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.

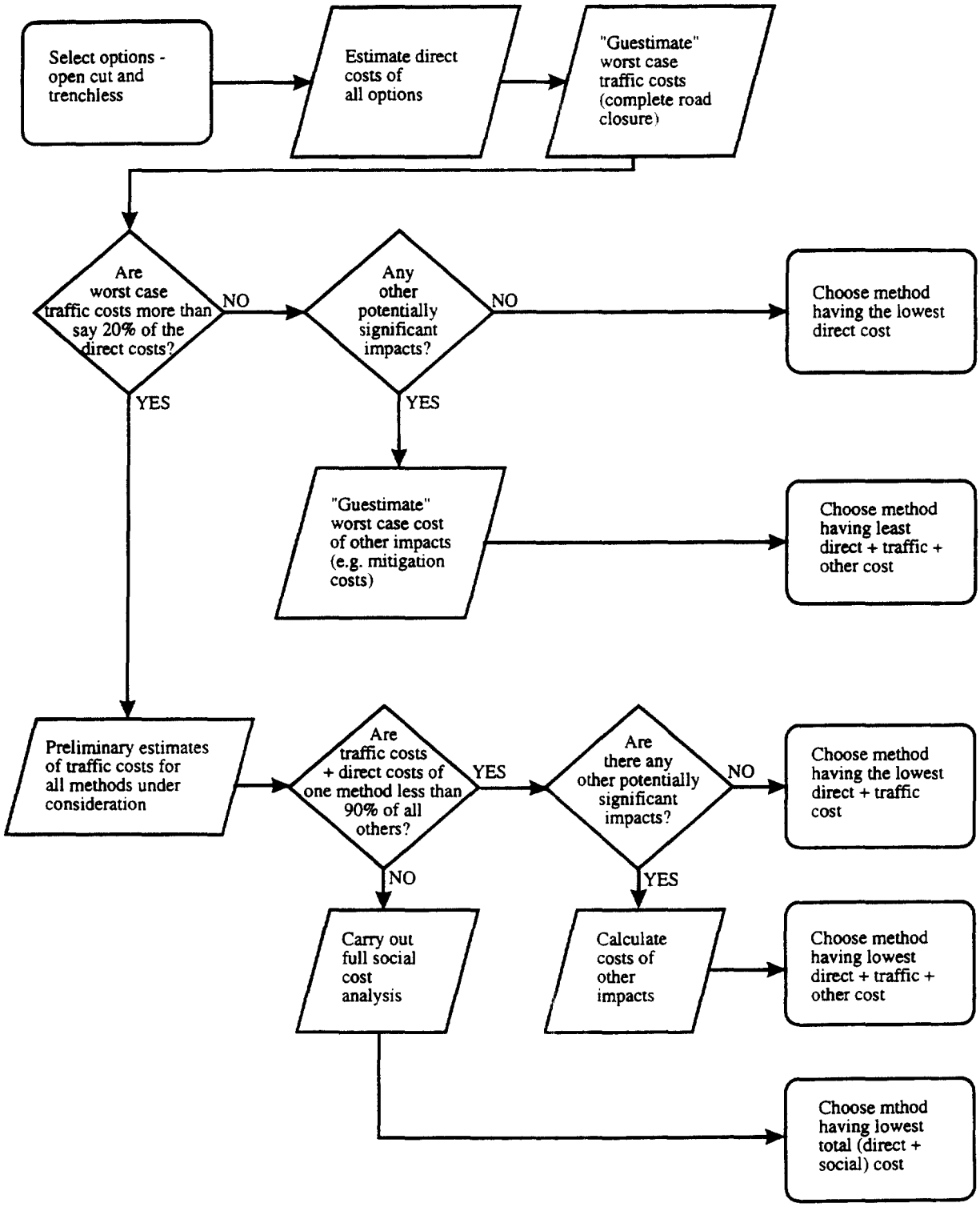

Figure 6 Inclusion of Societal Costs in Construction Method Selection

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 coordina 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

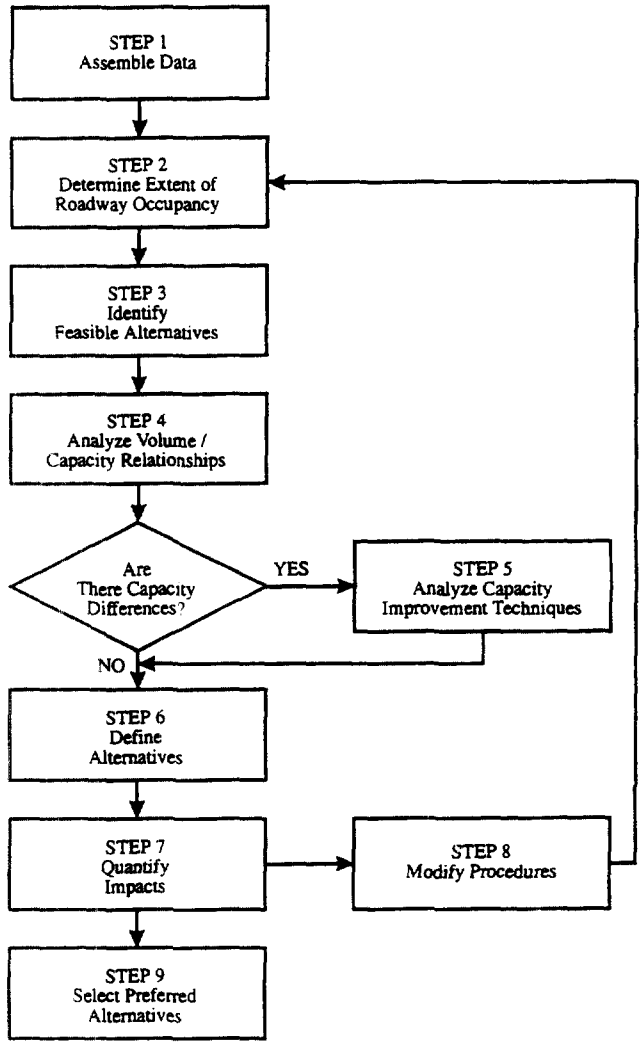

Figure 7 Work Zone Evaluation Planning Process

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:

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

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:

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

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

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:

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

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.

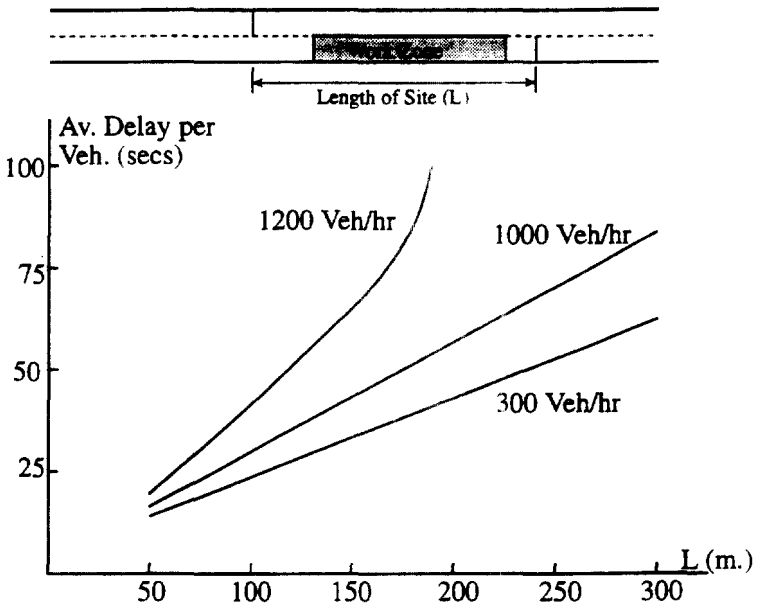

Figure 8 Average Traffic Delay for Different Lengths of Shuttle Working

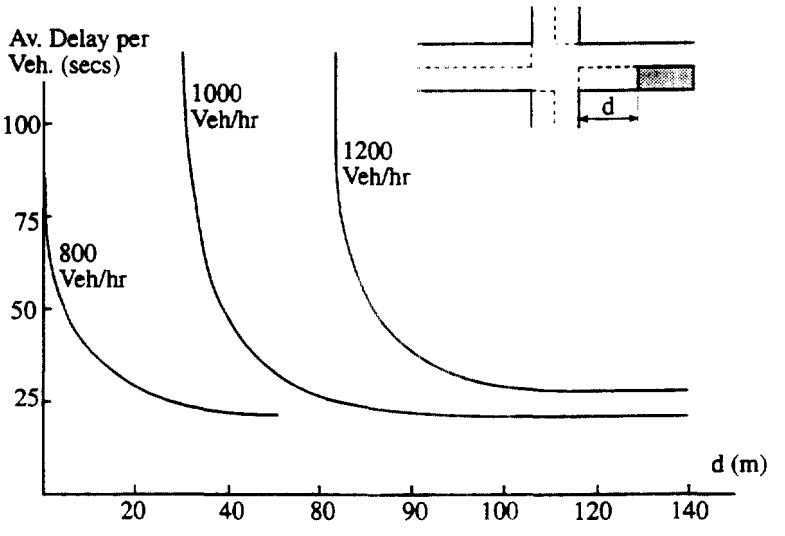

Figure 9 Average Traffic Delay Caused by Roadworks for Traffic Flows Approaching a Signal-Controlled Junction

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.

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.

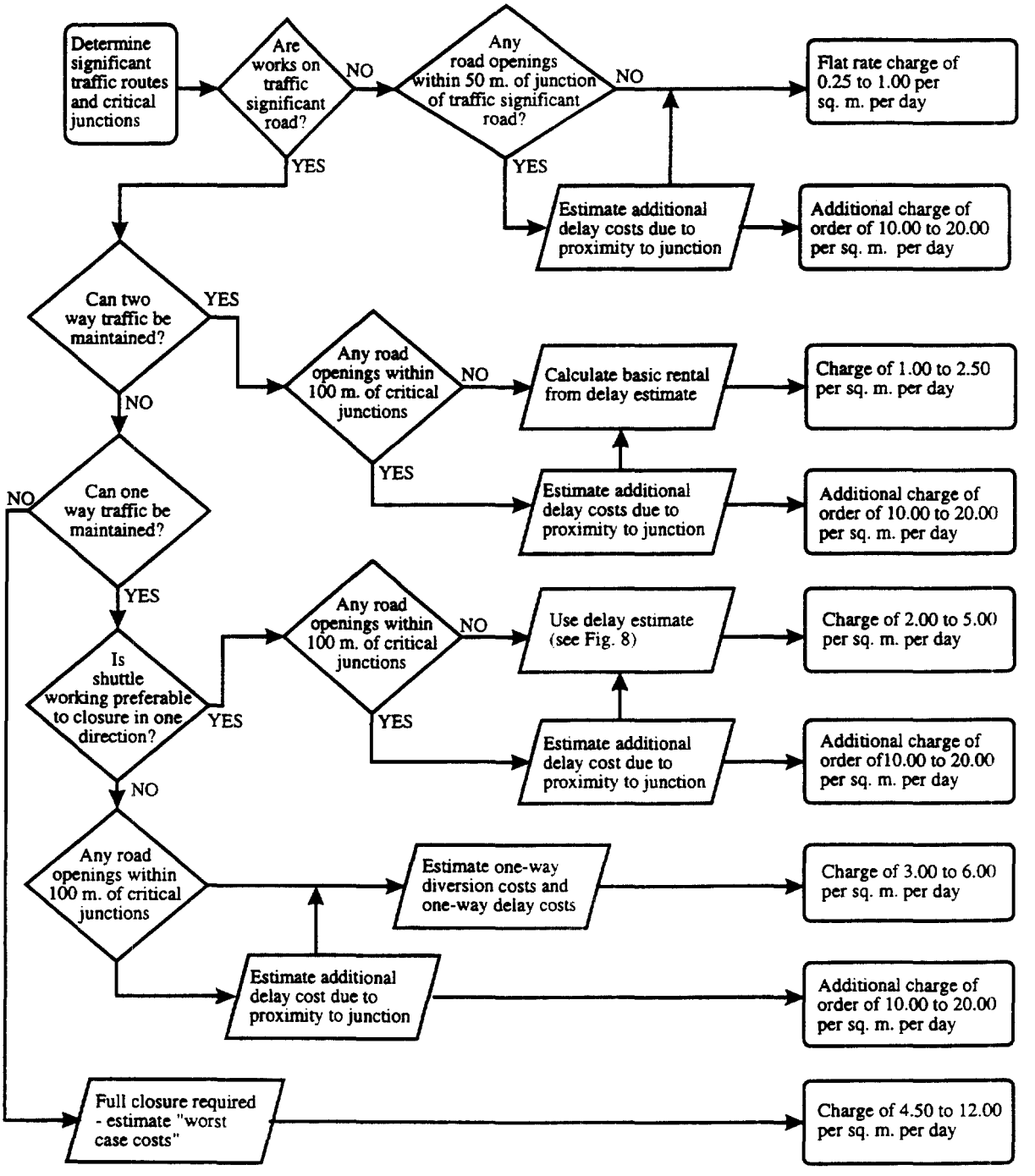

Figure 10 Determination of Road Space Rental Charges

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.