Department for Transport

Assessing the Extent of Street Works and Monitoring the Effectiveness of Section 74 in Reducing Disruption

Third Annual Report - April 2003 to March 2004

Volume 3 - Estimation of the Cost of the Delay from Utilities' Street Works

July 2004

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Executive Summary

ES1. Objective of the Study

ES1.1 This study was undertaken at the request of the Steering Group for the project to investigate the likely impact of individual utility street works on road users, in order to enable local highway authorities to identify those works which are likely to prove especially disruptive and aid them in seeking to reduce this disruption.

ES2. Method Used

ES2.1 Street works are modelled as constrictions that reduce the capacity of the carriageway, reduce traffic speeds and increase delay. A variety of street works, typical of the range found in EToN notices kept by local authorities has been assessed. The impact of the street works is derived from the following information:

(i) the dimensions of the works, using information contained in the notices

(ii) the standard of the road link on which the works are being carried out, which is approximated by using the reinstatement category parameter from the authorities' gazetteers

ES2.2 The modelling techniques take into account the availability of diversionary routes to road users, which tend to be more restricted in the case of rural networks than congested urban networks. Further work has also been done to relate the area of reinstatement from the notices to the actual area of occupation of the carriageway during the works, as this has been found to affect the extent of the disruption.

ES2.3 The information from traffic models has been used to construct tables of daily delay cost rates. Two tables have been created, for urban roads and rural roads respectively. Each table contains delay cost rates for street works of different dimensions, and streets with different reinstatement categories. This simplifies the process of estimating the daily cost of the delay from any works.

ES3. Estimation of Cost of Delay from Street Works

ES3.1 The estimation of delay using these methods is likely to result in a low value for total delay, for a number of reasons:

(i) Reinstatement category (RC) is used as a proxy for traffic volume by relating the number of commercial vehicles (CV, measured in million standard axles) to total traffic flow on a link. The relationship between traffic flow and RC obtained from the notice is system is not precise as the bands are quite broad, and there are general concerns regarding the quality of the authorities' gazetteers

(ii) In a number of cases the default category of 4 (the lowest) has been assigned where no category has been assigned by the authority in its gazetteer. This affects the estimation of delay on heavily trafficked roads that may be assigned a reinstatement category of 4

(iii) Works that do not involve excavation have not been included, even though these constitute a substantial proportion of the works and may require occupation of the carriageway from for instance safety fences or parked vehicles

(iv) Estimation of the impact of the works is affected by their location in relation to the carriageway. This means that it is possible for the impact of works of a given size to vary considerably according to whether, for example, they are situated wholly or partly in the footway, or placed centrally within the carriageway. A preliminary estimate of the percentage of footway works that also encroach on the footway has been made from a limited survey of street works in the North of England. This survey indicated that about 30% of works that are designated as works in the footway also encroach on the carriageway.

(v) The use of traffic models, particularly in congested urban situations, can result in a wide range of values of delay for links with similar traffic flows and works dimensions, due both to the algorithms used in the assignment process, and the complex nature of the networks being modelled.

We have used these figures to attempt to assess the possible annual cost of delay from street works in England. Our estimate is some £4.3 billion per year. In arriving at this figure, as the report makes clear, we have had to make a number of simplifying assumptions about certain factors that impact on any assessment of delay costs. Nevertheless, we believe that it is useful to provide a broad indicator of the negative costs of disruption from such works, in order to focus attention on the case for examining how this disruption can be reduced. We should stress, however, that this study is looking at the potentially negative effect of works on road users. As such, we have not sought to cover the benefits to the country which flow from the maintenance of England's gas, water, electricity and telecommunications networks and the provision of new services.

1. Background to the Study

1.1 Objective

1.1.1 Volume 3 of the Third Annual Report describes studies undertaken to quantify the impact of disruption caused by street works in terms of delay and associated costs e.g. increased vehicle operating and accident costs. In pursuit of this objective, a programme of work was developed to test three hypotheses:

(iii) that delay is experienced by road users due to street works;

(iv) that it is possible to quantify that delay; and

(v) consequently it is possible to arrive at an indicative estimate of the costs of delay associated with such works.

1.2 Principles Used

1.2.1 The underlying principle involves the use of data on street works from the notice system and the derivation of estimates of delay obtained from traffic models and surveys, for a range of road types and traffic volumes. Subsequently the estimate of delay is converted to a cost, based on the concept that each person values their time to a greater or lesser extent, according to the activity in which they are involved at that time.

1.2.2 Two general strands of investigation have been used to assess the amount of delay and the associated costs for a particular street works type.

The first strand involves the interrogation of data from the copies of the electronic notices that have been sent to Halcrow by the authorities participating in the overall Study (Volume 1 of this Report). To assess the impact of street works, it is necessary to acquire information about the dimensions of the works, and the traffic characteristics of the road on which the street works are carried out. The dimensions of the works can be obtained from the system of notices. The reinstatement category of each street is described in the gazetteers provided by the highway authorities and is used as a proxy for the traffic characteristics of that street. From these two parameters an estimate of journey cost can be made.

The second strand involves the estimation of delay for the full range of works types identified from the notices. To evaluate the range of delay caused by the various types of street works, the concept of a delay matrix has been developed. Individual cells of the delay matrix tabulate size of works (measured as length) against reinstatement category, being a simple measure of traffic flow and capacity. Matrices were developed for two broad road types, urban and rural, to reflect the differences in character of street works in these two situations.

1.3 Estimation of Delay

1.3.1 The estimation of delay used two methods:

(i) measurement of delay at a 'live' site (the "measurement method"), and

(ii) the use of modelling techniques to replicate street works on the ground.

1.3.2 The measurement method(method (i) above) involved the observation of delay at a major works site, using a number of survey techniques. However, these surveys provided only an restricted illustrative example of the impact of typical street works on travellers, rather than as a general model from which the estimation of delay could be developed.

1.3.3 Computer modelling techniques were widely employed to test the impact of a range of works types on delay. The models available include the following:

(i) the Department's QUADRO (Queues and Delays at Roadworks) program;

(ii) SATURN, which is used to model congested urban networks; and two micro-simulation models

(iii) (VISSIM and AIMSUN), which replicate the interaction of individual vehicles in the network.

1.3.4 Notice information is available for all street works records held for a sample of 25 highway authorities forming a representative sample of County Councils, Unitary Authorities, Metropolitan Boroughs, Inner London Boroughs and Outer London Boroughs. Each notice can be allocated a delay and hence a cost from the matrices. The individual values of cost of delay associated with each street works are then aggregated to provide an estimate of the total cost of all works in the sample. Finally, by factoring the sample up to the total number of authorities in England (150), a broad estimate of the total national annual delay cost for street works may be obtained. The results of this analysis are tabled in Section 4 "Estimation of Cost of Delay".

1.4 Principles of Cost Evaluation

1.4.1 The concept of cost is central to this exercise. It is a commonly held view amongst both business and private individuals that time is precious: indeed, the aphorism 'time is money' is in common use. This is recognised by the Department in its evaluation of the costs of travel, and particularly in the cost of road congestion, which falls on users and government alike.

1.4.2 User delay costs at street works are made up of a number of different elements. The most significant element is that cost directly experienced by road-users as a result of delay at the street works site. This is the element that is being considered in this report. There are, in addition, increased vehicle operating costs because of lower speeds through the works and extra mileage travelled on diversionary routes where used. Accidents also impose additional costs, both through both the delay occurring through blockage of the carriageway, and directly through the casualty accident costs. These latter cost elements are included in the costs calculated in QUADRO.

1.4.3 This is achieved by adopting values of time used in government economic analysis. When applied to transport analysis, a range of cost rates is available, as it is known that people value their time according to the reasons for their journey, and the vehicle that is used. For example, someone travelling in a firm's car during the course of firm's business will value their time more highly than a family travelling in their own car on holiday. QUADRO adopts a range of values which vary accordingly. For example, drivers value travelling time during work at a much higher value than their non-work time. Values also differ according to vehicle occupancy, and vehicle type (e.g. Light Goods, Other Goods or Public Service Vehicles).

1.4.4 The use of separate values of time is justified where local information of journey purpose, vehicle occupancy or vehicle type is available. In the absence of such information from the notice system, an average value of time has been used in this analysis. Using recommended government monetary values for economic appraisals, the average cost is £11.28/hr at 2002 values and market prices [source: *Values of time and operating costs, DfT TAG Unit, April 2004*].

1.4.5 It should be appreciated that the Department's QUADRO program is most applicable to major trunk road maintenance schemes and may not be totally suitable for assessing the impact of short-term road works on local authority roads. What is being assessed is effectively a 'maintenance job' in QUADRO terms, although the costs of the 'maintenance', i.e. the works carried out by the utility, are of no concern to the Department, and so do not form part of any delay cost equation. Nevertheless, the principles behind the programme are valid in that they identify the traffic costs of road works, whether it involves the use of alternative routes or just the vehicle delay and other associated costs connected with the existing route.

1.5 Use of the Notice System

1.5.1 The system of exchange of notices between the utilities and the highway authorities (EToN) is fully described in Volume 1 of this Report. Individual EToN records contain information on the start and finish dates of works, area of excavation, works category and traffic sensitivity.

1.5.2 The works category of street works is important only insofar that works of a given category are deemed to have similar delay characteristics. However, to accurately establish the level of delay it is necessary to use some indicator that identifies the road class and its level of congestion.

1.5.3 One of the key elements, traffic volume, is not directly available from information within the EToN system. Initial consideration was given to the use of traffic sensitivity [as defined in *The Street Works (Register, Notices, Directions and Designations) Regulations 1992*]. This is effectively an indicator of congestion that limits access by utilities to a road according to the time of day. From this information the flow or capacity of a street might be judged. In practice, this has not proved very useful because it is a crude measure (a street is either traffic sensitive or not), and is greatly influenced by the standard of the highway link under examination.

1.5.4 However, it is possible to cross-reference EToN records to data held by the local authority on its National Street Gazetteer (NSG), a nationwide street referencing system supported by the local authorities. This contains a parameter, reinstatement category (RC), which is a function of Commercial Vehicle (CV) traffic volumes. From these parameters it is possible to derive for a given RC an estimate of traffic flow in terms of the proportions of CVs. Streets are categorised into five types, each with a limiting capacity expressed in millions of standard axles (MSAs). In order to obtain a relationship between MSA and the 'all traffic' figure normally used for network assessment (e.g. Annual Average Daily Traffic, or AADT), assumptions need to be made about the traffic mix in terms of the number of CVs.

1.5.5 In the absence of traffic data for each EToN record, a simplifying assumption in calculation of MSA values was considered. This was to adopt the default traffic proportions such as those used in COBA (The Department’s cost/benefit analysis program for determination of the costs and benefits of highway schemes). However, these proportions are mostly applicable to inter-urban roads with relatively high proportions of CVs, whilst delay is usually more of an issue in congested inner city situations where CV proportions tend to be lower.

1.5.6 To investigate this aspect further, the Department provided traffic flow data for streets in the Boroughs of Hammersmith & Fulham and Kensington & Chelsea. It was noticeable, but not unexpected, that the CV proportions on these links are considerably lower than the standard proportions used in the Department's COBA program. It is clear that the assumptions made about the proportion of CVs for a traffic flow on a given street can have a considerable impact on the MSA calculation, and alter the RC for that street. Consequently, it is not possible to provide a definitive relationship between link traffic flow and reinstatement category that suits all situations. This limitation can only be overcome by the establishment of a system of indicators of traffic volume on individual streets.

2. Use of Information from the Notices and Gazetteers

2.1 Overall Information Requirements

2.1.1 For the assessment of the costs of delay, the key parameters used from the notice information are:

(i) The area of works

(ii) The duration of works

(iii) The reinstatement category of the street (obtained from the authority's gazetteer)

(iv) The location of the works

Items (i), (ii) and (iv) can be obtained from the notices.

2.2 Area of Works

2.2.1 The area of the works is relevant to the extent that it can be converted into a 'typical' measure in terms of its effect on reducing road width and hence capacity. Assumptions need to be made about the width and length of the typical works, which may vary according to works category or utility sector.

2.2.2 For this study, a 'typical' length and width is calculated based on the assumption that standard works reduce carriageway width by 2.5m. From this, the length of the works along the street is calculated.

2.2.3 However, the area of works quoted in the notices, and therefore estimated length of the works, is a net figure, referring only to the size of the reinstatement. Initial work assumed that the notice defined the length of that section of street affected by the reinstatement, and estimates of delay were based purely on this length. It became apparent that when allowance was made for the protection of the site required to comply with the Safety at Street Works Code of Practice, the impact of individual works on a street was considerably greater. This is because the excavation should be surrounded by a working space for storage of materials and contractors' plant and equipment, and a further safety zone whose dimensions are a function of the road type and speed limit.

2.2.4 Typically these factors can increase the effective length of the works (the critical factor as far as model estimation of delay is concerned) by between 50m and 150m depending on the speed and class of road. Table 1 below illustrates the differences for a 10m length. It will be apparent that the full impact of a small site in terms of its carriageway take-up can be considerably greater than its nominal length. These considerations have had a significant effect on the estimation of delay from street works.

Table 1 Relationship between Excavation Length and Site Length

Speed limit / road type	Excavation length	Total site length
30 mph S2	10m	56m
40 mph S2	10m	92m
50 mph S2	10m	123m
40 mph D2	10m	107m
60 mph D2	10m	153m

2.3 Duration of Works

2.3.1 Data on the duration of street works is used to extrapolate estimated delays from periods modelled in traffic models (usually peak hours) to delay times for both one day and for the total works period. However, it is generally accepted that street works of short duration (for example one day) have a proportionately greater effect on delay, because traffic has less time to adjust and look for alternative routes to so that delay is reduced for the individual driver. In contrast, for long-term works, regular travellers have time to investigate alternative routes so that delay is minimised, and, in time, traffic flows in the vicinity of the works reach an equilibrium situation in which additional delay is minimised.

2.4 Reinstatement Category of the Street

2.4.1 The relationship between street works notices and traffic flow is assessed using reinstatement category (RC). RC is effectively a proxy for traffic flow and capacity, and provides a broad indicator of link standard. Its use is necessary because the level of congestion experienced on a link is a function of link standard, and the additional disruption and associated delay caused by street works on a given link will vary depending on the standard of the link.

2.4.2 In order to establish the relationship between MSA and the traffic flow period normally used in traffic modelling (e.g. peak-hour flow or AADT), assumptions must be made about the traffic mix especially in terms of the number of CVs. Because the notice system does not specify flow data, it is necessary to develop simplifying assumptions for the relationship between CV content and total traffic flow to enable RC to be used.

2.4.3 To deal with this uncertainty, two scenarios were proposed for the modelling of delay. One scenario, where CV percentages are relatively high (and similar to the default value used in QUADRO), has been used for streets in rural and interurban situations which tend to occur normally in County Council-type local authorities. The second scenario, where CV proportions are lower (as in west London) has been applied to built-up urban situations in major cities, and has been adopted for streets in London Boroughs, Metropolitan Boroughs and Unitary Authorities.

2.4.4 The only source of traffic flow for a given street is derived from information on RC. (The relationships between RC, CV content and traffic flow are based on the *Specification for the Reinstatement of Openings in Highways - Second Edition*, and *Design Manual for Roads and Bridges, Vol. 7, HD24/96*). In developing the relationship between traffic flow and RC, two caveats need to be considered.

2.4.5 The first caveat is that, for a given RC, the estimated traffic flow may be applicable to more than one link type, and depending on link type, the relationship between flow and capacity will change. This is important, because for a given flow, a road of a higher standard will experience less delay that one of a lower standard. The EToN system has no simple way of indicating what link standard applies to the notice, and so simplifying assumptions have had to be made about its characteristics to arrive at a cost estimate for a 'typical' link associated with that RC.

2.4.6 The second caveat is that the numbers of notices in the various RCs are important in terms of the aggregation of data to provide a global estimate of delay. The lowest category, RC4 is used as a default where full information is not provided in the gazetteer. The importance of this category (particularly for small works) can be gauged from Table 2 which shows the percentage breakdown of notices by RC. 58% of all notices fall into RC4 category, where nominally at least, traffic flows are lowest. Furthermore, over 85% of openings fall into the smallest dimension category (i.e. 10m or less long) where the proportionate occupation of ancillary areas (by barriers, parking, loading areas and on-street storage) is greatest. Thus it is important for the estimation of total delay that the identification of RC is as reliable as possible.

Table 2 Percentage of Notices by Reinstatement Category and Excavation Length

Rural /Urban traffic characteristics		Percentage of notices				
Reinstatement category (RC)	**Typical AADT flow**	**10m**	**30m**	**50m**	**100m**	**200m**
Rural 0	32,000	0.2	0.1	<0.1	<0.1	<0.1
Rural 1	16,000	0.5	0.1	<0.1	<0.1	<0.1
Rural 2	12,000	2.6	0.2	0.2	0.1	0.2
Rural 3	8,000	2.5	0.2	0.1	0.1	0.1
Rural 4	4,000	25.9	1.9	1.4	1.2	0.9
Urban 0	40,000	0.4	<0.1	<0.1	<0.1	<0.1
Urban 1	24,000	4.4	0.4	0.2	0.2	0.2
Urban 2	16,000	8.2	0.5	0.3	0.2	0.3
Urban 3	8,000	9.5	0.5	0.2	0.2	0.3
Urban 4	4,000	32.1	1.6	0.9	0.6	0.4

2.5 The Location of the Works in the Highway

2.5.1 The location of street works within the carriageway is also significant in estimating costs of delay. It is possible for the impact of works of a given size to vary considerably according to whether, for example, they are situated wholly or partly in the footway, or placed centrally within the carriageway. Limited surveys of works that were noticed as being in the footway (Volume 1 of this Report, Section 6) indicate that about 30% involved occupation of the carriageway. For the purposes of this study it is assumed that in addition to works that are noticed as taking place on the carriageway, 30% of footway works impact on the carriageway and have been taken into account in estimating the extent of disruption from street works.

3. Traffic Modelling Techniques

3.1 Techniques Used

3.1.1 Rather than test the impact of individual street works by direct observation, it was decided to develop a standard set of works that could be related to information contained in the EToN database. This was because, if reliance were to be placed on site observations from local authority notifications, it would be unlikely that a full range of works could be tested using available computer based models.

3.1.2 An investigation was made of suitable model types. Three types of model were considered to be suitable for the assessment of the impact of street works on disruption:

(i) Queue / delay models (i.e. the Department's QUADRO, to show the impact of a range of street works in rural and urban situations);

(ii) Assignment models (i.e. SATURN, using a model of West London covering LB Fulham & Hammersmith and RB Kensington & Chelsea, to replicate congested inner urban situations); and

(iii) Micro-simulation models (e.g. VISSIM, using a model of Morpeth, Northumberland, and AIMSUN using a model of Preston), to show the impact of localised short-term street works (modelled as road constrictions) on freestanding urban networks in the central areas of freestanding towns.

3.1.3 The type of model adopted to assess the impact of particular street works is dependent upon the nature of the network (i.e. whether it is open or dense, or free-flowing or congested), the type of local authority (the authority group), works category, and a measure of traffic volume. It has been previously stated that reinstatement category provides a suitable proxy for traffic volume and road capacity.

3.1.4 QUADRO may be used to model situations where alternative routes are limited. Traffic models using capacity restraint assignment algorithms or micro-simulation techniques may be used to evaluate the impact of street works over a wider, urban, network. In all cases, the aim is to provide an estimate of delay for peak and off-peak periods, from which a daily or weekly delay profile can be created remaining consistent for a given works type in terms of its category, utility sector or local authority group.

3.1.5 Several scenarios encompassing a range of traffic flows, road types and street works have been tested, using the types of traffic model identified above to assess the impact of planned street works and establish relationships between these parameters and the costs of delay. The outcome of these modelling exercises is a set of tables that indicates, for differing road types, the costs of delay in terms of the volume of traffic and the extent of the street works.

3.2 QUADRO

3.2.1 The primary purpose of the Department's QUADRO program is to assess the delay costs resulting from alternative major trunk road maintenance schemes. As it is not designed to model congested urban situations where multiple route choice can occur, its use was initially confined to testing the effects of a range of street works types for principal roads of predominantly rural or inter-urban character, where alternative routes are limited. These tests are particularly applicable to the notices likely to be received by the County Councils.

3.2.2 The program has been validated using a large number of surveys and its use is authorised by ITEA Division. It also forms the basis of calculation of Lane Rental Type Contracts under the Highways Maintenance Code ("Trunk Road Maintenance Manual" (TRRM) Vol. 1).

3.2.3 QUADRO has been used here to evaluate the impact of a range of street works varying by class of road, traffic flow and street works characteristics. The program models a seven-day period, with Friday, Saturday and Sunday being modelled separately as flow patterns through the day are different. Daily and hourly delay estimates may also be obtained. In interpreting the results for this study, figures for an 'average' day have been used, the delay being obtained by dividing the weekly figure by seven. This is done on the grounds that although delay in commonly experienced throughout the week, the use of a weekday figure would ignore the impact of street works over the weekend, where the impact is normally somewhat less.

3.2.4 The model is also able to put an upper limit on delay by specifying the length of an alternative route, or a time limit to the delay before an alternative route is taken. For this analysis, an upper time limit of twenty minutes was adopted.

3.2.5 QUADRO contains a range of rates for the value of time, the use of which is justified where information on journey purpose, vehicle occupancy or vehicle type is available. As such information is not available through the notice system, the value of time adopted for this exercise is the 'average vehicle' cost. Using recommended government monetary values for economic appraisals, this cost is £11.28/hr at 2002 values and market prices [source: *Values of time and operating costs, DfT TAG Unit, April 2004*].

3.2.6 Delay due to street works is assessed whether it involves the use of an alternative route (specified in terms of length) or just capacity reductions on the existing route. The range of tests undertaken is provided in Table 3 below.

3.2.7 The outcome of this exercise is a set of values that indicates, for differing road types, the costs of delay in terms of the volumes of traffic and the extent of the street works. These are reported in Section 4 "Estimate of Cost of Delay".

Table 3 Range of QUADRO tests

Road Types	Traffic flow range (AADT)	Length of works (m)	Traffic management layout
D2	20,000 to 75,000	10 to 200	Lane closure in one direction
S2	2,000 to 20,000	10 to 200	Shuttle working

3.3 SATURN

3.3.1 SATURN is an equilibrium assignment model particularly applicable to urban situations where congestion is commonplace and a range of alternative routes is available. At equilibrium, the model represents a situation that has come about as a result of motorists testing a number of alternatives, where local knowledge on route choice has been employed, and the most efficient answer has been achieved in terms of total kilometres travelled on the network.

3.3.2 A number of SATURN models were identified for possible further investigation before it was decided to concentrate on the use of WILTRAM96 (the West Inner London Traffic Model), which covers the LB of Fulham & Hammersmith and RB of Kensington & Chelsea. The model is validated to 1996, and replicates congested inner urban situations.

3.3.3 Tests were carried out for a range of traffic flows on a congested network, using the West London (WILTRAM96) model. Links were selected to be typical of the road class and traffic volume to be tested, and modifications made to that model network to replicate the impact of the street works on individual links. These changes reflect the length of the street works and type of traffic management employed. The changes are calculated against the control network and tabulated.

3.3.4 The assignment methodology in SATURN uses a number of iterations to model route choice, based on relative change in journey times for closely competing routes. Therefore, the impact of an individual site is best estimated over the adjacent network, comprising links within 3 km of the street works site, rather than considering just the link in isolation. The alternative of considering the impact over a wider area (for example the whole of the four Boroughs contained in the model) means that the measure of impact is diluted by marginal changes in route choice in parts of the wider network unaffected by the street works.

3.3.5 Nevertheless, the results from these model analyses do show that wide range of delays is obtained for links of a given type. When examining just the link on which street works have been modelled, occasional runs show a decrease in journey time, which at first sight appears counter-intuitive, although this may be a reflection of what happens in practice for long running works, once traffic patterns have stabilised. For street works involving one-way working over 200m length with flows of up to 2,000 vehicles per hour, equivalent daily costs typically range between £600 and £11,000 depending on link type and location.

3.4 Micro-Simulation Models Employed

3.4.1 VISSIM and AIMSUN are micro-simulation models that can be used to reproduce congested peak-hour conditions, particularly in urban centres. Their main strength is that, by modelling individual vehicle movements they can, for example, reproduce the impact of short-term delay caused by emergency street works. Localised works are modelled as road constrictions. This is useful because they can model the situation in urban areas before traffic assigns to alternative routes, rather than that when equilibrium flow is attained, as is the case with SATURN modelling. In the short term, delays are expected to be higher than at the equilibrium stage when traffic has searched out alternative routes.

3.4.2 Micro-simulation models are stochastic, i.e. they involve chance or probability. Runs are often carried out to compare alternative options or designs. Each replication of a micro-simulation model shows a possible outcome. This is just one point in a sample of feasible results from the model. To achieve statistically robust conclusions in a comparative analysis of alternative options, many simulation runs need to be carried out for each option tested, each run using a different random number seed.

3.4.3 VISSIM was used to estimate costs of small street works in the centre of a small town (Morpeth). The output from the modelling process is similar to that undertaken in the SATURN analyses. For works equivalent to a 10m^2 excavation on a main street with a peak hour flow of around 1,000 vehicles, daily cost was estimated at £400. For larger works involving a longer stretch of works (up to 50m) this figure increases to around £3,000.

3.4.4 Again, caution is required in extrapolating from these figures. The VISSIM model covered a relatively small area, comprising 16 zones, with three entry links. This reduces the possibilities for rerouting within the model and therefore increases delay as alternative routes are unavailable.

3.4.5 Partly because of this, further work was undertaken using an AIMSUN model for a larger urban centre. A model of the central area of the City of Preston was made available to test the impact of short-term street works in congested urban conditions. This micro-simulation model operates in a similar way to VISSIM. Carriageway width restrictions based on notice information were been modelled as well as a situation in which a street is completely blocked. For each option tested twenty simulation runs were carried out, each with a different random number seed to give a range of possible values.

3.4.6 Most of the streets modelled fall into the RC3 or RC4 categories with hourly flows not normally exceeding about 1,000 vehicles in a peak hour (an AADT equivalent would be not more than 12,000 vehicles). The results of this modelling exercise again show a wide range of delay cost estimates between £250 and £7,000 per day, dependent on link flow and location in the network.

3.5 Consolidation of Modelling Approach Using QUADRO for Urban Networks

3.5.1 Due to the uncertainty associated with the results obtained from SATURN and the micro-simulation models, other options were discussed. One option was to carry out a much wider-ranging exercise using a variety of models for locations throughout England. This would provide a wider geographical spread and reduce the likelihood of delay cost estimates being skewed by the constructs of particular model networks. It was agreed that such a study would be both time-consuming and expensive and so a simpler approach was investigated. It was decided to revert to the use of QUADRO for urban situations, subject to careful comparison of results with those obtained from traffic models, and careful interpretation of the results.

3.5.2 Although QUADRO is not normally used to model the networks typical of urban situations, it does make explicit allowance for additional delays experienced by the use of diversion routes taken by traffic once it diverts as the time limits set for maximum queue delay in the program are exceeded. The results have a greater consistency than those obtained from SATURN or the micro-simulation models provided by other traffic models, whilst remaining broadly in line with average figures obtained from these models.

4. Estimation of Cost of Delay

4.1 Delay Cost Matrix

4.1.1 Output from the various model runs was used to populate the cells of the matrix of delay costs. The cells of the delay matrix tabulate RC (as a proxy for traffic flow) against length of works (as a proxy for works area) for both rural and urban road networks. The cost matrices for rural and urban situations are shown in Tables 4 and 5.

4.2 Rural Roads

4.2.1 In interpreting Table 4, two key factors were considered:

(i) QUADRO considers a street works link in isolation, although a maximum delay or length of diversion route is specified, effectively capping the level of delay reported. A maximum delay of twenty minutes has been specified for this analysis.

(ii) there is a minimum length of works (30m) below which QUADRO is unable to complete its processing. However, as allowance needs to be made for working space and safety zones around street works sites, works lengths of less than 30m in length are unlikely, even for the smallest excavation. Thus, as an excavation of 10m would be expected to require a site length of at least 60m, the minimum length constraint in QUADRO is not considered a problem.

4.2.2 The standard of the link is also important in assessing delay, as QUADRO will give different levels of delay depending on link standard. For example, links with flows in excess of 1,400 vehicles per hour may fall in a number of classes (e.g single 7.3m [S2], wide single 10m [WS2] or dual 7.3m [D2] carriageways). There is no easy way to ascertain from the EToN system what link class applies to such a notice, so simplifying assumptions have had to be made. Therefore an average figure has been used where overlap occurs between link classes.

4.2.3 The table also shows lower delay costs for the highest reinstatement category (0, assigned a value of 5 for the analysis) compared with the lowest i.e. 4. This is because those links with a reinstatement category of 0 were modelled as dual carriageways in QUADRO, whereas links with reinstatement categories in the range 1 to 4 inclusive were modelled as single carriageways. The dual carriageway has more space for queueing and passing traffic, hence lower delay costs even though the traffic flows were higher.

Table 4 Daily Cost of Rural Street Works (£) by Reinstatement Category and Length

RURAL					
Reinstatement category	**Typical AADT flow**	**10m**	**50m**	**100m**	**200m**
0(=5)	<320,00	2,500	3,000	3,300	4,000
1	16,000	7,850	9,050	10,250	11,000
2	12,000	1,610	2,100	2,600	3,530
3	8,000	780	970	1,200	1,625
4	4,000	335	415	515	700

Table 5 Daily Cost of Urban Street Works (£) by Reinstatement Category and Length

URBAN					
Reinstatement category	**Typical AADT flow**	**10m**	**50m**	**100m**	**200m**
0=5	40,000	25,000	25,000	25,000	25,000
1	24,000	9,000	12,000	15,000	17,000
2	16,000	3,450	5,150	7,000	8,800
3	10,000	385	535	710	1,025
4	6,000	200	280	375	550

4.2.4 Application of the costs in Tables 4 and 5 from the 25 sample authorities to the fully expanded dataset for all 150 local authorities produces the estimate shown in Table 6 below. This shows that the estimate of annual delay at street works in England based on the assumptions of this study is now about £4.3 billion.

Table 6 Delay costs (£ millions) All authorities by Sector

Period	Elec	Gas	Telecom	Water	Total
Apr 01 – Mar 02	1,055	1,263	604	1,338	4,260
Apr 02 – Mar 03	1,241	1,202	535	1,382	4,360

Not all the notices for 2004 were available at the time of compilation of this Report. As a result the estimate of cost of delay from street works was ignored. Based on our findings from data regarding the extent of street works, we have no reason to believe that the cost of delay would be different from the values estimated above.

5. Comments on the Estimate of Delay

5.1 Variation in Estimates

5.1.1 Work carried out so far using a variety of methods shows that a wide range of values can be obtained for the daily costs of delay for individual street works. Lower values relate to works that are small in nature, occur on roads carrying relatively low traffic flows (typically RC4), and are situated in urban congested conditions where alternative routes are available. Higher values relate to works that are larger scale, often involving one-way working, and are on major roads with higher traffic flows where route choice is more limited.

5.2 Overall Cost of Delay

5.2.1 A first estimate of the national cost of street works for England has been made using the delay cost matrix values contained in Tables 4 and 5, and applying them to the street works records dataset. The total cost of delay obtained by this method is currently estimated to be about £4.3 billion per year.

5.3 Sensitivity Tests

5.3.1 A number of sensitivity tests have been carried out to evaluate the effects of changes in delay cost estimates for individual works types by capping the costs associated with large works on high flow roads, or with works over 100m in length, as calculated from area. The tests confirm that reducing the costs associated with capped works has a downward effect on the total cost estimate. However, this effect is proportionately small due to the relatively low numbers of works with these characteristics.

5.4 Level of Estimate of Cost of Delay

5.4.1 The £4.3 billion figure may represent an underestimate for a number of reasons as follows:

(i) Lack of accurate definition of area occupied and of location of the works in the carriageway;

(ii) the omission of minor works without excavation, some of which entail occupation of the carriageway;

(iii) the uncertain relationship between flow/capacity and reinstatement category.

(iv) In the absence of reliable gazetteer information, the lowest reinstatement category (4) has been assumed for 85% of all works.

(v) The estimation of disruption caused by street works to other users, particularly to pedestrians, cyclists and public transport users has not been assessed. Measurement of delay experienced by these users depends on the availability of data not presently collected through the noticing system, the availability of suitable models, the scale of monitoring it is possible to undertake on roads affected by street works, and the cost effectiveness of collecting the necessary data for short period works. No account has been taken of delay to such road users in this analysis.