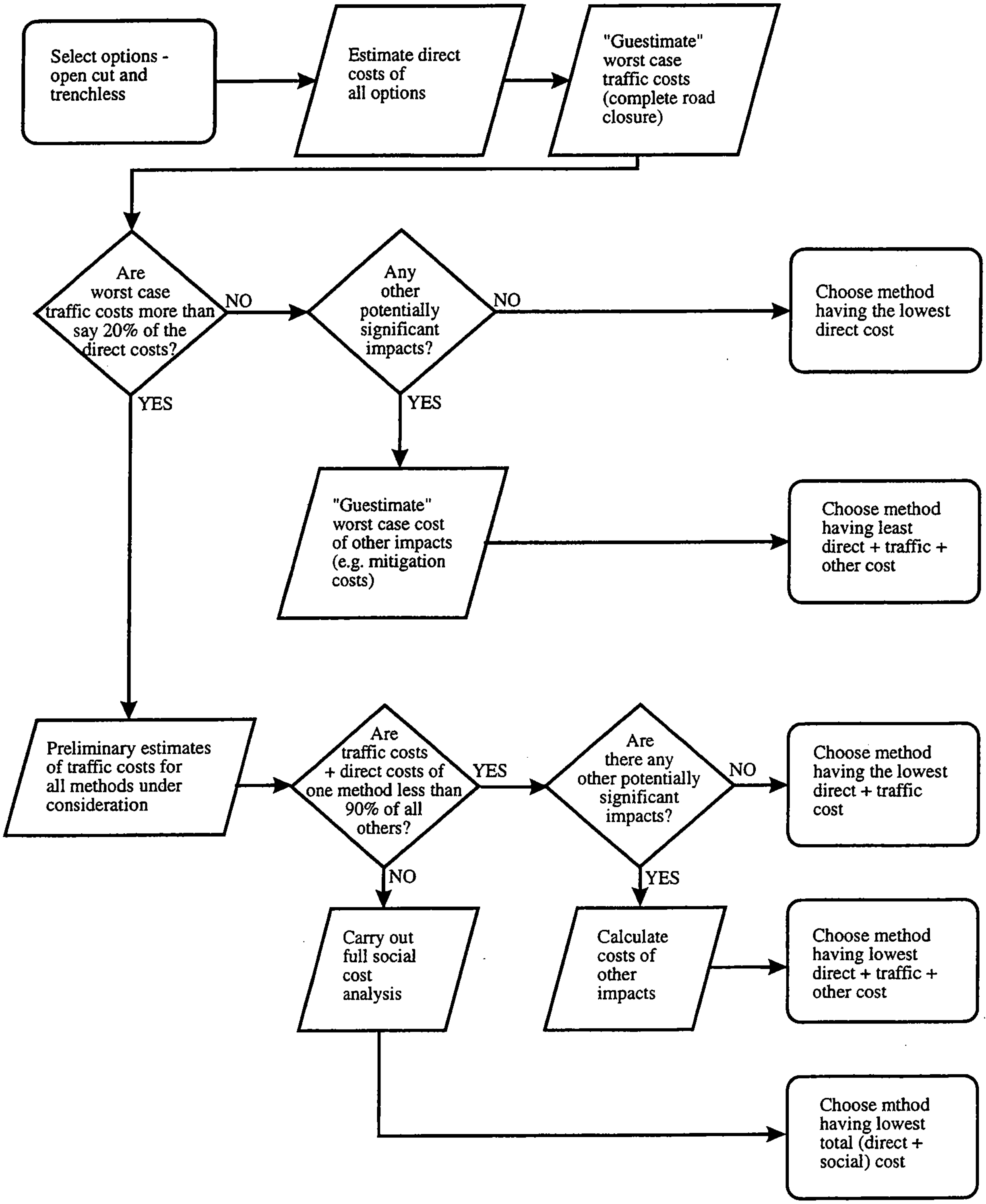

Figure 6 Inclusion of Societal Costs in Construction Method Selection

3.3 Assessment of Indirect Costs for Roadwork in the U.S.

The indirect costs associated with street or highway projects and/or deficiencies of existing highways are already well established as an appropriate component of transportation investment planning in the U.S. The Highway Performance Monitoring System (HPMS) analytical process (FHWA 1987), for example, provides simulated user "costs" represented by average overall travel speed, fuel consumption, vehicle operating costs, emissions and accidents.

To include an indirect cost as an integral part of a cost/benefit analysis for transportation planning, monetary values must be assigned to the indirect costs or benefits deemed to apply to a particular project option. This has been done for some of the typically major variables in the analysis but not for all. For example, the HPMS analysis addresses vehicle operating costs in detail but does not convert the pollution emission into monetary value.

The newer Highway Economic Requirements System (HERS) utilizes the HPMS database but provides an analysis with more emphasis on user cost considerations in the selection of the most economic set of projects and alternatives to be carried out under given funding constraints (McElroy 1992). The HERS model recognizes reduction in travel time, incidents, vehicle operating costs, maintenance costs and residual value.

The HERS model calculates a benefit-cost ratio (BCR) as:

$$BCR = \frac{User\ Cost + Agency\ Cost + Residual\ Value}{Improvement\ Cost}$$

The development of the HERS model indicates the continuing growth in emphasis on trying to minimize overall societal costs in public works projects using estimated values for indirect costs. The HERS model is,

however, configured for overall project selection by a Department of Transportation rather than a detailed cost-benefit analysis among construction method alternatives.

3.4 Assessment of Components of Indirect Cost

3.4.1 HPMS Performance Measures

Table 2 provides tabulated estimates of typical performance measures for various types of highway or street. Except in the case of vehicle operating cost, these values do not directly provide financial estimates but rather the expected performance for various types of roadways which can be used in comparing the performance of changes in roadway type, travel distances and roadway configurations.

The vehicle operating costs in the 1987 HPMS simulation program are based on 1980 prices given in a report on vehicle operating costs, fuel consumption and pavement type and condition factors by Zaniewski et. al. (1982). They are based on the following parameters:

- costs and fuel based on grade
- costs and fuel adjusted for effects of curve
- costs and fuel adjusted for speed change and stop cycle effects
- costs and fuel adjusted for pavement condition
- costs and fuel adjusted for idling time

Table 2 HPMS Performance Measures for Investment/Performance Analysis

Performance measure	Operating Cost	Carbon Monoxide Emissions	Nitrous Oxide Emissions	Hydro-carbons Emissions	Property Damage Accident	Fatal Accident	Non-fatal Accident
Units	\$ per 10^3 veh. km	kg. per 100×10^6 vehicle km			Number per 100×10^6 vehicle km		
RURAL							
Interstate	166.6	7.5	4.9	0.9	57.8	1.4	20.5
Other Principal Arterial	141.8	8.7	3.1	1.0	108.1	2.7	38.6
Minor arterial	139.3	9.8	2.3	1.0	134.2	3.5	46.6
Major Collector	144.7	10.5	2.1	1.1	135.5	3.9	46.6
Minor Collector	137.3	11.2	1.8	1.1	131.8	4.1	44.8
TOTAL RURAL	146.8	9.3	3.0	1.0	111.9	3.0	39.2
URBAN							
Interstate	197.4	29.0	9.1	3.2	231	1.1	81
Other Freeway & Expressway	196.2	28.97	8.7	3.2	253	1.5	85
Other Principal Arterial	233.3	47.0	5.5	4.6	581	2.8	178
Minor Arterial	236.9	45.4	5.3	4.5	569	3.4	171
Collector	242.8	47.6	5.1	4.6	460	3.5	138
TOTAL URBAN	218.5	38.7	6.9	4.0	419	2.3	132

Source: HPMS (FHWA,1987). Data is for 1986.

3.4.2 Calculating Indirect Costs for Utility Work under FHWA/AASHTO Guidelines

The calculation of user costs for utility work can be carried out using the guidance provided in *Planning and Scheduling Work Zone Traffic Control* (FHWA, 1981) and *A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements* (AASHTO, 1977). Detailed guidance on the provision of traffic controls for such work is provided in the *Manual on Uniform Traffic Control Devices, Part VI, Traffic Controls for Street and Highway Construction and Maintenance Operations* (FHWA, 1978).

The basic planning process is outlined in Figure 7. Techniques used to increase capacity or reduce volume are shown in Table 3.

Table 3 Techniques to Increase Capacity or Reduce Volume

Technique	Applicable Roadway Type	Necessary Conditions
Restrict work to off-peak hours only	All types	Roadway occupancy duration can be reduced to less than 8 hours
		Volume exceeds capacity during peak hours only
Nighttime work	Multi-lane highways in non-residential area and freeways	Roadway occupancy duration can be reduced to less than 8 hours
		Work does not require coordination between contractors
Remove parking	Urban streets	Off-street parking available
Postpone work to off-season	All types	Significant volume reduction during off-season period
Work only on weekends	All types	Work does not require coordination between contractors
Selective ramp closure	Freeways/expressways	Reasonable detour routes available
Use reversible lanes	Multi-lane roads	Significant peak hour directional imbalance
Restrict turns at signals	Urban streets	Effective signing possible
Modify signal timing	Urban streets	Good parallel route available

Source: FHWA, 1981.

In the FHWA manual, quantification of impacts is suggested for the following variables:

Traffic Impacts

- Delay
- Stops
- Fuel consumption
- Operating Costs
- Accidents

Project Cost Impacts

- Cost of Traffic Control
- Cost of Construction

Environmental Impacts

- Air pollution
- Business Loss

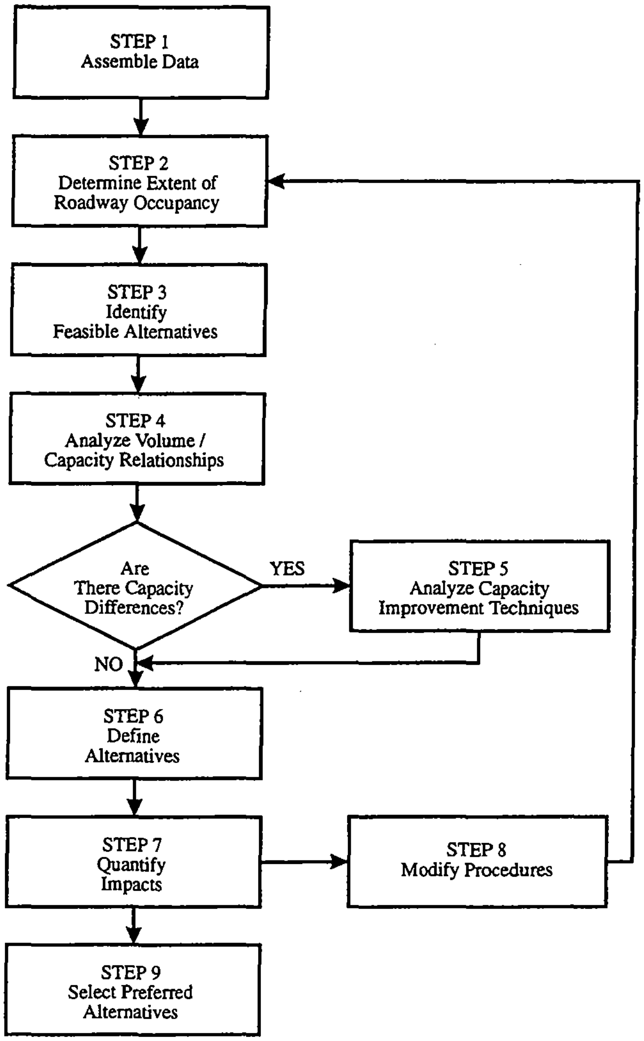

Figure 7 Work Zone Evaluation Planning Process

It is clear that not all the potential indirect costs which could affect a total-societal-cost tradeoff analysis among construction alternatives are included in this procedure (see section 3.2). Noise was deliberately omitted on the basis that the noise impact of changed traffic patterns was not significant compared to the noise of construction equipment. This assertion may follow from the fact that total duration of roadway occupancy is not considered as a variable in the analysis. If differences in length of time of roadway occupation, diversion, etc. are considered, noise should become a more significant variable. Likewise, the impact of the method of working on future pavement life also is not considered because differences in construction techniques were not taken as variables. Other variables can be added to the analysis procedure when the issue is considered relevant and data exists to provide numerical comparisons among the alternatives. In the absence of numerical data for variables considered to be important, it will be necessary to make a judgement based only partly on the quantitative benefit-cost analysis or to provide subjective weightings to components of the analysis as shown below.

Selection of the preferred alternative is based on a benefit-cost analysis where the benefit-cost ratio is calculated as:

$$B/C = \frac{W_T*(TI_j - TI_i) + W_B*(BL_j - BL_i)}{TCC_j - TTC_j}$$

where

i,j Represent alternative work zone strategies
TI = Total traffic impact cost of i or j (TI_i = Di + Oi + Ai)
D = Total delay cost
O = Total operating cost
A = Total accident cost
TCC = Total construction cost (TCCi = TCi + CCi)
TC = Traffic control cost
CC = Construction cost
BL = Business loss
W_T = Weight given to traffic impact (not less than 1)
W_B = Weight given to business loss (not less than 1)

The weightings may be used where it is difficult to properly calculate the value of time, the cost of accidents or the business loss factor. They provide a means of adjusting the preferred alternative according to critical local impact issues.

Guidance on the calculation of each component of the cost for each alternative is given in the manual. For example, Table 4 provides an indication of the magnitude of the estimated value of time in 1979 dollars which is used in the analysis procedure. Note that the value is not a linear function of delay time.

Table 4 Cost of Time in Dollars per Vehicle

Time Lost (Mins.)	Cost Per Vehicle ($)
1	0
5	0.01
10	0.23
20	1.69
30	3.04
40	4.04
50	5.06
60	6.06

Source: FHWA Highway Statistics (1975-) updated to July 1979

More detailed guidance on estimating the value of time is provided in the AASHTO manual on user benefit analysis (AASHTO, 1977).

Accident costs in 1980 dollars used in the analysis are shown for reference in Table 5. Further guidance on the selection of accident costs is given in the AASHTO manual on user benefit analysis (AASHTO, 1977) providing accident cost data by type of accident (fatal, non-fatal injury, property damage only). These estimated costs from various sources vary by a factor of more than 16 from lowest to highest fatal accident cost ($18,800 to $307,210 in 1975 dollars). The costs depend greatly on the components included in the analysis (direct costs only, provision for gross future earnings, discounting for future maintenance costs of deceased, etc.).

The manual does not provide a cost relationship between the anticipated levels of pollutants and a social cost for an alternative. Guidance on business loss is also not provided in the manual due to the variability in the impacts in the cases studied. It was recommended in the manual that business loss not be considered unless specific data is available upon which to base a conclusion. Despite this recommendation, business loss can be a very serious concern for major roadworks extending over a long period of time.

Table 5 Cost of Accidents by Road Type

Road Type			Cost Per Accident (US$)
Rural	No Access Control	2 Lanes	7360
		Multilane, undivided	5070
		Multilane, divided	7370
	Partial Access Control	2-Lane Expressway	8740
		Divided Expressway	7460
	Freeway		7520
Suburban	No Access Control	2 Lanes	4000
		Multilane, undivided	3310
		Multilane, divided	3520
	Partial Access Control	2-Lane Expressway	8000
		Divided Expressway	5660
	Freeway		4140
Urban	No Access Control	2 Lanes	3030
		Multilane, undivided	2690
		Multilane, divided	2690
	Partial Access Control	2-Lane Expressway	4450
		Divided Expressway	2890
	Freeway		2890

Source: Faigin (1976) updated to 1980 in FHWA (1981)

3.4.3 Effect of Utility Work on Life Cycle Costs of Pavements

It is clear to any casual road user that reinstatement of portions of a road pavement surface following pavement cuts for utility work or other purposes often is far from the ideal of restoration of the pavement surface to its original condition. If backfilling of the excavation and pavement reinstatement is specified and carried out correctly, then, theoretically, the utility work involving the pavement cut should have no impact on the lifetime of the pavement prior to general replacement or on the driving characteristics of the road. In practice, this is not the case. Patches in the road surface are often not level with the surrounding surface creating a road with poor riding characteristics and sometimes interfering with pavement surface drainage. The patches or their junctions with the surrounding surface may allow additional moisture to enter the road base causing accelerated pavement deterioration and potholing. These problems add to the total societal costs of utility work involving pavement cuts because:

- Vehicle operation costs are increased on roads with poor pavement conditions
- An affected roadway may need more frequent and/or extensive maintenance to keep the pavement in an acceptable condition
- A major road surface reconstruction may be required at a shorter interval in a roadway with many utility cuts than in a roadway with few or none
- Reconstruction or resurfacing may be carried out earlier for aesthetic reasons (the poor appearance of multiple utility cuts) as well as for structural reasons

The impact on the user costs associated with pavement condition has been addressed in previous studies. The HPMS simulation (FHWA 1987) uses the following equations to provide the relationships:

$$\textit{Fuel Consumption} = 1.25 - \frac{0.25 * PSR}{PSR + \dfrac{5.0 - PSR}{37.5 * PSR}}$$

$$\textit{Vehicle Operating Cost} = 0.9818182 + \frac{5.0 - PSR}{20.0 + 5.0 * (PSR - 3.0)}$$

where
PSR = Pavement Condition Rating (present serviceability rating)

With regard to the cost impact on the pavement life cycle, most of the engineers contacted in this study involved in the maintenance of city streets had significant concern about the impact of utility cuts on the life cycle costs of maintaining the streets. They also felt that the cost of the permit(s) for such work did not recover the resulting cost to the public agency responsible. The problem in taking this factor into account in setting permit fees and/or conducting a total-societal-cost analysis of construction/repair options is that there are no correlations available to relate the presence of a utility cut in a street or highway to any impact it may have on the life-cycle cost of the pavement. Considerable effort is currently underway to improve pavement management practices through the periodic assessment of pavement condition, better diagnostic tools, better record-keeping and improved maintenance decision-making capabilities. It does not appear at present, however, that sufficient linking of pavement cut information for utility purposes to the pavement management database is available to allow a statistical correlation of utility cuts to their eventual cost impact on a road pavement. This issue appears worthy of further study and is discussed further in Chapters 4 and 5.

3.5 Experience in the U.K.

In the U.K., the Public Utilities Street Works Act in 1950 established a framework governing utility street works in the U.K. At that time there were 4 million vehicles on the road. In 1984, an independent committee under Professor Horne was invited by the Government to carry out a comprehensive review of the work of the Public Utilities in relation to the highway network. The recommendations of the Horne Report (1985) formed the basis of the New Roads and Street Works Act 1991.

The cost to road users of utility works in 1983 was estimated at UK£35 million (US$52.5 million). In 1989, this cost was estimated to be UK£55 million (US$ 82.5 million) by the Department of Transport, U.K (Ling et. al., 1991). To address this issue, several research efforts in the U.K have been carried out to estimate and mitigate the social cost impacts of utility work. The University of Manchester Institute of Science and Technology (UMIST), the Water Research Center of the U.K Department of the Environment and the Transportation Research Laboratory of the U.K. Department of Transportation have been important entities in this research..

3.6 Procedures for Estimation of Indirect Costs in the U.K.

The following discussion is taken from the work of the UMIST group as described during a visit to UMIST in April 1993 and from their papers on the subject.

The nature and extent of the analysis of indirect costs for utility work will vary with the type of roadway affected. Table 6 illustrates the major conditions considered for the analysis of traffic delay costs.

Table 6 Roadway Conditions Considered for Analysis

Isolated Roadway	Diversion available	
	Diversion not available	Narrowed lanes
		One-way working
Urban Roadway	Limited blockage	
	Major closure	Clear diversion route
		Multiple diversion routes

To analyze the additional vehicle costs (including a value for time lost) the following procedure is proposed in the case of a simple diversion:

$$\text{Total cost} = VPD*(VOC*AL + VOT*AT)*T$$

where

VPD = No. of vehicles per day
VOC = Vehicle operating cost
AL = Additional distance
VOT = Value of time per vehicle per hour
AT = Additional time
T = Construction time

If the conditions of the roadwork will result in a carriageway width of less than 3 m (9.85 ft.) being left, this is evaluated as a complete road closure. If more than 5.5 m (18 ft.) of carriageway is available, then two-way traffic is possible and the effect of the constriction on traffic delays are evaluated. For intermediate widths of carriageway, one-way or shuttle working is evaluated. If the shuttle working length is greater than 150 m (492 ft.) and the two-way traffic volume is greater than 1300 vehicles per hour then social costs should prove to be significant in the project evaluation.

Special situations may require careful analysis even if the road affected does not carry significant traffic. Examples include road works within 50 m (164 ft.) of a traffic-significant junction where traffic can back up into the junction and cause major delays. Figures 8 and 9 illustrate the impact on delay of the length of lane occupancy and the distance from an intersection respectively.

If delay costs are small compared to the construction cost (less than 20 percent - Vickridge et al, 1992) and no significant other social costs apply, there may be no need for an elaborate analysis of the social costs. In most cases of utility work, a detailed analysis will not be necessary if the work can be arranged to minimize traffic delays. The analysis will be necessary if the social costs will be high and the difference in initial construction costs for measures to reduce the social costs are also high.

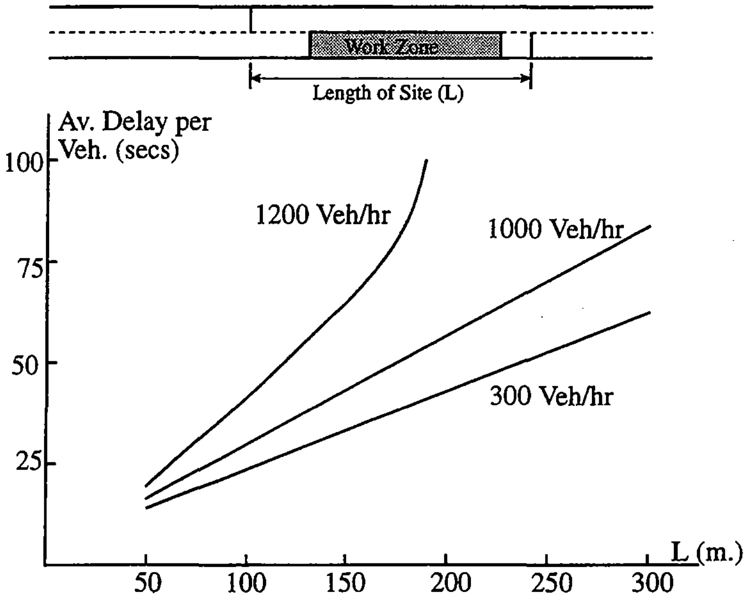

Figure 8 Average Traffic Delay for Different Lengths of Shuttle Working

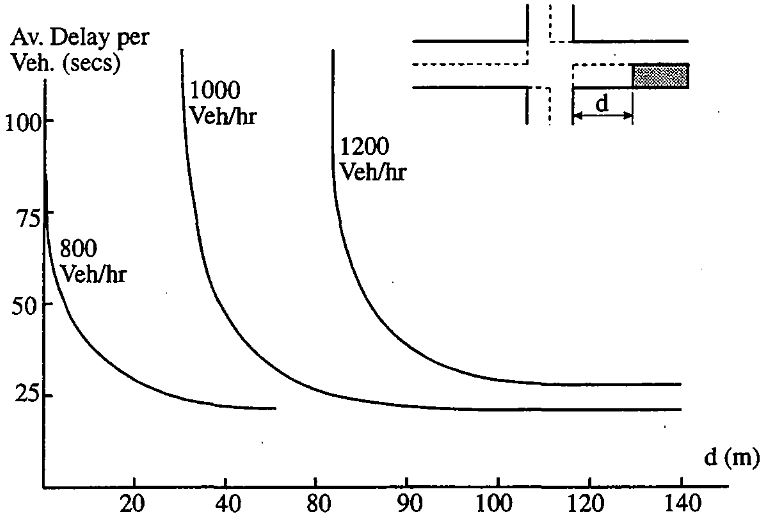

Figure 9 Average Traffic Delay Caused by Roadworks for Traffic Flows Approaching a Signal-Controlled Junction

So far the discussion has centered on the traffic delay costs which are the most amenable to calculated estimates. The other indirect costs must also be considered. These costs may include effects away from the direct site of the road work. For example, when traffic is diverted onto alternate routes, the volume and also the size and weight of traffic on the alternate routes can increase significantly. Increased traffic volumes and loadings will have several potential impacts on such alternate routes. The pavement surface and buried utilities may suffer physical damage from the increased loadings especially if the pavement surface was designed for much lighter loading conditions and the diversion continues for an extended period. The local environment along the diversion route may deteriorate and the increased traffic on unsuitable routes plus the frustration of diverted drivers may increase accidents. The geometrical implications of large vehicles on diversion routes may also increase damage to curb and gutter, pavement shoulders and street furniture. Non-personal injury damage is often underreported compared to personal injury accidents so existing statistics may underestimate such occurrences (Ling and Read, 1991).

The greatest concerns of local residents to diverted traffic have been reported as accidents, followed by noise and vibration, followed by air pollution (Sando and Batty, 1974 and Mackie and Davies, 1981 in Ling and Read, 1991).

A case study of the effects of a 14-month traffic diversion in south Manchester resulted in an estimate (compared to a control site) of an additional major roadway deterioration of 10.5 percent and additional minor deterioration of 18.5 percent in a period between June 1987 and August 1988. Using prevailing unit costs for the repair work resulted in a total extra maintenance cost of UK£9260 (approx. US$14,000). In the same case study, no significant difference in gas utility damage was noted for the diversion route during the diversion period. Accident data, however, indicated an increase of 15 accidents (over that in control areas) which on this type of road would result in an estimated 1988 cost to the community of UK£470,000 (US$705,000) although it could not be established that the change in accident levels was statistically significant. Travel time studies indicated that the use of the official alternative routes only would have cost UK£702,000 (US$1,053,000) in travel time and vehicle operating costs. This figure was estimated to have been reduced to UK£249,400 (US$373,500) by the use of unofficial routes but this reduction in time delay involved traffic choosing less suitable routes from a community and safety perspective.

The major indirect cost impacts in the Manchester case study are clearly related to the high costs of travel time delays and accidents rather than any identified road or utility damage.

In extreme situations, it was estimated that the traffic costs for utility works could be up to ten times the direct construction cost and if roadway space rental charges were used to offset this, the charges could be as high as US$150 per m^2 ($14 per ft^2) per day.

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Chapter 4
Implementing Changes in Practice to Minimize Overall Societal Costs

4.1 Mechanisms for Change

In addition to the difficulties inherent in calculating indirect costs so that the lowest societal cost option may be selected, there are several very significant policy questions to be addressed in how to utilize such knowledge in improving construction/repair practices:

- What mechanisms can be used to limit societal costs?
- How can these mechanisms be implemented in the existing governmental and procurement structure?
- When financial incentives or penalties are provided to encourage the minimization of overall societal costs, who pays and who benefits in terms of the adjustment of direct costs?

The mechanisms used to limit social costs in general terms can include:

- Direct prohibition or control of street occupance
- Preferential public investment in low social impact projects
- Compensation payments to affected communities
- Environmental taxes (including the use of lane rental fees)

There is a significant problem in devising suitable bidding arrangements and contractual practices for the utility work so that the goal of minimizing societal costs is reflected in the contractor's method of working without overspecifying procedures and limiting bid competition. The use of lane rental fees (already used in road pavement repair work for major highways) provide an incentive to reduce the occupance of roadway lanes but can raise other contractual or construction quality concerns (see section 4.2).

In the case of road pavement repair for major highways, a single national agency is involved in determining the societal impacts of different approaches to the repair work, contracting for the work, paying the additional direct contract price so that overall costs to society may be lowered, and receiving any lane rental fees from the contractor. With accurate bidding and good contract performance, the net financial position should be that the agency pays a higher direct cost for the work on the basis of the societal savings thus requiring a policy tradeoff against using the additional costs to do more direct repair or construction work. The situation becomes more complicated when local roads are involved due to the potential net financial transfers involved among various levels of government entities. For example, one problem in a wider use of lane rental for local roads is the issue of whether lane rental fees received belong in the community as a surrogate for the social costs experienced or whether the road agency should keep them to offset their higher bid costs. As an additional complication, in the U.K., it was reported that the national government wanted to reduce local grants by the amount of any lane rental fees received. When lane rental (or similar provisions) for utility work is considered, the financial transfers involve public and private utility entities as well as the potential interests of the various agencies and levels of government.

The options available to mitigate indirect costs on a local level basically are to:

- Integrate the work of different utilities so that as many problems or upgrades to utility systems are taken care of with a single street occupation
- Utilize "no-dig" or "trenchless" options which require much less street occupance and pavement cutting than conventional trenching operations
- Limit the occupancy time of the street or highway to minimize the congestion costs and many of the accompanying social costs
- Improve the repairability and upgradeability of utility systems by installing them in a common facility with person access (e.g. a "utilidor")
- Improve the quality and/or capacity of the buried system so that less frequent repairs/upgrades are needed
- Improve the quality of the reinstatement of utility pavement cuts so that the roadway surface is less affected

Some of the more detailed factors to be considered in mitigating societal costs for a project are (Bristow and Ling, 1989):

- Control of site working hours to minimize peak period delays
- Acceleration of site work to minimize the total period of roadway occupation
- Minimization of lane occupation
- Minimization of roadway occupation in critical locations
- Impact on social costs of changes in utility work practices e.g. disturbance arising from 24 hour working
- Impact on safety from minimum site clearances and accelerated construction
- Impact on direct cost of the work arising from any additional restrictions on the method of working
- Impact on competitive bidding related to the specified method of working
- Liability for compensation to businesses for loss of trade
- Compensation to bus companies for additional costs
- Road space rental provisions
- A congestion tax based on congestion actually caused by the works
- Who determines the cost of roadway space?
- How and when is it determined? - effect on contracting practices

Lane rental for trunk highways is more straightforward to apply than lane rental or street occupancy charges in urban areas. On trunk highways, especially in rural areas, the impact of the roadwork on delays can be more readily estimated and a fair charge included in the contract. In urban areas where a multitude of potential alternate routes exist, detailed predictions of congestion costs may be impossible without prior experience at the same location. For these conditions the research group at UMIST in the U.K. envisages the preparation of maps of the urban area with the road network divided into zones of estimated severity with regard to traffic congestion. This should broadly categorize the most heavily trafficked roads and areas of the city, the areas with the least ability for traffic diversion, areas where commerce would be significantly affected or areas with a particularly sensitive environment. On a finer scale, the charges would be developed to reflect the nature of the detailed roadway occupance, e.g. at or near an intersection, partial blockage of lanes versus full blockage, or occupance of sidewalks in commercial areas.

In the envisaged, but not implemented, concept, certain roads would be designated as "traffic significant" and certain junctions as "critical." A flat fee may be used for works not on a traffic significant route based on whether the road is in a residential, commercial or industrial area. A surcharge could be added for the occupance of roadspace at or within 50 - 100 m (165 - 330 ft.) of an junction with a traffic significant route. Figure 10 illustrates the proposed flow chart for determination of road space rental charges in the U.K. from Vickridge et. al., (1992).

The new Roads and Street Works Act 1991 in the U.K. places a greater emphasis on the need to keep delays and diversions in utility work to a minimum. Local authorities are given powers to designate traffic sensitive streets and limit the times at which works can be undertaken in such locations. It has been suggested that 10 percent to 20 percent of the highway network might be so designated (Vickridge et. al., 1992). Limited powers for "highway rental" provisions for utility work also are included in the act but only as a reserve power (they are already used for pavement maintenance on busy roads). Vickridge et. al. indicate that the U.K government wished to avoid lane rental charging systems for utility work unless the other provisions of the new act failed to reduce the traffic problems currently experienced. Part of the objections to the use of lane rentals has been differences of intention as to who would receive the benefit from the road space charges - the local authority or the national government.

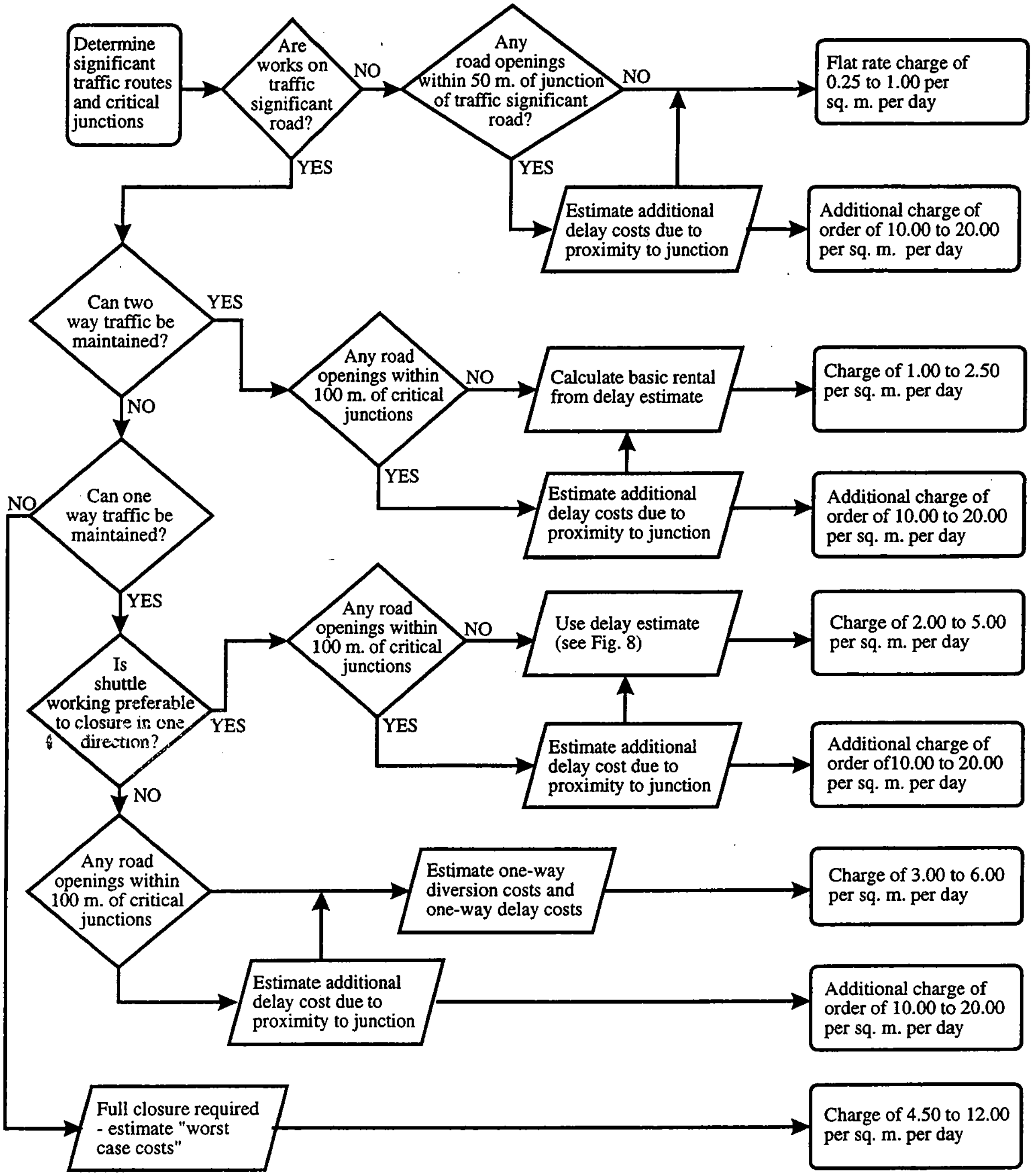

Figure 10 Determination of Road Space Rental Charges

4.2 U.K. Experience with Lane Rental Provisions

The concept of lane rental has been discussed as a means of reducing some of the societal costs of road and utility work. The U.K. has had approximately ten years of experience with contracts involving some form of lane rental.

The U.K. Department of Transportation has used several forms of lane rental contract. The following discussion of their experience from 1984 to 1988 is taken from a review by Bodnar (1988):

Bonus/Rental Charge	Introduced in 1984, in this form of contract, the contractor is asked to submit a price for the work and a time for completion. The selection of the contractor is based on the construction costs plus a time cost based on an assessment of the indirect costs caused by the roadwork. If the contractor finishes early, the contractor receives a bonus based on the daily rate. If the contractor finishes late, a penalty must be paid. This is similar to what, in the U.S., has been termed cost-plus-time or A+B bidding.
Continuous Site Rental	Introduced in 1985, this contract did not require a time for completion to be submitted in the bid and hence had no bonus provision for finishing early. Instead the contractor was required to pay a daily site rental fee for each day on the site. The form of contract also required that the contractor distribute the costs of the site rental over the normal bid items. This in turn required limiting the distribution of the contractor costs over the bid items to avoid unbalanced bids.
Lane-by-lane Rental	Introduced in 1985/86, this form of contract is similar to continuous site rental except that the rental charge is based on the number and configuration of lanes occupied rather than on a flat site charge. The intent is to encourage contractors to keep roadway obstruction to a minimum in terms of both lanes and days.

The U.K. experience with lane rental was reported to be that it had its desired effect with average time savings of roadway occupance of 33 percent to 38 percent. Contractors tended to organize more ahead of the work and tended to be more capital and equipment intensive in their approach to the work. In one set of contracts using lane rental, it was estimated that the cost of the work to the Department of Transportation increased from UK£87.7 million to UK£90.4 million but that the value of the savings in traffic delays were UK£25 million.

Concerns expressed have been impacts of long construction hours on the staffing for inspection of the work, possible effects of the incentives for speed on quality of the end product, and the manner in which weather delays are handled in the contract provisions. To address the undesirable effects on the way in which the continuous site rental was handled in the early contracts (distribution of costs among other bid items), this form of contract was modified so that a separate bid item was included for the site or lane rental. This made the different forms of contract very similar except for some differences in the way in which weather delays were handled.

4.3 Other Experience in Europe with Related Contracting Practices

In June 1992, the Federal Highway Administration conducted an Innovative Contracting Reconnaissance Scanning in Europe visiting Sweden, Denmark, Germany and France (FHWA 1992). The main experience discussed was that related to design/build contracting, public/private financing and warranties for the constructed product. The experience with lane rental or cost-plus-time (A+B) bidding in these countries reported was:

Denmark	One experience with cost-plus-time bidding in Copenhagen.
Germany	Cost-plus-time bidding has been applied in Germany on major projects since the late 1970s. A contractor may submit an alternate bid for a contract duration less than that indicated in the contract documents. Award is based on an analysis of total costs and may not be to the lowest direct cost bidder. However, no value is usually put on user costs related to time delays. In one form of contract, no incentive is paid to the contractor if the work is completed earlier than the proposed duration but there is a penalty for late completion. This type of bidding which has been used on 100 out of 7,000 projects with a cost of over DM25,000 is considered very successful. Another approach which is sometimes used is that a bonus is paid for early completion.
Sweden	Liquidated damages are used in Sweden to penalize contractors for late completion. Typically, the rate of liquidated damages is 0.5 percent of the total contract amount per week. The rate of damages may be as high as 5 percent on critical projects. Although there was acceptance of the benefits of incentives for early completion when large traffic volumes were affected, there was concern on the effect on quality for such incentives. It was felt that warranty clauses should be used in conjunction with such incentives to protect quality.

4.4 U.S. Experience with Related Contracting Practices

In January 1988, a TRB task force was formed to explore innovative contracting practices (Task force A2T51). The task force issued its findings and recommendations in a report in December 1991 (TRB 1991) and included in this report was the recommendation:

> *The cost-plus-time bidding concept should be considered for wider implementation with the caveat that appropriate controls must be in place. However, careful selection of the types of projects as well as accurate determination of the time value are required. Cost-plus-time bidding represents a variation to traditional lowest-initial-cost bidding that can reflect the additional costs to highway users from inconvenience and delay during construction activities.*

Anticipating the recommendations of the task force report, the Federal Highway Administration established in 1990 an experimental project on Innovative Contracting Practices (Special Experimental Project No. 14) (TRB briefing paper, Feb. 1993).

Three forms of innovative contracting practices were of particular interest:

- Functional contracts (design/build)
- Warranties of riding surfaces
- Lane Rental

The Lane Rental or Cost plus Time Bidding (A + B) concepts are of the most relevance to the current study. The States of California, New Jersey, Washington and Michigan have used cost-plus-time bidding under SEP14 and Colorado has used lane rental under SEP14. Others states which have used cost plus time bidding independent of SEP14 are Washington D.C., Delaware, Georgia, Kentucky, Maryland, Mississippi, Missouri, North Carolina, Pennsylvania, and Texas. Challenges to the award of contracts on other than lowest first cost and also to the value used for liquidated damages in conventional contracts have been made. The results have not been consistent (e.g. opposite decisions in similar cases in Alabama and Arizona on liquidated damage assessments) but it is clear that it is important that the value assigned to early completion or the penalties assigned to time delays must be shown to have been derived from an analysis of the real costs involved. For example, the lane rental fee used in the Colorado lane rental project was $2850 per lane per day.

The lane rental concept was described in a November 18, 1991 memorandum to regional federal highway Administrators. This memorandum provided standard contract language for both the A + B method of bid selection and the lane rental concept with the proviso that the road user cost and the rental charge should be well documented. Reference for further guidance was made to FHWA Technical Advisory T 5080.10.

4.5 Implementation of Pavement Life Cycle Cost Considerations

Very little work appears to have been done on an analysis of the life cycle cost impacts of utility work on street or highway pavements. This is not surprising due to the statistical and political complexity of fairly reflecting the costs among the agency responsible for road maintenance, utilities and/or contractors who ensure excellent pavement reinstatement, and those who do less well. Since the damage is theoretically avoidable, the problem does not lend itself to a mechanistic analysis or to an identification of long-term road damage associated with a specific case or set of cases of utility cuts. The only reasonable approach would appear to be to make an attempt to develop statistical correlations from a database developed to answer the questions of interest. It is not clear that this data currently exists anywhere in the form that would be necessary to conduct such an analysis. It will be necessary to both expand some existing pavement management data sets to include utility cut information from existing records and also to create a preferred data set organization for the collection of new data. It was not possible within the time constraints of this project to develop this idealized data structure or to try to work with or modify existing data sets to extract useful information. The need for this task has however been submitted as a Research Problem Statement to the Transportation Research Board committees dealing with Pavement Maintenance (Committee A3C05) and Subsurface Soil-Structure Interaction (Committee A2K04).

The data needs expected to be useful in an analysis include:

Roadway type and location
Traffic data (loading history)
Records of date(s) and expense for pavement management expenses:
- Pavement maintenance expenses, locations within roadway
- Major resurfacing or reconstruction
- Costs of any special work to restore sub-base conditions in utility cut areas

Records of utility work in the roadway:
- Utility cut location within roadway, size, date(s)
- Nature of construction/repair, e.g. depth of excavation
- Procedures/specifications used for reinstatement
- Nature of quality control on reinstatement
- Assessment of quality of reinstatement (short term, mid-term and long-term)

Records of payments associated with utility work in the roadway
- Permit fees
- Utility or contractor payments for unsatisfactory reinstatement

Pavement Assessment Information
- Pavement serviceability rating and when assessed
- Complaints regarding pavement condition and utility work
- Reason(s) for decision to resurface or reconstruct at the time chosen

Chapter 5
Conclusions and Proposed Future Work

There were two principal issues examined in this report:

- Whether current planning and decision making with respect to the use of underground space beneath public rights-of-way properly takes into account the present and future value of this resource.

- Whether the total societal costs of utility work in streets and highways is properly reflected in the manner in which utility work is carried out.

These issues both were considered to be important under the right set of conditions and part of an assessment of these issues has to be whether they are worth considering in a particular case.

The land cost and land opportunity issue is a difficult issue to tackle because of the lack of a direct market for most public land and the long-range nature of the trade-offs involved in spending more today to preserve space for future uses. It should be the hallmark of good city planning to take such issues into account, however, and it is recommended that towns and cities with the expectation of substantial future growth examine these issues closely and take steps to preserve underground space for future needs. Such efforts may include identifying and preserving future underground transportation corridors.

A substantial amount of work has been done to evaluate the indirect costs of disruption caused by utility work. This work can build on the procedures available for evaluating the indirect costs of partial or full road closure for road works. The costs in terms of time delays and increases rate of accidents can be substantial in already congested areas. The procedures described in the various papers on the U.K. work (see bibliography) currently include the cost of time delays, increased operating costs of vehicles, the cost of accidents, the level of air pollutants and the impact on local businesses. The U.K procedures also include increased costs to other public agencies (such as transit operators), increased road damage on diversionary roads, and additional environmental impacts of dust, noise on affected communities. Despite the listing of some factors to be considered, the data on impacts and the monetary value of these impacts is often unavailable. This is particularly true in the area of the impact of pavement cuts for utility work on the life cycle cost of a street or highway. The public works engineers with whom this was discussed felt that there was an impact but could not quantify the impact in order to be able to take this into account in their decision-making.

The research and discussions which were a part of this project have led to two main thrusts for follow on work. The first thrust has been a gathering of several Departments at the University of Minnesota into the preparation of a major proposal to the National Science Foundation for an Engineering Research Center on Underground Infrastructure Technology. This proposal also includes the cooperation of local public works agencies and some national geotechnical consultants. The second thrust has been towards the creation of a database which would allow the question of the impact of utility cuts on pavement life-cycle costs to be addressed. A Research Need Statement was prepared and submitted to two committees of the Transportation Research Board at their January 1994 meeting.

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APPENDIX A

TRB RESEARCH PROBLEM STATEMENT

TRB Research Problem Statement

Submitted to the Transportation Research Board committees dealing with Pavement Maintenance (Committee A3C05) and Subsurface Soil-Structure Interaction (Committee A2K04) in January 1994

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Member TRB Committee A2K05, NRC
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A significant contributor to the deterioration of road pavements in urban areas is the repeated cutting of the pavement and excavation of pits and trenches for utility installation and repair. Although properly specified and executed backfilling techniques work well, these techniques often are not followed - especially on small projects. The result is an unsightly and uneven road surface which often causes earlier pavement replacement than would otherwise be the case. Techniques for repairing and installing utilities with only limited access from the surface are under rapid development. Often, however, they 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 statistical impact of a road cut on the life cycle cost of a pavement. When established, this indirect cost can be applied to utility pavement cut decisions in the same way as congestion costs and accident costs are applied to highway alignment decisions.

Objectives

1. To evaluate the available data from selected public works agencies on the history of road pavements under their control. The data would be evaluated to determine if the available data were sufficient to establish a relationship between the number, size, quality control, etc. of pavement cuts and the resulting pavement condition assessment and/or life. Neural network evaluation probably would be suitable for this assessment since it can be open-ended in terms of the parameters considered.

2. To define the data collection needs which would allow a better future evaluation of the relationships involved.

Key Words

Pavement repair, utility repair, utility installation, pavement maintenance, life cycle costing, trenchless technology.

Related Work

The U.S. National Committee on Tunneling Technology has identified trenchless technologies and microtunneling as having major potential impacts on the provision and repair of underground infrastructure in the U.S.

Europe and Japan are very actively engaged in developing these technologies and are also wrestling with the indirect cost issues. In the U.K, for example, recent legislation requires the consideration of the indirect costs of road work in terms of traffic congestion and other costs when such projects are planned. The North American Society for Trenchless Technology (primarily an industry group) is a focus for the developments in the technology in the U.S.

Urgency

This is an important cost issue for public works agencies and the public. The available data probably is not of the extent and quality desired for a thorough analysis but many public works managers intuitively understand there to be a relationship. It is important that current efforts at improving the data collection aspects of pavement management include this problem as an issue. This study would provide the necessary input to do this.

Cost

$200,000

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