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THE SIMULATION OF ROUTE GUIDANCE AND TRAFFIC INCIDENTS

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to Corine

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ABSTRACT

Various route guidance systems have been developed in several countries. These systems are assumed to offer great benefits to the equipped vehicles, as well as some savings to all the others vehicles. However, the estimation of these benefits is still very imprecise, especially in case of incidents. For this reason, and also to compare different designs of systems (physical systems and guidance strategies), it was necessary to elaborate a program of simulation which can model route guidance and incidents on any network.

The following work describes such a program, based on the simulation model CONTRAM, which includes different models of incidents, a sophisticated model of non-guided vehicles and an assignment of route guided vehicles with several kinds of strategies. Numerous tests have then been undertaken on three networks with different characteristics, and have led to some quantitative estimates of benefits, for both guided and non-guided vehicles, and also for the overall-network, with varying proportions of equipped vehicles.

LIST OF ABBREVIATIONS

IVU - in-vehicle unit
LISB - route guidance system used in Berlin
O-D - origin-destination
UTC - urban traffic control

FC - fixed cycle   OC - optimised cycle
FS - fixed split   OS - optimised split

C   - car   B - bus   L - lorry

c   - cycle time   g - green time   r - red time
g   - flow

GUI - guided
UNG - unguided

JT - journey time
TJT - total journey time
DT - distance travelled
TT - travel time

K   - constant specifying distribution of link distortion weights

| 1 | INTRODUCTION |

Traffic congestion is commonplace in all the large cities of the world, despite substantial improvements in traffic control through the introduction of traffic responsive Urban Traffic Control systems such as SCOOT in England (Hunt, 1981) or PRODYN in France (Farges & Henry, 1985), which achieve significant benefits. However, these systems can only optimise signals according to existing traffic patterns, and studies have shown these to be non-optimum by typically 6 to 10% on average. An efficient route guidance system, guiding equipped drivers into optimum routes could therefore offer further benefits.

Automatic route guidance systems in which drivers are guided to their destination by equipment within their vehicle have been shown to be technically feasible in a wide variety of forms. A number of theoretical and practical studies have also shown that such techniques, particularly those incorporating roadside beacons offering on-line route guidance responsive to changing traffic conditions, could yield significant economic benefits. These findings have led to increasing activity in the development of automatic route guidance systems around the world. Of particular note are the CACS system in TOKYO (Yumoto, 1979), the LISB system in BERLIN (Von Tomkewitsch, 1987) and the AUTOGUIDE system in LONDON (DTp, 1986), (DTp, 1988).

The main benefit of these systems is usually expressed as a reduction in journey time, distance travelled or generalized cost for equipped drivers, with a small benefit to other drivers through a reduction in congestion. However, when a traffic incident occurs, such as an accident, a breakdown or road works, significant additional benefits may be expected from an on-line route guidance system which can quickly identify the incident and recommend a revised route to avoid it.

Although these potential benefits have been widely recognized, there has only been limited research into their quantifications or the appropriate control strategies required to achieve them. One way of studying the potential of route guidance systems is to use a program of simulation of traffic sufficiently elaborated to consider all kinds of networks and guidance systems. The other way would have been to test them on a real network, which means a full scale implantation into a city or part of a city, which is obviously not possible.

1.1   Objectives

In the light of the above, the objectives of this study were defined as being to:

(i)   Develop procedures for use with the CONTRAM traffic assignment model for estimating the benefits of an on-line route guidance at urban traffic incidents, to cover networks of varying sizes and characteristics.

(ii)   Use the above procedures to estimate the benefits of such route guidance and to examine the importance of different aspects of the system in urban networks for variations in:

- network size and characteristics;
- traffic volume;
- location, severity and duration of incidents;
- subscription level of guidance system;
- the network available to the guided vehicles;
- the guidance strategy;
- the guidance system criteria.

1.2   Methods of Approach

The benefits from the route guidance largely derive from the optimization of vehicle routing. They will therefore be related to the degree of non optimization already on the network. That means that the non-guided drivers behaviour will be of the greatest importance, because of their interaction with the guided drivers onto the same roads.

The work described below was aimed at developing differential assignments for the non-guided vehicles and the guided vehicles. Several approaches were possible: either create a new program of simulation, or develop one of the existing programs. However, as the development of a program such as CONTRAM has taken nearly 10 years of work (Leonard, Tough and Baguley, 1978), and it had many features required for this study , it was considered worthwhile to use it as a base.

After a description of the existing route guidance systems (§2.1) and of the different kinds of traffic simulation and the requirements in this application (§2.2), the CONTRAM traffic assignment model, enhanced and used in this study is presented in the section §2.3.

The development of the simulation of non-guided vehicles and of incidents within CONTRAM is described in the sections §3 and §4 respectively, followed by the modelling of guided vehicles in the networks (§5).

A comparison between the run of the simulation program without guided vehicle and then, the runs with different percentages of guided vehicles could underline the efficiency of the guidance systems in a standard case network. A re-run of the program when a incident occurs somewhere in the network, should emphasize the benefits of the guidance systems.

Different strategies of routing can be compared, particularly by changing the criteria and by restricting the route guidance network to the main roads and streets. It is also possible to compare a strategy using historical data and a real-time strategy.

2.1   Route Guidance Systems

Urban Traffic Control (UTC) systems, which have been successful in reducing congestion in many cities, have been mainly based on fixed time plans calculated from historical data (e.g. TRANSYT). More recently, operating systems, adjusting signal timings in frequent small increments to match the latest traffic situation, have shown a further delay saving (e.g. SCOOT and PRODYN). However, such systems are still limited in the improvement of the journey times by the fact that they are not affecting the driver behaviour.

One of the few remaining methods of improving journey times for some or all vehicles, without introducing traffic or network constraints, is to guide the vehicles onto the shortest journey time routes, from their origin to their destination.

A number of methods have been identified in recent years for the transfer of traffic and route guidance information to drivers (Southampton university, 1984), and numerous systems have been developed. Such route guidance methods may be classified into a number of categories according to the communication link.

2.1.1   Out-of-Vehicle Navigation Aid

Route Maps
A wide variety of printed road maps is currently available for route planning, with many different scales, degrees of complexity and methods of presentation. For instance, the 'speed maps' have roads colour coded according to the speeds that drivers can expect to travel. Computerized maps and route planning services are also available from a number of national motoring organizations (e.g AA, RAC in England).

Signing
Whilst travelling, the principal sources to obtain route information apart from maps, are the road signs which now include electronically controlled 'variable message' signs. These latter

are increasingly used, particularly on motorways and on major urban corridors, and have been generally associated with warnings and hazards, speed restrictions and lane closures. However, a number of other systems also incorporate traffic detection devices, usually via buried loops, so that messages can be directly related to levels of traffic flow.

2.1.2   Autonomous In-Vehicle Navigation Aid

The autonomous in-vehicle navigation aids units are systems which do not require any communication link with outside infrastructure. They have been developed recently, and fall into two general categories:

- The 'navigation units' in which origin and destination data are input and the unit gives guidance in the form of an arrow pointing towards the destination.

- The 'route computer' which contains an electronic map of the network and gives precise route details for any origin and destination. These systems are usually based on 'dead reckoning' principles and map matching.

2.1.3   Area Broadcasting

Systems ranging from local radio to a national network with a dedicated 'traffic' frequency can be used to broadcast traffic information such as details of congestion and traffic incidents to drivers. More than 70% of all motor vehicles are now equipped with radios, allowing a potentially good communication system. Use could be made of area broadcasting in on-line signal controlled networks for route guidance purposes at various levels. An immediate possibility would be to broadcast the relevant congestion and other information output from an UTC system.

2.1.4   Local Roadside Transmitters

A number of systems of local roadside transmitters have been proposed and/or developed to provide drivers with either local traffic information or fully automatic route guidance in real time. With these latter systems, the driver has only to specify his destination on an in-vehicle unit and the system ensures that he continues to receive guidance to that destination regardless of where this vehicle is in the road network. This system provides one-way communication

from the transmitting centre such as a junction beacon, electronic signpost or roadside loop to the vehicle.

2.1.5   Mobile Radio Systems

These systems provide a two-way communication link between drivers and control centres. These are currently used mainly for hazard warning, emergency calls and vehicle location/monitoring. The main problem with the use of mobile radios is the interference which occurs between users of the same frequency. This could be reduced by making more channels available and has led to the development of 'cellular' radio.

Cellular Radio

The availability of a comparatively wide band of frequencies for mobile communication has led to the design of mobile radio schemes in which frequencies are re-used within small cells. These cellular schemes can provide an extension of the public switched telephone system to mobile units and also allow communication between vehicles. It is thought the system may have a capacity constraint, although the use of cellular radio for route guidance is currently researched by a large European consortium within the DRIVE programme.

2.1.6   Local Roadside Transponders

These automatic route guidance systems based on two-way communication between the vehicles and equipment at each significant junction offer the greatest potential benefit of all systems. The controlling authority has responsibility for continual updating and maintenance of the route guidance system. In urban areas, this could potentially be linked to an on-line UTC computer.

The ALI-SCOUT / LISB system (Von Tomkewitsch, 1987) currently implemented in Berlin is an example of an automatic on-line route guidance system in which two-way communication is achieved using infra-red beam. Roadside transmission/receiving units are then able to be mounted on existing traffic signal poles, avoiding the need for buried loops which are expensive and vulnerable to damage. Some 20 % of all traffic signals in Berlin are currently being equipped: 250 beacons in urban area, over a total of about 1300 signalized intersections in Berlin, cover approximately 1500 kilometers of network and 7000 links. Interest in this system has recently grown in the United Kingdom, and a demonstration AUTOGUIDE system

- similar in operational characteristics to the LISB system- is now in progress at London. Several other countries from the EEC are also involved in an European project (PROMETHEUS DRIVE) to develop a common route guidance system. In the same way, the USA and the Japan develop their own route guidance systems: RACS or AMTICS for the Japan, and PATHFINDER, MOBILITY 2000, ADIS or IVHS for the USA (CCCT'89).

2.1.7   Description of the AUTOGUIDE System

AUTOGUIDE is a system for guiding drivers through the London area, including the M25 Orbital Motorway, to their destination.

The route guidance system consists of (see figure 2.1):

> - a computer centralizing all the data;
> - in-vehicles units which pass information from the vehicles;
> - a two-way communication link between the both, which is provided by roadside

units.

The equipped vehicles will only be cars and lorries. Effectively, the buses are always assigned on fixed routes, and are in communication with an operator who centralizes their timings or their problems, but they do not need any guidance advice.

For the equipped vehicles, the **in-vehicle unit** (IVU) comprises a calculator-style keypad, a micro-computer, a display screen, a receiver/transmitter, and can also include a compass, a distance sensor, a speedometer, an aerial and any equipment useful to receive information about the state of the vehicle and its location in the network. The driver enters the destination (map reference or street name), and the computer then provides information on the direction to follow, the distance to the next junction and the speed recommended, through the small screen or even through synthetic speech.
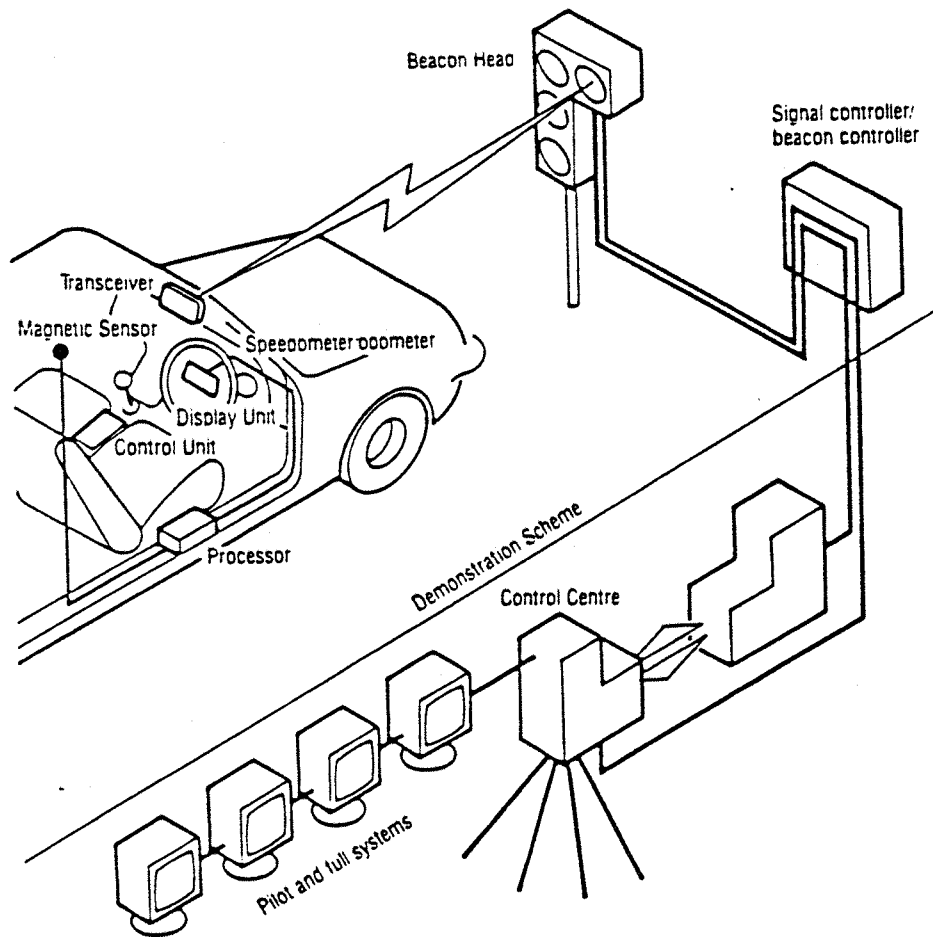
Figure 2.1 : Elements of AUTOGUIDE

In the London area, it has been estimated (Jeffery and others, October 1987) that 370,000 vehicles should be able to buy and fit in-vehicle units for about £150. This figure represents 14% of the 2.6 millions of vehicles registered in London, and should be mainly working cars or Light Good Vehicles (LGV) for 54%, then non-working cars for 27%, and finally Heavy Good Vehicles (HGV) for 19%.

The **central computer** uses the data received from the beacons, the buried loops and/or the UTC system, as well as the data from historical tables. Algorithms of optimization are then applied on these data to calculate the 'best' assignment according to a specific criterion. The choice of the criterion and algorithms is part of the guidance strategy (see §5). A second identical computer can be on permanent standby in case the first fail. The total cost of the control centre has been estimated (same source) in the region of £5m. to £10m.

The two-way **communication link** between the central computer and the roadside units is done by telephone-type cables, and between a roadside unit and the vehicles by aerial way. Depending on the use of buried loops or beacons, the communication will be done by electromagnetic field or infra-red beam. It can also be any form of hertzian communication (microwave communication is used in the CACS system at Tokyo). About 750 junctions will have to be equipped with these units in the M25 Orbital area. The cost is estimated at £14000 per junction for a buried loops system.

The total cost based on the previous estimations is about £73m. for a loop system, and about £93m. for an infrared beacon system. The running cost being in the region of £2m. to £3m. per annum.

The savings shown with the early CACS system are between 9 and 14 per cent of the journey time between pairs of origins and destinations. So, savings averaging about 10 per cent are expected from the AUTOGUIDE system, which could give a total benefit of about £170m. per annum, plus some safety and environmental benefits.

2.2   Programs of Simulation

In all the areas of physics and economy, the complexity of phenomena and studied systems has conducted the scientists to elaborate various models allowing a better knowledge of the reality. The creation of these models has led to the construction of simulations, used to test an hypothesis, the influence of parameters or a whole strategy. Nowadays, most of these simulations are under the form of software packages installed in a computer, generally inter-connected with some electronics.

In the transportation area, the first tools of simulation were born in the 1960's, mainly for scientific applications. Recently, the increase of traffic problems has conducted the authorities to use these programs for a better regulation. With the increasing use of the simulations, new performances were asked from the simulations, and some of them have known many developments.

Today, in terms of transportation or traffic planning, a program of simulation is a software package used to evaluate the potential benefits of a modification into a real network, for instance, a new signal timing, a new road, or a new signal.

According to the characteristics of the problem given, different models are available and they can be classified into different categories:
- urban or inter-urban;
- assignment or turning movement;
- continuous or discrete model;
- microscopic or macroscopic model.

However, the boundaries in these categories are not precise, and this classification is far from exhaustive.

Urban or Inter-urban Model

An inter-urban network is a set of long routes, fast routes, motorways connected with few simple junctions, generally uncontrolled or give-way. The model is particularly developed towards the speed-flow relationship and/or the interaction between vehicles (car following law and overtaking model).

An urban network is composed of short streets and routes, with many junctions of different type: uncontrolled, give-way or signalized. The model must mainly include the control of the

signals and the building of the queues.

Assignment or Turning Movement

There are different possibilities for the assignment of the vehicles. Some programs of simulation need a demand matrix which fix the assignment of the vehicles from each origin to each destination (later called O-D pair). When the vehicles enter the network, their whole route is calculated or fixed, from the origin to the destination.

Others create themselves a pseudo-random matrix and assign the vehicles according to this matrix, or just let the vehicles enter the network regularly, then decide their direction chosen at each junction following a turning movement percentage.

Continuous or Discrete Model

The continuous models require the same laws as the fluids mechanic, (i.e. the laws of propagation for the queues). The vehicles are seen as a continuous flow moving along the links (streets and routes), with a conservation law at the nodes (junctions). The variables are the average flows, and the data are the average time or average speeds.

On the opposite, the discrete models count the vehicles, independently or by packets, and move them according to their preceding, by a pursuit law. The variables are the number of vehicles, and the data can be the travel time or the speed for one or all vehicles.

Microscopic or Macroscopic Model

The microscopic models individualize each vehicle. Behavioural and interaction laws are used to simulate the trajectory of these vehicles in a specific environment. They are generally limited in the number of vehicles, by the constraints in memory and running time. So they are mainly used to simulate few junctions, in the assessment of regulation strategies.

The macroscopic models deal with packets of vehicles or with continuous flow. The great advantage is the simplicity of the model and the possibility to simulate the traffic onto large networks. They are useful to simulate the traffic into a whole city or just a part, but there validity for the study at particular points is poor.

Other Classification

Other categories can include the management of the events. There are two types:

 - the step-by-step events, where the events are succeeding in the time. It is a synchronous pattern.

- the 'asynchronous' pattern, where an event is switched on after the occurrence of another one, without any time influence. These models are not frequent.

Simulation requirements

It must be clear in mind that the boundaries of this categories are very vague, and some simulations can be, for instance, at the same time discrete for a part of the network, and continuous for an other part.

In the context of this study, it was intended to simulate the urban route guidance onto large networks. This means that we needed a program of simulation with the ability to:

- -i-   Model a network of sufficient size to develop such realistic alternative routes as may be found in urban areas;
- -ii-   Model a variety of junction and link types;
- -iii- Predict queues, delays and journey times under conditions of time varying traffic demand;
- -iv-   Allow for blocking-back effects where a queue on one link restricts the capacity of upstream links;
- -v-   Optimize traffic settings;
- -vi-   Carry out traffic assignments;
- -vii- Model fixed routes through which specified volumes and classes of vehicles can be sent (e.g. buses);
- -viii- Represent traffic incidents;
- -ix-   Offer route guidance to different proportions of vehicle at required times during the simulation;
- -x-   Give output information for each individual link and for the entire network covering such items as flows, delays and queues at any time.

The two main programs of simulation actively used in the United Kingdom, are CONTRAM and SATURN. The both have similar characteristics partially corresponding to those required (except for the items -viii- and -ix-), but the first one works on packets assignment, rather than flow profile, which seemed potentially easier to model guided vehicles, and it has also time dependent queueing, which is better for modelling peak periods. Moreover, it had the advantage to be immediately available. For these different reasons, CONTRAM has been chosen for this project.

2.3   CONTRAM: A Traffic Assignment Model

This following section describes a computer-based time-varying assignment and queueing model called CONTRAM -for CONtinuous TRaffic Assignment Model- which has been developed since 1978 at the Transport and Road Research Laboratory. For further information on this model, it is recommended to refer to the documentation (Leonard, Tough and Baguley, 1978), (Leonard and Gower, 1982) and (Leonard, Gower and Taylor, 1989)

2.3.1   The CONTRAM Model

CONTRAM is a traffic assignment model which can deal with time-varying traffic conditions in a network. The network of streets in a town is represented by a series of unidirectional links and junctions. Traffic demands enter the network at origins and leave it at destinations. Origins and destinations may occur within the network as well as on the periphery. Time-variation is modelled by dividing the simulation period into a number of consecutive time intervals of, typically, ten to twenty minutes duration. The demands for each origin-destination movement are specified as a flow rate (vehicles/hour) for each time interval. The size of the network (links, junctions and origin - destination movements), is only limited by the capacity of the computer used and by a reasonable computing time. Any link can feed up to five links, and there is a limit of 13 time intervals.

Vehicles from each origin-destination pair are grouped together to form 'packets'. The packets from any origin-destination pair enter the network equally-spaced in each time interval. The vehicles in a packet are assumed to remain together, for computational purposes, as they travel through the network; each packet is assigned to its minimum perceived cost route.

The journey time for a packet along each link of its route consists of two parts: a cruise time (i.e. a free running time), which corresponds to an average unimpeded travel time; and a delay time , which is dependent on the level of flow on a link and on the method of junction control. Three types of junction are modelled: signal controlled, give-way and uncontrolled. The latter arise where roads merge or diverge with no traffic stream having priority, and are the controlling links at give-way junctions. Roundabouts are modelled by considering each approach road as a give-way link and the road around the island as a series of uncontrolled links.

Delay calculations are based on an estimate of the average queue on each link at the end of each

time interval. The estimate of queue length depends on the queue at the end of the previous time interval (the 'initial' queue), the number of arrivals at the stop-line in the interval, the maximum rate at which vehicles can leave the link (the junction capacity) and the duration of the time interval. The theory of time-varying queues is used to take account of random variations in vehicle arrival patterns and the type of junction. It is assumed that the queue varies linearly between the queue values at the start and the end of the interval. The delay for an individual packet is calculated from the length of the queue encountered by the packet at the time that it reaches the stop-line (stop-line arrival time = entry time to link + cruise time on link). The delay is then the time taken for the queue encountered by the packet to be discharged. The rate of discharge is the maximum throughput capacity rate for that link.

CONTRAM uses an iterative procedure to predict the patterns of routes, flows, queues and delays on a network which result when drivers are familiar with network conditions. An iteration of the model consists of assigning each packet of vehicles to its minimum journey time route through the network using a tree building algorithm (Taylor, 1989). This produces patterns of traffic on the network which are used in the next iteration when each packet is reassigned to its new quickest route.

Before each packet is assigned, the flow corresponding to that packet is removed from each link of the route determined in the previous iteration. Thus a packet does not incur delays due to itself when being assigned to a new route.

As the reassignment of packets is made in the time order in which packets enter the network then the delays calculated for a given packet will be determined by flows due to packets which have entered the network prior to that packet, during the current iteration, and by flows due to subsequent packets assigned to routes in the previous iterations. This iterative process can be considered as modelling the gradual familiarization of drivers to network and traffic conditions.

There are three options for calculating signal settings in the model:
- The fixed cycle/fixed split (FC/FS) option using prescribed data values for cycle and split times;
- The fixed cycle/optimized split (FC/OS);
- The optimized cycle/optimized split (OC/OS) where the optimized values are calculated using the link flows from the previous iteration. The signal setting options do not model response to individual packets and hence do not model vehicle-actuated signals. This is not considered to be too restrictive as option OC/OS is thought to give a satisfactory approximation to vehicle-actuated control if small time intervals are modelled. Signal options

for junctions are selected from a signal plan list in which the different types of options can be mixed. This allows considerable flexibility in specifying plans for individual junctions as different plans can be selected for each time interval.

CONTRAM models the growth and decay of queues from time interval to time interval including the effects of temporary over-saturation, such as occurs during peak periods, resulting in the growth and decay of queues. Allowance is made for blocking back effects at junctions when vehicles queue back along the full length of links, blocking upstream junctions, and thereby restricting the flow of vehicles from links feeding these junctions.

The 'banned vehicle' facility can be used to prevent selected vehicle classes from using specified links in a network. This provides an easy method for examining, for example, the pedestrianisation of links, or restricted access for heavy goods vehicles.

The modelling allows for up to three classes of vehicles (C, B and L which usually represent cars, buses and lorries). Bus routes are modelled using a 'fixed route' option in which the routes for specified origin-destination movements are prescribed even though they may not correspond to the minimum journey time routes for those movements.

For each time interval the amount of fuel consumed is estimated for each class of vehicle, for economic assessment purposes. The 'linear' or 'cross-flight' speeds are calculated for selected origin-destination pairs as a measure of 'fairness' so that the effect of alternative traffic management schemes on individual journeys can be compared.

2.3.2   Inputs and Outputs Requirements

There are three types of data required for CONTRAM:
- Network and time data;
- Traffic demand;
- Control data.

Each group of data comprises a 'title card', consisting of any alpha-numeric string up to 80 characters. Then the data are normally input by 'cards'. A card is a line in the data file, containing 16 fields of 5 characters each, i.e. a total of 80 characters. The fields must contain right-justified integers, generally positives.

The numerical data cards for the Network and time and the Control packs are each identified by

a type number. In general, all data with the same type number must be grouped together.

Network and Time Data

The TIME data defines the time period to be simulated, divided in time intervals.The NETWORK data define the geometric properties of the network. They describe how origins, links and destinations are interconnected, link properties such as length, cruise time and saturation flow, as well as certain junction parameters.

Card type number	Contents of card
-	Title card
1	Time
3	Origin
4	Uncontrolled link
5	Give-way link
6	Signal controlled link
7	Signal lost time
8	Change of mind
9	Vehicle classes
10	Fuel consumption
11	Saturation flow by time interval
12	Capacity by time interval
13	Default turning speeds/times onto fed links
14	)
15	} Extra link data
16	)
18	Range check on destination numbers

Table 2.1 : Network Data Cards Type

Notice: The card type 8 (change-of-mind card) is no longer used in the latest version.

Traffic Demand

The TRAFFIC DEMAND data specifies the flow rate during each time interval for each origin-destination movement (O-D pair). The following cards are required. It can be noted that there are no card type numbers in this data pack, but the cards are easily recognizable by their structure.

Card type number	Contents of card
-	Title card
-	Origin-destination demand
-	Change of mind

Table 2.2 : Traffic Demand Cards Type

Control Data

The data in the CONTROL data pack has two 'control' functions. The first, describing the running of the program, defines the number of iterations to be carried out and the types of output required. The second provides the additional data required for signal controlled junctions. The data required for vehicles with fixed routes are also specified in this pack (generally used for the buses).

Card type number	Contents of card
-	Title card
50	Number of iterations
51	Output options
52	Link-by-link convergence matrix
53	Link-by-link each time interval
54	Link-by-link all-interval tables
154	Same as 54 with selection of tables
55	Measure of fairness
56	All turning movements
57	Selected turning movements
58	Vehicle-minutes preferred
59	Alternate printer files
60	Algorithm control
61	Scale and name perceived cost units
62	Perceived cost formulae
63	Scale and name resource cost units
64	Resource cost formulae
70	Global signal linking
71	Signal plans (FC/FS)
72	Signal plans (FC/OS)
73	Signal plans (OC/OS)
77	Plan numbers for each time interval

Card type number	Contents of card
81	Fixed routes
85	O-D movements with fixed routes

Table 2.3 : Control Data Card Type

Output

The main output from CONTRAM consists of two parts: a printout of the input data, and the output for the simulation period. The appendix B describes a typical output for the network number 1 (Leonard and Gower, 1982).

In general, the results used will be:

- the free-moving time;
- the queueing time;
- the total journey time;
- the distance travelled;
- the overall network speed;
- the number of packets or vehicles.

All these results are in the SUMMARY INFORMATION output table, as well as some additional informations.

Two others kinds of output are available:

- the post-analysis output (PAO) file;
- the route file.

The Post Analysis File

The PAO file contains the same informations as in the results file, but in a compacted form, easily usable for the computer. This file can be used by a post-analysis program (as UFPASC on IBM-PC) for specific outputs as details of individual links in graphic or tabular form for flows or queues, and comparison of outputs from different runs of CONTRAM.

The route file

The route file contains informations about the routes used by all the packets entering the network at the last iteration. For each packet, they are:

- the origin;
- the destination;
- the size of the packet;
- the type of vehicle;

- the start time;

- all the links used on the route;

- the elapsed time at the stop line of these links.

With a program to study it, this route file will be very useful to analyse the differences of the assignment between guided and non-guided vehicles.

2.3.3   Structure of the Program

The program is written in FORTRAN, and run on microVAX/VMS, or on IBM-PC compatible. The major part of this study has been conducted on the microVAX due to the superior capacity, editing and running facilities, but due to a changing of computer during the period of this work, a new version has been adapted for a SUN/UNIX Sparkstation. However, all the context dependent routines are concentrated in a unique file (VAXSYS, PCSYS or SUNSYS).

The original version 5.61 consists of a main program and 48 modules (subroutines and functions), allocated in 15 different sections (or files).

The two following flow charts describe the main structure of the program:

The first one is CONTRAM itself, and permits to understand the basic functioning and the management of the computer memory. It set-up the environment of the program, and control the right achievement of the run.

The second one, ASSIGN, describes the core of the packets assignment onto the network, and the storage of the routes.

start

-Initialise some variables
-Identify and open principal files
-Pre-read data (network, demand, control) to
acquire array dimension
- Calculate lengths of variable arrays
- Calculate how many OD pairs can be stored
- Place arrays optimally in divided memory

- Read and store network data and flow traffic
demand data

- Dimension other variable arrays
- Decide how many heuristic tables can be
pre-calculated

- Process linear distance information
- Read control file
- Calculate inter-packet spacings for each OD

- Initialise some arrays and signal setings

Last iteration done ?

- Next iteration : ITERN+

- Calcuate fixed or optimised signal
settings
- Adjust saturation flows accordingly

- Assign the packets

- Print out summary
tables
- Print out all tables

- Accumulate all summary and convergence
tables
- Print out these tables every 15 iterations

end

Figure 2.2 : Flow Chart of CONTRAM

```
                            ╭─────────╮
                            │  Start  │
                            ╰─────────╯
                                 │
                                 ▼
        ┌────────────────────────────────────────┐
        │ - Initialise local variables           │
        │ - Initialise capacities in all time periods │
        └────────────────────────────────────────┘
                                 │
                                 ▼
              ◇ Is it the first iteration ? ◇──── No ────┐
                                 │                        │
                                 │                        ▼
                                 │        ┌────────────────────────────────────┐
                                 │        │ - Get next packet origin, destination and │
                                 │        │   previous route from packet sequence generator │
                                 │        └────────────────────────────────────┘
                                 │                        │
                                 │                        ▼
                                 │        ┌────────────────────────────────────┐
                               Yes        │ - Substract packet from flows on its 'old' │
                                 │        │   route and adjust 'usual' traffic patterns │
                                 │        └────────────────────────────────────┘
                                 │                        │
                                 ▼◄───────────────────────┘
                    ┌──────────────────────────┐
                    │ - Find minimum cost route │
                    └──────────────────────────┘
                                 │
                                 ▼
        ┌──────────────────────────────────────────┐
        │ - Compare old and new routes, which are   │
        │ considered to be the same if all links and time │
        │ intervals match                           │
        └──────────────────────────────────────────┘
                                 │
                                 ▼
                    ◇ Are they identical ? ◇──── No ────┐
                                 │                       │
                                 │                       ▼
                                 │      ┌──────────────────────────────────────┐
                                 │      │ - Add packet to new flows on new route │
                                 │      └──────────────────────────────────────┘
                               Yes                       │
                                 │                       ▼
                                 │      ┌──────────────────────────────────────┐
                                 │      │ - Record change of route              │
                                 │      │ - Check for blocking back effect      │
                                 │      │ - Adjust reduced capacity             │
                                 │      │ - Accumulate data                     │
                                 │      └──────────────────────────────────────┘
                                 │                       │
          ╭───╮                  ▼                       ▼
          │ 1 │               ╭───╮                   ╭───╮
          ╰───╯               │ 2 │                   │ 3 │
                              ╰───╯                   ╰───╯
```

Figure 2.3 : Flow Chart of ASSIGN

Figure 2.3 : Flow Chart of ASSIGN (end)

It was shown earlier that the basis of CONTRAM is the assignment of packets of vehicles to minimum time (or minimum generalized cost) routes through a network, using an iterative procedure. This results in an assignment approaching the optimum (according to a minimum total journey time or total generalized cost) for the overall network, whatever the O-D matrix and the state of the network are. However, observations have shown that not all drivers are able to choose their optimum route through the network (e.g. due to an imperfect knowledge of it) and average 'wastages' of some 6 to 10 percents have been recorded in mileage and journey time (University of Southampton, 1987). This wastage should therefore be reflected in CONTRAM's assignment.

When an unpredictable incident occurs somewhere in the network (e.g. road works, signal failure or accident), drivers then have no knowledge at all of the problem. After some time, the incident may be broadcast and then known by some drivers, and/or its effects may be realized (e.g. through unexpected queues). In any case, CONTRAM's assignment, which assumes all drivers have a perfect knowledge of networks conditions, is invalid and a different assignment methodology is required.

Two methods to get sub-optima results are described below, followed by the description of two methods to assign the vehicles using historical data and no real-time knowledge of the network conditions.

3.1   Journey Time Versus Generalized Cost

3.1.1   Algorithm

The CONTRAM traffic assignment program uses a variation of the DIJKSTRA quickest-route algorithm for finding routes between particular origins and destinations (Taylor, 1989). DIJKSTRA's algorithm works by gradually building a tree of routes outward from the trip origin, visiting nodes in order of their nearness to the origin (in terms of time or some other measure of cost). In CONTRAM, an heuristic rule has been introduced in the algorithm:

> *" Visit nodes in order of increasing value of the sum of their cost from the*
> *origin and a feasible estimate of the cost remaining to the destination ".*

This is achieved by building an heuristic table to each destination, with the D'ESOPO's algorithm.

In this rule, the 'cost remaining to the destination' is chosen as the cruise time to the destination, to speed up the computation. And the 'cost from origin' can be the journey time or any form of the generalized cost, as the perceived cost.

The generalized cost associated to a link is a function of the characteristics of this link. It can be written as :

$$GENCOS = a.LEN + b.TIM + c.LEN.SPE^2 + d.STO + e.QTI + f.TOL + g.RSK$$

where   GENCOS   = generalized cost associated to a link

          LEN   = length of the link

          TIM   = journey time of the link

          SPE   = average speed of travel on the link

          STO   = number of stops

          QTI   = queueing time

          TOL   = tolls

          RSK   = risk factor

          a,b,c,d,e,f,g   = coefficients determined by the user.

It has been shown (D.Tp., Highways Economic Tables), that the journey time and the link length are the two most important characteristics affecting the drivers behaviour on inter-urban links. In urban areas, a number of studies have shown that journey time is the predominant

route choice criterion, and the minimization of journey time is used in most urban assignment models. To show the effects of the length weighting on the criterion, all the coefficients except 'a' and 'b' have been set to zero. This gives the perceived cost:

PERCEIVED COST = a.LEN + b.TIM

This formulae is applied within the following algorithm (see figure 3.1), where the cost is actually the 'heuristic cost', and is initialized to a great value for the computer.

infinite = $2^{31} - 1 = 2147483647$, for a 32 bits signed integer

The 'marking' is made on the sign of the cost: marked 'off' when the cost is positive, and 'on' when it is negative.

At the end of the algorithm, the minimum cost route is recorded in reverse order, from the destination to the origin, in the set of preceding nodes.
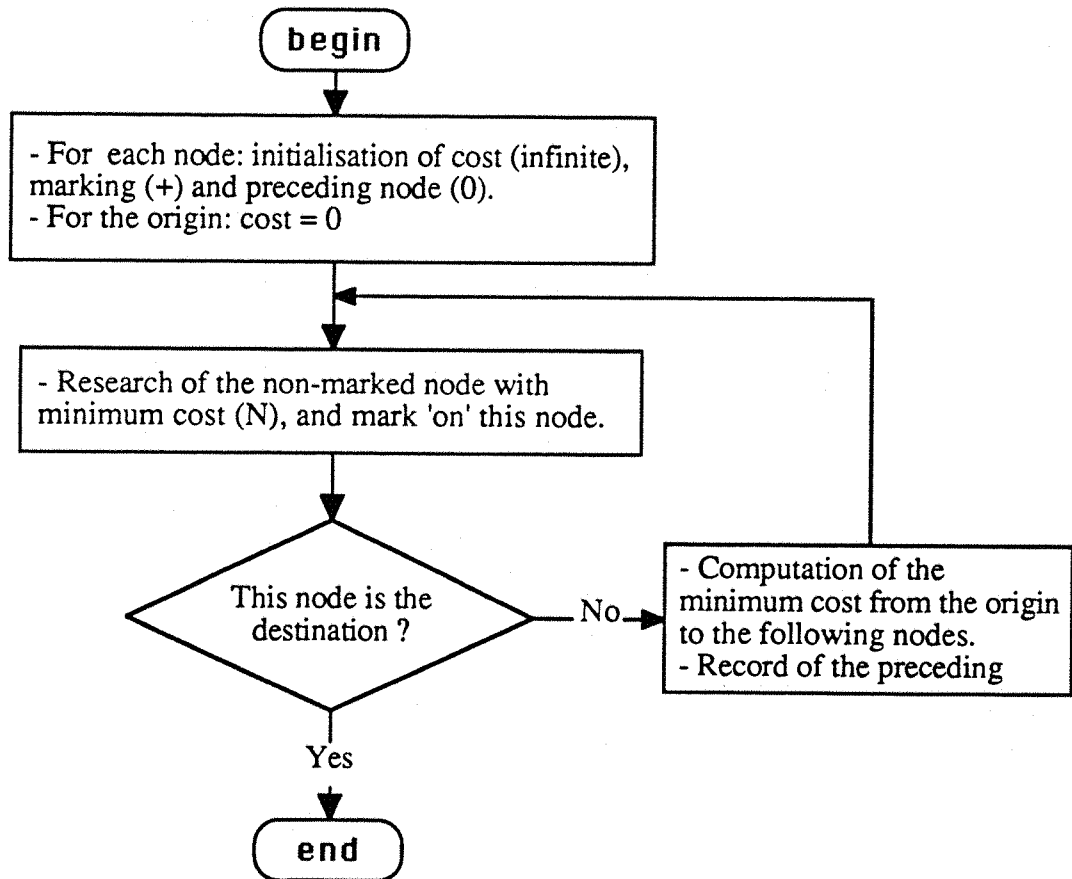
Figure 3.1 : Algorithm of Research of the Minimum Cost Route
(Variation of the DIJKSTRA's Algorithm)

3.1.2   Experiments and results

This method has been tested on the network number 1 (see Appendix A), and the following results have been achieved:

a	b	Overall Network Perceived Cost veh.hr	Total Distance veh.km	Overall Network Journey Time veh.hr	%	Distance Weighting
0	179	1376	25032	770		0
55	179	1557	24833	795	(+3.2%)	9
110	179	1717	24799	808	(+4.9%)	16
165	179	1878	24724	822	(+6.7%)	22
220	179	2058	24689	848	(+10.1%)	26
274	179	2213	24646	860	(+11.7%)	31

Table 3.1 : Distance Weighting on the Perceived Cost

The first line is the optimum total journey time, and is the reference. The last column, 'distance weighting', is a direct reflection of the importance of the total distance in the perceived cost. It is calculated as a percentage:

$$\text{distance\_weighting} = \frac{a * \text{total\_distance}}{100 * \text{perceived\_cost}}$$

The level of degradation is calculated as a percentage of excess journey time (JT) from the minimum JT to the sub-optimum JT, and is written in brackets next to the 'overall network journey time'. The different lines of the table give sub-optima results, degraded between 3.2% and 11.7% in total journey time.

The following graph shows the evolution of the excess journey time versus the distance weighting.
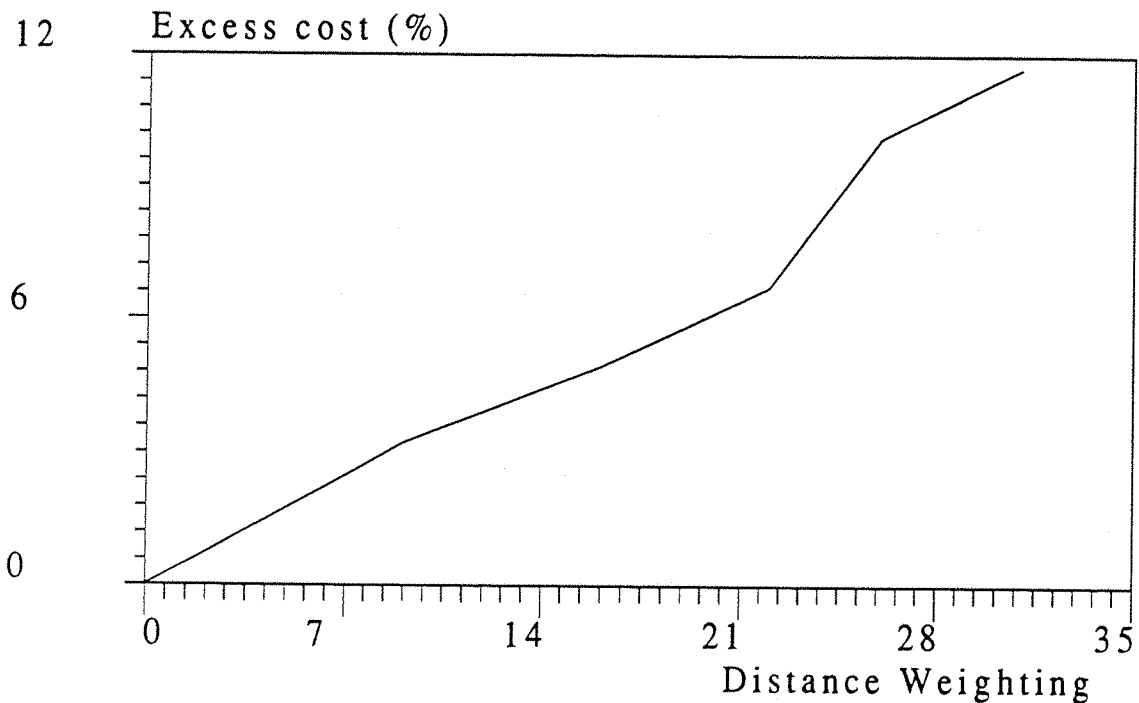
Figure 3.2 : Excess Cost vs. Distance Weighting

3.1.3   Conclusion

It is noticeable that by changing the weight of the distance (coefficient a) in the perceived cost of the links, the assignment of the vehicles will give a sub-optimum total journey time, reflecting the perception of distance in the network by non-guided drivers.

This is a first method to get a sub-optimum journey time which still reflects the real state of the network. Effectively, an unexpected high value of the journey time, for instance due to an incident on a link, will change the assignment of all the vehicles. However, in a network with normal conditions of traffic these results seem fully acceptable.

This met.hod assumes all drivers have similar perception of distance and give it equal. weighting in their route choice. In fact, inefficient route choice applies to some drivers who incorrectly perceive the wrong route. Therefore, a technique based on 'random errors' would appear better.

3.2   Pure Distortion of the Journey Time

Another approach to simulate the behaviour of unguided drivers is to say that they try to choose the quickest way from an origin to a destination, but their knowledge of the network, acquired from past experiences, is still imperfect. So, we can assume that the drivers know approximately the real journey times of the links and assign themselves on their own perceived quickest route.

In the simulation, that means that there is a random error on all the quickest routes, and these routes are not optimal. This can be represented by distorting the real journey time to get a dummy journey time, and using this value to compute the perceived optimum route.

3.2.1   Distortion of the Journey Time

The distortion of a link journey time can be implemented in the program in a simple way: each time a real journey time is computed for a link, a random value is added as follows:

$$Td = Tr + \eta(K, Tr)$$

where   Td is the dummy journey time

Tr is the real journey time

K is a distortion constant $(0 < K < 1)$

$\eta(K, Tr)$ is a random function defined thus:

$$\eta(K, Tr) = K.Tr.(2.Random - 1)$$

where Random is a uniformly distributed random number in the range:

$$0 < Random < 1$$

So the random function $\eta(K, Tr)$ is such as:

$$- K.Tr < \eta(K, Tr) < + K.Tr$$

The effect is a new journey time uniformly distributed in the range

$$(1 - K).Tr < Td < (1 + K).Tr$$

That is to say, the probability of the value Td: p(Td), is constant on this interval. This is illustrated as follows:
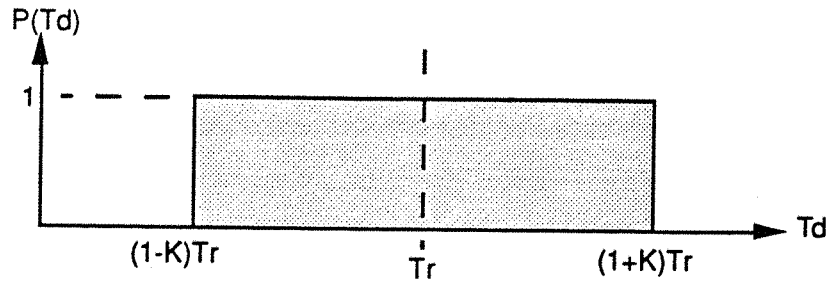
Figure 3.3 : Distribution of the Distorted Journey Time

A study on different kinds of network with the same kind of distortion (Meekums and Worster, 1988) has shown a high dependence between the size and topography of the network and the excess cost resulting from the distortion. Also, for a particular square grid network (64 nodes, 224 links), the excess cost has been shown to be a parabolic function of the distortion constant K.

A new card type has been added in the control file. It has the same format as the other cards. For a detailed study of the modifications, the reader can refer to the appendix D.

Card Type 90

> Columns 1-5   : card type number (90)
> Columns 6-10   : distortion constant (K) * 100
> Columns 11-80   : not used

3.2.2   Experiments and Results

The following table shows the excess costs obtained with the three networks and with different values for the coefficient of distortion K.The largest network (number 3) has been tested with two load levels (100% and 110% of the usual load).

3.2.3   Conclusion

The results illustrate the increasing excess cost with increasing values of K, although there is considerable variation between networks and the opportunities available for re-assignment. Through these curves, it is possible to recognize a parabolic form of excess cost in function of the distortion constant K, which can be written as:

$$Excess\ cost = \alpha.K^2 + \beta.K$$

where: K is the distortion constant,

α and β are two constants depending on the characteristics of the network and on the O-D matrix.

There is no apparent rule to calculate a and b as a function of the network characteristics and of the load of traffic. However, it seems that the tangent factor at the origin (β) increase with the load, although there is no mathematical evidence of this.

The method described above appears suitable for representing route choice inefficiency in 'normal' network conditions. Its use would, however, require experimentation with different distortion constants to achieve an 'acceptable' excess journey time. An examination of vehicle routing patterns could be carried out simultaneously to ensure that no unrealistic routes are produced.

Also, an unpredictable incident will still be modelled in CONTRAM as if all the drivers have a partial knowledge of it, this method will be used as a basis to create historical data for the non-guided drivers in the two following sections. The aim is to use data with approximately 6 to 10% of excess cost on the total journey time.

3.3   Historical File of Link Journey Time

It is not easy to determine the exact behaviour of drivers facing unpredictable events, because of so many parameters influencing their decisions. Research in this area is scarce, so it has been necessary to construct logical models for testing. One such model is based on the knowledge of the usual links journey time.

The journey time for each link, at every time interval, can be obtained from CONTRAM's table of average queueing time, added to the cruise time for the link. So, at the end of a CONTRAM run, an historical journey time file can be created, containing for each time interval the average journey time of each link.

The idea is to use these historical data to assign the non-guided vehicles, instead of the real journey times. In a second run of CONTRAM, using the preceding historical time table, a fixed journey time is associated (for each time interval) to a link and a shortest route is calculated for every packet entering the network. Because the journey time are fixed, there is no more need of several iterations (actually, CONTRAM needs at least 2 iterations to calculate the queues, which are initialized to zero at the first iteration).

For the same reason, there is only one route per O-D pair and per time interval, and all the packets of vehicles are assigned on the same route, which can then become quickly oversaturated. By using the same method of distortion as used previously (see §3.2), the historical journey time can be distorted and the non-perfect knowledge of these historical data modelled. The effects of this distortion is that several routes can now be found for the same O-D pair, and by this way, this method can be expected to be more representative of the behaviour of non-guided drivers.

It is relevant to note that the principle of routing drivers according to historical time is currently used at Berlin with the route guidance system LISB.

The historical time table is created when required by the card type 91, and the process of assignment is activated by the card type 92 , both in the control file (see appendix D for more details).

Card type 91:

> Columns 1-5   : card type (91)
> Columns 6-80   : not used

Card type 92:

> Columns 1-5   : card type (92)
>
> Columns 6-10   : coefficient for distortion * 100 (1 to 100)
>
> Columns 11-80 : not used

3.3.1   Results

This method has been tested with different values for the coefficient of distortion on the network number 1, submitted to different load levels.

In this following table, the total journey times (TJT) calculated when the vehicles are assigned according to the historical times are much greater than the TJT calculated in the standard case.(the reference) So it is more relevant to write the ratio of TJT rather than the excess cost (which would be greater than 100%).

Network number 1 with ... of the standard load	80%	90%	100%	105%
Total Journey Time in the standard case (veh.hr)	445.0	518.1	597.8	632.6
Ratio of TJT,for: K = 0.	4.86	3.03	7.76	3.99
K = 0.3	2.18	2.32	4.61	2.65
K = 0.5	1.72	2.23	4.23	3.05
K = 0.7	1.81	2.67	3.60	2.96

Table 3.3 : Comparison of Total Journey Time with the Assignment
According to the Historical Times.

It can be see in the table 3.3 that there is a huge difference in the total journey time calculated by a standard run of CONTRAM, and those calculated when the assignment is undertaken according to the historical journey time. The ratio (new TJT / standard TJT) varies between 7.76 when there is no distortion (K = 0), and 1.72 when there is the optimum distortion (K = 0.5).

Which is drawn on the next figure.
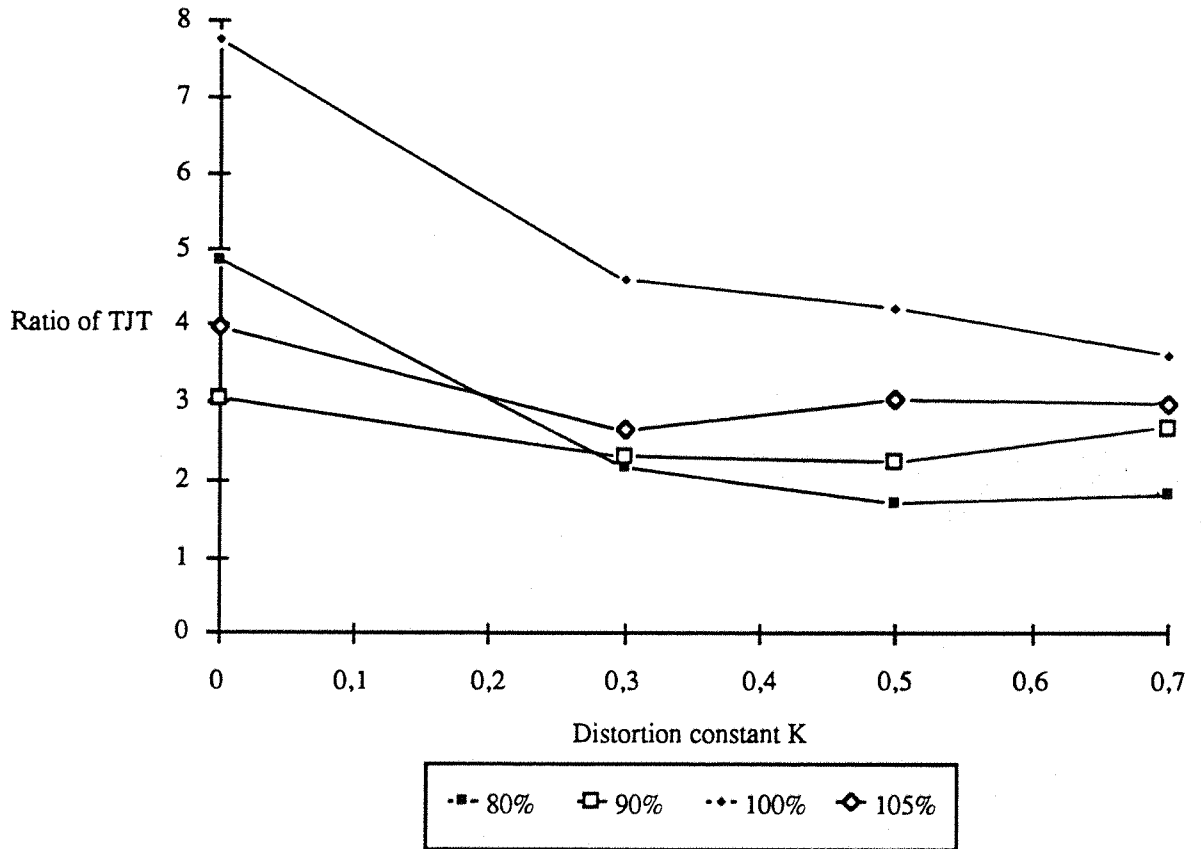
Figure 3.5 : Ratio of Total Journey Time vs. the distortion constant K

This result was more or less predicted in the case of no distortion. It comes from the fact that all the vehicles of an O-D pair are assigned on the same route during a particular time interval, creating a over-saturation of the links used, and so increasing the cost considerably.

When there is a distortion of the journey times, this result can be explained with a simple example: Let's have a single O-D pair with only two routes possible: (1) and (2), each of them with a cruise time (t_1) or (t_2), and a saturation flow (S_1) or (S_2). In general, the journey time can be written as a function of the current flow (q_1) or (q_2): This is the Wardrop formulation:

$$JT_i = \tau_i + \frac{r^2}{2*c} * \left(\frac{q_i}{S_i - q_i} \right)$$

In this formulation,

         JT_i is the journey time of the route i

         τ_i is the cruise time of the route i

S_i is the saturation flow of the route i

q_i is the flow onto the route i

r and c are the red time and the cycle time.

The normal assignment of CONTRAM would converge toward an equilibrium of the two journey times ($JT_1 = JT_2 = JT_0$), which would give the two flows: q_1 and q_2. This journey time JT_0, is stored in the historical file, and is used for the second assignment, for both routes. Because the perceived journey time is (approximately) the same on the both routes, and because the distortion gives them the same probability to occur, the flows onto both routes will be nearly the same:

$$q_0 = \left(\frac{q_1 + q_2}{2}\right)$$

This common flow q_0 will give two different journey times: JT'_1 and JT'_2

such as: $JT'_1 \gg JT_0 > JT'_2$

Therefore, the total journey time: TJT, which was:

$$TJT = JT_0 * (q_1 + q_2)$$

becomes: $TJT' = (JT'_1 + JT'_2) * q_0$

Because of the non linearity of the journey time profile, particularly near the saturation flow, it happens that:

$$TJT' \gg TJT$$

That is to say, the total journey time obtained with the second assignment (with historical journey times), is much higher than the one reached with the normal assignment of CONTRAM.

Let us have an example:

Let's consider two routes such as:

	route 1	route 2
cruise time (sec.)	45	65
saturation flow (veh/hr)	990	1105
$r^2/2c$ (sec.)	$50^2/2*100=12.5$	$50^2/2*100=12.5$

And let's have an historical travel time of 200 seconds, so the flows are: $q_1 = 915$ veh/hr and $q_2 = 1030$ veh/hr. (see figure 3.6).
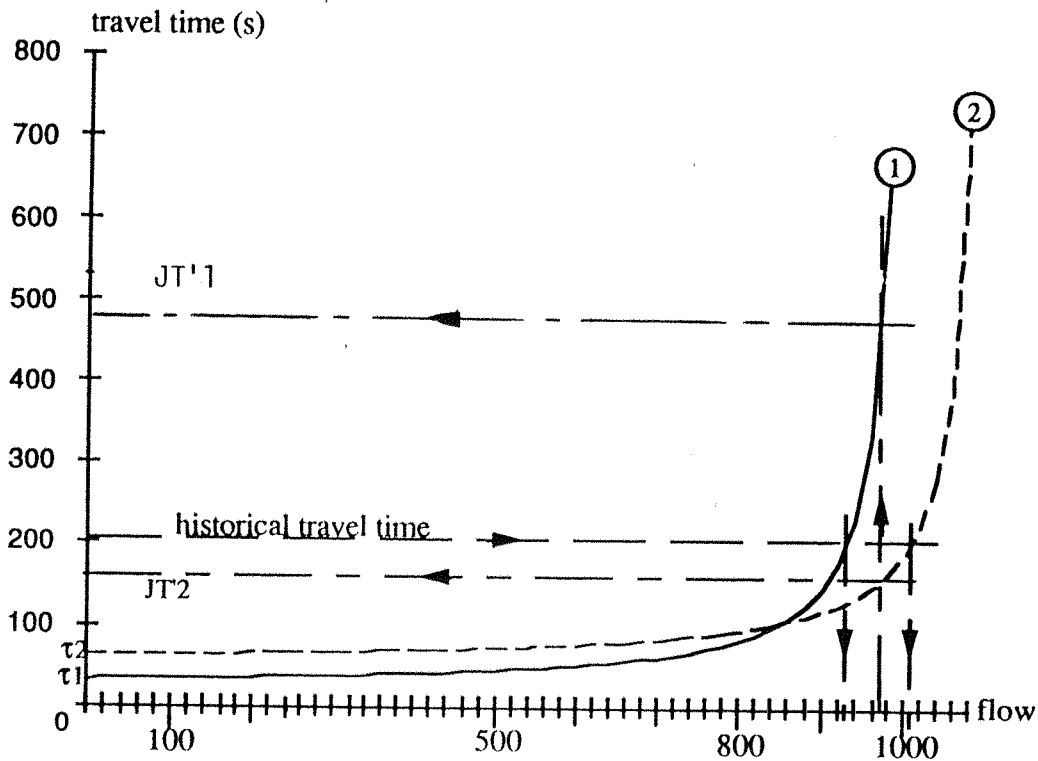
Figure 3.6 : Example to explain the differences in the assignments

The average flow is q_0 = 962 veh/hr, and gives the two travel times:

JT'_1 = 482 sec. and JT'_2 = 150 sec.

So the total trave times are: TJT = (915+1010)*200/3600 = 107 veh hours/hr

and   TJT' = (482+150)*962/3600 = 169 veh hours/hr

That is to say, an increase of 60%, just because the assignment is not the same.

3.3.2   Conclusion

Because the excess journey time obtained with this method is far too high, this assignment is definitely not valid for the non-guided vehicles.   No further development has been undertaken on this type of assignment, however it will be interesting to use it as a base for the assignment of guided vehicles, as it is currently done in the LISB system.

3.4   Historical route file

Another way to model the behaviour of drivers is to say that in a usual condition of the network they always choose the same route, or a route within a restricted set of routes, to reach their destination. In this case, the drivers no more refer to an historical journey time, but to an historical route.

3.4.1   Selection of the Route

CONTRAM, in its version 5, creates as output a route file (if the option 51 is selected in input) which is described in the Background (see §2.3).

This route file can be used in a later run of CONTRAM (version modified) to assign the packets on the same routes (i.e. preventing any computation of route by CONTRAM).

However, this route file is a sequential record of the packets information, in order of their start time. In the aim to allow more possibilities and flexibility, this route file must be modified to have the same record, but classified by O-D pair. So, it has been divided into two parts:

- The first part is a record of all the routes used, labelled and described by the link numbers, from the origin to the destination, and in order of O-D pair number.

- The second part is a record of the percentage of vehicles using each route per O-D pair and per time interval.

By this way, the number of packets (or vehicles) does not have to be the same in two following runs of the program. The packets are assigned to reach the desired percentage. That is to say, a packet must be assigned to the route where the real percentage of vehicles is the furthest from and less than the desired percentage of vehicles.

This last 'rule' is explained in the following example:

Example

Let's define an O-D pair into a network, with 3 different routes, labelled 1, 2 and 3. The total demand on this O-D pair is supposed to be 40 vehicles during the time interval, and the assignment in a standard case is such as there are:

34 vehicles on the route 1;

4 vehicles on the route 2;

2 vehicles on the route 3.

So, the desired percentages are: 85% for route 1;

10% for route 2;

5% for route 3.

In the next run of the program, when the packets are assigned on the same route, the sequence of assignment will be:

Packet Number	Route Chosen	Percentage of Vehicles on Route			Difference of Percentages on Route		
		1	2	3	1	2	3
-	-	0	0	0	85	10	5
1	1	100	0	0	-15	10	5
2	2	50	50	0	35	-40	5
3	1	67	33	0	18	-23	5
4	1	75	25	0	10	-15	5
5	1	80	20	0	5	-10	5
6	1	83	17	0	2	-7	5
7	3	72	14	14	13	-4	-9
8	1	75	13	13	10	-3	-8
9	1	78	11	11	7	-1	-6
10	1	80	10	10	5	0	-5
11	1	82	9	9	3	1	-4
12	1	84	8	8	1	2	-3
13	2	77	15	8	8	-5	-3
14	1	79	14	7	6	-4	-2
15	1	80	13	7	5	-3	-2
16	1	81	13	6	4	-3	-1
17	1	82	12	6	3	-2	-1
18	1	83	11	6	2	-1	-1
19	1	84	11	5	1	-1	0
20	1	85	10	5	0	0	0
21	1	86	9	5	-1	1	0

Table 3.4 : Sequence of the assignments in this example.

Note: In this table, the column 'Differences of Percentages' is:

(desired percentage) - (so far calculated percentage)

The underlined values determine the next 'Chosen Route'.

After 20 packet assignments, there are :   17 packets on the route 1

2 packets on the route 2

1 packet on the route 1,

and the 'desired percentage' is exactly reached. If the sequence continues to assign packets, we will notice that the calculated percentages stay very near of the desired values.

So, this method gives the right percentages (or very close) after a sufficient number of packets assignment. However, the order in which the packets are assigned is only dependent on the percentages themselves, and can be very different from the source order. As a result, exactly the same assignments occur over each time interval, but there is a small difference in the timing. The distance travelled is therefore the same, but not necessarily the queueing times and the journey times.

This process is activated with the card type 93 in the control file (see appendix D for further information).

3.4.2   Experiments and Results

The experiments have been done on the three networks described in the appendix A. A first run of the program is done to create the historical files, then a second run, with the same demand and traffic control data, is done with the assignment described above.

	First Run Journey Time (veh.hr)			Second Run Excess JT (%)		
	FT	QT	TJT	FT	QT	TJT
Network 1	453.4	166.9	620.3	0.02	4.25	1.16
Network 2	874.2	1108.4	1982.6	0.07	-0.39	-1.87
Network 3	660.2	401.8	1062.0	-0.02	1.32	0.48

Keys: FT   = Free-moving Time

QT   = Queueing Time

TJT   = Total Journey Time

Table 3.5 : Excess Journey Time when using the Historical Routes.

3.4.3   Analysis and Conclusion

The analysis of the routes shows that they are exactly the same in the both runs, and that they are used in the same proportion. So, the differences in the free-moving time (FT) is due to a cumulative rounding effect and is small enough to be neglected.

The differences in the calculation of the queueing time (QT) is due to a different departure time of the packets, creating different timing and therefore different queues.

However, this method is a good base for further work on route guidance and incidents studies, and it will be widely use for the non-guided vehicles.

3.5   Conclusion on unguided vehicles assignment

As it has already been written in this chapter, the behaviour of a 'normal' driver is unknown, and hard to model. However, four methods have been developed to improve the assignment of non-guided vehicles of the basic model CONTRAM (but three only are valid). By combining the second method (pure distortion of links journey times) and the last one (use of fixed historical routes), it is now possible to obtain sub-optima results matching with the user requirements.

Just by controlling one coefficient: the coefficient of distortion, the user can adjust the excess journey time to his/her expectations. So, these two methods will be used systematically in the next chapters.

It has been seen that the wastage due to the imperfect assignment of the non-guided vehicles is typically of 6 to 10% for the overall network journey time. However, in case of abnormal traffic conditions, such as may be caused by traffic incidents, the estimated average wastage would be between 10 and 20% (University of Southampton, 1987), but highly dependent on incident characteristics. These estimations are referenced to an assignment schemes where all the vehicles would be 'perfectly' guided.

Consequently, in a real network, the benefits due to a route guidance system can be up to 10% in normal conditions, and up to 20% in abnormal conditions. This value being highly dependent on three main factors:

      - The incident characteristics (duration, severity, location, etc);

      - The incident detection;

      - The guidance system characteristics and strategy. The last point concerning the guidance system only, it will be discussed in the next chapter.

With the aim of modelling them, it is interesting to have a review of the different studies which have been done on the incidents.

4.1   Incident Characteristics

The main characteristics of an incident are the location, the frequency, the duration, the severity and the predictability.

The location is given in term of network, link or junction number and precise location onto the link, for instance, distance referenced to the previous junction.

The frequency concerns the number of incidents per hour or per day, classified in different categories:

- The predictable incidents including the historical knowledge related incidents, such as road works and some special events as sport events;

- The road traffic accidents;

- The signal fault related incidents;

- The broken down or illegally parked vehicles, or any vehicles causing an obstruction;

- Any other not included in the above, i.e. road flooded, fire in house, burst water main, ...

Work undertaken by JMP Consultants (1989) in association with New Scotland Yard (NSY), on a eight week period has recorded an average of 50 incidents per day for the London area, that is between 0.6 and 2.0 serious incidents per year per kilometre of main road.

The following table (4.1) provides an analysis of urban incident by type:

Incident Type	Slough (1976)	Greater London (1976)	So'ton (1986)	London Area (1988)	Average
Predictable	34	19	32	12	24
Traffic Accidents	25	19	13	15	18
Signal Failures	17	12	5	31	16
Obstructions	8	23	28	16	19
Others	16	27	22	26	23

sources: Collins, 1983

University of Southampton, 1987

JMP Consultants Ltd, 1989

Table 4.1 : Urban Incident Frequencies

The duration is expressed in term of hours, minutes and seconds, associated with a start time.

The same work as above (JMP Consultants, 1989) has also recorded the delays caused by 206 incidents associated with the field surveys. These delays are in the range 1 to 33 minutes, with an average of about 12 minutes.

There is no specification about the start time of the incidents, but it is assumed that the frequency is higher during the peak periods.

A commonly adopted definition of a traffic incident (Collins, 1983) is:

> *"An unusual occurrence which reduces the capacity of the road on which it occurs."*

This reduction in capacity is measured by the severity, in percentage of the usual capacity. That is, a severity of 0% will mean no incident at all, when a severity of 100% will mean the link is totally blocked.

The predictability of an incident is the most difficult characteristic to quantify. Effectively, some occurrences are totally predictable or unpredictable, but most of them lie somewhere between these two limits, subject to a 'risk factor' of occurrence.

The planned road-works, the slow moving vehicles, some maintenance and the special events are generally classified as predictable incidents. The unpredictable events include the emergency road-works, the traffic accidents, the vehicle breakdowns and others kinds of obstruction, the traffic signal failures and others disasters (fire, flooding, hurricane, ...). Nevertheless, the predictability of these occurrences can be evaluated by using there frequency, the weather conditions prediction, a risk factor and/or any statistical law.

4.2   Incident Modelling

Incidents can be modelled within CONTRAM by adapting its standard facilities, as described below.

4.2.1   New signal and Signal Timing

By adding a signal into a link, it is possible to reduce the capacity of this link at a precise point. However, before inserting a new signal in a link, the user has to add a new link, a new signalized junction and a new signal timing.

Let be L a link from the junction A to the junction B. To simulate an incident occurring along this link, the user will have to create the links L_1 and L_2 and the new signalized junction C as shown on the figure 4.1.
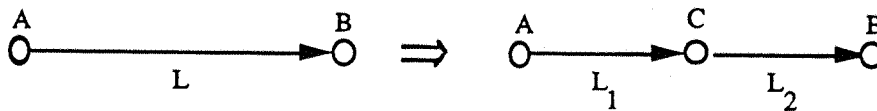
Figure 4.1 : Transformation of a Link with an Incident.

L_1 and L_2 are two links such that the sum of their length is equal to the length of the previous link L. C is the new signalized junction from which the signal timing will characterize the severity and the duration of the incident.

Once the location is determined and modelled in CONTRAM, it becomes easy to modify the severity and duration of this incident, just by changing the green and/or cycle time. Effectively, the capacity at a signalized junction is:

$$Cap = \frac{g}{c}*Sat$$

where: Cap is the capacity of the junction,

      g   is the green time of the signal,

      c   is the cycle time of the signal,

      Sat is the saturation flow of the junction, which is also the capacity of the link.

So, for a fixed cycle time, the capacity is proportional to the green time of the junction, and can vary linearly from the link capacity (g=c), i.e. no incident, to zero (g=0), i.e. link totally blocked.
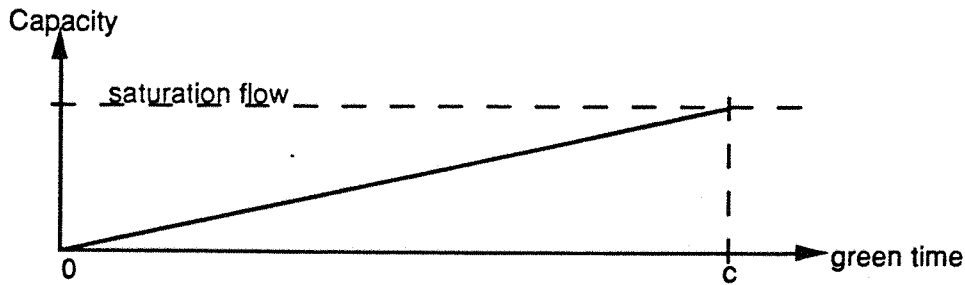
Figure 4.2: Capacity vs. green time

To check the effect of the insertion of the new signal, a first run of the program must be done with a green time equal to the cycle time, i.e. with no incident. Traffic performance should then be identical to that without the signal. After what, several runs with different values for the green time (in the range: $0<g<c$) will simulate incidents of different severities.

The severity is the percentage of reduction of capacity. It is the ratio of the capacity of the link while there is the incident, over the capacity of the link before the incident. It can be written as:

$$severity(\%) = \frac{100*Cap}{Sat} = \frac{100*g}{c}$$

where   Cap, Sat, g and c have been defined earlier.

In CONTRAM, the signal timing of a junction must be written for each time interval, so the duration will be determined in term of time intervals. Therefore, it is possible to define a profile for the capacity and for the incident duration.

The same kind of results can be obtained by using a signalized junction already existing, and modifying the green times during the time intervals chosen. Generally, a pedestrian junction (without crossing links) will be used to simulate incidents as it is simpler than having to create a new junction.

4.2.2   Capacity or Saturation Flow Reduction

One of the facilities of CONTRAM version 5, is the possibility to fix the saturation flow or the capacity of a link for each time interval. This is available with the cards type 11 or type 12.

Card types 11 and 12:

columns 1-5	: card type number (11 or 12)
columns 6-10	: link number
columns 11-15	: % factor
columns 16-80	: values in PCU/hr

Notice: The percentage factor (third field) is applied on the values of the saturation flow or capacity following (fields 4 to 16).

In a normal process, CONTRAM computes the capacities of the links as a function of the saturation flow and the signal timing if it is a signalized link, and as a function of the flow on the controlling link if it is a give-way link, and so on. In general, the capacity of a link depends on its own characteristics, and on the flow on the downstream links. When one of these cards is used, the corresponding value is fixed for the link. To simulate an incident, the fixed values must be lower than the usual ones.

For an incident located at or near a junction, the saturation flow will be reduced (card type 11), elsewhere the reduction of the link capacity will be used (card type 12). In this case, the capacity is not reduced at a particular point, but along the whole link. So, this is as if the incident was from the beginning of the link to the stop line, for instance some road works all along the link.

In both cases, the others characteristics of the link are not changed in the model. The cruise time, the storage capacity, etc... stay the same.
Here also, the duration of the incident is defined in terms of time intervals, as the profile of the saturation flow or capacity.

4.3 Incident with Unguided Vehicles: Self-diversion

This section is based on observations of traffic in case of incidents, and on an interview of some drivers relative to their behaviour in the face of abnormal traffic conditions. The literature on this subject is scarce and because there is no existing model, it has been necessary to found the following work on logical assumptions, checked with sensitivity testing. This is only valid for unguided drivers, as the guided vehicles are not concerned with the self-diversion.

The first assumption is that the drivers do not divert from their usual route if there is no evidence of an abnormal queue. That is, when a vehicle arrives at a junction, if the following link on its route is not saturated (or full), this vehicle can enter it. Moreover, when the following link on route is saturated, the driver refers to his/her historical knowledge of the occupancy level of this link. If it is usually full (historic occupancy level greater or equal 99%), the vehicle or packet of vehicles decides to queue, as it would be its or their normal expectation. In the other case (link not usually full), the vehicle or packet continues the process of self-diversion.

There are some vehicles which are not familiar with the network. They only know one route from an origin to a destination, and never try any other. Whatever happens on their route, they never change it, and even if a road is abnormally full, they feed the queue anyway. The percentage of this kind of vehicles is estimated at about 20% of the total number of vehicles (source), and are mixed with the others (random distribution). These 'fixed route' drivers are included in the subsequent modelling, their percentage being user selected.

The other vehicles prefer to use a particular route, but know sufficiently the network to divert themselves from this route to an alternative route in case of abnormal traffic conditions. The choice of the alternative route is such that it must be (or seems) 'better' than the saturated one. Several assumptions have to be done on the criterion chosen.

First of all, it is assumed that the driver will not feed an alternative route if it is already saturated. Effectively, the driver seeing two routes to his or her destination saturated, can assume that the whole network is submitted to a high level of traffic, and that his/her usual route is still the best. So, in the case of a full first link on the alternative route, there will be no diversion.

When a driver has decided that he/she could divert, he/she can use a map to check the

alternative routes, or refer to a mental image of the network. In both cases, the length, the speed expected, the width of the links, etc are used as criteria. The cruise time is a function of these factors and does not depend on the traffic pattern. Therefore, it can be used as simpler criterion. So the alternative route will be the optimum route, in terms of cruise time, from the current position of the vehicle to the destination and which does not use the saturated link.

Moreover, in the aim to assess if the alternative route found is a 'better' route, the total cruise time on this route and on the usual one are compared. It is supposed that the driver will choose a route longer (always in term of cruise time) than he/she is used to, and it has been established that the ratio:

$$\frac{\left(\text{cruise time on alternative route}\right)}{\left(\text{cruise time on usual route}\right)}$$

should be limited to a practicable value: COEFDIV. The value of COEFDIV (which stands for 'COEFficient of DIVersion') has been estimated to be in the range 1 to 2.5.

In practice, drivers diversion decisions are also likely to depend on their perception of like journey times on alternative routes. In incident conditions unknown to the driver (as here), these perceived journey times are likely to have high errors and, in any case, their calculation is difficult at the point of diversion. The simpler proposal used here, based on cruise time, is considered sufficiently realistic for this modelling.

All these conditions before diverting an unguided vehicle are summarized in the following figure, under the form of a flow chart. This flow chart can be translated in computer language, and inserted in the CONTRAM program. The corresponding modifications and the print-out of the routines are in the appendix D.

The alternative route is calculated with a DIJKSTRA's algorithm modified. Here, all the nodes already used are marked (even the nodes before the point of diversion). This marking prevents their re-use for the alternative route. It means that the packet of vehicles diverting will not come back on its tracks.
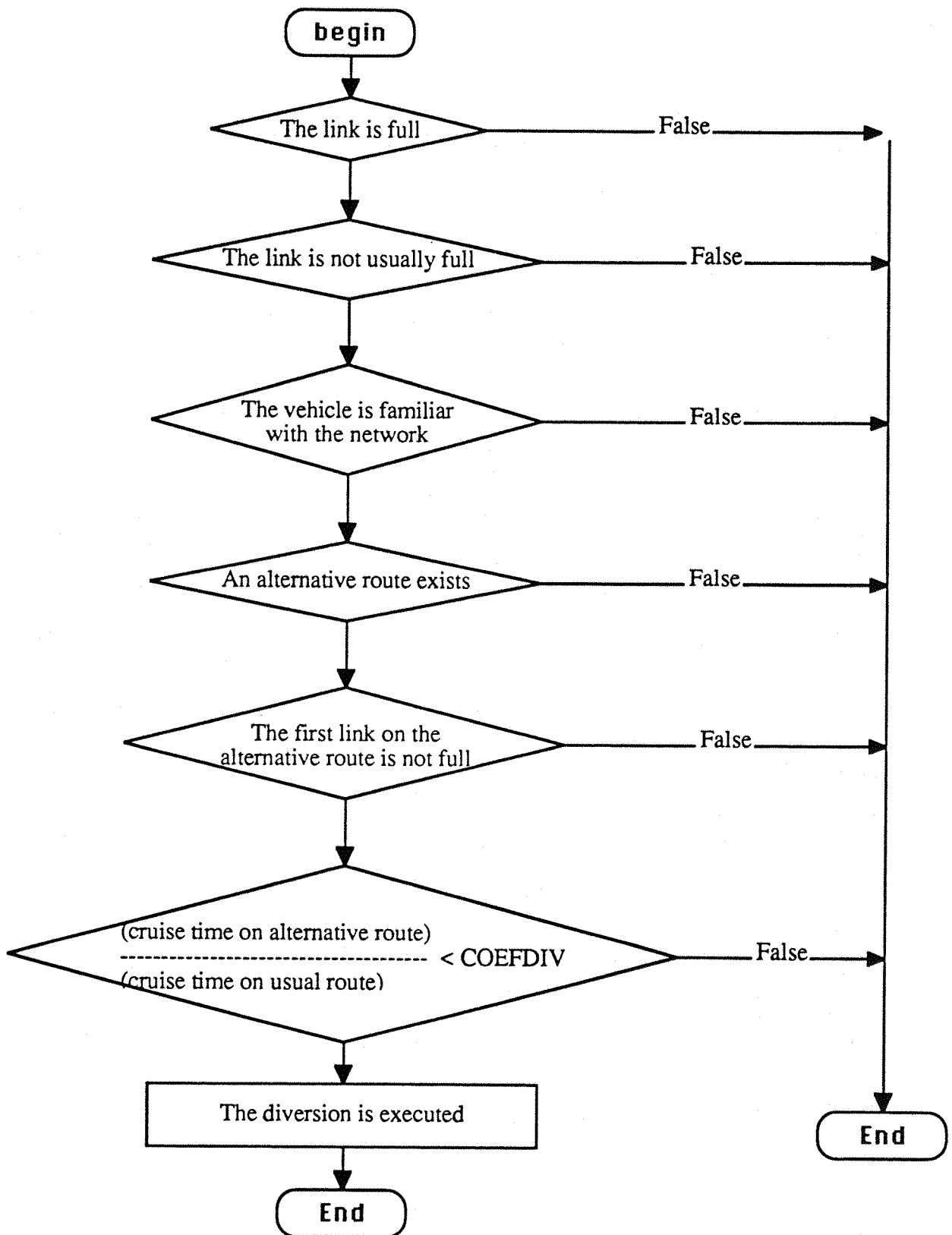
Figure 4.3 : Flow Chart Summarizing the Process of Diversion

4.4   Experiments and Results

Several experiments have been done with the three networks already used. Here are described the results obtained with different values for the coefficient of diversion (from 0 to 9.9 with steps of 0.1) and a severe incident on the network 1.

The incident used is a saturation flow reduction on the signal number 1. The green time is reduced from 30 seconds to 10 seconds, which means a severity of 60 %, during the time intervals 2, 3 and 4, that is one hour.

The percentage of vehicles never diverting is kept constant at the value of 20 %. The results have shown an evolution by steps with the coefficient of diversion. The following table summarizes the results:

coefficient of diversion	number of diversions	TJT (veh.hr)	DT (veh.km)
0.0 to 0.7	0	1019.3	21626.4
0.8 to 1.3	10	1133.5	21438.9
1.4 to 1.8	18	999.0	21612.7
1.9 to 9.9	21	886.8	21853.3

Note: TJT = Total Journey Time
        DT = Distance Travelled

Table 4.2 : Tests on the network 1 with variation of the coefficient of diversion

These results can also be viewed on the figure 4.4.

Different kinds of incidents have been tried on the three networks:

For the final results written in the appendix E, the network number 1 will have the same kind of incident (green time reduction), but only during the time intervals 3 and 4 (30 minutes), and with a severity of 50%.

The network number 2 is submitted to a capacity reduction on one of its link: link 321 with a severity of 30%, during the time intervals 3 and 4, that is 30 minutes.

The network number 3 has an incident of type saturation flow reduction. It is located on the link 1494, during the time intervals 3 and 4 (30 minutes) and the severity is 30%.

For these incidents, the results are included in the tests of the next chapter, with and without guided vehicles.
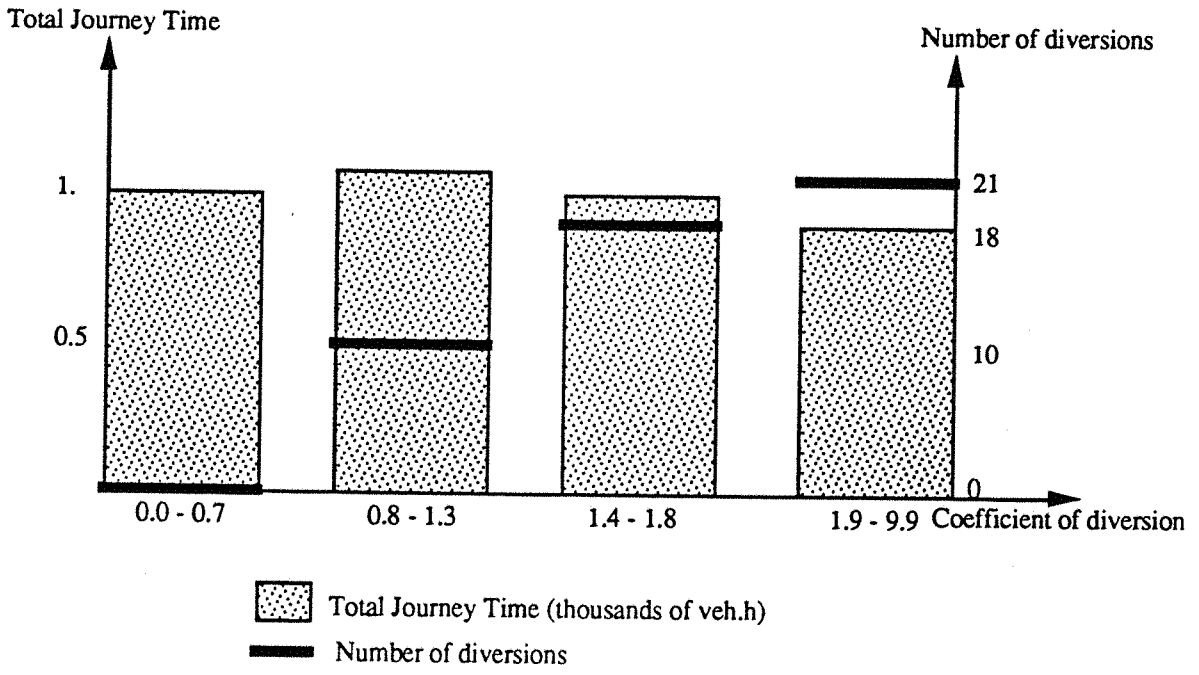
Figure 4.4 : Total Journey Time and number of diversions, vs. the coefficient of diversion

4.5   Conclusion on the incidents simulation

These results emphasize two phenomena:

⟹ The first, which is obvious with a small network as the number 1, is the effect of steps on the number of diversions carried out, which implicate the steps on the other variables. This comes from the comparison of the cruise times of the two routes: the 'normal' route and the alternative route, which is not done continuously: it is greater or not. So, the alternative route has two states: available for the diversion or not. With a bigger network, as the two others, the number of alternative routes increases and so, the steps are more frequent and smaller. This effect is less visible, and can be nearly continuous for a very large network.

⟹ The second is that, in spite of the increasing number of diversions with the coefficient, the total journey time and the distance travelled are not always predictable: the TJT increases then decreases, and the DT does the opposite, when it was expected a continuous decrease of the TJT and a continuous increase of the DT. This phenomenon shows that the user must be careful when using the diversion, and he/she must do several tests with different values of the coefficients (coefficient of diversion and proportion of vehicles never diverting) to valid the results.

For the three networks used in this work, different tests have shown that the networks 1 and 3 seem quite stable when using the self-diversion facility, but the network number 2 is not. Consequently, the diversions have been limited in this network, and the coefficients are 1.0 for the coefficient of diversion, and 60% for the percentage of vehicles never diverting.

The coefficients of diversion are 1.5 and 1.7 for the networks 1 and 3 respectively, and the percentage of vehicles never diverting is 20% for both networks.

5   SIMULATION OF GUIDED VEHICLES

It has been seen in the preceding chapters that the original version of CONTRAM was optimising the routes of all the packets of vehicles toward their destination, which is equivalent to all vehicles having nearly 'perfect' route guidance. This led to the modifications described in the chapters §3 and §4, so that the 'imperfect' behaviour of non-guided drivers could be simulated.

In a town using a dynamic route guidance system, the percentage of equipped vehicles will grow slowly from 0 up to 100%, and the resulting total journey time, for the same total number of vehicles, is expected to be less than the one without guidance, and greater than the one with a complete dynamic route guidance system. The problem is now to design and test route guidance control strategies and to assess the benefits expected from these strategies for intermediate percentages of equipped vehicles. That is to say, the program of simulation must include a model of guided vehicles, different of the non-guided one, and then assign separately the both categories into the networks.

5.1   The Guidance System

The route guidance system AUTOGUIDE has been described in the section §2.1.7. The same kind of system will be used as a base for the modelling.

However, in a first attempt to simulate the whole guidance system, it will be simplified considerably. The routes for the guided vehicles will be calculated as soon as they enter the network, and no diversion will be necessary for them. So, the beacons or loops, which are supposed to transmit the informations, will be modelled as if they were located at the origins.

In the AUTOGUIDE system, the routes are updated every 5 to 15 minutes. In the program, this can be modelled by using small time intervals. Moreover, there is a delay in the detection of incidents, and in the transmission of information in the AUTOGUIDE system. Although it is feasible to insert a delay in the calculation of the routes, this has not be modelled here so far. In effect, it is necessary to validate the program with simple results, before trying to simulate a complex system.

5.2   The Guidance Strategies

Several strategies of route guidance exist, which can be classified in two main categories. These two categories have been defined by Wardrop in the sixties under the form of two principles:

> "- First principle: *The result of the traffic assignment must give to the total journey cost its minimum value.*
>
> - Second principle: *The traffic assignment must realise the equality of the travel cost on the different routes for an O-D pair. This cost must be less or equal to the costs on the non-used routes.*"

The first principle gives a definition of the overall-network optimization. If such a traffic assignment is reached, it means that the overall-network cost is at its minimum, although it may be achieved at the expense of some vehicles (Breheret, 1988).

The second principle defines the individual optimum. That means, each time a vehicle requires a guidance advice, the system will provide him the 'best' route, regardless of the effects to the others vehicles. If not carefully controlled, this kind of strategy can cause instabilities of the traffic (Di Martino, 1987).

For both principles, it is possible to apply different cost formulae (travel time, distance, generalized cost, ...), calculated in real time or read from historical tables.

At present, the real route guidance systems are not using the whole network to assign the guided vehicles, but only a restricted network, also it is interesting to test this as part of a strategy.

5.3   Modelling within CONTRAM

There is a wide range of choices in the modelling of this new kind of vehicles. The choice which will be adopted must respond to some requirements, which are: to provide an accurate simulation of the guided vehicles; to manage the interactions between the guided and the non-guided vehicles; to offer all the results required; and not to introduce too many modifications in such a large program at one time, to avoid problems of interpretation and 'debugging'.

The progression of this work must be done step by step, and modifications must follow the structure of the basic program. The steps are: to input the data; to generate the guided vehicles; to assign them; to output the results. This logical order does not correspond to the order which will be followed. Effectively, all these steps are more or less depending on each others, and it is essential to start from the core, that is the assignment. Then the important part of the generation of the vehicles will follow. The inputs and outputs will result from the interfaces user/program and program/user.

At this stage, there are two main ways to implant the guided vehicles:
        - The first method is to split the packets of vehicles created in a way to come always closer to the desired percentage. In this case, the user of the program will have to provide only one number, representing the overall network subscription level of guided vehicles. The non-guided part of the packet will be assigned on a fixed route, while the guided part will have its route calculated. There is the problem to know which part of the packet must be assigned first. With low subscription levels, it would seem logical to assign unguided first. Also, it could be resolved by adding the choice as input option, leaving the user free to decide.
        - The second method is to have different packets: those which are guided, and those which are not, and here again there are two possibilities:
        either introduce an overall network subscription level and let the program choose among all the packets those which are guided and those which are not,
        or introduce a new category of vehicles (the guided) in the demand file, and let the program assign them differently.The first possibility seems simpler for the user but less flexible, as variations in subscription levels between different O-D pairs cannot be accommodated.For a low percentage of guided vehicles, it is intended that the size for the guided packets must be small. So, in the first case, all the packets are of small size, while in the second case, the guided packets can be of one vehicle only and the others bigger.In both cases, the subscription level is reached by creating the desired number of packets (guided and non-guided).

So, different methods seem possible to simulate the route guidance. Each of them will be considered with the generation and the assignment of the packets.

5.3.1   Assignment of the packets

The assignment of the non-guided vehicles has been seen in chapter 3 (§3.4), with the self-diversion described in chapter 4 (§4.3). Now, the guided vehicles must be assigned onto the 'best' routes, according to a chosen criterion (time or cost). In practice, the DRG system may not be able to achieve this optimum level of assignment, however it allows the maximum benefits of route guidance to be assessed in different circumstances. Later work, not described here, will study the effects of a non-optimum assignment of the guided vehicles (e.g. due to delay of incidents detection and calculations).

The original assignment done by CONTRAM uses the DIJKSTRA's algorithm slightly modified to calculate the route from an origin to a destination with 'minimum cost'.This is described in the chapters 2 (§2.3) and 3 (§3.1). By 'cost', it is intended any function of time, distance, fuel consumption, etc. When this algorithm is applied on one vehicle, it will calculate its optimum route, but when it is applied on several packets, the result is a sub-optimum assignment for all of them (except for the last packet assigned, which has always an optimum route), as well as for the overall network. However, the iterative process of computation (see §2.3), when converging, allows the traffic assignment to stabilise at a value near of the overall-network optimum (but it is not sure to be the network optimum).

This principle of assignment gives good results, and represents approximately the best way the guided vehicles could be assigned with a guidance system. Consequently, the same algorithm will be used for these vehicles in most of the tests.

However, while the subscription level to the route guidance system is low, the informations (real travel times, links occupancy levels, ...) coming from equipped vehicles are not sufficient to provide a good image of the network. So, historical data base will be used to complete the lack of informations. In the simulation program, it can be modellised by using historical travel time data to assign the guided vehicles. The same historical table as the one used for the non-guided vehicles will be utilized.

5.3.2   Generation of packets

For a particular O-D pair, the demand during a time interval gives the number of vehicles which will enter the network at that time interval. So, the number of packets corresponding can be deduced. Effectively, the size of the packets is either fixed by the user, or calculated by CONTRAM at the beginning of the run. Then the packets are equally spaced along the time interval, in the aim to get a practically constant input flow.

So, the 'start times' are computed for all the packets, which are then generated in order of their start time (subroutine PACKET). The origin, the destination, as well as some others characteristics are assigned to the next packet on list, and its route from its origin to its destination is then calculated.

Example

For instance, let's have a half hour time interval (1800 seconds), and three O-D pairs, with the following traffic demands (only cars):

        O-D pair 1:   600 veh/hr

        O-D pair 2:   700 veh/hr

        O-D pair 3:   800 veh/hr

and the packets size fixed to 10 vehicles.

So, during the time interval, there will be:

        30 packets for the O-D 1 (one every 58 sec.),

        35 packets for the O-D 2 (one every 50 sec.),

        40 packets for the O-D 3 (one every 44 sec.).When the start times for the three O-D pairs are superimposed, the result is a non-equally spaced set of packets (see figure 5.1).
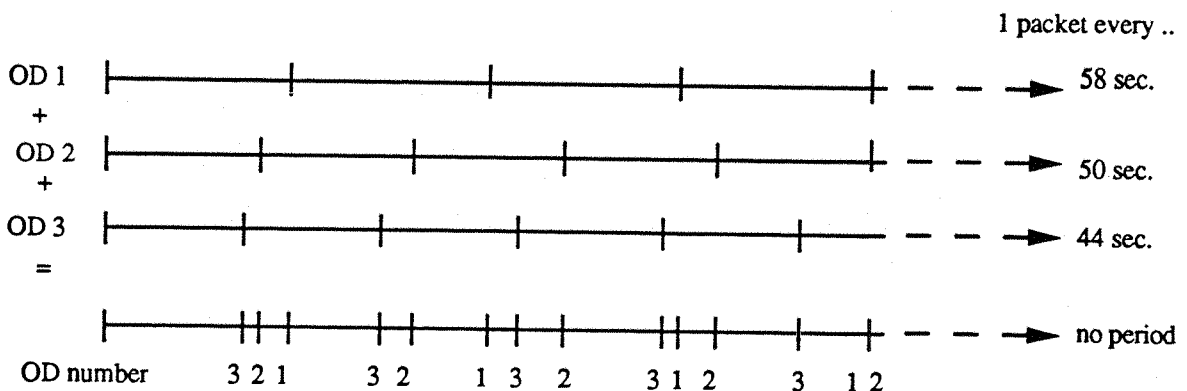
Figure 5.1 : Superimposition of the packets start times.

It can happen that several packets have the same start time. In this case, the order of starting is chosen arbitrarily by the program (generally in order of O-D internal number).

Now, the route guidance is simulated, with 10% of vehicles equipped, and three possibilities are considered:

-1-   If the packets are split (9 vehicles unguided + 1 vehicle guided), the sharing of the time interval will be the same as above (figure 5.1), but for each start time marked, there will be two packet assignments.

-2-   If all packets are small (1 vehicle per packet), some being guided, the others not. The numbers of packets (equal to the number of vehicles) will be:

	for the unguided	+	for the guided
O-D 1:	270	+	30
O-D 2:	315	+	35
O-D 3:	360	+	40

That is to say a total of 1050 packets, which is 10 times the previous number. A testing with the network number 1 (see appendix A) gives a running time of about 3 minutes with 10 vehicles per packet, 15 minutes with 2 vehicles per packet, and about 35 minutes with 1 vehicle per packet. So, it is obvious that the running time is proportional to the number of packets. Therefore this method is not possible for big networks. Effectively, the running time with the network number 3 is about 2 hours with 10 vehicles per packet, and it would be about 20 hours (nearly 1 day) with 1 vehicle per packet! Therefore, this method has not been studied further.

-3-   If the O-D pairs are duplicated: some with non-guided vehicles (10 vehicles per packet), and the others with guided vehicles (1 vehicle per packet), the demand will be:

for the unguided:	for the guided:
O-D 1A: 540 veh/hr,	O-D 1B: 60 veh/hr,
O-D 2A: 630 veh/hr,	O-D 2B: 70 veh/hr,
O-D 3A: 720 veh/hr,	O-D 3B: 80 veh/hr.

So, the total number of packets will be 190 (85 unguided + 105 guided), and the division of the time becomes totally different because there are now 6 O-D pairs to consider (see figure 5.2).
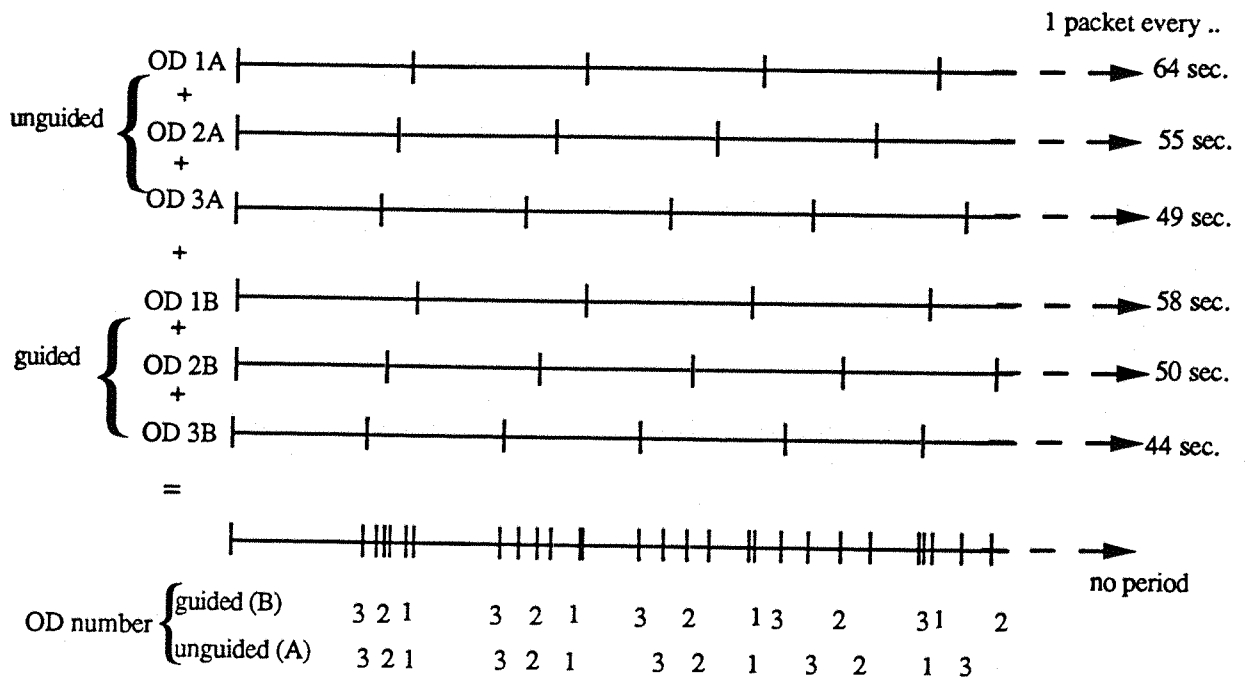
Figure 5.2 : Superimposition of the packets start times

With this third method, the program has to deal with nearly twice as many O-D pairs as with the first method, and consequently will need more memory space to store the data. However, the route guidance is better controlled than with the first method, because the user can choose the percentage of guided vehicles for each O-D pair. This flexibility is supposed to be appreciated later on for the study of particular systems.

Moreover, after a packet has been assigned, its route is stored to be re-used in the next iteration (in the array REM, subroutine STORET). In the following iteration, the packet will be withdrawn from its previous route, and a new one will be calculated and re-stored in the same array. In the case where the packet is split, two routes are computed and must be stored. But, at the next iteration, the two parts of the packet must be withdrawn apart, one on each route. This process seemed complicated and risky.

For these reasons, the third method, consisting in doubling the O-D pairs where the guidance is applied, has been chosen. The fact that the program user will have to re-write the O-D pairs using the guidance system is not really a problem with the facilities of the current text editors to copy several parts of text, and also with the facility in the reading of the demand data file within CONTRAM. The 'change-of-mind' cards (see table 2.2, §2.3.2) enable to multiply the value of the demand for a whole set of data.

5.3.3   Specific Inputs and Outputs

To use this method, the new O-D pairs must differ from the original ones by the category of the vehicles. That is to say, the program (and the user) must recognise which packets are guided and which are not. This is achieved by introducing three new classes of vehicles as shown in the table 5.1:

	non-guided	guided
Cars (C)	1	5
Buses (B)	2	(6)
Lorries (L)	4	8

Table 5.1 : Class numbers for guided and non-guided vehicles

Note 1: The buses cannot be guided, so the class number 6 will not be used. However this number is allowed by the program, because the class B can be defined for anything else than buses if the user wishes.

Note 2: To remember the class numbers, it can be noticed that, for the guided vehicles, it has been added +4 on the original class numbers.

In the output file, which re-write all the input data, the vehicle classes are now written C, B, or L, followed by UNG for the unguided vehicles, or GUI for the guided. A complete output file is available in the appendix B.

The 'SUMMARY TABLE' is an output page summarising all the main data. There are all the journey times (free-moving, flow delay, queueing and total), the distances travelled, the overall network speed, the final queues, the fuel consumption, and some others data, for each time interval, as well as the total for the simulation time, for all the vehicles.

In this table, some specific results for the guided vehicles have been added. They are all the journey times and the distances travelled at each time interval and the total, the total number of guided vehicles, the total number of packets diverting their route.

For all the vehicles, these results are computed at the last iteration, by accumulating the data by link (subroutine GATHER), and they are written together by the subroutine SUMMRZ.

5.3.4   Restriction of the network

The AUTOGUIDE system, which is used as model of route guidance, will guide the vehicles on the major roads in priority. It is supposed that the minor roads will be used only in case of an incident which could saturate the 'restricted' network. This restricted network is likely to be composed of the major links (Motorways and roads classified A and B). Thus, environmentally sensitive area, or accident prone links could be avoided in the guidance system, except in extra circumstances. It was of great interest to add this feature in the program.

The model

The idea is to assign the guided vehicles onto the restricted network in priority, but the program must allow the assignment onto the whole network in several cases. When there is no route with only major links between the location of the vehicle and its destination, when the origin is isolated from the restricted network, when the major links on its route are overloaded (whatever the reason is) are examples where a guided vehicle can use the minor links. In a general case, it can be modelled by writing that the perceived journey time of the route using only major links is much lower than the one of the route using also minor links.

Mathematically, it can be represented by using an impedance on the minor links. Here, this impedance will be a multiplicative factor applied on the journey time to change the perceived cost of the links.

$$PERCOS = (1 + Z) * LNKCOS$$

where   PERCOS is the perceived cost,

LNKCOS is the link cost (generally the journey time),

Z is the impedance applied on this link ($Z>0$).

The major links are characterised by a impedance of zero, while the minor links are characterised by a great impedance. By associating an impedance to each link, it is therefore possible to have several levels of classification for the links. A limit of 10 levels has been fixed arbitrarily (0 to 9). This limit seems quite enough to include all the classes of links.

After the specification of link impedance functions, the route for the guided vehicles are calculated by the algorithm described previously (§ 3.1), where the cost function associated to the links is this perceived cost PERCOS.

The drawing of the restricted network falls on the responsibility of the program user, when he or she draws the whole network. To write it in the network file, a new set of links have been defined. The links were previously written as:

        4 for the uncontrolled links;

        5 for the give-way links;

        6 for the signalised links.

In the new version of the program, these definitions are still accepted, but new link types can be written:

        400 to 409 for the uncontrolled links;

        500 to 509 for the give-way links;

        600 to 609 for the signalised links.

Here, the hundred defines the link type, and the unity defines the classification level (0 to 9). For instance, 400 will be a major uncontrolled link (motorway), and 509 will be a minor give-way link.

Once the network has been written with the specifications for the restrictions, the user may decide to compare the guidance on the whole network (unrestricted), and the guidance on the restricted network. So, the program must accept the network file as it is, that is, always with the specifications of restriction, but not necessarily use them. To do that, an overall factor has been introduced, which divides all the individual links classification levels. The equation is now:

$$PERCOS = \left(1 + \frac{Z}{RGFACT}\right) * LNKCOS$$

where: PERCOS is the perceived cost,

          LNKCOS is the link cost (journey time),

          Z is the impedance associated to the link (classification level),

          RGFACT is the 'route guidance factor', used for the overall network: RGFACT > 0.

RGFACT is an integer in the range 1 to 10. It represents the importance given to the restricted network. The lower it is, the more the guided vehicles will stick to the restricted network. If the user inputs zero for value of RGFACT, the network is not restricted at all. That is:

        if RGFACT = 0, then PERCOS = LNKCOS

All this process does that, depending on the coefficients associated to the links, and on the value of RGFACT, the guided vehicles are more or less attracted on the restricted network.

However, they always have the possibility to escape from it when it is not adequate to provide a route, or a 'cheap' route.

The links classification is written in the network file, but there is no output of these data.The overall factor RGFACT is written in the control file with the card type 96. Its value is written in the output file.

Card type 96:

        columns 1-5:   card type number (96)

        columns 6-10:   RGFACT, integer in the range 0 to 10.

5.3.5   Summary of the process

To summarise, when the program user wants to simulate a network equipped with route guidance, he/she will have:

    - to create the historical data, i.e. the route file and the occupancy level file, with the card type 91, and 90 if he/she wants sub-optimum results;

    - to decide which O-D pairs are equipped, and to duplicate them into the demand file, without forgetting to change the categories of vehicles (+4);

    - to fix the percentage of guided vehicles for these O-D pairs, with a 'change-of-mind' card before the list of O-D;

    - to draw the 'restricted network' with the different classes of links, and then to change the network file consequently (links numbered from major to minor: 400 to 409, 500 to 509 or 600 to 609);

    - to adapt the control file to the unguided vehicles with the card type 93 : coefficient of diversion and percentage of vehicles never diverting, and to the guided vehicles with the card type 96: multiplicative factor for the restricted network;

    - and then to run the program.

If the user wants to simulate an incident, he/she will have to fix the capacity or the saturation flow of one or several links (card type 11 or 12 in the network file), or, to change the green time of a signal previously inserted in the network.

5.4   Experiments and Results

All the modifications described in the previous chapters and in the appendix D have been conducted in the program CONTRAM, which has then been renamed SMARTI (for Simulation Model to Assess Route guidance and Traffic Incidents) in the aim to avoid any confusion. This program has been used to produce the following results.

5.4.1   Series of Experiments

The results listed in the tables of the appendix E are issued from several runs of the program SMARTI.

To summarise the results under the form of these tables, the runs are numbered, and only the more important results are written. The following table describes the different runs, with their utility.

run type	*Description*
1	This is the classic run of CONTRAM, which is done to test the network and the demand data, and to get the results which will be used as references.
2	It is the 'basic' run of SMARTI, used to create the historical data (time, occupancy level and historical routes) which will be used in the most of the next runs (card type 91). A distortion is applied on the network, in the aim to get a sub-optimum result (card type 90).The excess journey time is referenced to the journey time (JT) of the run number 1.
3	In this run, all the vehicles are non-guided, and are assigned with the previous historical routes. From this run, the unguided vehicles are authorised to divert their historical route to any alternative route (card type 93).The coefficients for the diversion are written in the chapter §4.5 for each network.The results issued from this run will be used as references to the following runs.The excess cost is referenced to the cost of the run number 1.
4a	In these runs, there is a percentage of vehicles which are guided (card type 96). There is no restriction in the network for the guidance system (RGFACT=0). The non-guided vehicles are assigned on the historical routes calculated at the run number 2,

with the possibilities of diversion described in the run type 3 (card type 93). The program is run with the following percentages of guided vehicles: 1%, 5%, 10%, 15%, 20%, 40%, 60% and 100% on all or part of the O-D pairs.

4b	These runs are quite similar to the previous ones. The only difference is that the network used by the guidance system is restricted. The factor used is: RGFACT = 5, for all the studied networks.The same percentages of guided vehicles are used.There is no run 4b for the network number 2 because it has no restricted network.
4c	At the difference with the runs 4a, in these runs, the guided vehicles are assigned by using only the historical journey time, and not the actual journey time (card type 93). These JT are read in the historical file. These runs have been done with the networks number 1 and 3, with the same percentages of guided vehicles.
5	In this run, the user must come back to the 100% of unguided vehicles, and insert an incident in the network. This incident must be chosen in a way to affect the existing traffic (that is to say, not on an link where there is no traffic), but of duration and severity close to those observed in the reality.The incidents used here for the networks are described in chapter §4.4.The excess cost is referenced to the TJT of the run type 1. It is sometimes called '6a_0', '6b_0' or '6c_0': the meaning is the same.
6a	This is the simulation of route guidance as described for the runs of type 4a, but with the traffic incident described in run type 5. The historical data used are still those from the run number 2. The calculation of excess cost for the overall network and savings for the both categories of vehicles are referenced to the run number 5 (with incident).Here again, the percentages of guided vehicles are: 1%, 5%, 10%, 15%, 20%, 40%, 60% and 100%.
6b	These runs are the same as those described above, except the fact that the network used by the guidance system is restricted, as for the runs of type 4b.The percentages of guided vehicles are still the same.This does not apply to the network number 2.
6c	These runs are similar with the 4c series, except the existence of an incident (generally the same as above).This apply to the networks 1 and 3 only.

Table 5.1 : Description of the runs of the program SMARTI

The results of these tests are related at the end of this report, in the appendix E.

5.4.2   Analysis of the Results and Graphs

The excess cost (or journey time), is representative of the benefits for the overall network. It is calculated as explained in the section §3.1, but weighted with the total number of vehicles (which is not always constant). That is, the excess cost of the run a, referenced to the run b can be written:

$$\text{Excess cost (a/b)} = 100 \cdot \frac{TJT_a \cdot NVEH_b}{TJT_b \cdot NVEH_b} \quad \text{(in \%)}$$

where TJT_a and TJT_b are the total journey times for the runs a and b respectively, and $NVEH_a$ and $NVEH_b$ are the total number of vehicles for the runs a and b respectively.

The journey times for the unguided vehicles are calculated with the overall network journey times, minus the specific JT for the guided vehicles:

$$FT_u + FT_g = FT$$
$$QT_u + QT_g = QT$$
$$TJT_u + TJT_g = TJT$$

where FT, QT and TJT are respectively the free-moving time, the queueing time and the total journey time, for unguided vehicles (u), for guided vehicles (g) or for the overall network ( ).

Of course, the following equations are also true:

$$FT_u + QT_u = TJT_u$$
$$FTg + QT_g = TJT_g$$
$$FT + QT = TJT$$

The savings for the unguided or guided vehicles are calculated as the benefits in TJTu or TJTg, referenced to the total journey time, weighted by the real percentage of concerned vehicles. They are expressed in percents.

That is to say:

$$\text{Savings (guided)} = 100 \cdot \left(1 - \frac{TJT_g}{TJT_{ref} \cdot Pergui/100} \right)$$

$$\text{Savings (unguided)} = 100 \cdot \left(1 - \frac{TJT_u}{TJT_{ref} \cdot \frac{Perung}{100}} \right)$$

where: TJT_g and TJT_u are the specific total journey times for respectively the guided and the unguided vehicles,

and TJT_{ref} is the total journey time of reference, from run type 3 (without incident) or 5 (with incident),

Pergui and Perung are the real percentages of respectively guided and unguided vehicles:

$$Pergui = 100 \cdot \frac{\text{number of guided vehicles}}{\text{total number of vehicles}}$$

$$Perung = 100 \cdot \frac{\text{number of unguided vehicles}}{\text{total number of vehicles}}$$

However, the formulae for the guided vehicles cannot be used with the network number 3. Effectively, the route guidance is applied on only 39 main O-D pairs (on a total of 294). So, in this case, the savings must be referenced to the total journey time associated with these 39 O-D pairs.

To do that, an external program must be used to analyse the output files.This program reads the network file and the routes file, both issued from SMARTI, and write for all the O-D pairs or for a particular one:

- a description of all the routes used,
- the number of vehicles using those routes per time interval,
- the average travel time (in sec.) per route and per time interval,
- the total numbers of vehicles per route, per time intervals, and overall,
- the total journey time (in veh.hr) associated with the O-D pair.

An other possibility of this program is to analyse the journey time profile of any particular link, as well as the O-D pairs using it. This program has been called RFA (which stands for "Route File Analysis"), and can be used with the graphic program done to draw the JT profiles, called GRAFIC. These two programs are written in FORTRAN.

So, the outputs from RFA, applied on the route file output from SMARTI run with the network number 3, have given, for the 39 specified O-D pairs:

outputs from run of	type 3	type 5
number of vehicles	9589	9589
TJT (veh.hr)	623.0	700.2

Table 5.2: Outputs from the RFA program

These values must then be used as references for the calculation of the savings for the guided vehicles.

With the same program RFA, it is also possible to study the savings for one particular O-D pair. The benefits are calculated for the unguided and guided vehicles by using all the data concerning this O-D pair alone.

The following graphs represent, for the three networks, the savings in journey time versus the percentage of guided vehicles.
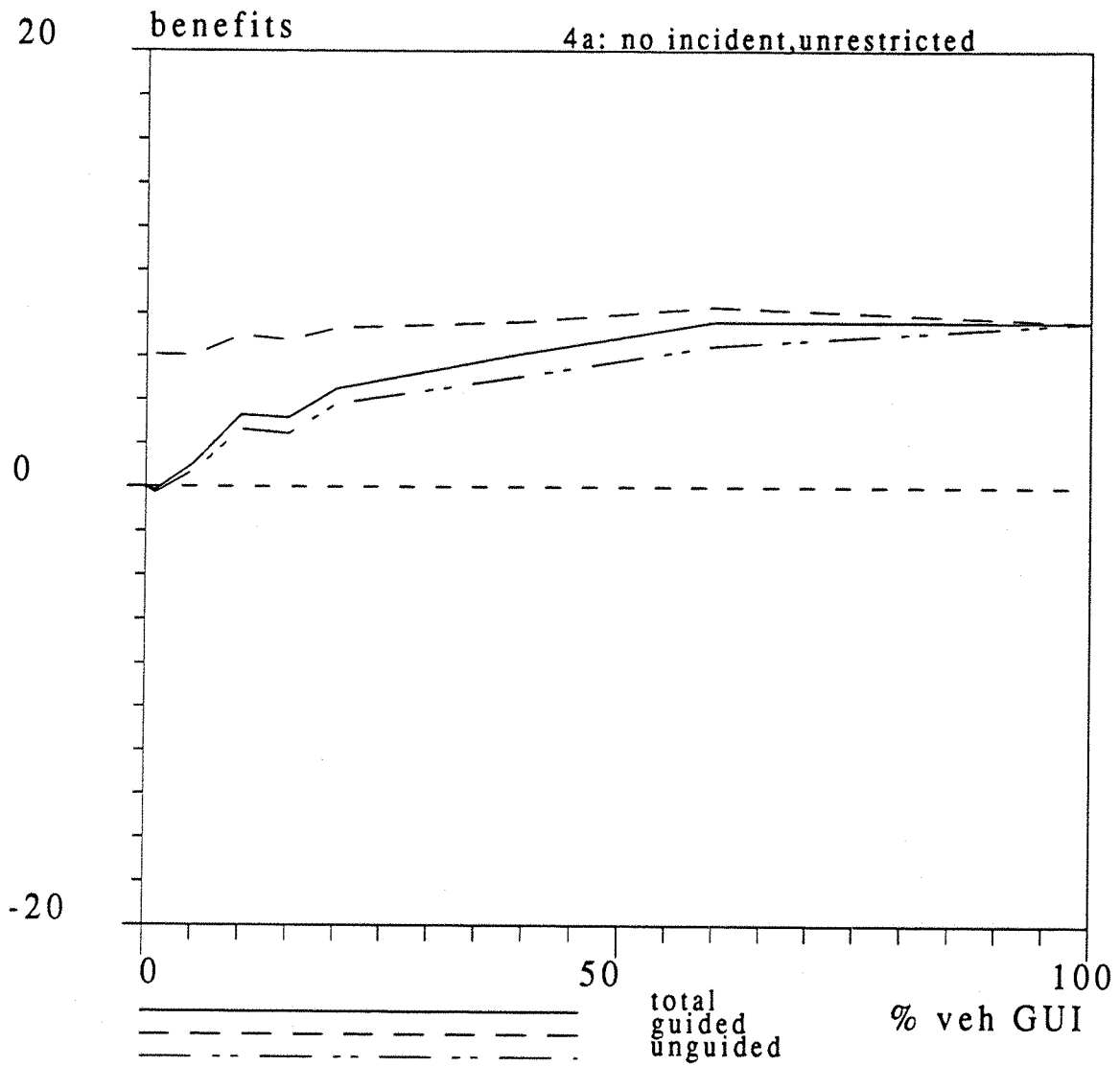
Figure 5.3 : Journey Time Savings vs. Percentage of Guided Vehicles
Case of the network 1, 4a: unrestricted; No incident.
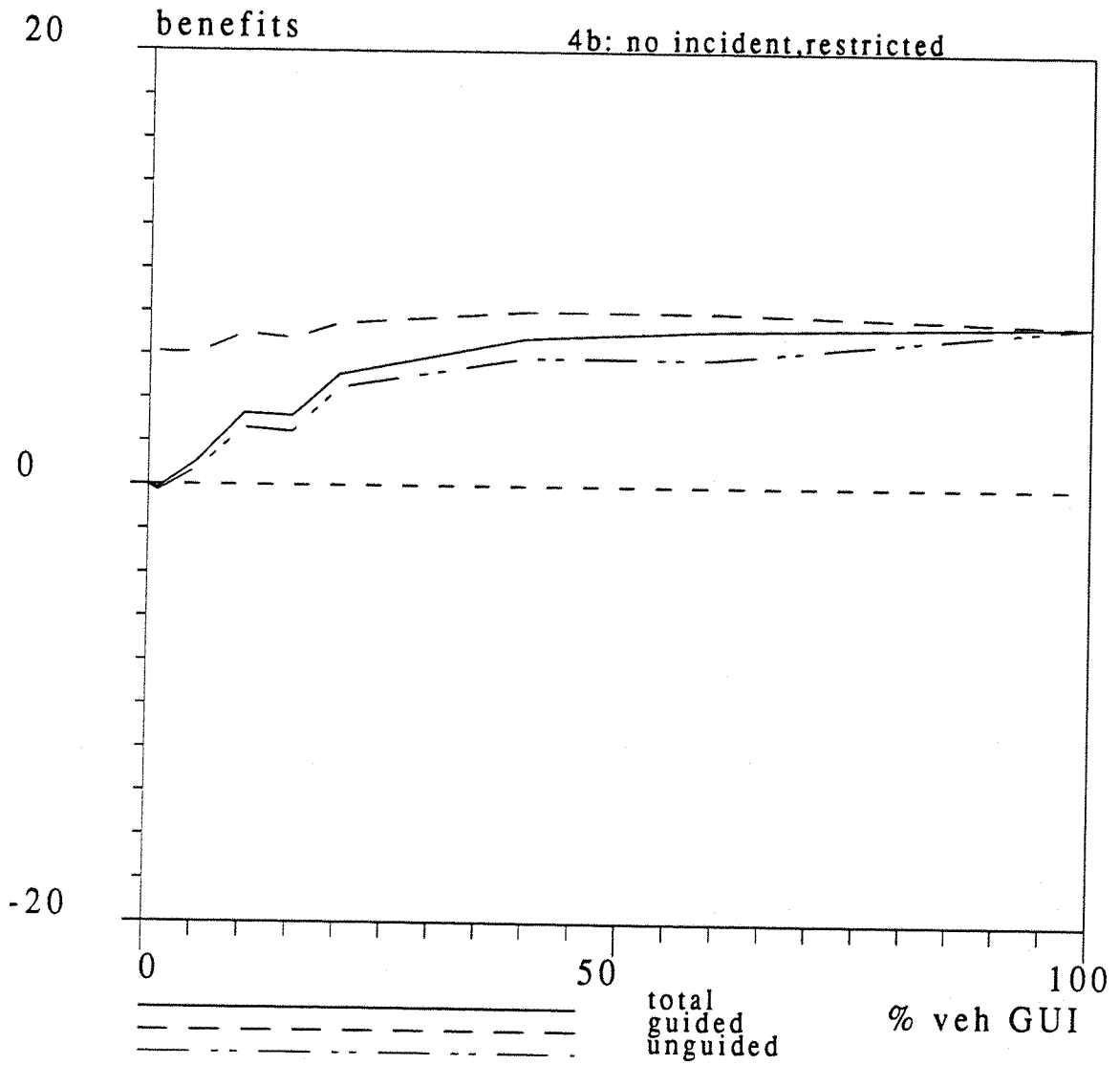
Figure 5.4 : Journey Time Savings vs. Percentage of Guided Vehicles
Case of the network 1, 4b: restricted; No incident.
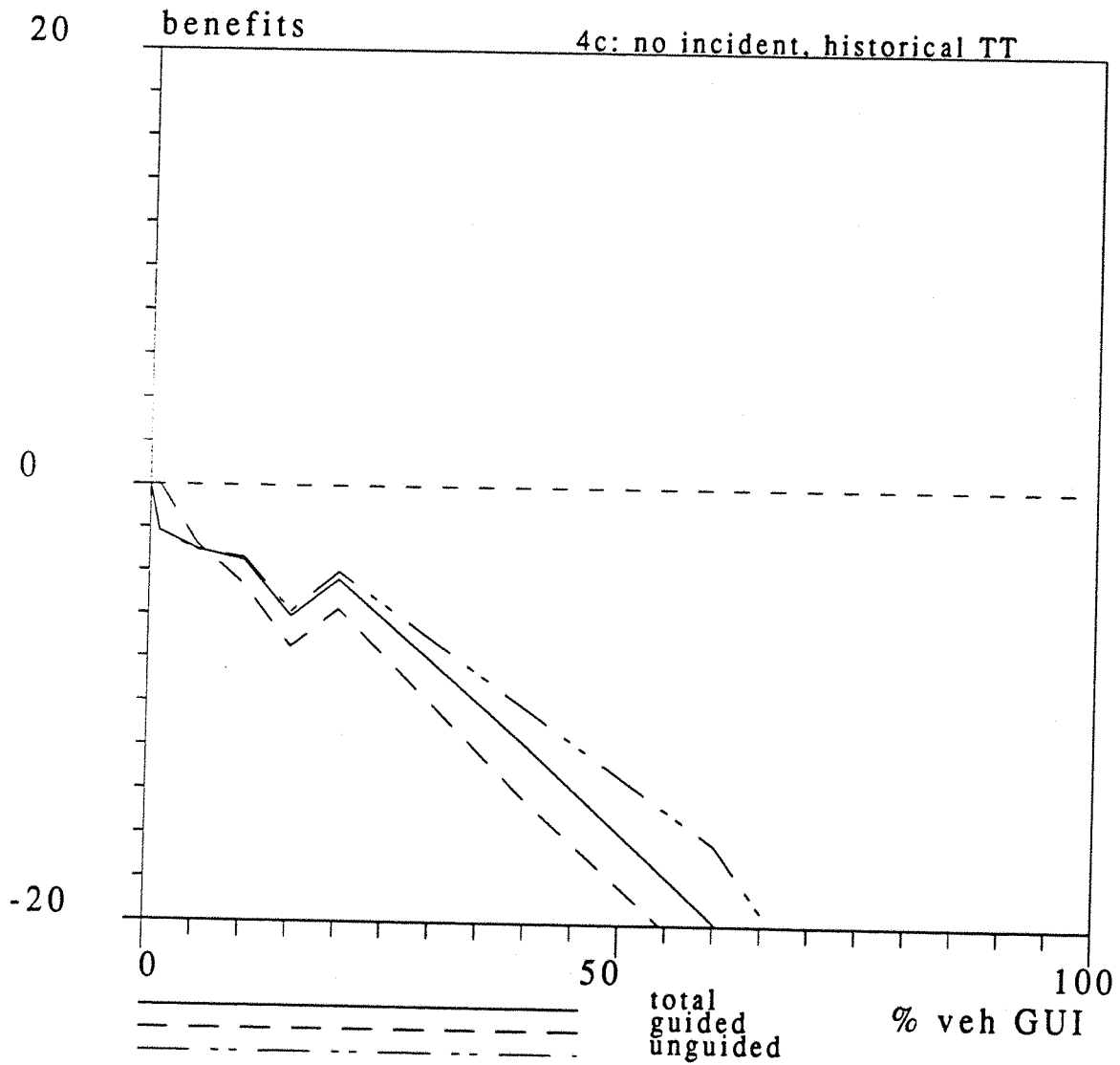
Figure 5.5: Journey Time Savings vs. Percentage of Guided Vehicles
Case of the network 1, 4c: assignment with historical TT; No incident.
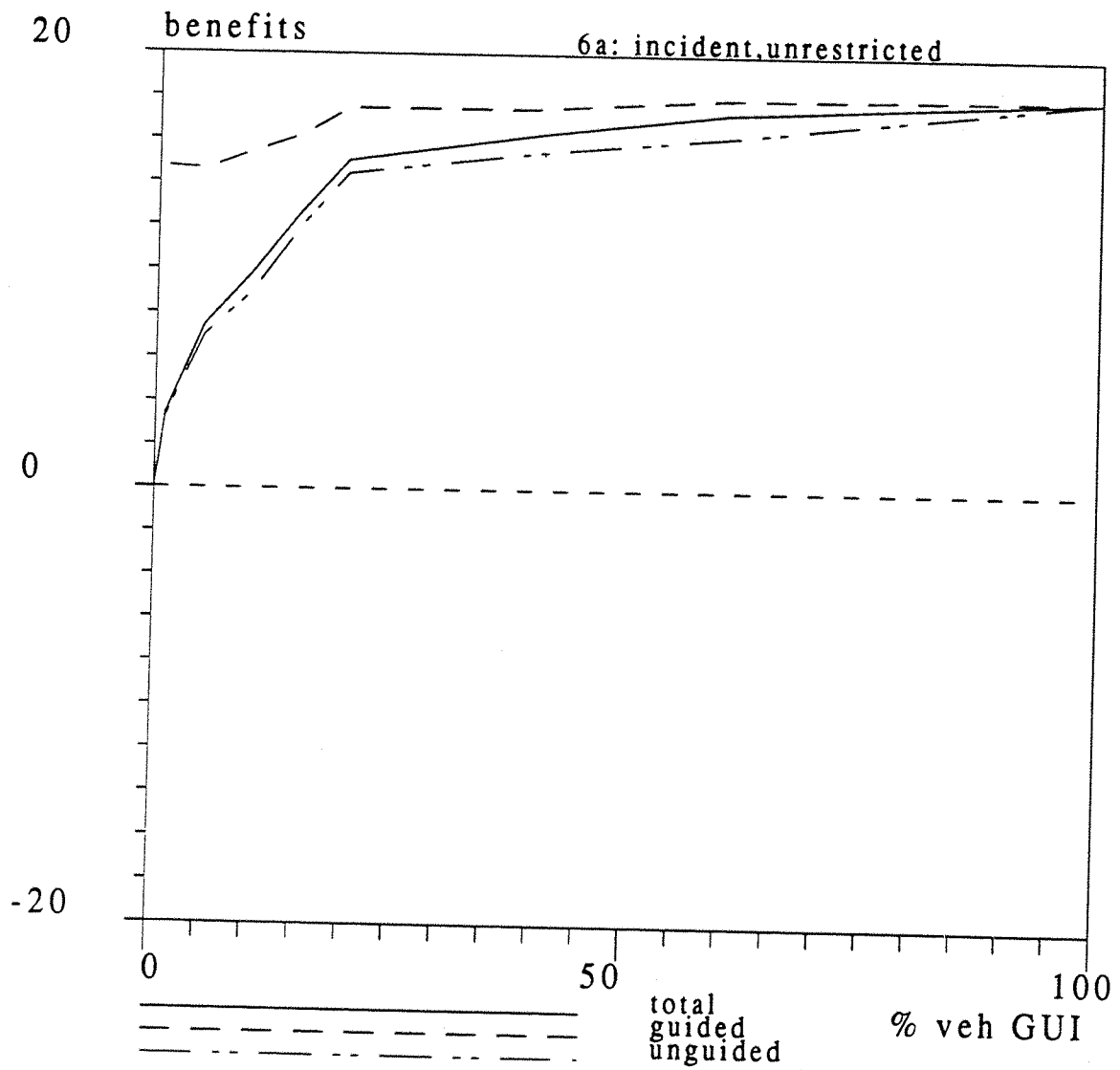
Figure 5.6: Journey Time Savings vs. Percentage of Guided Vehicles
Case of the network 1, 6a: unrestricted; With incident.
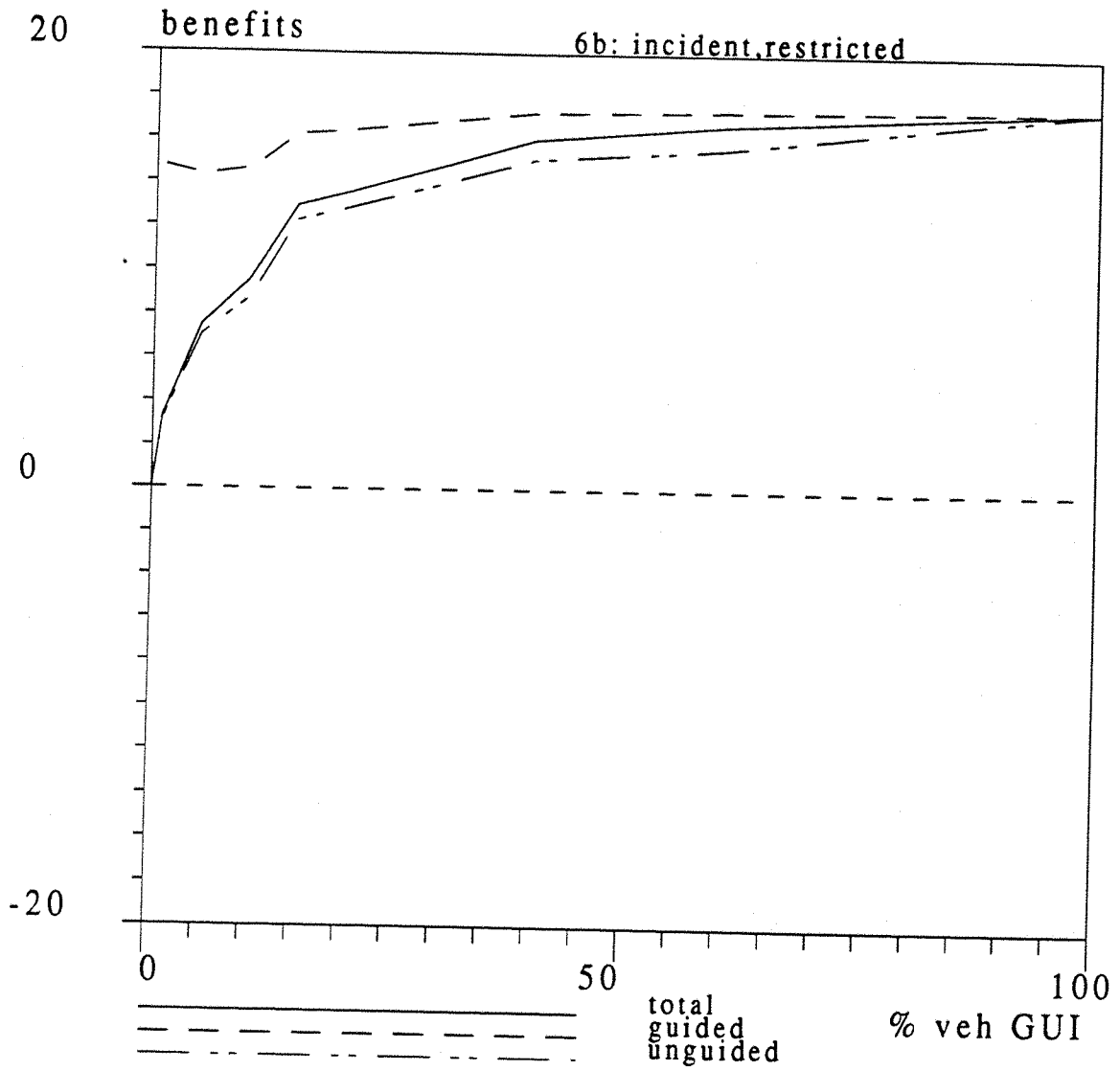
Figure 5.7: Journey Time Savings vs. Percentage of Guided Vehicles
Case of the network 1, 6b: restricted; With incident.
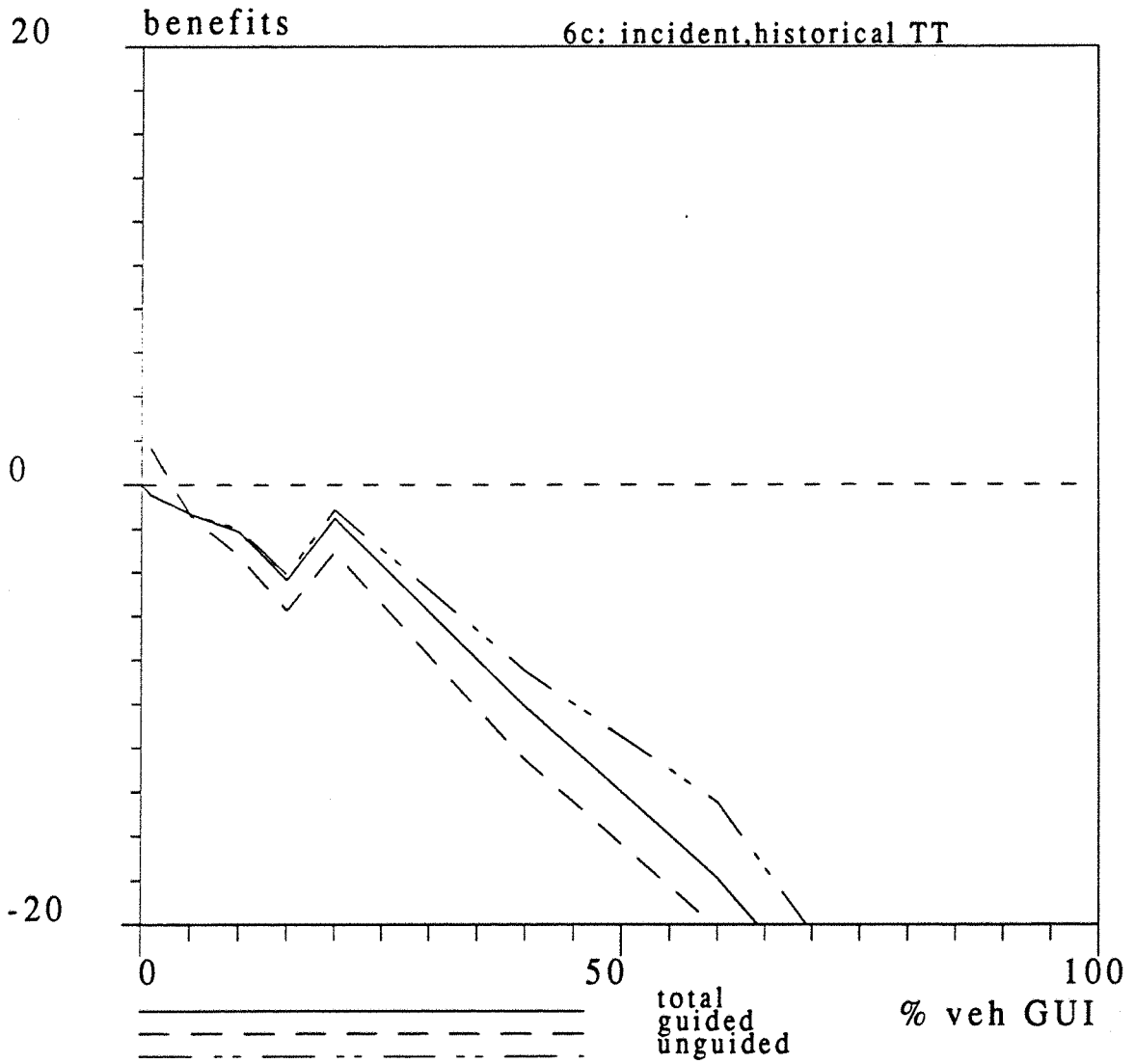
Figure 5.8: Journey Time Savings vs. Percentage of Guided Vehicles
Case of the network 1, 6c: assignment with historical TT; With incident.
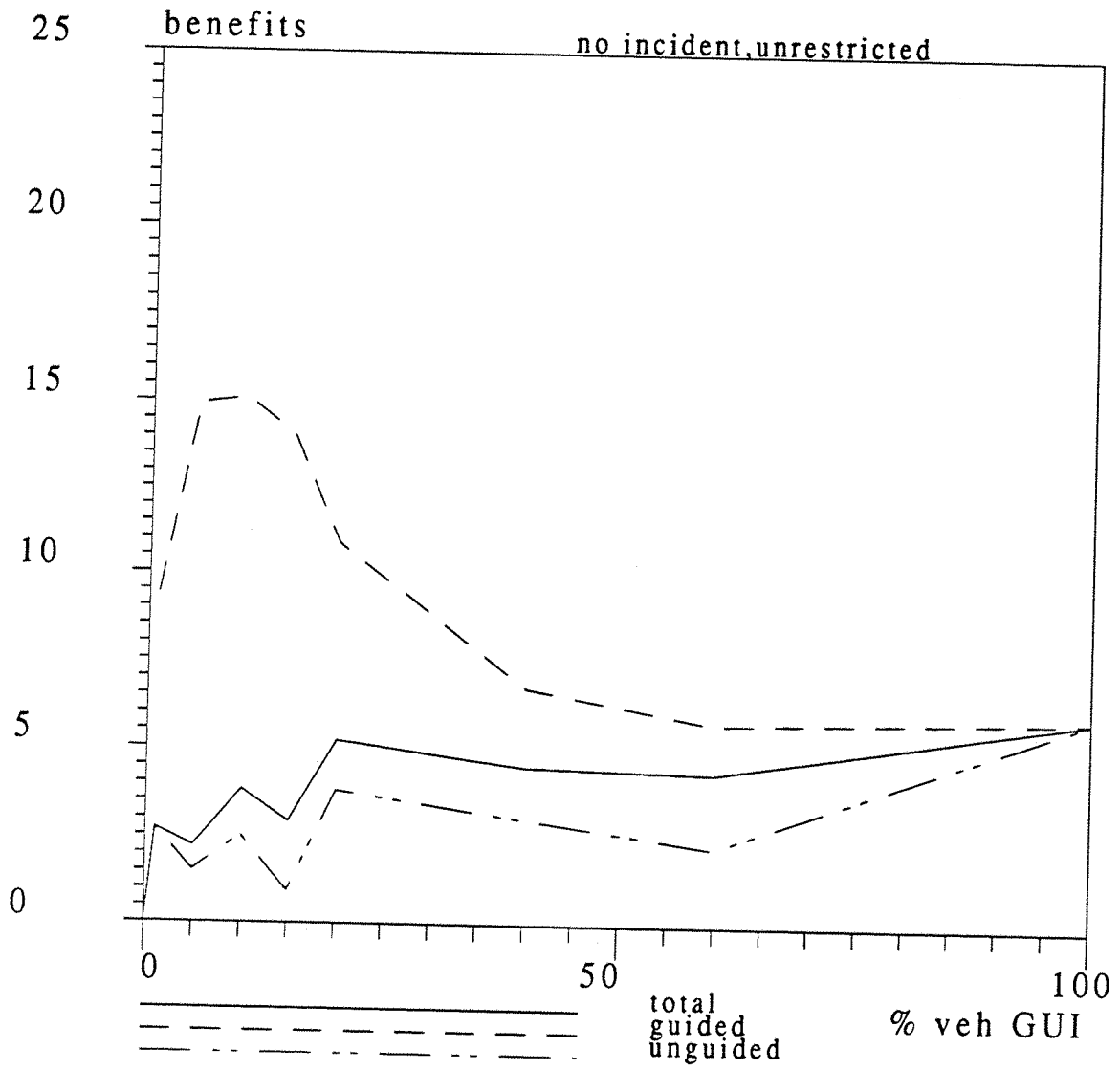
Figure 5.9: Journey Time Savings vs. Percentage of Guided Vehicles
Case of the network 2, 4a: unrestricted; No incident.
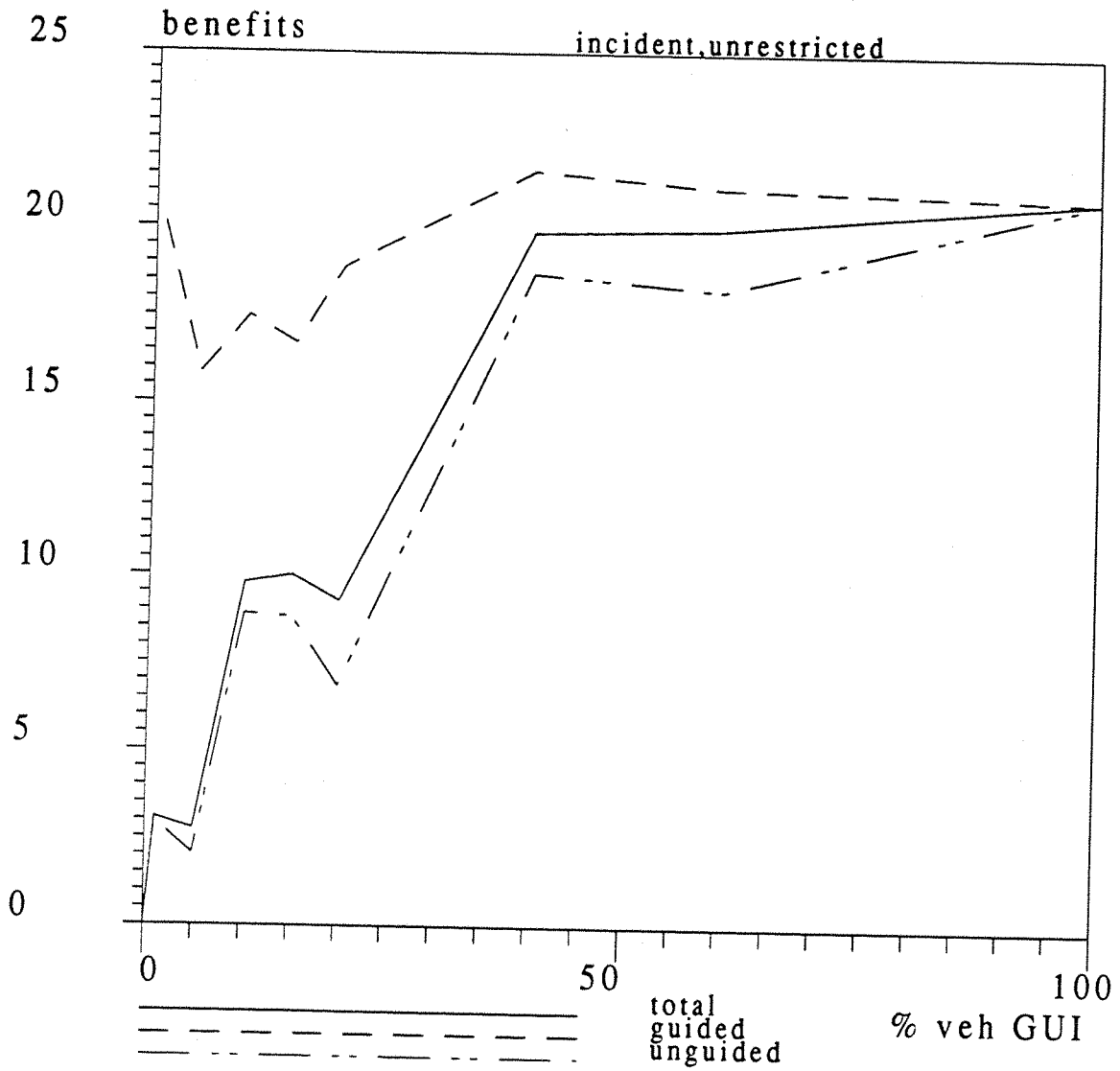
Figure 5.10: Journey Time Savings vs. Percentage of Guided Vehicles
Case of the network 2, 6a: unrestricted; With incident.
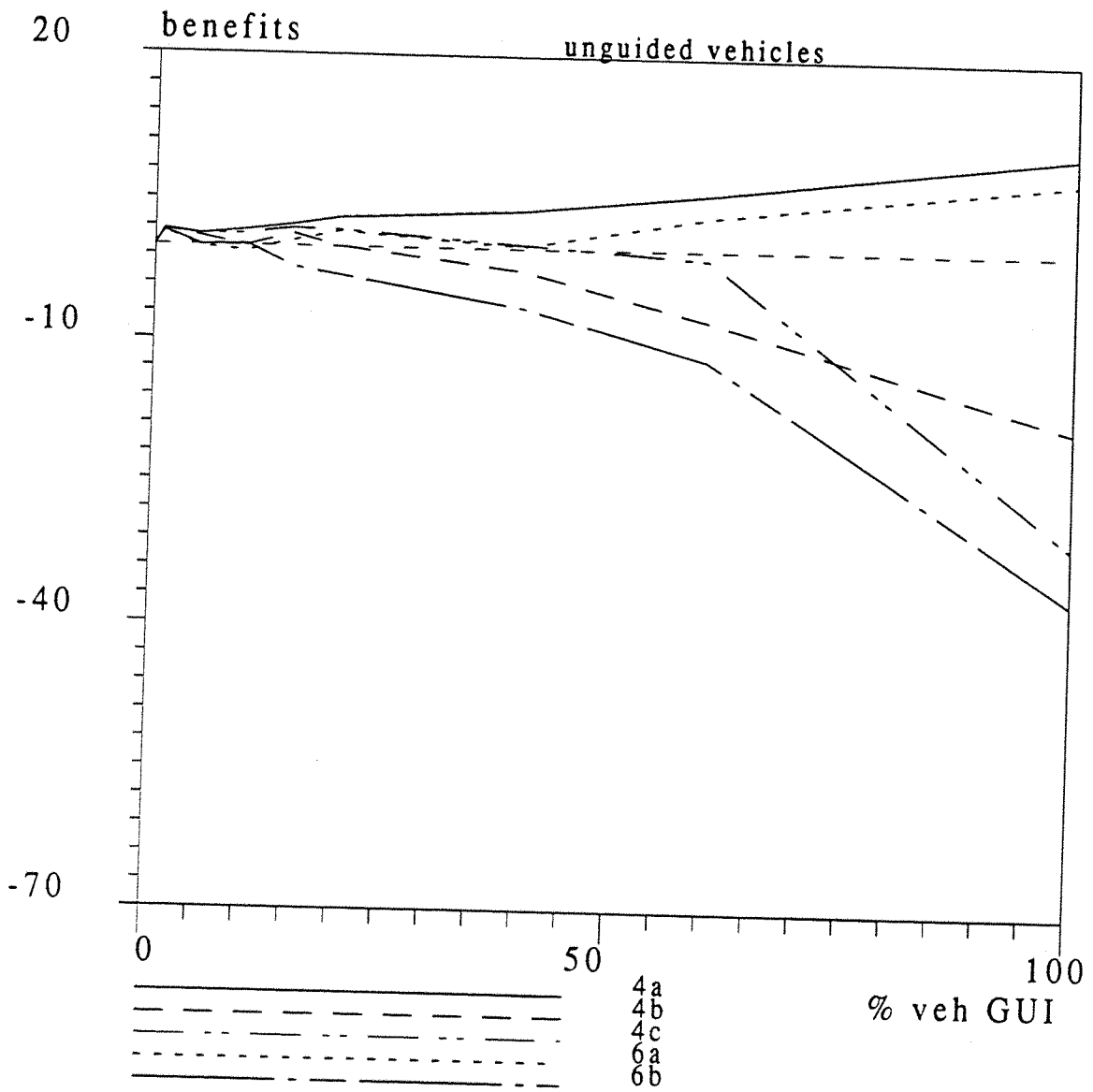
Figure 5.11 : Journey Time Savings vs. Percentage of Guided Vehicles
Case of the network 3, unguided vehicles.
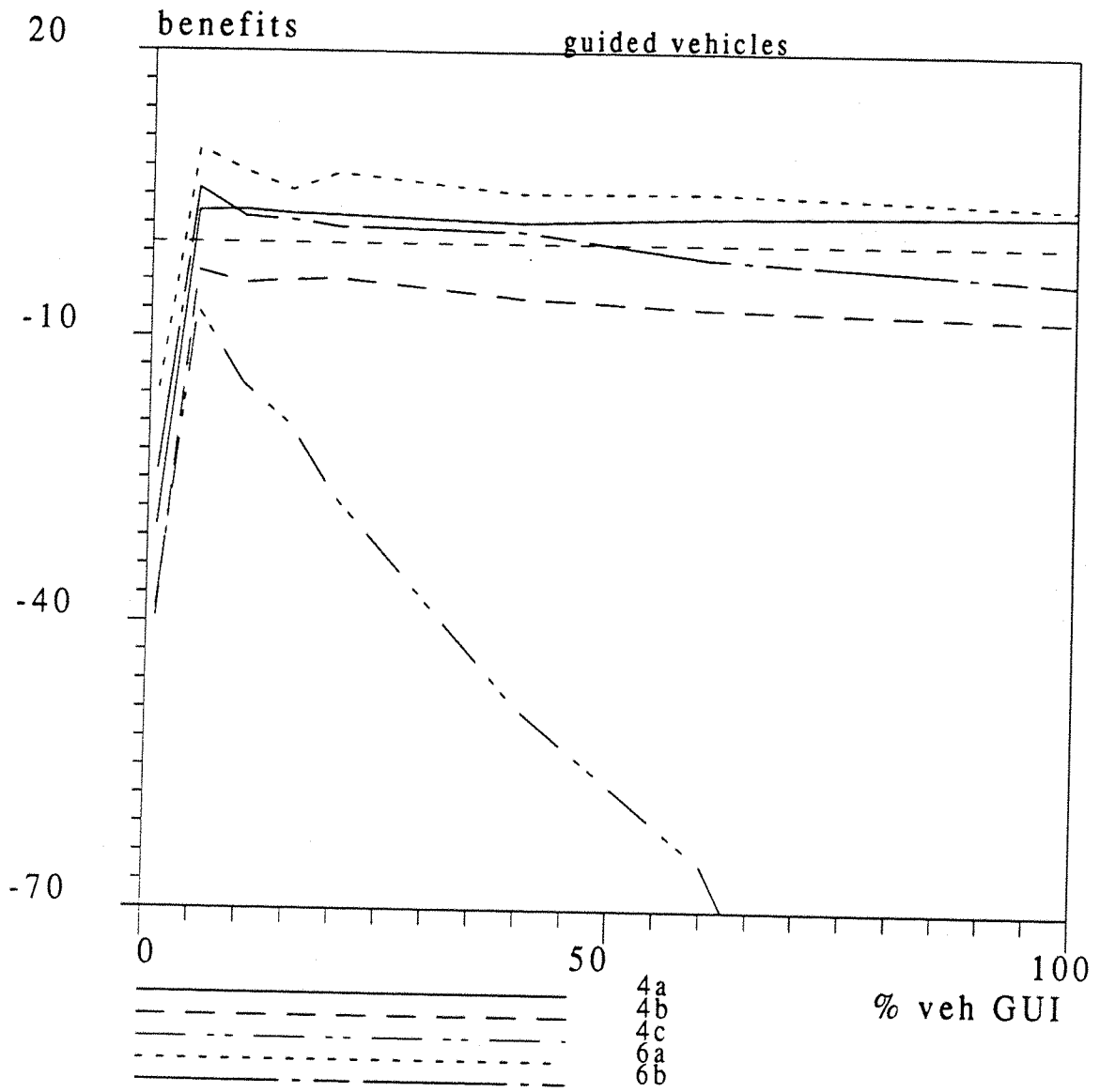
Figure 5.12 : Journey Time Savings vs. Percentage of Guided Vehicles
Case of the network 3, guided vehicles.
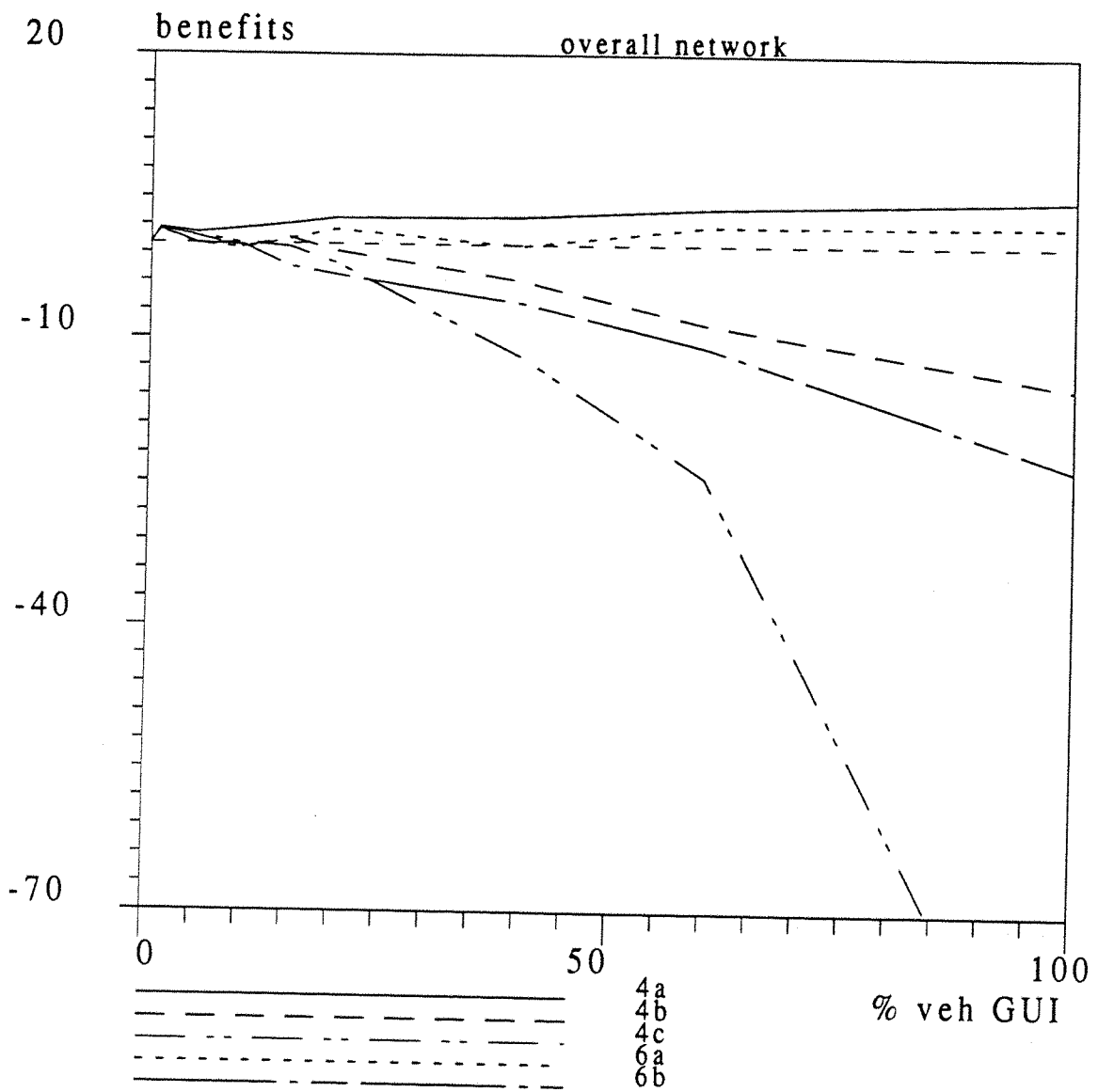
Figure 5.13: Journey Time Savings vs. Percentage of Guided Vehicles
Case of the network 3, overall network.
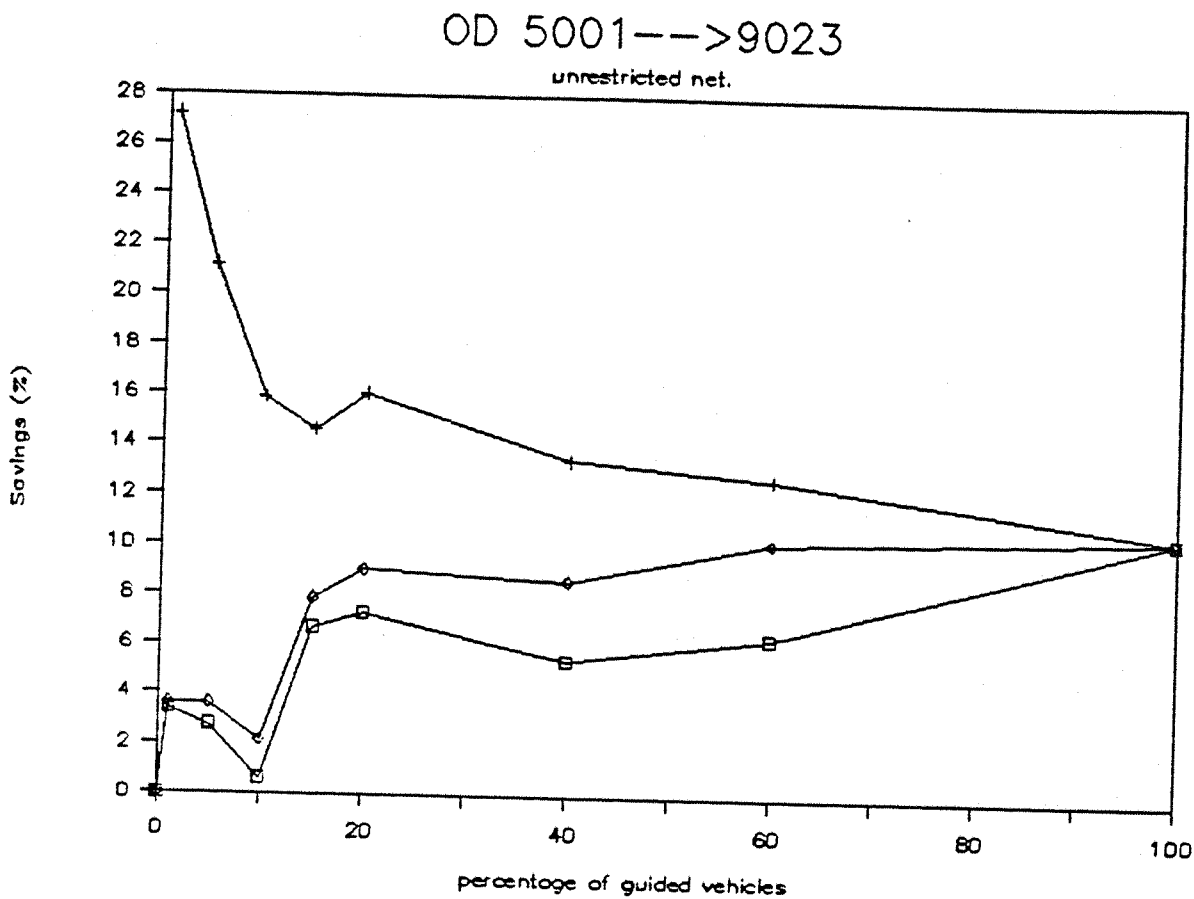
Figure 5.14 Journey Time Savings vs. Percentage of Guided Vehicles
Case of the network 3, OD: 5001 --> 9023, 6a: (unrestricted network, with incident).

Legend: guided vehicles   +
         unguided vehicles   □
         overall network   ◊

OD 5001-->9023
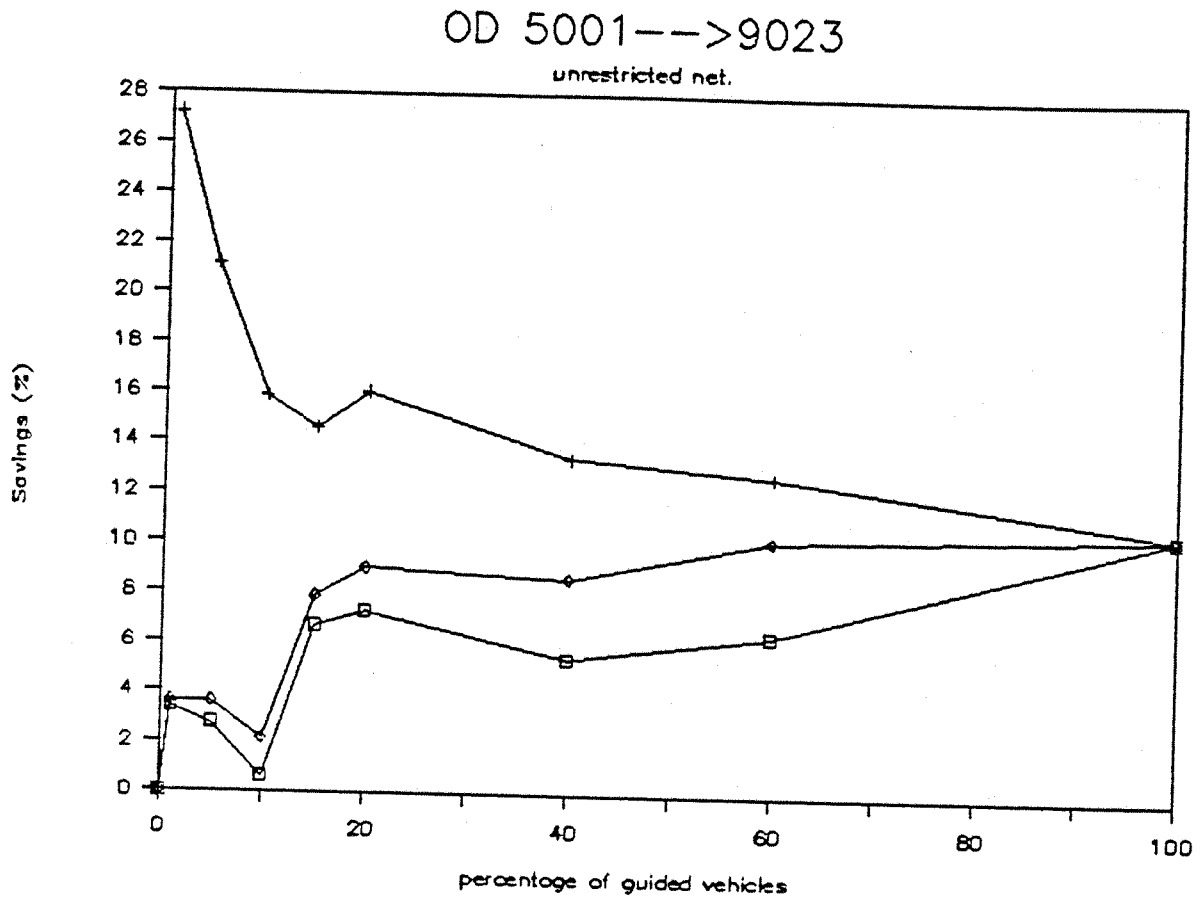
unrestricted net.

Figure 5.15 Journey Time Savings vs. Percentage of Guided Vehicles
Case of the network 3, OD: 5001 --> 9023, 6b: (restricted network, with incident).

Legend: guided vehicles   +

            unguided vehicles   ▫

            overall network   ◊
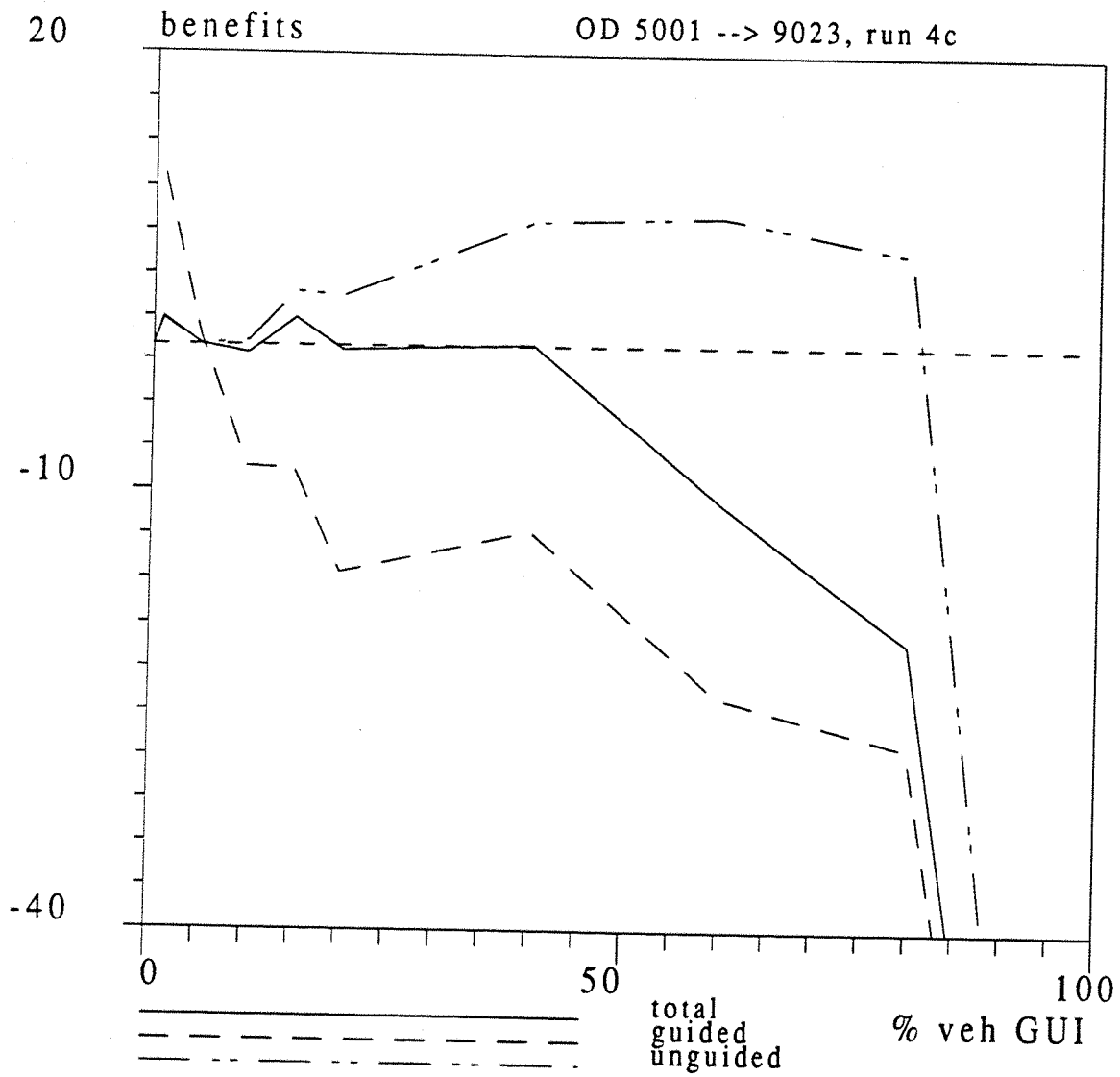
Figure 5.16: Journey Time Savings vs. Percentage of Guided Vehicles
Case of the network 3, OD: 5001 --> 9023, 4c: (assignment with historical JT).

As an example of the output from the analysis programs RFA and GRAFIC, the following graphs represent the travel time versus the elapsed time of simulation for the link 1494 (runs 5 and 6a with 40 % of guided vehicles) and the link 1421 (for the series of runs 4c) of the network number 3.

The link 1494 is the one where the incident is located That is to say, the incident occurs during the time intervals 3 and 4. The effect of the route guidance is clear on the diminution of the travel time, in peak and in average, for this link but also for most of the others.
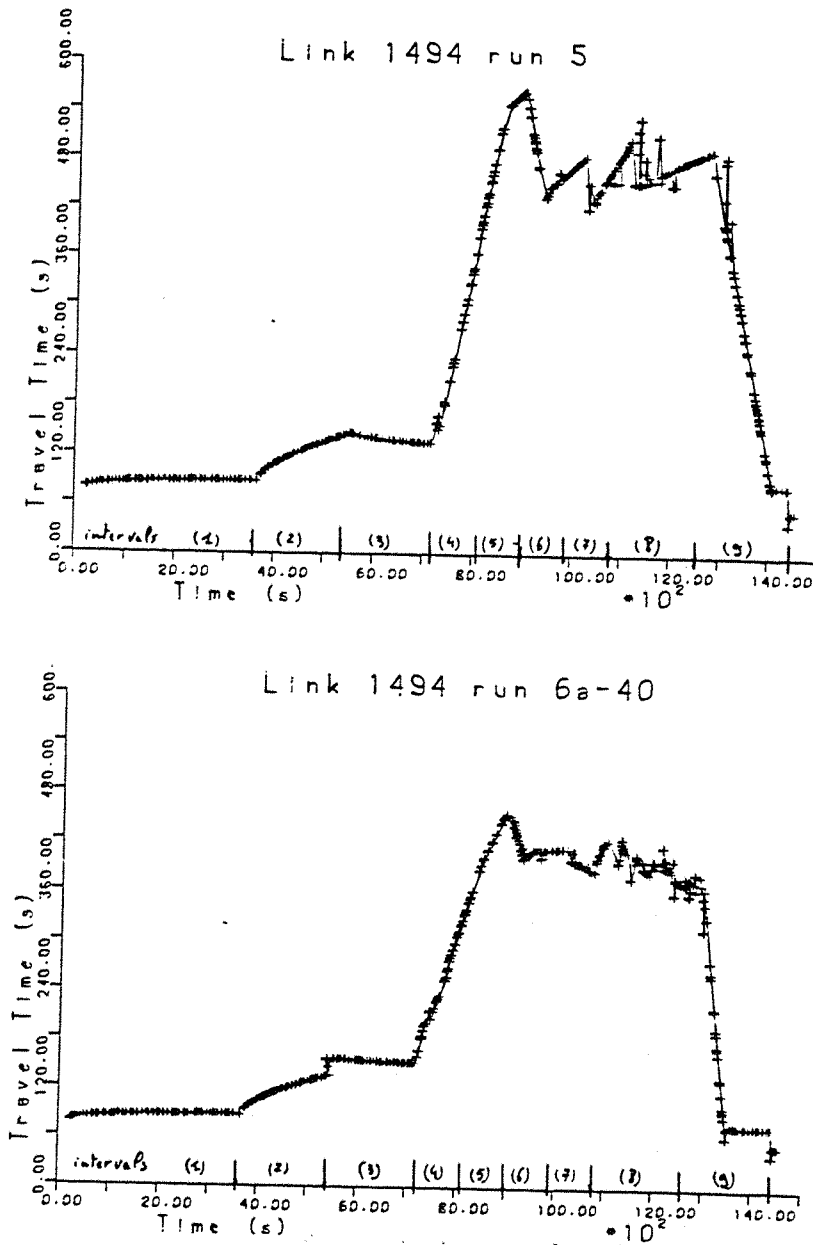
Figure 5.17 :Travel Time vs. elapsed time for the link 1494, network 3
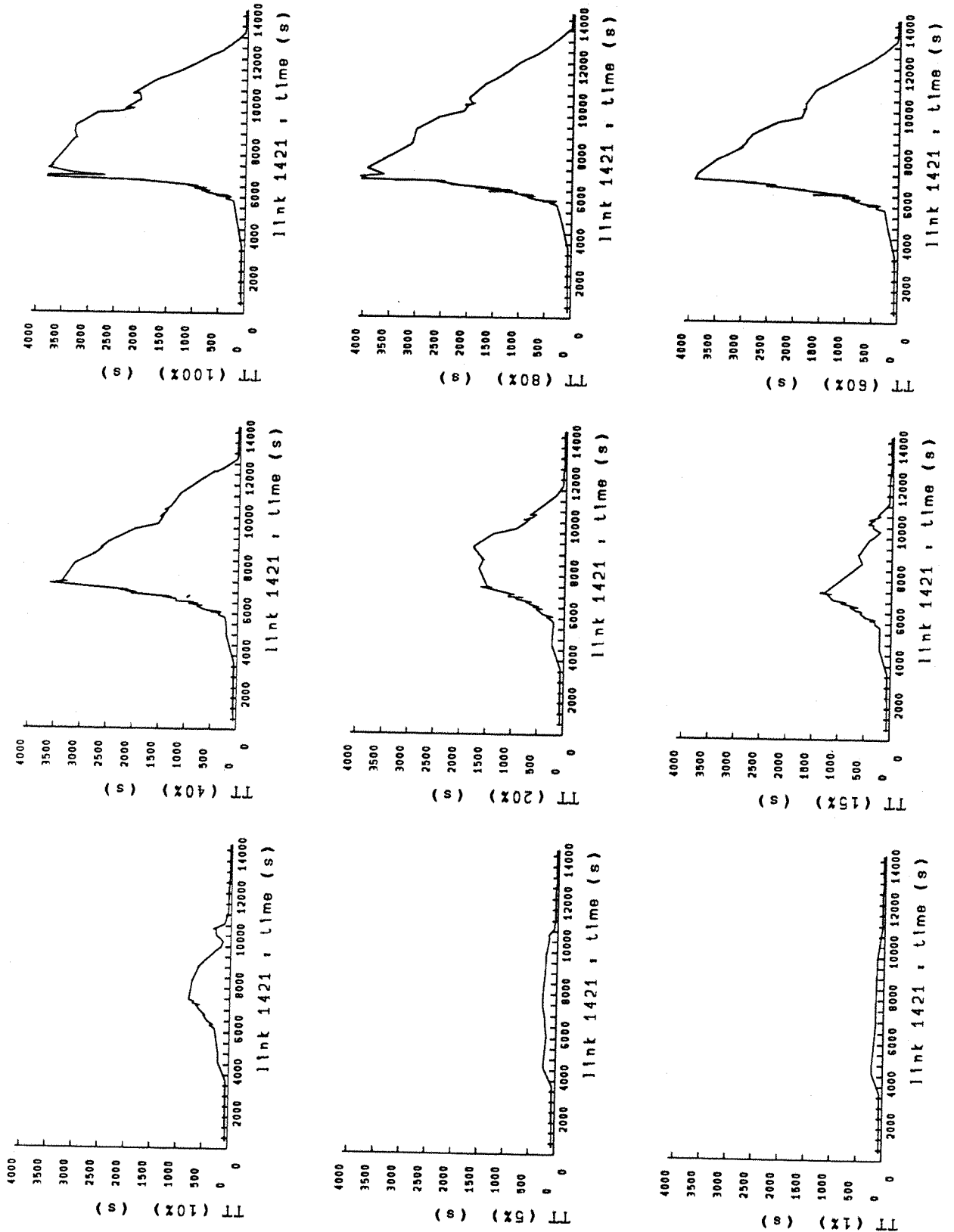
Figure 5.18 :Travel Time vs. elapsed time for the link 1421, network 3

5.5   Conclusion on Guided Vehicles

The calculation of the savings has been described in the previous section (§5.4), however it is important to know what is the validity of the results. An evaluation of the error of calculation is therefore essential. The total journey time given by CONTRAM and SMARTI are written with one decimal. That is the precision is $\varepsilon = \pm 0.1$ veh.hr.

The savings are calculated with an expression of the form:

$$S = 1 - \frac{a + \varepsilon}{b.x + \varepsilon'}$$

where: a is the total journey time of the current run,

b is the total journey time of reference,

x is the percentage of guided (or unguided) vehicles,

ε and ε' are the errors associated with the TJT.

Because ε and ε' are small, this expression can be approximated by using a formulation of Taylor at the first degree:

$$S = 1 - \frac{1}{b.x}.(a + \varepsilon).\left(1 - \frac{\varepsilon'}{b.x}\right)$$

$$S = 1 - \frac{a}{b.x} - \frac{\varepsilon}{b.x} + \frac{a.\varepsilon'}{(b.x)^2} + \frac{\varepsilon.\varepsilon'}{(b.x)^2}$$

instead of:

$$S = 1 - \frac{a}{b.x}$$

So, the error can be estimated by:

$$Err(S) = \frac{1}{(b.x)^2}.\left[b.x.\varepsilon + a.\varepsilon + \varepsilon.\varepsilon'\right]$$

Let's consider only the terms of first degree (the term in $\varepsilon.\varepsilon'$ is negligible). An estimation of the error can be calculated when it is the highest, that is, when x is the smallest (for x = 1% = 0.01).

For instance, with the network 3:   a = 2.7 veh.hr

b = 623 veh.hr

x = 32/9589 = 0.0033

The error can be evaluated at:

$$Err(S) = \frac{1}{(623*32/9589)^2} * \left(623*\frac{32}{9589} + 2,7\right) * 0,1 = 0.11$$

Which means an error of 11 per cents on the savings. In this example: $S = -29.9 \pm 11\ \%$

On this calculated error, due to the final rounding of the TJT, has to be added all the internal rounding, and the errors of the second degree.

That is why, particularly for the network number 3, the results obtained with the 1% of guided vehicles have not been taken in account.

Apart from this particular case, where the low percentage of guided vehicles induces a big error of calculation, the results correspond to the expectations: Generally, the benefits for the guided vehicles are higher than those for the unguided vehicles, and the benefits of the route guidance are better when the network is not restricted. However, when the network is very restricted (as the network 3), high subscription levels to the guidance system can produce great disbenefits for all the vehicles. Disbenefits can also accrue when out of date historical travel times are used to assign the guided vehicles.

6.1 General conclusion

The research so far described in this report covers the initial modelling and testing of route guidance systems in urban networks, operating both under 'normal' and 'incident' conditions. The simulation program which has been created, SMARTI, includes simple and logical representations of non-guided drivers behaviour in normal and incident conditions. The use of historical routes and the principle of self-diversion described here are simple but efficient models, and produce conceptually satisfactory results.

Three parameters have been selected to describe the responses of the **non-guided drivers**:
 ⇒ the coefficient of distortion, which quantifies the degradation level of the real intuitive assignment;
 ⇒ the coefficient of diversion, which quantifies the choice of the routes when there is self-diversion;
 ⇒ and the percentage of vehicles never diverting, which quantifies the number of vehicles always using the same route.

These allow a lot of flexibility to the program user, but can set some problems of calibration, only possible by further on-street measurements. However standard values, as those used in this work, can be taken by default.

The **incidents** can be modelled by different means, but the simplest are the lane capacity reduction, when it is located onto a link, or the saturation flow reduction when it is at a junction. This model is simple but efficient and powerfull, because of its flexibility.

Different strategies have been simulated for the **guided vehicles**, but always using an iterative shortest (or quickest) path algorithm, with sometimes heuristic rules. Just by changing the cost functions associated to each link, it is possible to simulate 'real time' assignment, or assignment with 'historical data'.

The results obtained with the simulation of route guidance, are shown to be highly dependent on the behaviour of the non-guided vehicles. Therefore, the benefits depend not only on the network, on the demand matrix, on the incident characteristics and on the subscription level but also on the values given to the parameters used for both guided and non-guided vehicles.

Nevertheless, general conclusions can be written concerning the benefits expected from a route guidance system:

⇨ The benefits for the guided vehicles is generally higher than the benefits for the non-guided when they share the same Origin-Destination pair. It is an expected and important result which means that it is always suitable for a driver to buy an up to date system.

⇨ When the percentage of guided vehicles is low, they can reach up to 20% of benefits, while the other vehicles have some savings (few percents). This is true whatever are the restrictions on the guidance network, and whatever is the type of assignment.

⇨ For a high proportion of guided vehicles, the overall network benefits increase only if there is no restriction in the network.and if tthe assignment is in real-time. There can even be great disbenefits for both guided and unguided vehicles if the network is restricted, or if only historical travel time data are used. To notice that in those simulations with historical travel time data, the historical tables were not up-dated between each run, which would have simulate a slow integration of the guided vehicles. A real system (as LISB/ALI-SCOOT) is supposed to have up to date time tables to take in account the progressive re-assignment of the non-guided vehicles.

⇨ On average, the benefits for each guided vehicle decrease with an increase in their number. This can be explained by saying that the 'good' routes which were first available are then used by more and more guided vehicles. However, with an efficient route guidance system, the benefits for the non-guided and for the overall network are always increasing.

6.2 Proposal for further works

The three networks used to do all the tests have been chosen for particular purposes. The network number 1 is very small and was used to test systematically the modifications of the program. The two others, larger, were used to valid the results. However, the use of a much larger network as, for instance, a model of the London area where the AUTOGUIDE system is tested, could be more interesting to evaluate the real benefits to expect from these systems.

Also, the model of guidance system used in SMARTI has been very simplified, and a model of the beacons, of the delay in the incident detection and in the calculation would be worthwhile to introduce.

Assignment using historical travel time has been simulated for the guided vehicles, as in the LISB/ALI-SCOOT system in Berlin, however different algorithms of time prediction (using the historical journey times table and the current journey times) could be introduced as well.

Some more testings could also be done on the network number 3, in the aim to study the effect of different restrictions for the network, for instance by varying the impedance of the major and minor links.

Finally, the behavioural model of the 'normal' drivers (the non-guided) is based on three coefficients: the coefficient of distortion, the coefficient of diversion and the percentage of vehicles never diverting. It would be interesting to study the effects of their variation on a particular network, and to draw some conclusion on the choice of these values.

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APPENDICES

Network number	1	2	3
Links:			
Uncontrolled	12	34	117
Give-way	6	23	51
Signalized	14	24	22
Total	32	81	190
Junction:			
Signalized	4	7	7
Total	13	30	71
Origins	5	7	28
Destinations	3	7	29
O-D movements	14	32	333
Length of the network (m)	24390	24500	34835
Approximate area (sq.km)	4.0	6.2	2.6
Time intervals	9	9	10
Busy period	3 hours	3 hours	4 hours

Network 1
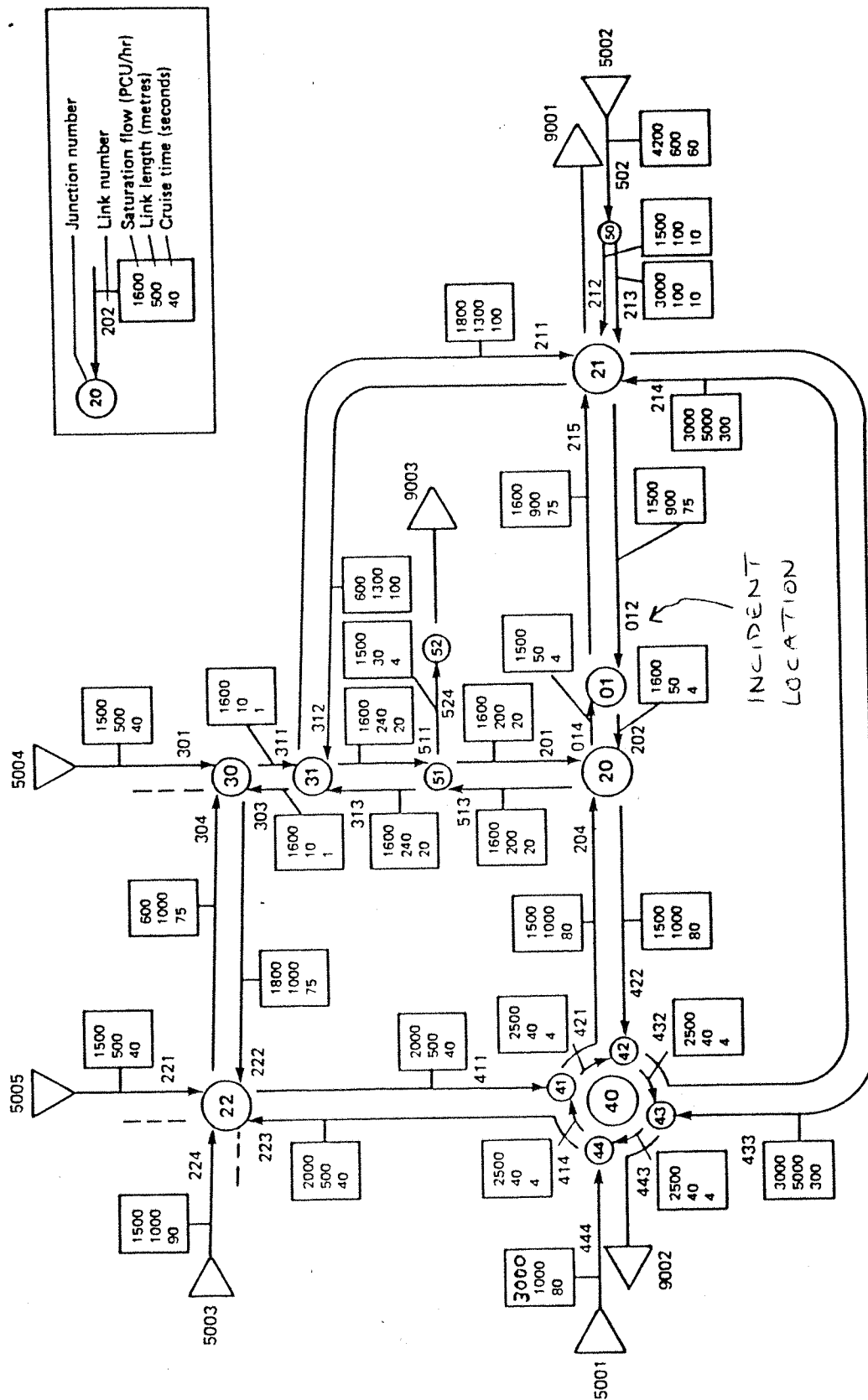
Link data for test network 1

Network 2

Network 2

Not on scale

7 Origin / Destination.
Junctions 20-26 : Signalised
30-40 : Give way →
50, 60, 70 : Roundabouts

INCIDENT LOCATION.

Network 3

Network 3 restricted

Legend: // = major links (00)
/: = links (01)
:: = links (02)
:: = other links: minor (05)
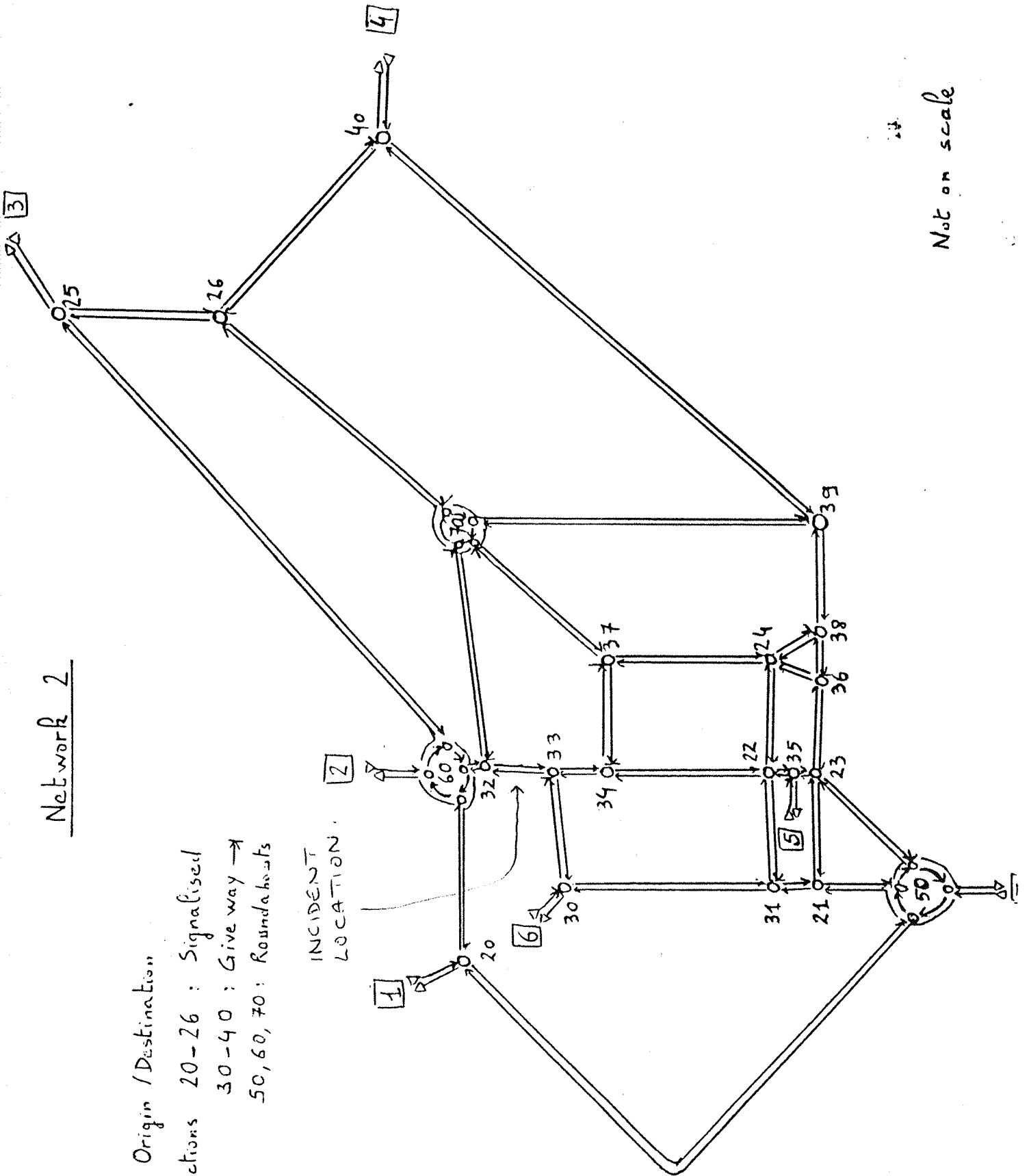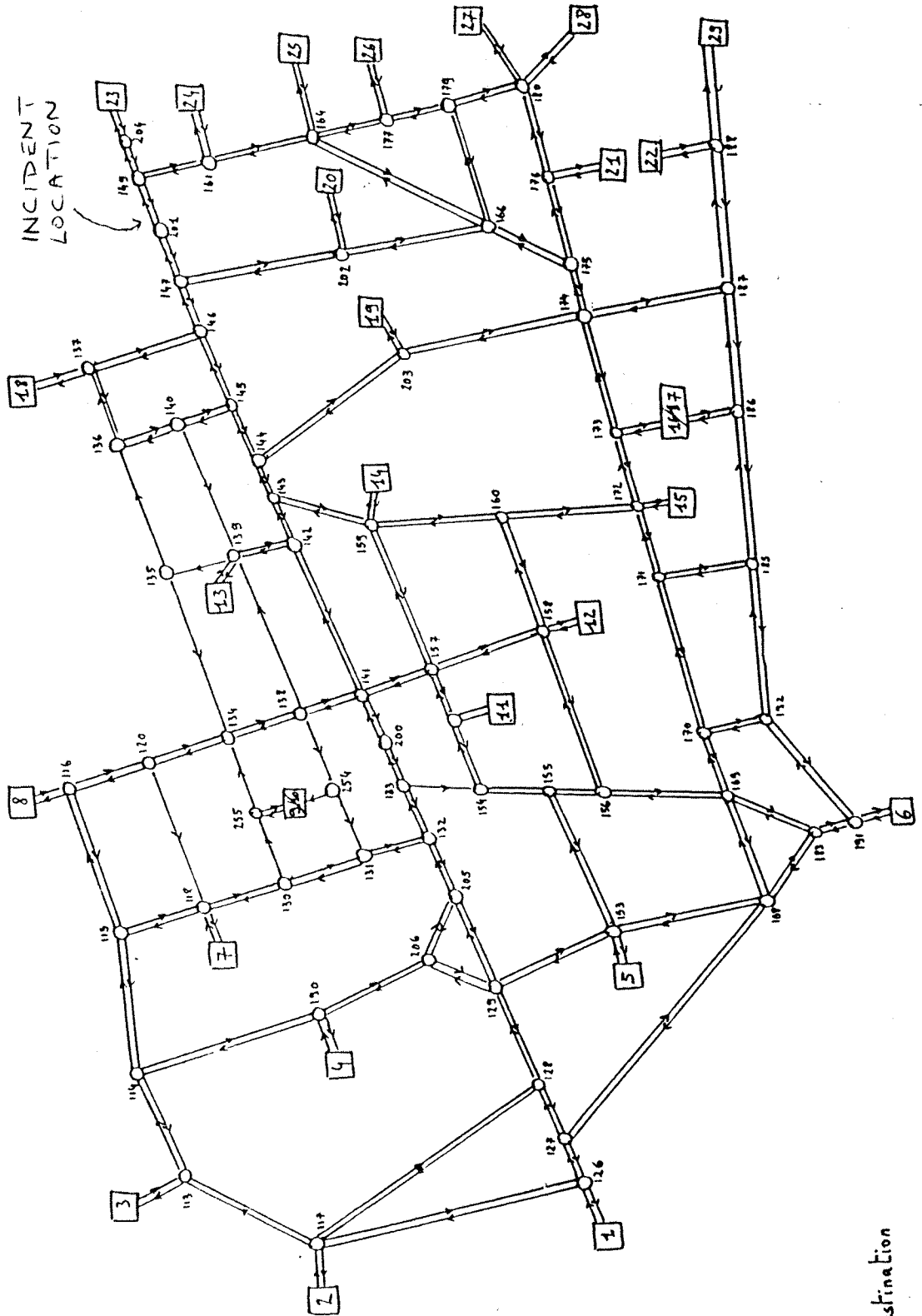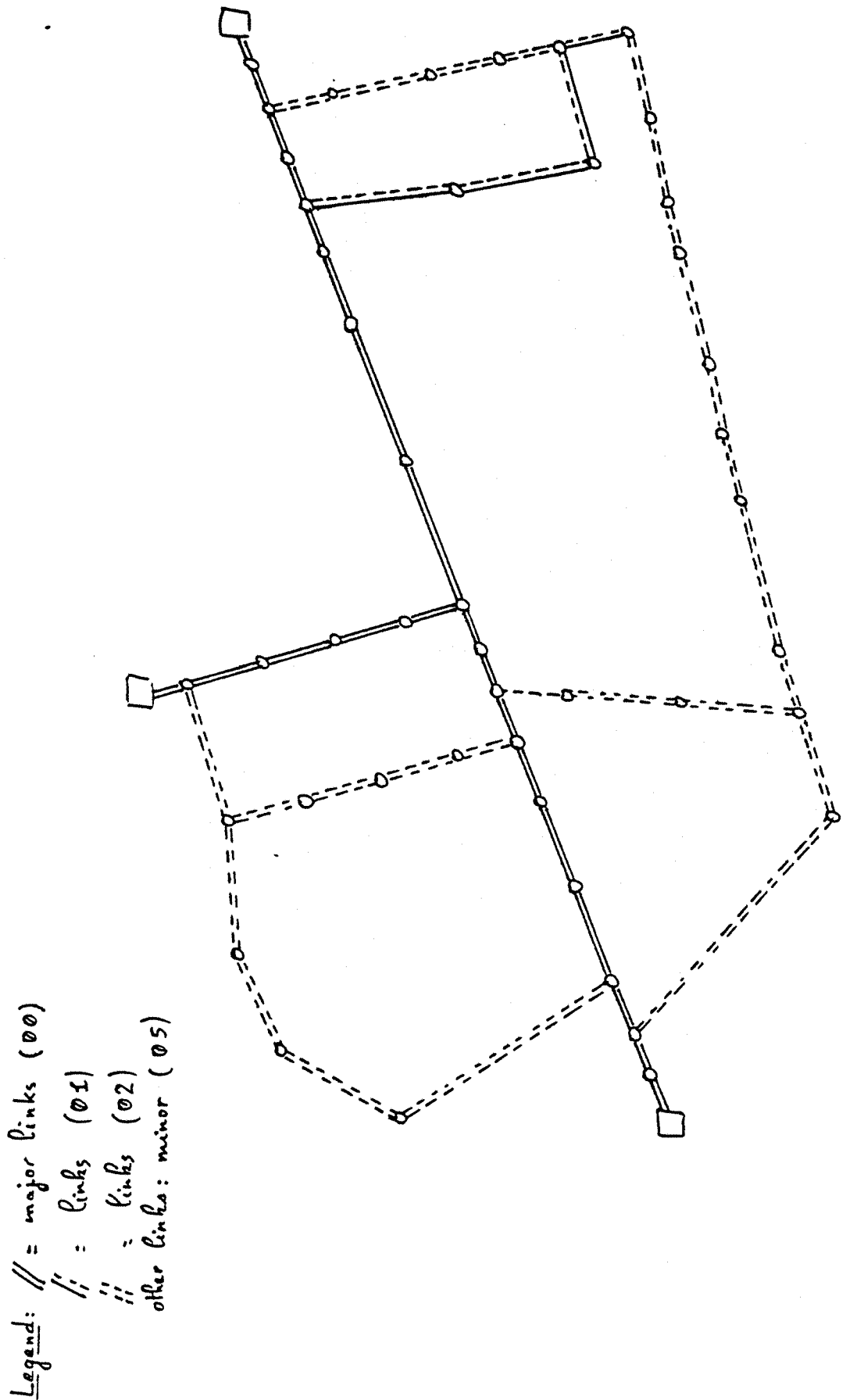
The next pages are a part of the output file, issued from a run of SMARTI with the network number one. In this run, tthere are 10% of guided vehicles, assigned onto the quickest routes among the whole network (the network is not restricted). The non-guided vehicles are asigned onto historical routes, with the possibility of self-diversion (coefficient = 1,5 and 20% of vehicles never diverting).

```
1      S I M U L A T I O N    M O D E L   T O   A S S E S S   R O U T E   G U I D A N C E
       A N D   T R A F F I C   I N C I D E N T S                    V E R S I O N  1          SMARTI 1.22 (21. 3.90)
                                                                                               RUN ON 15/ 5/90


                                        NETWORK  AND  TIME  DATA

Network 1: standard case

   CARD    (TIME)   TIME INTERVAL BOUNDARIES FOR SIMULATION PERIOD.  (HOURS AND MINUTES)
   TYPE    (UNIT)   INTERVAL  NUMBER :
                            1       2       3       4       5       6       7       8       9      10      11      12      13

    1        1     700     730     800     815     830     845     900     930    1000    1100      0       0       0       0
```

CARD TYPE	ORIGIN NUMBER	FEEDS UP TO 5 LINKS : (LETTERS DENOTE BANNED MOVEMENTS)				
3	5001	444	0	0	0	0
3	5002	502	0	0	0	0
3	5003	224	0	0	0	0
3	5004	301	0	0	0	0
3	5005	221	0	0	0	0

UNCONTROLLED ...

CARD TYPE	SET LINK NUMBER	FEEDS UP TO 5 LINKS OR DESTINATIONS : (LETTERS DENOTE BANNED MOVEMENTS)					CRUISE TIME (SECS)	LENGTH (METRS)	SAT/N FLOW (PCU/H)	STORE CAP. (VEHS)	JUNCTION NUMBER
4	301	311	222	0	0	0	40	500	1500	65E	30
4	303	222	0	0	0	0	1	10	1600	2	30
4	311	211	511	0	0	0	1	10	1600	2	31
4	313	303	211	0	0	0	20	240	1600	33E	31
4	414	204	421	0	0	0	4	40	2500	8E	41
4	421	214	432	0	0	0	4	40	2500	8E	42
4	432	9002	443	0	0	0	4	40	2500	8E	43
4	443	223	414	0	0	0	4	40	2500	8E	44
4	502	213	212	0	0	0	60	600	4200	219E	50
4	511	524	201	0	0	0	20	240	1600	33E	51
4	513	313	524	0	0	0	20	200	1600	27E	51
4	524	9003	0	0	0	0	4	30	1500	40	52

GIVE-WAY ....

CARD TYPE	SET LINK NUMBER	FEEDS UP TO 5 LINKS OR DESTINATIONS : (LETTERS DENOTE BANNED MOVEMENTS)					CRUISE TIME (SECS)	LENGTH (METRS)	SAT/N FLOW (PCU/H)	STORE CAP. (VEHS)	JUNCTION NUMBER	SLOPE *1000	CONTROLLING FLOWS LINK/A NUMBER	SLOPE *1000	LINK/B NUMBER
5	304	311	0	0	0	0	75	1000	600	180	30	250	303D	250	
5	312	511	303	0	0	0	100	1300	600	200	31	250	311D	250	313D
5	411	204	421	0	0	0	40	500	2000	86E	41	700	414D	0	0
5	422	214	432	0	0	0	80	1000	1500	173E	42	500	421D	0	0
5	433	9002	443	0	0	0	300	5000	3000	1304E	43	950	432D	0	0
5	444	223	414	0	0	0	80	1000	3000	260E	44	950	443D	0	0

SIGNALISED .....

CARD TYPE	SET LINK NUMBER	FEEDS UP TO 5 LINKS OR DESTINATIONS : (LETTERS DENOTE BANNED MOVEMENTS)					CRUISE TIME (SECS)	LENGTH (METRS)	SAT/N FLOW (PCU/H)	STORE CAP. (VEHS)	SIGNAL/ JUNCTION NUMBER	STAGES WHEN GREEN	% GREEN	% DELAY
6	12	202C	0	0	0	0	75	900	1500	117E	1	2		
6	14	215C	0	0	0	0	4	50	1500	8	1	2	100	60

NOTICE: SMARTI 1.20 PERMITS THE USE OF MULTIPLE GREEN STAGES AND COORDINATION IN PREFERENCE TO % GREEN AND/OR % DELAY FACTORS

CARD TYPE	SET LINK NUMBER	FEEDS					CRUISE TIME	LENGTH	SAT/N FLOW	STORE CAP.	SIGNAL/ JUNCTION	STAGES WHEN GREEN	% GREEN	% DELAY
6	201	14L	422	0	0	0	20	200	1600	27E	20	1		
6	202	422	513	0	0	0	4	50	1600	8	20	2		
6	204	513	14L	0	0	0	80	1000	1500	130E	20	2		
6	211	9001	433	12L	0	0	100	1300	1800	203E	21	1		
6	212	312	0	0	0	0	10	100	1500	13E	21	2	50	100
6	213	433	12L	0	0	0	10	100	3000	26E	21	2		
6	214	12L	312	9001	0	0	300	5000	3000	1304E	21	1		
6	215	312	9001	433	0	0	75	900	1600	125E	21	2	50	70
6	221	304	411	0	0	0	40	500	1500	65E	22	1		
6	222	411	0	0	0	0	75	1000	1800	156E	22	2		
6	223	304	0	0	0	0	40	500	2000	86E	22	1		
6	224	304	411	0	0	0	90	1000	1500	130E	22	2		

FLAGS:-   V - SPEED IN KM/H,   SF - SPEED-FLOW NUMBER,   E - ESTIMATED STORAGE CAPACITY,   D - DEPARTURES,   A - ARRIVALS

CARD TYPE	PCUS PER CLASS CAR	B	L	CRUISE TIMES (% CAR VALUE) CAR	B	L
9	1.0	2.2	1.8	100	140	120

CARD TYPE	VEH CLASS	FUEL COEFFICIENTS CRUISE A (ML/M)	B (ML/S)	C (ML/MV**2)	WEIGHT M (T)	EFFICIENCY E1	E2 (ML/KJ..)
D/F	C	0.024	0.361	0.000057	1.080	0.087	0.025
D/F	B	-0.040	2.272	0.000334	8.000	0.074	0.025
D/F	L	-0.040	2.272	0.000334	5.000	0.074	0.025

DESTINATIONS (DEDUCED FROM LINK DATA):

     9002   9003   9001

NETWORK COMPOSITION DEDUCED FROM DATA:

```
        12   UNCONTROLLED LINKS        )
         6   GIVE-WAY LINKS            )   TOTAL OF    32 LINKS OF ALL TYPES
        14   SIGNALISED LINKS          )
         4   SIGNAL JUNCTIONS              TOTAL OF    13 JUNCTIONS OF ALL TYPES

     NO. OF ORIGINS              5     NO. OF DESTINATIONS           3
     NO. OF TIME INTERVALS       9
```

1   TRAFFIC DEMANDS

O-D demands network 1 (10% guided)

```
ORIG  DEST  PKT VEH GUI- LIN.    ENTRY  FLOW-RATE  IN  TIME  INTERVAL (VEH/H) :
NO.   NO.   SIZE TYP -DE DIST      1      2      3      4      5      6      7      8      9
            (VEH)         (M)
```

NOTICE: O-D DATA ARE IN OLD FORMAT

```
FLOW MULTIPLYING FACTORS:         90%    90%    90%    90%    90%    90%    90%    90%    90%
 5001  9001  10   C UNG  2990     375    750   1125   1500   1350   1050    750    375     0
 5001  9003  10   C UNG  2270     150    300    450    600    525    375    300    150     0
 5002  9002  10   C UNG  2690     320    560    800   1200    950    700    600    300     0
 5003  9003  10   C UNG  2280      50    200    300    350    400    250    150     50     0
 5004  9002  10   C UNG  1840      40    120    200    300    270    240    210    150     0
 5005  9001  10   C UNG  2810      10     20     20     20     20     20     20     20     0
 5005  9002  10   C UNG  1080     100    120    150    200    180    150    120     80     0
FLOW MULTIPLYING FACTORS:         10%    10%    10%    10%    10%    10%    10%    10%    10%
 5001  9001   5   C GUI  2990     375    750   1125   1500   1350   1050    750    375     0
 5001  9003   5   C GUI  2270     150    300    450    600    525    375    300    150     0
 5002  9002   5   C GUI  2690     320    560    800   1200    950    700    600    300     0
 5003  9003   5   C GUI  2280      50    200    300    350    400    250    150     50     0
 5004  9002   5   C GUI  1840      40    120    200    300    270    240    210    150     0
 5005  9001   5   C GUI  2810      10     20     20     20     20     20     20     20     0
 5005  9002   5   C GUI  1080     100    120    150    200    180    150    120     80     0
```

TOTAL VEHICLE FLOW RATES FROM EACH ORIGIN DURING EACH TIME INTERVAL (VEH/H)

```
           ORIGINS        FLOWS

             5001          524   1050   1574   2100   1874   1424   1050    524     0
             5002          320    560    800   1200    950    700    600    300     0
             5003           50    200    300    350    400    250    150     50     0
             5004           40    120    200    300    270    240    210    150     0
             5005          110    140    170    220    200    170    140    100     0
```

TOTAL VEHICLE FLOW RATES DIRECTED TOWARDS EACH DESTINATION DURING EACH TIME INTERVAL (VEH/H)

```
           DESTINATIONS   FLOWS

             9002          460    800   1150   1700   1400   1090    930    530     0
             9003          200    500    750    950    924    624    450    200     0
             9001          384    770   1144   1520   1370   1070    770    394     0
```

TOTAL VEHICLE FLOW RATES ENTERING THE NETWORK DURING EACH TIME INTERVAL (VEH/H)

```
                          1044   2070   3044   4170   3694   2784   2150   1124     0
```

TOTAL NUMBER OF ORIGIN-DESTINATION CARDS (O-D MOVEMENTS) IS   14
LAST TIME INTERVAL WITH ANY DEMAND IS   8
LENGTH OF BUSY PERIOD IS   3H 0M

1   CONTROL DATA

Network 1 : no incident; unguided + guided vehicles

CARD
TYPE

   50   MAXIMUM NUMBER OF ITERATIONS = 15

   51   OUTPUT OPTIONS - MAXIMUM VALUES OF DATA IN COLS. 11-25
          OR AS SPECIFIED BY RUN-TIME PARAMETERS OR BY DEFAULTS:

          OPTION   VALUE   STATUS

          CONVERGENCE MONITOR   2   EXTENDED FORMAT
          PACKET ROUTE FILE   1   STANDARD FORMAT
          POST-ANALYSIS FILE   0   SUPPRESSED
```

| SIGNAL PLAN NO. | | PLAN TYPE | | CYCLE TIME (SEC) | STAGE 1 GREEN (SEC) | STAGE 2 GREEN (SEC) | STAGE 3 GREEN (SEC) | STAGE 4 GREEN (SEC) | STAGE 5 GREEN (SEC) | STAGE 6 GREEN (SEC) | ALL RED (SEC) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 71 | 1 | FIXED CYCLE & FIXED | SPLITS | 110 | 50 | 50 | 0 | 0 | 0 | 0 | 0 |
| 71 | 2 | FIXED CYCLE & FIXED | SPLITS | 110 | 50 | 50 | 0 | 0 | 0 | 0 | 0 |
| 71 | 3 | FIXED CYCLE & FIXED | SPLITS | 55 | 0 | 30 | 0 | 0 | 0 | 0 | 0 |
| 71 | 4 | FIXED CYCLE & FIXED | SPLITS | 110 | 40 | 60 | 0 | 0 | 0 | 0 | 0 |
| 71 | 5 | FIXED CYCLE & FIXED | SPLITS | 110 | 50 | 50 | 0 | 0 | 0 | 0 | 0 |
| 71 | 6 | FIXED CYCLE & FIXED | SPLITS | 55 | 0 | 10 | 0 | 0 | 0 | 0 | 0 |

```
          SIGNAL   PLAN NUMBER OPERATED IN EACH TIME INTERVAL,  OR PLAN NUMBER * 1000 + START OF STAGE 1 GREEN OFFSET IN SECONDS :
            NO.     1     2     3     4     5     6     7     8     9
 77          1      3     3     3     3     3     3     3     3     3
 77         20      2     2     2     2     2     2     2     2
 77         21      5     5     5     5     5     5     5     5
 77         22      1     1     1     1     4     4     1     1     1
```

```
91      CREATE A NEW HISTORICAL JOURNEY TIME AND OCCUPANCY DATA FILE


93      USE A FORMER HISTORICAL ,ROUTE, DATA FILE.

        COEFFICIENT FOR THE DIVERSION :  15
        PERCENTAGE OF VEHICLES NEVER DIVERTING :  20


96      FACTOR USED FOR THE RESTRICTED NETWORK OF THE ROUTE GUIDANCE SYSTEM:  0

DEFAULTED CONTROL DATA :

        OPTION TYPES  52-55  ENABLED

TOTAL MEMORY WORDS FOR NETWORK & TRAFFIC INFORMATION:   AVAILABLE   900000,   USED   900000,   EXCLUDING ROUTES   19955
1                                         SUMMARY INFORMATION          SMARTI 1.22 (21. 3.90)       RUN ON 15/ 5/90


    Network 1; standard case
    O-D demands network 1 (10% guided)
    Network 1 : no incident; unguided + guided vehicles
                                                                                      ITERATION NUMBER    5
                TIME INTERVALS :
                    1      2      3      4      5      6      7      8      9
                  700    730    800    815    830    845    900    930   1000   1100
                                                                                              TOTALS
            JOURNEY-TIME (VEH-H)
FREEMOVING     34.0   72.9   55.6   79.9   77.4   59.6   84.6   43.5    3.1                   510.5
FLOW DELAY      .0     .0     .0     .0     .0     .0     .0     .0     .0                      .0
QUEUEING        6.6   17.4   12.4   18.9   21.7   17.2   21.3    8.7     .5                   124.7
TOTAL          40.6   90.2   68.0   98.8   99.1   76.9  105.9   52.2    3.6                   635.2

            SPECIFIC OUTPUT FOR GUIDED VEHICLES
FREEMOVING      3.6    7.4    5.6    8.2    8.0    6.4    8.8    4.3     .2                    52.6
FLOW DELAY      .0     .0     .0     .0     .0     .0     .0     .0     .0                      .0
QUEUEING        .6    1.7    1.0    1.6    1.7    1.2    1.8     .9     .0                    10.5
TOTAL          4.2    9.1    6.7    9.9    9.7    7.6   10.5    5.2     .3                    63.2

        DISTANCE TRAVELLED (VEH-KM)
             1544.5 3470.4 2781.5 4111.5 4017.2 3057.5 4150.7 2003.7  143.9              25280.7
GUIDED        170.2  352.7  288.6  429.1  422.4  342.2  438.6  200.5   11.0               2655.2
    Total number of guided vehicles:                                                          672

        OVERALL NETWORK SPEED (KM/H)
               38.0   38.5   40.9   41.6   40.5   39.8   39.2   38.4   39.9                   39.8

        TOTAL FINAL QUEUES (VEH)
               13.3   37.5   54.4   79.0   95.5   59.9   40.9   16.8                          397.3


        FUEL CONSUMPTION (LITRES)
TRAVELLING   122.1  270.1  211.9  308.4  300.8  230.9  319.5  159.4   11.5                  1934.6
QUEUEING       5.0   18.9   14.0   23.5   27.2   21.2   25.4    7.0     .1                   142.3
TOTAL        127.1  288.9  225.9  332.0  328.0  252.1  345.0  166.4   11.6                  2076.9

        TOTAL LINK COUNTS (VEH)
ARRIVALS      2632   4920   3401   4329   4250   3516   5489   3420    299                   32256
PCU FACTOR    1.00   1.00   1.00   1.00   1.00   1.00   1.00   1.00   1.00                    1.00
STOPS          714   1653   1136   1623   1577   1166   1749    952     64                   10635
% STOPPED     27.1   33.6   33.4   37.5   37.1   33.2   31.9   27.8   21.5                    33.0
PACKET SIZE WITHIN EACH O-D MOVEMENT IS VARIABLE                ROUTES AND ROUTE MEMORY:
TOTAL NUMBER OF PACKETS ENTERING THE NETWORK       776         MEAN LINKS PER ROUTE      4.86
TOTAL NUMBER OF VEHICLES                          6639         WORDS AVAILABLE     880045  ( OUT OF 880045 )
TOTAL NUMBER OF PCUS                              6639         USED PER ITERATION        563
MEAN PCU FACTOR                                   1.00         CODONS PER WORD            10
1       CONVERGENCE MONITOR  -  SUMMARIES OF JOURNEY-TIMES, DISTANCES AND QUEUES  -  FOR ALL ITERATIONS       RUN ON 15/ 5/90


    Network 1; standard case
    O-D demands network 1 (10% guided)
    Network 1 : no incident; unguided + guided vehicles
                                                                                      ITERATION NUMBER    5
                TIME INTERVALS :
                    1      2      3      4      5      6      7      8      9
                  700    730    800    815    830    845    900    930   1000   1100
                                                                                             ITN.
    TOTAL JOURNEY-TIME (VEH-H)                                                                NO.

                40     84     63     92     94     75    100     52      4      0     0     0     0     604     1
                41     91     68     99     99     77    106     52      4      0     0     0     0     636     2
                41     90     68     99     99     77    106     52      4      0     0     0     0     635     3
                41     90     68     99     99     77    106     52      4      0     0     0     0     635     4
                41     90     68     99     99     77    106     52      4      0     0     0     0     635     5

    TOTAL DISTANCE TRAVELLED (VEH-KM)

              1529   3433   2738   4040   3952   2999   4108   1999    144      0     0     0     0   24943     1
              1545   3469   2797   4111   4021   3056   4134   2003    144      0     0     0     0   25281     2
              1544   3470   2781   4112   4017   3058   4151   2004    144      0     0     0     0   25281     3
              1544   3470   2781   4111   4017   3057   4151   2004    144      0     0     0     0   25281     4
              1544   3470   2781   4111   4017   3057   4151   2004    144      0     0     0     0   25281     5

    TOTAL FINAL QUEUES (VEH)

                14     43     73    120    145    145     73     17      0      0     0     0     0     630     1
                13     38     52     78     95     58     42     17      0      0     0     0     0     391     2
                13     38     54     79     96     60     41     17      0      0     0     0     0     397     3
                13     38     54     79     96     60     41     17      0      0     0     0     0     397     4
                13     38     54     79     96     60     41     17      0      0     0     0     0     397     5
1               CONVERGENCE MONITOR  -  CHANGES IN DEMANDS  -  FOR ALL ITERATIONS
```

```
Network 1; standard case
O-D demands network 1 (10% guided)
Network 1 : no incident; unguided + guided vehicles
```

```
            TIME INTERVALS :
            1       2       3       4       5       6       7       8       9
     700    730     800     815     830     845     900     930    1000    1100
```

ITN.NO.	RMS DEMAND CHANGES (ARRIVALS PLUS INITIAL QUEUES (VEH))													TOTAL	ITN.
1	106	197	141	190	185	149	221	137	14	0	0	0	0	1340	1
2	6	12	8	14	10	12	14	8	1	0	0	0	0	85	2
3	0	2	2	5	5	4	3	0	0	0	0	0	0	21	3
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5

ITN.NO.	NUMERICAL DEMAND CHANGES (ARRIVALS PLUS INITIAL QUEUES (VEH))													TOTAL	ITN.
1	2663	5035	3499	4521	4421	3655	5771	3533	316	0	0	0	0	33414	1
2	135	285	185	317	227	230	303	173	1	0	0	0	0	1856	2
3	0	35	30	62	62	41	50	0	0	0	0	0	0	280	3
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5

ITN.NO.	ROUTE CHANGES BY VEHICLES ENTERING NETWORK (VEH)													TOTAL	ITN.
1	526	1036	763	1046	927	697	1078	566	0	0	0	0	0	6639	1
2	17	33	38	57	36	30	44	10	0	0	0	0	0	265	2
3	8	5	5	4	0	0	15	0	0	0	0	0	0	37	3
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5

```
>>>> EXECUTION TIME    49.981   CPU SECONDS <<<<
```

APPENDIX C   DESCRIPTION OF THE ARRAYS AND VARIABLES

This appendix is totally technical and is of interest only for a person who would like to work on the programs CONTRAM or SMARTI. The users of these programs who are only interested by the results can avoid to read this appendix.

C1:   DESCRIPTION OF THE ARRAYS USED BY CONTRAM AND SMARTI

The arrays described in the next pages are used by CONTRAM and SMARTI to store all the data, and to make the different calculations. They are defined in the file SARRAYS.FOR.

The following descriptions are organized as:
- the name of the array, and its dimensions,
- a title describing the role of the array,
- the category of its content (integer, integer*4 or real),
- a list of parameters with their value and a description of their content.

The arrays are classified in alphabetic order.

AD (2 , XXOD)   Traffic demand data and temporaries.   (integer*4)
FIXRUT = 1   Description of the fixed routes
PKTGO = 2   Loading time of the next packet

AL (XXAD4 , XXLINK)   Long integer array: Link constants and pointers.
                                                              (integer*4)

LNKTIM = 1   basic cruise time
SATFLO = 2   saturation flow
QUVEHS = 2   sum of arrival
MINCOS = 3   minimum travel cost
SIGRD7 = 3   signal temporary
QUTIME = 3   sum of queue time
TOLLS = 4   fixed cost or toll
HEUR   = 4   tables of heuristic costs

ALIN (XXALIN , XXLIND)   Linear distance information.   (integer*4)
LINORG = 1   origin
LINDES = 2   destination
LINVCL = 3   vehicle class
LINSUM = 3   sum of vehicles * speed and sum of vehicles for each time interval
LINDIS = 4   distance

ASV (2 , XXSIGL , XXINT)   Time varying signals.   (integer*4)
SUMCEF = 1   sum of flow * coordination * 1000
FIXCEF = 2   as above for frozen trips

AT (16 , XXAL1)   Working array used in assignment.   (integer*4)
TREBAK = 1   previous link in tree or on route
TREFOR = 2   next link on route
TRETIM = 3   time from origin of arrival on link
TREPEC = 4   perceived cost from origin
TREFAN = 5   fan-out number relative to previous link
TREDEP = 6   time from origin of exit from link
TRESET = 7   indicator of previous signal link
TRECEF = 8   coordination
TRESTP = 9   number of stops
USED   = 10   information about this or previous route
TRAVEL = 11   total travel time on link
GDELAY = 12   geometric delay component
CRUISE = 13   cruise component (free-moving)
IQUEUE = 14   total queue on link
TREREC = 15   resource cost from origin
TREMAR = 16   not used

AV (16 , XXLINK , XXINT)   Time varying volumes and queues.   (integer*4)
UARRIV = 1   usual arrivals (all classes)

VCCARR = 2   current arrivals (class C)
BUSARR = 3   current arrivals (class B)
UCAPAC = 4   usual capacity
UQUEUE = 5   usual queue, excluding phase
UENTRY = 6   usual entering flows
UDEPAR = 7   usual departing flows
ACCVEH = 8   accumulated vehicles present
ACCPCU = 9   accumulated PCUs present
MONITA = 10   demand changes convergence monitor
CARRIV = 11   current arrivals (all classes)
CCAPAC = 12   current capacity
CQUEUE = 13   current queue, excluding phase
CENTRY = 14   current entering flows (not used)
SUMORG = 14   flow from origins
CDEPAR = 15   current departing flows   - equivalent
SUMDES = 15   flow to destinations
MAXCAP = 16   maximum capacity of exit - blocked link

'USUAL' quantities (from the second iteration on) are maintained totals due to all traffic.
'CURRENT' quantities account for only those packets which have been assigned so far during the iteration.
At the end of each iteration, the both must be equivalent.

FANIN (XXFAND)   (integer)
no parameter

HAD (XXAI9 , XXOD)   Traffic demand data and temporaries.   (integer)
INDECK = 1   pointer used by packet sequencer
ORIGIN = 2   origin index
DESTIN = 3   destination index
PKTVCL = 4   vehicles of the packet
PKTSIZ = 5   preferred or specified packet size
PKTGUI = 6   vehicle guided (1 = yes; 0 = no)
NEXPKZ = 7   size of next packet to be loaded
QUANT = 8   ⎫
FRACT = 9   ⎬ used when calculating size and timing of packets
TALLY = 10   ⎭
RATE   = 10   load or load rate in each time interval (from RATE + 1 to RATE + (XINT-1)

HAF (8 , XXSFRL)   Speed-flow relation constants.   (integer)
SFCODE = 1
FRESPE = 2
ASLOPE = 3
BSLOPE = 4
BFLOW = 5
FLOOR = 6
HEFREE = 7

MGFLOW = 8

HAL (32 , XXLINK) Link constants and pointers.	(integer)

UQUEOK = 1	maximum interval usual queue valid
UCAPOK = 2	maximum interval usual capacity valid
CQUEOK = 3	maximum interval current queue valid
CCAPOK = 4	maximum interval current capacity valid
ROUTE = 5	link information for fixed routes
LTYPE = 5	link card type information
ROUTX = 6	link information for fixed routes
ENTLNK = 6	entry link number
RUTCOM = 7	arrival interval on route
RUTGO = 8	departure interval on route
RUTFAN = 9	fan-out number on route
SLIND = 10	index to signal link information
LNKLEN = 11	link length
STOCAP = 12	storage capacity
SFIND = 13	index to speed flow information
SCIND = 14	index to fixed capacities (-PCU/h*10), or fixed saturation flow (+PCU/h*10)
FANDEL = 14	turning speeds/times to next links (from FANDEL+1 to FANDEL + 5)
PCTRSK = 20	percentage risk factor
MINORS = 20	give-way links controlled (from MINORS + 1 to MINORS + 4)
MAJORS = 24	controlling links for give-way (from MAJORS + 1 to MAJORS + 4)
SLOPES = 25	slopes associated with above (interleaved with MAJORS)
SJIND = 29	index of controlling signal }
PCTGRN = 30	percentage green factor } for signal links only
PCTDEL = 31	percentage delay factor }
LNKCAT = 32	link category used for the restriction of the network in the guidance system (0 to 9)

HAN (16 , XXORGN) Network constants.	(integer)

FANOUT = 0	next link in forward direction (from FANOUT + 1 to FANOUT + 5), dummy parameter: array addressed directly
LNKNUM = 6	external number of link
JUNCTN = 7	number of terminating junction
DESNUM = 7	destination number
LNKORD = 8	link indices in order of external number
DESPOT = 8	pointer to heuristic table
INSET = 9	set number
SIGJUN = 10	number of signal (by signal index)
FANBAN = 10	vehicle banned from next movement (from FANBAN + 1 to FANBAN + 5)
FANDEX = 16	pointer to table of previous links

HAP (2 , 8 , XXPLAN) Signal plan temporaries.	(integer)

SIGTIM = 1	
SIGOPS = 2	

HASSGN
see Appendix D for more information.

HAST (13 , XXSIG , XXINT)   Signal timings and offsets.   (integer)
SIGCYC = 1   cycle time
SIGGRN = 1   green times for each stage (from SIGGRN + 1 to SIGGRN + 6)
SIGOPT = 7   optimization parameters (from SIGOPT + 1 to SIGOPT + 4)
SIGRED = 12   all red times
SIGOFF = 13   cycle offset for coordinated signals

HASV (7 , XXSIGL , XXINT)   Time varying signals.   (integer)
ARMGRN = 0   (from ARMGRN + 1 to ARMGRN + 2)
OFFSET = 2   (from OFFSET + 1 to OFFSET + 2)
UPHASE = 5
CPHASE = 6
OLDCEF = 7

HAT (2 , XXAL1)   Array used in assignment.   (integer)
COMINT = 1   arrival interval
GOINT = 2   departure interval

HOLEVL
see Appendix D for more information.

HTIME
see Appendix D for more information.

HTRIP
see Appendix D for more information.

REM (MAXREM)   Remainder of memory, used for storing the routes.   (integer*4)
no parameter

SETCAP (XXSETC , XXINT)   Fixed saturation flows or capacities for some links.
(integer*4)
no parameter

SIGARM (4 , 6 , XXSIG)   Links facing green at each stage of signal.   (integer)
no parameter

WAR (XXAR , XXLINK , XXINT)   Accumulated real results.   (real)
VEHHF = 1
VEHHS = 2
VEHHQ = 3
VEHKM = 4

VEHTT = 5
ENTRF = 5
VEHQT = 6
VEHST = 7

C2:DESCRIPTION OF THE VARIABLES IN THE COMMON-BLOCK USED BY CONTRAM AND SMARTI

The following pages consist on a list of all the variables which are defined in the common-block SCOMMON.FOR, and which are part of the programs CONTRAM and SMARTI. Some others variables, defined as parameters in the files SPARAMS.FOR and SSYMBOL.FOR are also written. The variables are classified in alphabetic order.

The description contains:
- the name of the variable,
- the category (logical,integer, integer*4 or real), as well as the dimensions in the case of an array,
- the location (name of the common or name of the file in the case of a variable which is not part of a common-block),
- and a brief description of the variable.

As the previous part of this appendix, this can be useful only for a potential user of the programs who would like to modify it for his or her own purpose.

Variable name	Dimension	Location	Description
AAORGN	int	/CONSTS/	Base value of index for origins
AADEST	"	"	Base value of index for destinations
AORGN	"	"	Lower bound of index for origins
ADEST	"	"	Lower bound of index for destinations
ANHEUR	"	"	
ALTLP	int(6)	/INOUT1/	Used to divide the listing between several files (see CARD_TYPE 59)
ACTIVE	int*4(2)	/ROUTES/	Indicate which block of the packet route memory is currently being used for reading and writing respectively (see subroutine VIRMEM)
AL	int*4(XXAD3,XXLINK)	SARRAYS.FOR	Link constants and pointers
AD	int*4(2,XXOD)	"	Traffic demand
AV	int*4(16,XXLINK,XXINT)	"	Time varying volumes and queues
ASV	int*4(2,XXSIGL,XXINT)	"	Time varying signals
AT	int*4(16,XXALI)	"	Working array used in assignment
ALIN	int*4(XXALIN,XXLIND)	"	Linear distance information
A	int(ZM)	ARRANG	
ASLOPE	Parameter	SSYMBOL.FOR	3 (HAF)
ACCPCU	"	"	9 (AV)
ACCVEH	"	"	8 (AV)
ARMGRN	"	"	0 (HASV)

Variable name	Dimension	Location	Description
BUSY	int*4	/CONSTS/	Length of busy period
BEGIN	int*4(14)	"	Date of the beginning of each period
BADLNK	int	"	
BASE	int*4(2,2)	/ROUTES/	Contains the logical addresses of the first words of each block of the packet route memory, which may be different for read and write (see subroutine VIRMEM)
BSLOPE	Parameter	SSYMBOL.FOR	4 (HAF)
BFLOW	"	"	5 (HAF)
BUSARR	"	"	3 (AV)

Variable name	Dimension	Location	Description
CPU	real(3)	/INOUT1/	CPU(1)=Absolute start time CPU(2)=Time since start of run CPU(3)=Time since last call CONCPU
CONTLE	int*4(20)	/INOUT2/	Title of control data file
CLOCK	int(14)	"	Dates for time intervals
CONPKZ	log.	/CONSTS/	Mode for creation of packets
CURNT	int	"	Used to calculate CURRENT queues
CAPRED	log.	"	TRUE if capacity reduced
CODBUF	int(20)	/ROUTES/	Codon buffer
CODONS	int	"	Constant = (ZB - 1) / 3. Calculated in SMARTI
COEFDIS	int*4	/UNGUIDED/	Cefficient of distorsion for the historical datas
CONMAT	int*4(13,15)	/REPORT/	
CQUEOK	Parameter	SSYMBOL.FOR	3 (HAL)
CCAPOK	"	"	4 (HAL)
CARRIV	"	"	11 (AV)
CCAPAC	"	"	12 "
CQUEUE	"	"	13 "
CENTRY	"	"	14 "
CDEPAR	"	"	15 "
CPHASE	"	"	6 (HASV)
COMINT	"	"	1 (HAT)
CRUISE	"	"	13 (AT)

Variable name	Dimension	Location	Description
DAN	int	/INOUT1/	Network and time data file
DAD	"	"	Demand data file
DAC	"	"	Control data file
DAX	"		DAN or DAC, depending on flow control
DOHEUR	log.	/CONSTS/	
DOUBLE	int	"	
DENSE	log.	"	
DNO	int	/ONETRP/	Destination number
DENSER	log.	SPARAMS.FOR	Parameter = .FALSE.
DESPOT	Parameter	SSYMBOL.FOR	(HAN) =8
DESNUM	"	"	" =7
DESTIN	"	"	(HAD) =3

Variable name	Dimension	Location		Description
EARLY	int*4	/INOUT2/		
EARINT	int	"		
ENTLNK	Parameter	SSYMBOL.FOR	(HAL) =6	
ENTRF	"	"	(WAR) =5	

Variable name	Dimension	Location	Description
FLOTLE	int*4(20)	/INOUT2/	Title of flow demand file
FISTAT	int*4(32)	/INOUT1/	Return the file status
FUELCO	real(8,3)	/CONSTS/	
FIFTY	log(8)	"	Used for the card type 50 to 59
F54	log(8)	"	
FINT	int	"	(= XINT-1) Number of time intervals working
FIXED	log	/ONETRP/	
FANIN	int(XXFAND)	SARRAYS.FOR	
FANOUT	parameter	SSYMBOL.FOR (HAN) = 0	
FANBAN	"	" " =10	
FANDEX	"	" " =16	
FANDEL	"	" (HAL) =14	
FLOOR	"	" (HAF) = 6	
FRESPE	"	" " = 2	
FRACT	"	" (HAD) = 8	
FIXRUT	"	" (AD) = 1	
FIXCEF	"	" (ASV) = 2	

```
Variable *        Dimension    * Location *          Description
   name  *                     *          *
******************************************************************************
GENCOS    log(2)                 /CONSTS/   Generalised cost functions active
                                            1 = perceived cost
                                            2 = resource cost
GOINT     Parameter            SSYMBOL.FOR (HAT) = 2
GDELAY       "                      "       (AT)  =12
```

Variable name	Dimension	Location	Description
HI	int	/INOUT1/	Historical data file
HISNEW	log	/UNGUIDED/	Creation of a new historical file
HISOLD	log(2)	"	Use of a former historical file. (1) for historical journey time (2) for historical route file
HAD	int(XXAI10,XXOD)	SARRAYS.FOR	
HAF	int(6,XXSFRL)	"	
HAL	int(32,XXLINK)	"	
HAN	int16,XXORGN)	"	
HAP	int(2,8,XXPLAN)	"	
HAST	int(13,XXSIG,XXINT)	"	
HASV	int(7,XXSIGL,XXINT)	"	
HIST	int*4(XXLINK,XXINT)	"	
HIJKLM	int	SCOMMON.FOR	
HEUR	Parameter	SSYMBOL.FOR	(AL) = 4
HEFREE	"	"	(HAF)= 7

```
Variable *        Dimension      * Location *          Description
  name   *                       *          *
**************************************************************************
IDATE      int*4(3)              /INOUT1/    Date
ITERN      int                      "        Current iteration number
ISTAR2     int                   /CONSTS/
IJKLMN     int*4                 SCOMMON.FOR
INSET      Parameter             SSYMBOL.FOR (HAN) = 9
INDECK        "                     "        (HAD) = 1
IQUEUE        "                     "        (AT) =14
ISASIG(x)  Logical function      (SLNKSGN.FOR ==> x > 0   Establish the rules for
ISAUNC(x)     "                  (    &       ==> x = 0   distinguishing the 3
ISAGIV(x)     "                  (SCOMMON.FOR ==> x < 0   types of link
```

Variable name	Dimension	Location	Description
JUNCTN	Parameter	SSYMBOL.FOR	(HAN) = 7

Variable name	Dimension	Location	Description
LP	int	/INOUT1/	Output file (line printer) (=10)
LRO	int	"	Holds route links and times after the last iteration (=20)
LINENO	int	"	Line number
LATE	int*4	/INOUT2/	
LOSTIM	int	/CONSTS/	Lost time at signal in ms (see card type 2)
LENIN	int*4(13)	"	
LONGER	int*4	"	
LENMIN	int*4(13)	"	
LARGE	int*4	"	
LAST	int*4(2)	/ROUTES/	Contains the base address of the last block of packet route memory in the scratch file which is currently being used (see subroutine VIRMEM)
LINOUT	character*8(XXINT)	(FIGURE &	
LINTOT	"	(TABLIN	
LNKNUM	Parameter	SSYMBOL.FOR	(HAN) = 6
LNKORD	"	"	" = 8
LNKLEN	"	"	(HAL) =11
LTYPE	"	"	" = 5
LNKTIM	"	"	(AL) = 1
LINORG	"	"	(ALIN)= 1
LINDES	"	"	" = 2
LINVCL	"	"	" = 3
LINDIS	"	"	" = 4
LINSUM	"	"	" = 3

Variable name	Dimension	Location	Description
MELT	int*4	/INOUT2/	
MAXCON	int*4	/CONSTS/	= 3600 * speed (m/s) at which traffic would flow along a single lane of standard capacity at maximum concentration, asuming a PCU factor equal 1 (see card type 2)
MAXMEM	int*4	"	
MAXARA	"	"	
MAXVAL	"	"	
MAXREM	"	"	
MINCAP	int*4(13)	"	
MONEY	int(11,2)	"	
MAXROM	int*4	/ROUTES/	
MIDDLE	"	"	
MAXUSE	"	"	
MAJORS	Parameter	SSYMBOL.FOR (HAL)	=24
MINORS	"	" "	=20
MINCOS	"	" (AL)	= 3
MGFLOW	"	" (HAF)	= 8
MAXCAP	"	" (AV)	=16
MONITA	"	" "	=10

Variable name	Dimension	Location	Description
NETTLE	int*4(20)	/INOUT2/	Title of network data file
NPKT	int*4	"	Total number of packets entering the network
NWARNS	int	"	Number of warning issued (cf CONERR)
NERRS	int	"	Number of errors issued (cf CONERR)
NHEURS	"	"	
NDEST	"	"	Number of destinations
NQCAMU	int*4	"	
NQCAMR	"	"	
NQCAFU	"	"	
NQCAFR	"	"	
NOACDC	log	/CONSTS/	If .TRUE. suppresses speed-change delay effect (see card type 2)
NVEH	int*4	"	Total number of vehicles
NPCU	"	"	Total number of PCUs
NOTOLL	int	"	
NLINKS	int	/ONETRP/	
NEWCOD	"	/ROUTES/	
NEWPOD	INT*4	"	
NEXPKZ	Parameter	SSYMBOL.FOR (HAD) = 6	
NJUNCT		NETWRK	Number of junctions all types
NSIGJ		"	Number of signalised junctions

Variable name	Dimension	Location	Description
ONO	int	/ONETRP/	Origin number
OGO	int*4	"	Start time
ORGINT	int	"	Time interval when the packet enters the network
OLDPOD	int*4	/ROUTES/	
OLDCOD	int	"	
OPTION	int*4(4)	/CONSTS/	
ORIGIN	Parameter	SSYMBOL.FOR (HAD) = 2	
OFFSET	"	" (HASV)= 2	
OLDCEF	"	" " = 7	

Variable name	Dimension	Location	Description
PAF	int	/INOUT1/	
PASON	log	"	
PARAM	int*4(16)	"	
PASSED	int*4	/INOUT2/	
PRINT	log	"	
PCUS	int(3)	/CONSTS/	
PCUENT	int*4(13)	"	
PCUOUT	"	"	
PTFVEH	int	"	Number of vehicles in a packet
PTFPCU	"	"	Number of PCU in a packet
PTF	"	/ONETRP/	Packet size (see subroutine PACKET)
POINT	int*4(2)	/ROUTES/	Pointer for read (1) and write (2) of the route memory (see subroutine VIRMEM)
PHYS	int*4(3)	"	Contains the physical addresses of the first words of the blocks of packet route memory (see VIRMEM)
PROPFIX	int	/UNGUIDED/	Proportion (as a percentage) of vehicles never diverting their usual route (for unguided vehicles only)
PSET		}	
PARM		}	
PFAN		}	
PHAN		}	
PAL		}	
PHAF		}	
PHAP		}	
PHAST		}	
PAV		}	Pointers in the main array C
PHASV		}	
PASV		}	
PAT		}	
PWAR		}	
PHAD		}	
PAD		}	
PALIN		}	
PREM		}	
PHIST		}	
PMAX		}	
PCTGRN	Parameter	SSYMBOL.FOR (HAL)	=30
PCTDEL	"	" "	=31
PCTRSK	"	" "	=20
PKTVCL	"	" (HAD)	= 4
PKTSIZ	"	" "	= 5
PKTGO	"	" (AD)	= 2

Variable name *	Dimension	* Location *		Description
QUVEHS	Parameter	SSYMBOL.FOR	(AL) = 2	
QUTIME	"	"	" = 3	
QUANT	"	"	(HAD) = 7	

Variable name	Dimension	Location		Description
REDUCE	log	/ONETRP/		
ROUMAT	int*4(13,15)	/REPORT/		
ROUTCH	int*4(13)	"		
REM	int()	SARRAYS.FOR		
REAL4	Parameter	SPARAMS.FOR		
ROUTE	"	SSYMBOL.FOR	(HAL) = 5	
ROUTX	"	"	" = 6	
RUTFAN	"	"	" = 9	
RUTCOM	"	"	" = 7	
RUTGO	"	"	" = 8	
RATE	"	"	(HAD) = 9	

Variable name	Dimension	Location		Description
SUMERR	int	/INOUT2/		
SYSLNK	int	/CONSTS/		
SCRTCH	"	"		
START	"	"		
SETFUN	int(3,10,2)	"		
STATE	int	/ONETRP/		
SUMRUT	int*4	/ROUTES/		
SUMPTF	"	"		
SUMARY	int*4(14,15,3)	/REPORT/		
STAR2	Parameter	SPARAMS.FOR		=1
STOCAP	"	SSYMBOL.FOR	(HAL)	=12
SLOPES	"	"	"	=25
SFIND	"	"	"	=13
SCIND	"	"	"	=14
SJIND	"	"	"	=29
SLIND	"	"	"	=10
SIGJUN	"	"	(HAN)	=10
SFCODE	"	"	(HAF)	= 1
SATFLO	"	"	(AL)	= 2
SIGRD7	"	"	"	= 3
SIGTIM	"	"	(HAP)	= 1
SIGOPS	"	"	"	= 2
SIGCYC	"	"	(HAST)	= 1
SIGGRN	"	"	"	= 1
SIGOPT	"	"	"	= 7
SIGRED	"	"	"	=12
SIGOFF	"	"	"	=13
SUMORG	"	"	(AV)	=14
SUMDES	"	"	"	=15
SUMCEF	"	"	(ASV)	= 1

Variable name	Dimension	Location	Description
TOTGUI	integer	/REPORT/	Total number of guided vehicles
TALLY	Parameter	SSYMBOL.FOR	(HAD) = 9
TREBAK	"	"	(AT) = 1
TREFOR	"	"	" = 2
TRETIM	"	"	" = 3
TREPEC	"	"	" = 4
TREFAN	"	"	" = 5
TREDEP	"	"	" = 6
TRESET	"	"	" = 7
TRECEF	"	"	" = 8
TRESTP	"	"	" = 9
TRAVEL	"	"	" =11
TREMAR	"	"	" =16
TREREC	"	"	" =15
TOLLS	"	"	(AL) = 4

Variable name	Dimension	Location		Description
USUAL	int		/CONSTS/	Used to calculate the USUAL queue (see subr. QUEUES)
UQUEOK	Parameter	SSYMBOL.FOR	(HAL) = 1	
UCAPOK	"	"	" = 2	
UARRIV	"	"	(AV) = 1	
UCAPAC	"	"	" = 4	
UQUEUE	"	"	" = 5	
UENTRY	"	"	" = 6	
UDEPAR	"	"	" = 7	
UPHASE	"	"	(HASV) = 5	
USED	"	"	(AT) = 10	

Variable name	Dimension	Location	Description
VERSNO	int*4	/INOUT1/	
VERDAT	int*4(3)	"	
VMR	int	"	Virtual Memory Read; scratch file unit 31
VMW	"	"	Virtual Memory Write; scratch file unit 32
VEHTYP	int(3)	/CONSTS/	Vehicle type : 1 = car
			2 = bus
			3 = lory
VCLTIM	"	"	
VALINT	int(3,60)	"	
VALDIS	int*4(60)	"	
VALTIM	int*4(60)	"	
VALDVD	int*4(2)	"	
VEHENT	int*4(13)	"	
VEHOUT	"	"	
VALTOL	int*4(60)	"	
VALQUE	"	"	
VALDET	"	"	
VALSTP	"	"	
VALGIV	"	"	
VALSIG	"	"	
VEHGC	int	"	
VCL	int	/ONETRP/	Vehicle class (see VEHTYP)
VGU	int	"	Vehicle guidance (not yet used)
VCCARR	Parameter	SSYMBOL.FOR	(AV) = 2
VEHHF	"	"	(WAR)= 1
VEHHS	"	"	" = 2
VEHHQ	"	"	" = 3
VEHKM	"	"	" = 4
VEHTT	"	"	" = 5
VEHQT	"	"	" = 6
VEHST	"	"	" = 7
VERSN	int	SPARAMS.FOR	Version number of ROGUS
VERDAY	"	"	Day of the version
VERMTH	"	"	Month of the version
VERYR	"	"	Year of the version

Variable name	Dimension	Location	Description
WALVSQ	real(60)	/CONSTS/	
WALNOR	real(2)	"	
WERSNO	real	"	
WERALL	"	"	
WCONMT	real(13,15)	/REPORT/	
WVCLHF	real(3,13)	"	
WVCLHS	"	"	
WVCLHQ	"	"	
WVCLGC	real(3,13,2)	"	
WVCLKM	real(3,13)	"	
WFUELT	"	"	
WFUELQ	"	"	
WFRZKM	real(13)	"	
WFRZHR	"	"	
WALLHR	"	"	
WALLKM	"	"	
WEXTIM	real	"	
WVGUHF	real (3,13)	"	}
WVGUHS	"	"	}
WVGUHQ	"	"	} Refer to the guided vehicles
WVGUGC	real (3,13,2)	"	}
WVGUKM	real (3,13)	"	}
WAR	real( )	SARRAYS.FOR	

Variable name	* Dimension	* Location *	* Description
XITERN	int	/INOUT1/	Maximum number of iterations
XXLINK	"	/CONSTS/	Max. number of links
XXORG	"	"	Max. number of origins
XXDES	"	"	Max. number of destinations
XXORGN	"	"	= XXORG + AAORGN
XXDEST	"	"	= XXDES + AADEST
XXFAN	"	"	Max. number of fan-out links (= 5)
XXSIG	"	"	Max. number of signalised junctions
XXOD	"	"	Max. number of OD pairs
XXPLAN	"	"	Max. number of signal plans
XXAL1	"	"	XXLINK + 1
XXAD4	"	"	
XXSFRL	"	"	Max. nber of speed-flow relationship
XXSIGL	"	"	Max. nber of signalised links
XXALIN	"	"	2*XXINT + 4
XXLIND	"	"	Max. number of straight line O-D pairs
XXINT	"	"	Max. nber of time intervals
XXFAND	"	"	XXFAN*XXDEST
XXSETC	"	"	
XXFUNC	"	"	
XINT	"	"	Nber of time intervals
XORGN	"	"	Nber of origins + XLINK
XDEST	"	"	Nber of destinations + XLINK
XLINK	"	"	Nber of links
XUNCO	"	"	Nber of uncontrolled links
XGIVW	"	"	Nber of give-way links
XSIGL	"	"	Nber of signalised links
XSIG	"	"	Nber of signals
XSFREL	"	"	Nber of speed-flow relationship
XOD	"	"	Nber of OD pairs
XFUNC	"	"	
XFIX	"	"	
XLIND	"	"	
XHEUR	"	"	Number of heuristic tables
XF	"	"	
XEXDC	"	"	
XXAR	"	"	
XXNODL	"	"	
XGC	int(2)	"	
XHI1	int	"	)
XHI2	"	"	} 3 dimensions of array HIST()
XHI3	"	"	)

Variable name	Dimension	Location	Description
YLINK	int	/CONSTS/	XLINK + 1

Variable name	Dimension	Location	Description
ZR	int*4	SPARAMS.FOR	
ZN	"	"	
ZM	"	"	Parameter = 225000
ZB		"	= 32
ZC		"	= (ZB - 1) / 3
ZO		"	= 50
ZS		"	= 50
ZL		"	= 200
ZT		"	= 500
ZD		"	= 50
ZI		"	= 13
ZH	int*4	"	= ZM
ZF		"	= 200
ZR		"	= (ZF + ZL) / ZC

D.1   Inputs and Outputs

<u>Reading of the network:</u>

The reading of the network is done by the subroutine NETWRK. Previously, there were three types of links (4 = uncontrolled link; 5 = give-way link; 6 = signalized link). Now, for each of these types, there are 10 categories of links (0 = major link, to 9 = minor link), which characterize the importance of the links in the network used for the route guidance (restricted network). So the links types can be 400 to 409, 500 to 509, or 600 to 609. To notice that: both kind of coding work. For each link, the category (major-minor) is stored in the array HAL(LNKCAT,*), where LNKCAT = 32. The link category is not printed out in the output file.

<u>Reading of the demand:</u>

The vehicles classes were 1,2 and 4. Now, the classes 5,6 and 7 are also available. They are reserved for the guided vehicles (generally cars, buses and lorries). When the demand file is read, by the subroutine TRAFIC, the data are stored in the array HAD. If the packet of vehicles is guided, the value of HAD(PKTGUI,*) is 1, else it is 0. The packet guidance is written in the output file by GUI (for GUIded) or UNG (for UNGuided), next to the vehicle class.

<u>Reading of the control file:</u>

Five types of card have been added in the control file. They allow the creation and the use of the historical data, and define the characteristics of the non-guided or guided vehicles. They are the cards 90, 91, 92, 93 and 96, read by the subroutine CONTRL.

Card type 90: Activate the pure distortion.

    Columns 1-5   : card type number (90)
    Columns 6-10   : distortion constant (K) *100   (0 to 100)
    Columns 11-80   : not used

Card type 91: Create the historical time and occupancy level table.

   Columns 1-5 : card type number (91)

   Columns 6-80 : not used

Card type 92 : Activate the assignment with the historical time table.

   Columns 1-5 : card type number (92)

   Columns 6-10 : coefficient of distortion * 100 (1 to 100)

Card type 93 : Define the two main characteristic s of the non-guided vehicles.

   Columns 1-5   : card type number (93)

   Columns 6-10 : coefficient for the diversion * 10 (1 to 100)

   Columns 11-15 : percentage of vehicles never diverting (0 to 100)

   Columns 16-80 : not used

Card type 96: Used to activate the route guidance, and to input the factor of network restriction.

   Columns 1-5 : card type number (96)

   Columns 6-10 : factor used for the restriction of the network (0 to 10)

   Columns 11-80 : not used

All the values input by these cards are stored in integer, mostly in the commons /UNGUIDED/ and /GUIDED/.

   <u>Outputs</u>:

When there is a card type 91, the logical variable HISNEW is true and the historical journey time is written, by the subroutine OUTPUT, at the end of the last iteration. The journey times are calculated by adding the cruise time to the delay for each link.

The specific outputs for the guided vehicles, as well as some results for the non-guided, are written by the routine SUMMRZ. The same scheme as for the overall network is followed:

   Freemoving Time

   Queueing Time

   Total Journey Time

   Distance Travelled

plus Number of non-guided packets diverting at the last iteration

   Number of guided vehicles at the last iteration

D.2   Calculations

New variables:

Two commons have been added in the common-block SCOMMON.FOR:

* common /UNGUIDED/ with the variables:

    logical: HISNEW, HISTIM, HISRTE

    integer: COEFDIS, COEFDIV, PINT, TOTDIV, PROPFIX

* common /GUIDED/ with variables:

    integer: TOTGUI, RGFACT

    real: WVGUKM(3,13), WVGUHF(3,13), WVGUHS(3,13), WVGUHQ(3,13), WVGUGC(3,13)

HISNEW is true when the program must create a new historical data file (journey time and occupancy level). If no file name is written in the configuration file (SMARTI.CFG), the data will be written in the file unit 26 (FOR026.DAT). Elsewhere, the name written will be used.

HISTIM is true when the packets are assigned by using the historical journey time. In this case, the historical data file must be accessible by the program, its name has to be written in the configuration file and it must not be empty.

HISRTE is true when the unguided vehicles are assigned by using the historical route file. The route file must exist and not be empty. Its name has to be written in the configuration file.

COEFDIS is 10 times the value of the coefficient of distortion (integer in the range 0 to 100). It is used for both 'pure distortion' (card 90), and 'historical time distortion' (card 92). This value is read by the subroutine CONTRL, and used by the subroutine QDELAY to calculate the distorted links journey time.

COEFDIV is 10 times the value of the coefficient of diversion (integer in the range 0 to 100). It is read by the subroutine CONTRL, and used by the routine DIVERT, described later.

PINT is a variable used to store the number of the previous time interval when the assignment is done with the historical routes.

TOTDIV is the total number of diversions carried out during the iterations. This number is printed out at the end of the last iteration.

PROPFIX is the percentage of vehicles never diverting (integer in the range 0 to 100). It is read by the routine CONTRL, and used by the routine DIVERT.

TOTGUI is the total number of guided vehicles. It is calculated for each iteration, but printed out only for the last one.

RGFACT is 10 times the factor applied on the whole restricted network (integer in the range 0 to 100). When it is null, no restriction at all is applied, then the restriction effect is increasing for RGFACT = 1 to 100.

WVGUKM, WVGUHF, WVGUHS, WVGUHQ and WVGUGC are arrays which are used to store and calculate real results, as the distance travelled, the speed, the average queues, etc... They are used by the routine GATHER to accumulate the outputs.

New arrays:

According to the card types in the control file several arrays can be created. They are described in the group of arrays from SARRAYS.FOR, which are included in the main array C(ZM).

They are: HTIME(XHT1,XHT2)

                 HOLEVL(XHOL1,XHOL2)

                 HTRIP(XHTR1,XHTR2,XHTR3)

                 HASSGN(XHA1,XHA2,XHA3)

where the dimensions of these arrays: XHT1, XHT2, XHOL1, XHOL2, XHTR1, XHTR2, XHTR3, XHA1, XHA2 and XHA3 are defined in the common /CONSTS/, and calculated in the subroutine ARRANG as follow:

They are all initialized to 0, then...

if HISTIM is true:

                 XHT1 = XXLINK

                 XHT2 = XXINT

if HISRTE is true:

                 XHTR1 = XXOD

                 XHTR2 = XXRTE

                 XHTR3 = XXLINK/2+1

                 XHA1 = XXOD

                 XHA2 = XXINT+2

                 XHA3 = XXRTE+1

XHOL1 = XXLINK

XHOL2 = XXINT

if HISNEW is true:

XHOL1 = XXLINK

XHOL2 = XXINT

where   XXOD is the maximum number of O-D pairs;

XXINT is the maximum number of time intervals;

XXLINK is the maximum number of links.

XXRTE is the maximum number of routes per O-D pair

Reading of the historical files:

When the card type 93 and/or 96 are used, the program reads the file(s) name(s) in the configuration file, then the contents of the file(s). The file units are: HI = 26 for the historical time and occupancy level file; and LRO = 20 for the historical route file.

When HISTIM is true, the array HTIME contains the average journey time per link and per time interval. These values are read by the subroutine CONTRL

When HISRTE is true, the arrays HTRIP and HASSGN contain respectively all the routes used by the non-guided vehicles, recorded by the links number, and all the percentages per time intervals and per O-D pair of non-guided vehicles using these routes.

Self-diversions:

The diversion is activated during the assignment of the non-guided packets, when the queue calculated onto the link is equal to length of this link. Then, the subroutine DIVERT manages the diversion with the algorithm described in the chapter 4. A simple shortest route algorithm (DIJKSTRA/MOORE like) is used to compute the alternative route.

D.3   Print-outs

The 20 following pages are the print-outs of the subroutines GUIDAN, WATRTE and DIVERT: GUIDAN is used to dispatch the packets toward WATRTE if they are unguided, or toward ROUTAG if they are guided; WATRTE carries out the assignment of the non-guided

vehicles; DIVERT deals with the diversions; and ROUTAG is the same subroutine as OPTIMR (the initial CONTRAM assignment).

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```
C
C                    This file contains the routines :
C                              - GUIDAN
C                              - WATRTE
C                              - DIVERT
C                              - ROUTAG
C
C===============================================================================
C
      SUBROUTINE GUIDAN (STABLE,FAIL,TMOUTS,IRAND,
     .    SETCAP,FANIN,HAD,HAN,HAL,AL,HAF,HAST,AV,HASV,ASV,HAT,AT,HTIME,
     .    HASSGN,HTRIP,HOLEVL)
      INCLUDE 'SSYMBOL.FOR'
      INCLUDE 'SCOMMON.FOR'
C
      INTEGER HAD(XXHAD,XXOD),
     .          HAN(16,XXORGN),
     .          HAL(32,XXLINK),
     .          HAF(8,XXSFRL),
     .          HAST(13,XXSIG,XXINT),
     .          HASV(7,XXSIGL,XXINT),
     .          HAT(2,XXAL1),
     .          FANIN(XXFAND)
      INTEGER*4 HTIME(XHT1,XHT2),
     .          HASSGN(XHA1,XHA2,XHA3),
     .          HTRIP(XHTR1,XHTR2,XHTR3),
     .          HOLEVL(XHOL1,XHOL2),
     .          SETCAP(XXSETC,XXINT),
     .          AL(XXAD4,XXLINK),
     .          AV(16,XXLINK,XXINT),
     .          ASV(2,XXSIGL,XXINT),
     .          AT(16,XXAL1)
C
      INTEGER*4 IRAND
      LOGICAL FAIL,STABLE
C
C        -- Decision if the packet is guided or not.
       IF (VGU.EQ.1) GO TO 200
C
C     Unguided vehicles.
C
  100  CALL WATRTE (2,FAIL,IRAND,
     .            SETCAP,HAD,HAN,HAL,AL,HAF,HAST,AV,HASV,ASV,HAT,AT,HTIME,
     .            HASSGN,HTRIP,HOLEVL)

       GO TO 900
C
C     Guided vehicles.
C
  200 CALL ROUTAG (STABLE,FAIL,TMOUTS,IRAND,
     .          SETCAP,FANIN,HAN,HAL,AL,HAF,HAST,AV,HASV,ASV,HAT,AT,HTIME,
     .          HASSGN,HTRIP,HOLEVL)
C      TOTGUI = TOTGUI+PTF
C
  900 CONTINUE
      RETURN
```

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    END

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```
C
C=======================================================================
C
      SUBROUTINE WATRTE ( MODE,FAIL,IRAND,
     .      SETCAP,HAD,HAN,HAL,AL,HAF,HAST,AV,HASV,ASV,HAT,AT,HTIME,
     .      HASSGN,HTRIP,HOLEVL)
C
C      This routine reads the network and the file FOR020 (route file created
C      by CONTRAM or SMARTI).
C      It describes  the routes  used by each packet OF vehicles in the
C      scratch files SCRF1.
C
C         MODE = 1  :  Writing of the files SCRF1;
C         MODE = 2  :  Reading of the fixed route.
C
      INCLUDE 'SSYMBOL.FOR'
      INCLUDE 'SCOMMON.FOR'
C
      INTEGER HAD(XXHAD,XXOD),
     .          HAN(16,XXORGN),
     .          HAL(32,XXLINK),
     .          HAF(8,XXSFRL),
     .          HAST(13,XXSIG,XXINT),
     .          HASV(7,XXSIGL,XXINT),
     .          HAT(2,XXAL1)
      INTEGER*4 HTIME(XHT1,XHT2),
     .          HASSGN(XHA1,XHA2,XHA3),
     .          HTRIP(XHTR1,XHTR2,XHTR3),
     .          HOLEVL(XHOL1,XHOL2),
     .          SETCAP(XXSETC,XXINT),
     .          AL(XXAD4,XXLINK),
     .          AV(16,XXLINK,XXINT),
     .          ASV(2,XXSIGL,XXINT),
     .          AT(16,XXAL1)
C
      INTEGER*4 TIME,ITIME,
C                Elapsed time when the packet entering the network
     .          LNKCOS(2),
     .          PCOST,RCOST,
     .          IRAND,ISTOP
      LOGICAL   TIMOUT,FAIL
      CHARACTER*130 TITLE
C
      INTEGER*4 LINE(18)
C
      PARAMETER (MAXOD=335)
      INTEGER*2 OD(MAXOD)
C   This array contains the total number of routes per OD
C
      INCLUDE 'SLNKSGN.FOR'
C begin FORMAT
    1 FORMAT (1X,A130)
    2 FORMAT (1X,18I7)
    3 FORMAT (18I5)
    4 FORMAT (1X,'ERROR : You must modified the parameter in the ',
```

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```
              'routine WATRTE.',/,9X,'The actual value is:',I9,
       .      ' for the maximum number of OD pairs.')
    5 FORMAT (1X,'ERROR : There are not enough links to use the route ',
       .      'guidance facility.',/,9X,'The minimum number of links is 17.')
    6 FORMAT (1X,'ERROR : The departure time is after the end of the ',
       .      'last time interval!',/,9X,'route file, line ',I6)
   10 FORMAT (1X,'ERROR : This program can not read a route containing'
       .           ' more than 283 links .',/,9X,'Stopped line ',I5,
       .           /,15X,'Sorry...')
   14 FORMAT (1X,3I8)
   15 FORMAT (1X,I5)
   16 FORMAT (1X,I3,1X,2(I4,1X),14(I3,1X,I3,1X))
   20 FORMAT (1X,I3,2X,21I6)
   23 FORMAT (//' ERROR when reading the route file,   line :',I6,//)
   25 FORMAT (//1X,'ERROR, too many routes for this OD pair.'/,
       .           9X,'Stoped line ',I5)
C
      IF (MODE.GE.2) GO TO 500
C
C####################### MODE = 1 #####################################
C
      IF (XOD.GT.MAXOD)   THEN
         NERRS = NERRS+1
         WRITE(LP,4) MAXOD
         RETURN
      ENDIF
      IF (XXLINK.LT.17) THEN
         NERRS = NERRS+1
         WRITE(LP,5)
         RETURN
      ENDIF
      CALL REWYND(LRO,STAT)
      IF (STAT.EQ.0) GO TO 90
        NERRS = NERRS+1
        RETURN
   90 DO 91 I = 1,MAXOD
   91   OD(I) = 0
      LINENO = 1
C        LINENO is the line number in the route file (LRO)
      READ(LRO,1) TITLE
C
C     Reading of the 'first' lines (route description)
C
C              LINE(1) : Number of figures following
C              LINE(2) : Origine number
C              LINE(3) : Time when the packet entering the network
C              LINE(4) : Vehicle type
C              LINE(5) : Packet size
C              LINE(6) : Destination number
C              LINE(7) and followings : Links number on the route
C
C        AT is used as a temporary array.
C
  100  DO 102 K = 1,16
          DO 102 J = 1,XXLINK+1
  102        AT(K,J) = 0
```

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```
C
      READ(LRO,2,ERR = 300,END = 350) LINE
      LINENO = LINENO+1
      NV = LINE(1)
      IF (NV.GE.288) THEN
C
C        If there is more than 283 links for a route, this route is not read and
C        the program prints out a message and return.
         WRITE(LP,10) LINENO
         NERRS = NERRS+1
         RETURN
      ENDIF
C
      DO 105 I = 1,17
  105    AT(1,I) = LINE(I+1)
      NL = 1
C
  120 IF (NV.LE.17) GO TO 140
      NV = NV-18
      READ(LRO,2,ERR = 300,END = 350) LINE
      LINENO = LINENO+1
      NL = NL+1
      DO 125 I = 1,18
  125    AT(NL,I) = LINE(I)
      GO TO 120
C
C     Record of the OD if it is a new one.
C
  140 NOOD = 0
      GU = 0
      IF (AT(1,3).LE.4) GO TO 141
         AT(1,3) = AT(1,3)-4
         GU = 1
  141 DO 142 IOD = 1,XOD
         IF ( ( AT(1,1).EQ.HAN(LNKNUM,HAD(ORIGIN,IOD)) ).AND.
     .        ( AT(1,5).EQ.HAN(DESNUM,HAD(DESTIN,IOD)) ).AND.
     .        ( AT(1,3).EQ.HAD(PKTVCL,IOD) ).AND.
     .        ( GU.EQ.HAD(PKTGUI,IOD) )                    ) THEN
            NOOD = IOD
            GO TO 143
         ENDIF
  142 CONTINUE
      WRITE(LP,23) LINENO
      NERRS = NERRS+1
      RETURN
C
C        NOOD is now the number of the OD pair.
C
  143 TIME = AT(1,2)
      DO 144 IT = 1,XINT
  144    IF ( (TIME.GE.BEGIN(IT)).AND.(TIME.LT.BEGIN(IT+1)) ) GO TO 145
  145 CINT = IT
      IF (CINT.GT.XINT) THEN
         NERRS = NERRS+1
         WRITE(LP,6) LINENO
         RETURN
```

```
        ENDIF
C
C         CINT is the current time interval..
C
        IF (NL.GT.1) GO TO 170
C
C         Only one line (short route)
C
        DO 150 RTE = 1,OD(NOOD)
            DO 147 I = 1,NV-5
  147           IF (AT(1,I+5).NE.HTRIP(NOOD,RTE,I)) GO TO 150
            HASSGN(NOOD,CINT,RTE) = HASSGN(NOOD,CINT,RTE)+AT(1,4)
            GO TO 220
  150   CONTINUE
        OD(NOOD) = OD(NOOD)+1
        IF (OD(NOOD).GT.XHTR2) THEN
            NERRS = NERRS+1
            WRITE(OUT,25) LINENO
            RETURN
        ENDIF
        DO 155 I=1,NV-5
  155       HTRIP(NOOD,OD(NOOD),I) = AT(1,I+5)
        HASSGN(NOOD,CINT,OD(NOOD)) = AT(1,4)
        GO TO 220
C
C         Long route
C
  170   DO 190 RTE = 1,OD(NOOD)
            DO 180 I = 1,12
  180           IF (AT(1,I+5).NE.HTRIP(NOOD,RTE,I)) GO TO 190
            DO 185 K = 2,NL
                DO 185 I = 1,18
  185               IF (AT(K,I).NE.HTRIP(NOOD,RTE,18*(K-2)+I+12)) GO TO 190
            HASSGN(NOOD,CINT,RTE) = HASSGN(NOOD,CINT,RTE)+AT(1,4)
            GO TO 220
  190   CONTINUE
        OD(NOOD) = OD(NOOD)+1
        IF (OD(NOOD).GT.XHTR2) THEN
            NERRS = NERRS+1
            WRITE(OUT,25) LINENO
            RETURN
        ENDIF
        DO 200 I = 1,12
  200       HTRIP(NOOD,OD(NOOD),I) = AT(1,I+5)
        DO 205 K = 2,NL
            DO 205 I = 1,18
  205           HTRIP(NOOD,OD(NOOD),18*(K-2)+12+I) = AT(K,I)
        HASSGN(NOOD,CINT,OD(NOOD)) = AT(1,4)
        GO TO 220
C
C
C         Reading of the 'second' lines (timing description)
C         This line is not used, so not recorded
C
  220   READ(LRO,2,ERR = 300,END = 350) LINE
        LINENO = LINENO+1
```

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```
         NV = LINE(1)
         IF (NV.GE.283) THEN
C
C           If there is more than 283 links for a route, this route is not read and
C           the program prints out a message and return.
            WRITE(LP,10) LINENO
            NERRS = NERRS+1
            RETURN
         ENDIF
C
C        DO 225 I = 1,17
C 225        AT(1,I) = LINE(I+1)
         NL = 1
C
  230    IF (NV.LE.17) GO TO 250
         NV = NV-18
         READ(LRO,2,ERR = 300,END = 350) LINE
         LINENO = LINENO+1
         NL = NL+1
C        DO 235 I = 1,18
C 235        AT(NL,I) = LINE(I)
         GO TO 230
C
  250    GO TO 100
C
C Error
  300    WRITE(LP,23) LINENO
         NERRS = NERRS+1
         GO TO 400
C
C        Output
C
  350    CONTINUE
C
C     The route is translated in internal number
         DO 355 NOOD = 1,XOD
            DO 355 RTE = 1,OD(NOOD)
               DO 354 I = 1,XLINK
                  IF (HTRIP(NOOD,RTE,I).EQ.0) GO TO 355
                  DO 353 LN = 1,XLINK
                     IF (HTRIP(NOOD,RTE,I).NE.HAN(LNKNUM,LN)) GO TO 353
                     HTRIP(NOOD,RTE,I) = LN
                     GO TO 354
  353             CONTINUE
  354          CONTINUE
  355    CONTINUE
C
         ENDHR = XXRTE+1
         DO 380 NOOD = 1,XOD
            DO 360 NINT = 1,XINT
  360          HASSGN(NOOD,NINT,ENDHR) = 0
C
C           Total number of packets in the time interval NINT, for the OD pair NOOD
C
            DO 375 NINT = 1,XINT
               DO 365 RTE = 1,OD(NOOD)
```

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```
365               HASSGN(NOOD,NINT,ENDHR) = HASSGN(NOOD,NINT,ENDHR)
      .                                  + HASSGN(NOOD,NINT,RTE)
              IF (HASSGN(NOOD,NINT,ENDHR).EQ.0) GO TO 375
              DO 370 RTE = 1,OD(NOOD)
370               HASSGN(NOOD,NINT,RTE) = 1000 * HASSGN(NOOD,NINT,RTE)
      .                                  / HASSGN(NOOD,NINT,ENDHR)
375       CONTINUE
380   CONTINUE
C
  400 CALL REWYND(LRO,STAT)
      IF (STAT.EQ.0) RETURN
          NERRS = NERRS+1
          RETURN
C
C########################### MODE = 2 ###################################
C
C         Computation of the current time interval : CINT
C
  500 TIME = OGO
      CINT = ORGINT
C
C     Find the Current time interval: CINT
C     and the previous time interval: PINT
C
      IF (CINT.EQ.PINT) GO TO 600
C
      DO 520 IOD = 1,XOD
         DO 520 RTE = 1,XXRTE
             HASSGN(IOD,XINT+1,RTE) = 0
             HASSGN(IOD,XINT+2,RTE) = 0
  520 CONTINUE
      PINT = CINT
C
C     Find the current OD pair number: COD.
C
  600 COD = 0
      DO 602 COD = 1,XOD
  602    IF ( (HAD(ORIGIN,COD).EQ.ONO).AND.
      .          (HAD(DESTIN,COD).EQ.DNO) )    GO TO 603
      NERRS = NERRS+1
      WRITE(LP,*) 'ERROR: Impossible to recognise the OD pair number',
      .            ' during WATRTE (MODE=2).'
      GO TO 900
C
C         Choice of the route with the largest ECART
C
  603 MAXI = 0
      DO 605 RT = 1,XXRTE
         ECART = HASSGN(COD,CINT,RT)-HASSGN(COD,XINT+2,RT)
         IF (MAXI.GE.ECART) GO TO 605
             MAXI = ECART
             CHOSEN = RT
  605 CONTINUE
      IF (MAXI.NE.0) GO TO 608
          DO 606 RT = 1,XXRTE
              IF (MAXI.GE.HASSGN(COD,CINT,RT)) GO TO 606
```

```
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                   MAXI = HASSGN(COD,CINT,RT)
                   CHOSEN = RT
  606     CONTINUE
C
C        Assign the packet on the CHOSEN route
C
  608 HASSGN(COD,XINT+1,CHOSEN) = HASSGN(COD,XINT+1,CHOSEN)+PTF
C
      TOTAL = 0
      DO 610 RT = 1,XXRTE
  610    TOTAL = TOTAL+HASSGN(COD,XINT+1,RT)
      DO 612 RT = 1,XXRTE
  612    HASSGN(COD,XINT+2,RT) = 1000*HASSGN(COD,XINT+1,RT)/TOTAL
C
C     Reading of the CHOSEN route
C
      DO 616 I=1,XLINK
  616    HAL(RUTFAN,I) = 0
C
      DO 620 L = 1,XXFAN
  620    IF (HTRIP(COD,CHOSEN,1).EQ.HAN(L,ONO)) GO TO 621
       NERRS = NERRS+1
       L = 1
  621 HAL(RUTFAN,1) = L
      INROUT = 1
      L2 = HTRIP(COD,CHOSEN,1)
      DO 630 J = 2,XHTR3
         IF (HTRIP(COD,CHOSEN,J).EQ.0) GO TO 631
         L1 = L2
         L2 = HTRIP(COD,CHOSEN,J)
         DO 625 L = 1,XXFAN
  625       IF (L2.EQ.HAN(L,L1)) GO TO 626
         NERRS = NERRS+1
         L = 1
  626    INROUT = INROUT+1
         HAL(RUTFAN,J) = L
  630 CONTINUE
C
C     Assignement
C
      IF (NERRS.GT.0) GO TO 900
  631 NL = ONO
      FAIL = .FALSE.
      TMOUTS = 0
      PCOST = 0
      RCOST = 0
      NEWSET = -1
      DO 633 I = 1,XLINK
  633    AT(TREBAK,I) = -1
C
      DO 680 I1=1,XLINK
         J1 = HAL(RUTFAN,I1)
         IF (J1.EQ.0) GO TO 700
         K = HAN(J1,NL)
         AT(TREBAK,K) = NL
         AT(TREFAN,K) = J1
```

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```
         AT(TRETIM,K) = -TIME
         AT(TREPEC,K) = -PCOST
         AT(TREREC,K) = RCOST
         AT(TRESET,K) = NEWSET
         NL = K
         ENTER = TIME
         CALL QDELAY ( NL,TIME,EINT,DINT,TIMOUT,IRAND,QUELEN,ISTOP,
     .        SETCAP,HAN,HAL,AL,HAF,HAST,AV,HASV,ASV,HAT,AT,HTIME,
     .        HASSGN,HTRIP,HOLEVL)
         ITIME = TIME-ENTER
C

         NSL = HAL(SLIND,NL)
         DO 640 ICOS = 1,2
           LNKCOS(ICOS) = ITIME
           IF (.NOT.GENCOS(ICOS)) GO TO 640
           ESET = HAN(INSET,NL)
           N = SETFUN(VCL,ESET,ICOS)
  635      IF (N.LE.3) GO TO 637
             IF (EINT.GE.VALINT(1,N).AND.EINT.LE.VALINT(2,N))
     .           GO TO 637
             N = VALINT(3,N)
             GO TO 635
  637      VALJUN = 0
           IF (ISAGIV(NSL))  VALJUN = VALSIG(N)
           IF (ISASIG(NSL))  VALJUN = VALSIG(N)
           LNKCOS(ICOS) = VALDIS(N)*HAL(LNKLEN,NL)/100 +
     .          HAL(PCTRSK,NL)*(VALDET(N)*DETERR+VALJUN)/100 +
     .          VALTIM(N)*ITIME +
     .          VALQUE(N)*(NOW-ISTOP) +
     .          VALTOL(N)*AL(TOLLS,NL) +
     .          VALSTP(N)*AT(TRESTP,NL)
           IF (WALVSQ(N).EQ.0) GO TO 640
           WV = 3.6*HAL(LNKLEN,NL)/MAX(ITIME , 1)
           WV = MIN(WV , 200.)
           LNKCOS(ICOS) = LNKCOS(ICOS)+WALVSQ(N)*WV*WV*HAL(LNKLEN,NL)
  640    CONTINUE
C
  650    IF (TIMOUT) GO TO 900
C
C        If the length of the queue QUELEN when the packet enters the link NL
C        is greater or equal the store capacity of the link STOCAP, then the
C        packet can be diverted.
C
         IF ( (QUELEN.GE.HAL(STOCAP,NL)).AND.(I1.GT.1).AND.
     .        (I1.LT.XLINK-1) )
     .      CALL DIVERT ( FAIL,IRAND,
     .           AT(TREBAK,NL),NL,I1,PCOST,RCOST,
     .           SETCAP,HAN,HAL,AL,HAF,HAST,AV,HASV,ASV,HAT,AT,HTIME,
     .           HASSGN,HTRIP,HOLEVL)
         PCOST = PCOST+LNKCOS(1)
         RCOST = RCOST+LNKCOS(2)
         NEWSET = AT(TRESET,NL)
  680    CONTINUE
C
  700    AT(TREBAK,YLINK) = NL
         AT(TRETIM,YLINK) = TIME
```

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```
      AT(TREPEC,YLINK) = PCOST
      AT(TREREC,YLINK) = RCOST
      NL = YLINK
C
  900 IF (NERRS.GT.0) FAIL = .TRUE.
      RETURN
      END
```

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```
C================================================================================
C
      SUBROUTINE DIVERT ( FAIL,IRAND,
     .            ORI,SL,IND,PC,RC,
     .            SETCAP,HAN,HAL,AL,HAF,HAST,AV,HASV,ASV,HAT,AT,HTIME,
     .            HASSGN,HTRIP,HOLEVL)
C
C     This subroutine deals with the case of self diversion of a packet
C     arriving to a saturated (full) link (SL).
C
      INCLUDE 'SSYMBOL.FOR'
      INCLUDE 'SCOMMON.FOR'
      INTEGER HAN(16,XXORGN),
     .        HAL(32,XXLINK),
     .        HAF(8,XXSFRL),
     .        HAST(13,XXSIG,XXINT),
     .        HASV(7,XXSIGL,XXINT),
     .        HAT(2,XXAL1)
      INTEGER*4 SETCAP(XXSETC,XXINT),
     .          AL(XXAD4,XXLINK),
     .          AV(16,XXLINK,XXINT),
     .          ASV(2,XXSIGL,XXINT),
     .          AT(16,XXAL1),
     .          HTIME(XHT1,XHT2),
     .          HASSGN(XHA1,XHA2,XHA3),
     .          HTRIP(XHTR1,XHTR2,XHTR3),
     .          HOLEVL(XHOL1,XHOL2)
C
      PARAMETER ( MAXLIN = 200 ,
     .            MAXJUN = 260 )
      INTEGER   MARK(MAXJUN)
      INTEGER*4 IRAND,ISTOP,
     .          PC,RC,
     .          INICOS(2),
     .          CCOST,
     .          COSDES,
     .          ARRA2(MAXLIN),
     .          ARRA1(MAXLIN),
     .          LNKCOS(2)
      REAL PROB,RANVAL
      LOGICAL ERR,FAIL,BANNED(0:7,3)
      DATA BANNED/
     .  .FALSE.,.TRUE.,.FALSE.,.TRUE.,.FALSE.,.TRUE.,.FALSE.,.TRUE.,
     .  .FALSE.,.FALSE.,.TRUE.,.TRUE.,.FALSE.,.FALSE.,.TRUE.,.TRUE.,
     .  .FALSE.,.FALSE.,.FALSE.,.FALSE.,.TRUE.,.TRUE.,.TRUE.,.TRUE./
      DATA MINLEN/1/
C
      INCLUDE 'SLNKSGN.FOR'
C
C     Arguments :
C       FAIL      Flag (not used)
C       IRAND     Random value
C       ORI       Pseudo-origin link number
C       SL        Saturated link
C       IND       Link index on the route
```

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```
C        PC          Perceived cost
C        RC          Resource cost
C        SETCAP,HAN,HAL,AL,HAF,HAST,AV,HASV,ASV,HAT,AT,HTIME,HASSGN,HTRIP,HOLEVL
C
C        'ARRA1' is used  to record the  alternative  route  backward at first,
C            then the same route in the right order and in fan-out number.
C        'ARRA2' is used  at  first to  calculate  the cost at each link in the
C            algorithme of DIJKSTRA, then to copy the alternative  route in
C            reverse order and in compacted form.
C
      ERR = .FALSE.
C
C            - If the length of the saturated link is less than MINLEN meter,
C        or - If the link before (LN) is an origin,
C            then, there is no self-diversion.
C
      IF ((HAL(LNKLEN,SL).LE.MINLEN).OR.
     .    (ORI.GT.XLINK))                          RETURN
      IF (XLINK.GT.MAXLIN) STOP 'DIVERT'
      LN = ORI
      DES = DNO
      CCOST = 0
      INICOS(1) = PC
      INICOS(2) = RC
      TIME = -AT(TRETIM,SL)
C     write(6,*) '    Diversion attempted at ',TIME,' from ',
C     .                                ORI,' --> ',SL
C
C        --Calculation of the time interval number : NINT
      NINT = 0
      DO 40 NINT = 1,XXINT
   40    IF ( (TIME.GE.BEGIN(NINT)).AND.
     .       (TIME.LT.BEGIN(NINT+1)) )  GO TO 42
   42 IF (NINT.LE.0)    STOP 'DIVERT1'
      IF (NINT.GT.XXINT) NINT = XINT
C
C        --If the saturated link is usually full (historical data) there is no
C            diversion.
      IF (HOLEVL(SL,NINT).GE.99) GO TO 900
C
C        --There is a proportion of vehicles which are never diverting their
C            route (PROPFIX). These vehicles are chosen randomly.
      PROB = 100.*RANVAL(IRAND)
      IF (PROB.LE.PROPFIX) GO TO 900
C
C        Calculation of the cost on the initial fixed route.
C
      DO 50 I1 = IND,XLINK
         J1 = HAL(RUTFAN,I1)
         IF (J1.EQ.0) GO TO 60
         K = HAN(J1,LN)
         LN = K
         CCOST = CCOST+AL(LNKTIM,LN)
   50 CONTINUE
C
C     Route of minimal cost, not using the saturated link (SL).
```

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```
C
C        --Initialisation.
  60 COSDES = LARGE
     COUNT = 0
     PREDES = 0
     DO 62 XL = 1,XLINK
        ARRA2(XL) = LARGE
        ARRA1(XL) = 0
  62 CONTINUE
     DO 65 JN = 1,MAXJUN
  65    MARK(JN) = 0
C
C        --Mark on the links already used by the packet.
     LN = ONO
     DO 67 I = 1,IND-1
        J = HAL(RUTFAN,I)
        K = HAN(J,LN)
        MARK(HAN(JUNCTN,K)) = 1
        LN = K
  67 CONTINUE
C
C        --Specific marks for the new origin (ORI).
     ARRA2(ORI) = 0
     LN = ORI
     ERR = .TRUE.
     GO TO 100
C
C        --Research of the link not marked with minimum final cost.
  70 MINI = LARGE
     LN = 0
     DO 80 XL = 1,XLINK
        JN = HAN(JUNCTN,XL)
        IF ( (MARK(JN).EQ.1).OR.(ARRA2(XL).GE.MINI) ) GO TO 80
        MINI = ARRA2(XL)
        LN = XL
  80 CONTINUE
     IF (LN.NE.0) GO TO 90
C
C     There is no alternative route
     GO TO 900
  90 MARK(HAN(JUNCTN,LN)) = 1
C
C        --Research of the links (FL) following the link LN.
 100 DO 200 I = 1,XXFAN
        FL = HAN(I,LN)
        IF (FL.EQ.0) GO TO 200
        IF (BANNED(HAN(FANBAN+I,LN),VCL)) GO TO 200
        IF (FL.EQ.SL) GO TO 200
        IF (FL.LE.XLINK) GO TO 105
           IF (FL.NE.DES) GO TO 200
C
C           --The destination is reached..
           COSDES = ARRA2(LN)
           PREDES = LN
           GO TO 210
 105    IF (LN.NE.ORI) GO TO 110
```

```
C
C               --If  all  the  links  following  ORI  are  also  saturated  (full)  the
C                 diversion is aborted, and the original route is kept.
C                 ENTER = TIME
                CALL QDELAY (FL,TIME,EINT,DINT,TIMOUT,IRAND,QUELEN,ISTOP,
       .            SETCAP,HAN,HAL,AL,HAF,HAST,AV,HASV,ASV,HAT,AT,HTIME,
       .            HASSGN,HTRIP,HOLEVL)
C               ITIME = TIME-ENTER
C               NSL = HAL(SLIND,NL)
             DO 530 ICOS = 1,2
                LNKCOS(ICOS) = ITIME
C                IF (.NOT.GENCOS(ICOS)) GO TO 530
C                ESET = HAN(INSET,NL)
C                N = SETFUN(VCL,ESET,ICOS)
C 525            IF (N.LE.3) GO TO 527
C                 IF (EINT.GE.VALINT(1,N).AND.EINT.LE.VALINT(2,N))
C       .              GO TO 527
C                 N = VALINT(3,N)
C                 GO TO 525
C 527            VALJUN = 0
C                IF (ISAGIV(NSL))  VALJUN = VALSIG(N)
C                IF (ISASIG(NSL))   VALJUN = VALSIG(N)
C                LNKCOS(ICOS) = VALDIS(N)*HAL(LNKLEN,NL)/100 +
C       .              HAL(PCTRSK,NL)*(VALDET(N)*DETERR+VALJUN)/100 +
C       .              VALTIM(N)*ITIME +
C       .              VALQUE(N)*(NOW-ISTOP) +
C       .              VALTOL(N)*AL(TOLLS,NL) +
C       .              VALSTP(N)*AT(TRESTP,NL)
C                IF (WALVSQ(N).EQ.0) GO TO 530
C                WV = 3.6*HAL(LNKLEN,NL)/MAX(ITIME , 1)
C                WV = MIN(WV , 200.)
C                LNKCOS(ICOS) = LNKCOS(ICOS)+WALVSQ(N)*WV*WV*HAL(LNKLEN,NL)
  530        CONTINUE
             IF (QUELEN.LT.HAL(STOCAP,FL)) ERR = .FALSE.
C
  110    IF (ARRA2(FL).LE.ARRA2(LN)+AL(LNKTIM,FL)/100) GO TO 200
             ARRA2(FL) = ARRA2(LN)+AL(LNKTIM,FL)/100
             ARRA1(FL) = LN
  200 CONTINUE
         COUNT = COUNT+1
         IF ( (COUNT.LT.XLINK).AND.(.NOT.ERR) ) GO TO 70
C
C        --Destination not reached
      GO TO 900
  210 CONTINUE
C
C        --Decision for the diversion
      IF (1000*COSDES.GT.COEFDIV*CCOST) GO TO 900
C
C        Changement of the route.
C
      XL = PREDES
      I = 3
      ARRA2(1) = DES
      ARRA2(2) = PREDES
  220 XL = ARRA1(XL)
```

```
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```

```
         ARRA2(I) = XL
         IF (XL.EQ.ORI) GO TO 230
         I = I+1
         GO TO 220
  230 INROUT = I
         IF (INROUT.LE.2) GO TO 900
         L2 = ORI
         DO 245 J = 1, INROUT-1
           L1 = L2
           L2 = ARRA2(INROUT-J)
           DO 240 L = 1, XXFAN
  240       IF (L2.EQ.HAN(L,L1)) GO TO 242
           ERR = .TRUE.
           L = 1
  242    ARRA1(J) = L
  245 CONTINUE
         IF (ERR) GO TO 900
C
         DO 250 I = 1, INROUT-2
  250    HAL(RUTFAN,IND+I-1) = ARRA1(I)
         DO 260 I = IND+INROUT-2, XLINK
  260    HAL(RUTFAN,I) = 0
C
         J1 = HAL(RUTFAN,IND)
         K = HAN(J1,ORI)
C
         AT(TREBAK,K) = ORI
         AT(TREFAN,K) = J1
         AT(TRETIM,K) = AT(TRETIM,SL)
         DO 270 I = 1,2
  270    INICOS(I) = INICOS(I)+LNKCOS(I)
         AT(TREPEC,K) =   - INICOS(1)
         AT(TREREC,K) =      INICOS(2)
         AT(TRESET,K) = AT(TRESET,SL)
         SL = K
         write(6,*) ORI,SL,'                  DIVERSION  SUCCEEDED'
         TOTDIV = TOTDIV+1
  900 CONTINUE
         RETURN
         END
```

```
C
C==================================================================================
C
        SUBROUTINE ROUTAG (STABLE,FAIL,TMOUTS,IRAND,
     .          SETCAP,FANIN,HAN,HAL,AL,HAF,HAST,AV,HASV,ASV,HAT,AT,HTIME,
     .          HASSGN,HTRIP,HOLEVL)
        INCLUDE 'SSYMBOL.FOR'
        INCLUDE 'SCOMMON.FOR'
C
C       To  calculate  minimum  cost  route or time fixed  route from specified
C       origin to specified destination.
C       -- 'HAN(I,J)' is to be read as 'HAN(FANOUT+I,J)' in cases where 'I' is
C          not a symbolic first index.
C
        INTEGER*4 SETCAP(XXSETC,XXINT),
     .            AL(XXAD4,XXLINK),
     .            AV(16,XXLINK,XXINT),
     .            ASV(2,XXSIGL,XXINT),
     .            AT(16,XXAL1),
     .            HTIME(XHT1,XHT2),
     .            HASSGN(XHA1,XHA2,XHA3),
     .            HTRIP(XHTR1,XHTR2,XHTR3),
     .            HOLEVL(XHOL1,XHOL2)
        INTEGER FANIN(XXFAND),
     .            HAN(16,XXORGN),
     .            HAL(32,XXLINK),
     .            HAF(8,XXSFRL),
     .            HAST(13,XXSIG,XXINT),
     .            HASV(7,XXSIGL,XXINT),
     .            HAT(2,XXAL1)
C
        INTEGER*4 NOW,PCOST,RCOST,
     .            BASTIM,IRAND,ISTOP,
     .            LNKCOS(2),HCOST,INCOST,K
        LOGICAL STABLE,STOPLN,BANNED(0:7,3),FAIL,TIMOUT
        DATA BANNED/
     .        .FALSE.,.TRUE.,.FALSE.,.TRUE.,.FALSE.,.TRUE.,.FALSE.,.TRUE.,
     .        .FALSE.,.FALSE.,.TRUE.,.TRUE.,.FALSE.,.FALSE.,.TRUE.,.TRUE.,
     .        .FALSE.,.FALSE.,.FALSE.,.FALSE.,.TRUE.,.TRUE.,.TRUE.,.TRUE./
C
        INCLUDE 'SLNKSGN.FOR'
C
   10 FORMAT (' ERROR: DESTINATION NOT FOUND WHEN TRACING FIXED'
     .        ,' ROUTE FROM ',I5,' TO ',I5,' CLASS ',A1
     .        ,'    STARTING AT ',I5
     .        /' (ERROR: FIXED ROUTE IS INCONSISTENT WITH O-D)')
   20 FORMAT (' ERROR: DESTINATION NOT REACHED WHILE CALCULATING'
     .        ,' ROUTE FROM ',I5,' TO ',I5,' CLASS ',A1
     .        ,'    STARTING AT ',I5 ,' IN ITERATION ',I3
     .        /' (ERROR: DISCONNECTED NETWORK OR CORRUPT PROGRAM)')
C
C       Initialise state for assignment/timing of packet.
C
        FAIL = .FALSE.
        TMOUTS = 0
```

```
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        NL = ONO
        NOW = OGO
        PCOST = 0
        RCOST = 0
        NEWSET = -1
        IF (.NOT.(FIXED.OR.STABLE)) GO TO 490
C
C         FIXED ROUTES
C         ============
C
        DO 220 I1 = 1,XLINK
          J1 = HAL(RUTFAN,I1)
          IF (J1.EQ.0) GO TO 470
          K = HAN(J1,NL)
          AT(TREBAK,K) = NL
          AT(TREFAN,K) = J1
          AT(TRETIM,K) = -NOW
          AT(TREPEC,K) = -PCOST
          AT(TREREC,K) = RCOST
          AT(TRESET,K) = NEWSET
          NL = K
          ENTER = NOW
          CALL QDELAY (NL,NOW,EINT,DINT,TIMOUT,IRAND,QUELEN,ISTOP,
     .        SETCAP,HAN,HAL,AL,HAF,HAST,AV,HASV,ASV,HAT,AT,HTIME,
     .          HASSGN,HTRIP,HOLEVL)
C
        TIME = NOW-ENTER
        NSL = HAL(SLIND,NL)
        DO 210 ICOS = 1,2
          LNKCOS(ICOS) = TIME
          IF (.NOT.GENCOS(ICOS)) GO TO 210
          ESET = HAN(INSET,NL)
          N = SETFUN(VCL,ESET,ICOS)
200       IF (N.LE.3) GO TO 205
            IF (EINT.GE.VALINT(1,N).AND.EINT.LE.VALINT(2,N))
     .          GO TO 205
            N = VALINT(3,N)
            GO TO 200
205       VALJUN = 0
          IF (ISAGIV(NSL))   VALJUN = VALSIG(N)
          IF (ISASIG(NSL))   VALJUN = VALSIG(N)
          LNKCOS(ICOS) = VALDIS(N)*HAL(LNKLEN,NL)/100 +
     .        HAL(PCTRSK,NL)*(VALDET(N)*DETERR+VALJUN)/100 +
     .        VALTIM(N)*TIME +
     .        VALQUE(N)*(NOW-ISTOP) +
     .        VALTOL(N)*AL(TOLLS,NL) +
     .        VALSTP(N)*AT(TRESTP,NL)
          IF (WALVSQ(N).EQ.0) GO TO 530
          WV = MIN(3.6*HAL(LNKLEN,NL)/MAX(TIME,1) , 200.)
          LNKCOS(ICOS) = LNKCOS(ICOS)+WALVSQ(N)*WV*WV*HAL(LNKLEN,NL)
210     CONTINUE
        FAIL = TIMOUT
        IF (FAIL) GO TO 485
        PCOST = PCOST+LNKCOS(1)
        RCOST = RCOST+LNKCOS(2)
        NEWSET = AT(TRESET,NL)
```

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```
  220 CONTINUE
C
C            Finish fixed route chain, checking on first pass that fixed route
C            reaches destination.
C
  470 IF (.NOT.FIXED.OR.ITERN.GT.1) GO TO 480
      DO 475 I1 = 1,XXFAN
  475    IF (HAN(I1,NL).EQ.DNO) GO TO 480
      WRITE(LP,10) HAN(LNKNUM,ONO),HAN(DESNUM,DNO),VEHTYP(VCL),OGO
      FAIL = .TRUE.
  480 AT(TREBAK,YLINK) = NL
      AT(TRETIM,YLINK) = NOW
      AT(TREPEC,YLINK) = PCOST
      AT(TREREC,YLINK) = RCOST
      NL = YLINK
C
C            -- Go to exit
  485 GO TO 630
C
C            REASSIGNED ROUTES
C            =================
C
C            Initialise to construct minimum cost route tree.
C
  490 PTOP = 0
      PEND = 0
      DO 500 I = 1,YLINK
         AT(TRETIM,I) = LARGE
         AT(TREPEC,I) = LARGE
         AT(TREREC,I) = LARGE
  500 CONTINUE
      STOPLN = .TRUE.
      H = HAN(DESPOT,DNO)
C
C        Build heuristic table for this destination if one is not already
C        appointed.
C
      IF (H.GT.0) GO TO 510
        H = XHEUR
        CALL HEURTB (DNO,H,FANIN,HAN,AL,AT)
        IF (ANHEUR.GT.0) HAN(DESPOT,ANHEUR) = 0
        HAN(DESPOT,DNO) = H
        ANHEUR = DNO
        NHEURS = NHEURS+1
C
C        Extend tree by adding exits from current link as branches.
C        Branch is suppressed if heuristic indicates that  no route to the
C        destination exists. Otherwise  links are placed in  next-visit table
C        in increasing order of their current cost-from-origin plus heuristic
C        cost-to-destination.
C
  510 DO 600 I = 1,XXFAN
         EXIT = HAN(I,NL)
         IF (EXIT.EQ.0) GO TO 600
         IF (EXIT.LE.XLINK) GO TO 515
         IF (EXIT.NE.DNO) GO TO 600
```

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```
             EXIT = YLINK
             GO TO 517
   515       IF (AL(HEUR+H,EXIT).GE.LARGE) GO TO 600
   517       BASTIM = AT(TRETIM,EXIT)
             IF (BASTIM.LT.0) GO TO 600
             V = HAN(FANBAN+I,NL)
             IF (BANNED(V,VCL)) GO TO 600
C
C            Check whether cost to exit from downstream junction (ie queue
C            on base link) has been calculated. If not, do this.
C            If time or cost on base link is excessive skip it.
C
   520       IF (STOPLN) GO TO 550
             ENTER = NOW
             CALL QDELAY (NL,NOW,EINT,DINT,TIMOUT,IRAND,QUELEN,ISTOP,
            .     SETCAP,HAN,HAL,AL,HAF,HAST,AV,HASV,ASV,HAT,AT,HTIME,
            .     HASSGN,HTRIP,HOLEVL)
C
             IF (HISTIM) THEN
C
C   Use historical travel time table
             PROVI = 0.02*RANVAL(IRAND)-0.01
             PROVI = FLOAT(COEFDIS)*FLOAT(HTIME(NL,EINT))*PROVI
             LNKCOS(1) = HTIME(NL,EINT)+INT(PROVI)
             LNKCOS(2) = HTIME(NL,EINT)
             GO TO 535
             ELSE
             ITIME = NOW-ENTER
             ENDIF
C
C   Distortion of link journey time
             IF (COEFDIS.NE.0) THEN
             PROVI = RANVAL(IRAND)
             PROVI = FLOAT(COEFDIS)*FLOAT(ITIME)*(2.*PROVI-1.)/100.
             ITIME = ITIME+INT(PROVI)
             ENDIF
C
C   And in all case:
             NSL = HAL(SLIND,NL)
             DO 530 ICOS = 1,2
                LNKCOS(ICOS) = TIME
                IF (.NOT.GENCOS(ICOS)) GO TO 530
                ESET = HAN(INSET,NL)
                N = SETFUN(VCL,ESET,ICOS)
   525          IF (N.LE.3) GO TO 527
                 IF (EINT.GE.VALINT(1,N).AND.EINT.LE.VALINT(2,N))
            .         GO TO 527
                 N = VALINT(3,N)
                 GO TO 525
   527          VALJUN = 0
                IF (ISAGIV(NSL))  VALJUN = VALSIG(N)
                IF (ISASIG(NSL))  VALJUN = VALSIG(N)
                LNKCOS(ICOS) = VALDIS(N)*HAL(LNKLEN,NL)/100 +
            .         HAL(PCTRSK,NL)*(VALDET(N)*DETERR+VALJUN)/100 +
            .         VALTIM(N)*TIME +
            .         VALQUE(N)*(NOW-ISTOP) +
```

```
      .                  VALTOL(N)*AL(TOLLS,NL) +
      .                  VALSTP(N)*AT(TRESTP,NL)
                 IF (WALVSQ(N).EQ.0) GO TO 530
                  WV = MIN(3.6*HAL(LNKLEN,NL)/MAX(TIME,1) , 200.)
                  LNKCOS(ICOS) = LNKCOS(ICOS)+WALVSQ(N)*WV*WV*HAL(LNKLEN,NL)
530      CONTINUE
C
535      IF (TIMOUT) THEN
                  TMOUTS=TMOUTS+1
                  GO TO 610
         ENDIF
         PCOST = PCOST+LNKCOS(1)
         RCOST = RCOST+LNKCOS(2)
         NEWSET = AT(TRESET,NL)
         STOPLN = .TRUE.
C
C           Add heuristic minimum cost-to-destination , as measured from
C           upstream end of next link (exit).
C
550      HCOST = PCOST
         IF (EXIT.LE.XLINK) HCOST = PCOST+AL(HEUR+H,EXIT)
         IF (HCOST.GT.AT(TREPEC,EXIT)) GO TO 600
         IF (HCOST.LT.AT(TREPEC,EXIT)) GO TO 555
         IF (NL.GT.AT(TREBAK,EXIT))    GO TO 600
555      AT(TRETIM,EXIT) = NOW
         AT(TREPEC,EXIT) = HCOST
         AT(TREREC,EXIT) = RCOST
         AT(TREBAK,EXIT) = NL
         AT(TREFAN,EXIT) = I
         AT(TRESET,EXIT) = NEWSET
         J = PEND
C
C     Add link (exit) to next-visit table.
C
         IF (BASTIM.EQ.LARGE) GO TO 570
560       K = AT(TREFOR,J)
          J = J-1
          IF (EXIT.EQ.K) GO TO 580
           IF (J.GT.0) GO TO 560
           NERRS = NERRS+1
           GO TO 630
C
570          PEND = PEND+1
580      IF (J.EQ.0) GO TO 590
         K = AT(TREFOR,J)
         INCOST = AT(TREPEC,K)
         IF (HCOST.GT.INCOST) GO TO 590
         IF (HCOST.LT.INCOST) GO TO 585
         IF (K.LE.XLINK)      INCOST = INCOST-AL(HEUR+H,K)
         IF (PCOST.GT.INCOST) GO TO 590
         IF (PCOST.LT.INCOST) GO TO 585
          IF (EXIT.GE.K) GO TO 590
585      AT(TREFOR,J+1) = K
         J = J-1
         GO TO 580
590      AT(TREFOR,J+1) = EXIT
```

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```
C
 600  CONTINUE
C
C        Get next base link from top of next-visit table perceived+heuristic
C        cost is replaced by minus perceived cost.
C
C
 610  STOPLN = .FALSE.
      PTOP = PTOP+1
      IF (PTOP.GT.PEND) GO TO 620
      NL = AT(TREFOR,PTOP)
      NOW = AT(TRETIM,NL)
      IF (NL.EQ.YLINK) GO TO 630
      PCOST = AT(TREPEC,NL)-AL(HEUR+H,NL)
      RCOST = AT(TREREC,NL)
      NEWSET = AT(TRESET,NL)
      AT(TRETIM,NL) = -NOW
      AT(TREPEC,NL) = -PCOST
      GO TO 510
C
C        -- Table exhausted without reaching destination.
C        -- Write message only if not due to timing out on any link.
  620 IF (TMOUTS.EQ.0)
    .  WRITE(LP,20) HAN(LNKNUM,ONO),HAN(DESNUM,DNO),VEHTYP(VCL)
    .   ,OGO,ITERN
      FAIL = .TRUE.
C
  630 RETURN
      END
```

In the following tables, the three first columns are the journey times, expressed in vehicle.hour:

FT is the free-moving time;

QT is the queueing time;

TJT is the total journey time.

The fourth column, DT is the Distance Travelled by all the vehicles concerned.

The overall network speed, noted O.N.S., represents the average speed onto the network.

The next columns are:

Nveh, for the number of vehicles;

Pa.diverting, for the number of non-guided packets diverting.

The two columns Excess cost and Savings represent the excess cost for the whole network and the savings for the guided vehicles or the non-guided vehicles. Their caculations have been described in the chapter 5.

The two last columns, called time/veh and dist/veh, represent the average time (in seconds) spent into the network by a vehicle, and the average distance travelled (in kilometres) by a vehicle.

For the different runs, when there is one line, the results are for the total network, and when there are three lines, the results are:

first line for the total network,

second line for the unguided vehicles,

third line for the guided vehicles.

NETWORK 1		FT	QT	TJT	DT	CNS	Nveh	Pa. diverting	Excess cost	Savings	time/veh	dist/veh
run 1		449,1	148,7	597,8	21196,1	35,5	6624				325	3,20
run 2		456,8	159,4	616,2	21545,4	35,0	6624		3,08		335	3,25
run 3		457,0	189,8	646,8	21555,4	33,3	6624		8,20		352	3,25
run 4a-1	Total	458,0	190,1	648,1	21607,3	33,3	6626		0,17		352	3,26
	Unguided	453,1	188,4	641,5	21372,2		6554	0		-0,27	352	3,26
	Guided	4,9	1,7	6,6	235,1		72			6,09	330	3,27
run 4a-5	Total	457,4	183,0	640,4	21601,9	33,7	6629		-1,06		349	3,26
	Unguided	434,4	175,2	609,6	20500,6		6293	0		0,72	349	3,26
	Guided	23,0	7,8	30,8	1101,3		336			6,05	330	3,28
run 4a-10	Total	458,4	168,7	627,1	21654,8	34,5	6639		-3,26		342	3,25
	Unguided	411,9	154,3	566,2	19413,7		5967	0		2,60	342	3,25
	Guided	46,5	14,4	60,9	2241,1		672			6,98	326	3,33
run 4a-15	Total	456,9	169,9	626,8	21571,2	34,4	6629		-3,17		343	3,25
	Unguided	388,2	147,8	536,0	18274,5		5631	0		2,44	343	3,25
	Guided	68,7	22,1	90,8	3296,7		998			6,75	328	3,30
run 4a-20	Total	457,4	160,4	617,8	21631,7	35,0	6624		-4,48		338	3,26
	Unguided	366,1	131,4	497,5	17267,6		5295	0		3,78	338	3,26
	Guided	91,3	29,0	120,3	4364,1		1329			7,30	326	3,28
run 4a-40	Total	455,4	151,9	607,3	21526,9	35,5	6626		-6,14		333	3,26
	Unguided	275,0	93,4	368,4	12964,0		3977	0		5,10	333	3,26
	Guided	180,4	58,5	238,9	8562,9		2649			7,61	325	3,23
run 4a-60	Total	452,9	144,9	597,8	21421,7	35,8	6626		-7,60		329	3,26
	Unguided	182,7	59,1	241,8	8617,3		2649	0		6,49	329	3,25
	Guided	270,2	85,8	356,0	12804,4		3977			8,30	322	3,22
run 4a-100	Total	449,1	148,7	597,8	21196,1	35,5	6624		-7,58	7,58	325	3,20

NETWORK 1		FT	QT	TJT	DT	ONS	Nveh	Pa. diverting	Excess cost	Savings	time/veh	dist/veh
run 4b-1			as 4a-1									
run 4b-5			as 4a-5									
run 4b-10			as 4a-10									
run 4b-15			as 4a-15									
run 4b-20	Total	456,2	157,7	613,9	21560,2	35,1	6624		-5,09			
	Unguided	365,5	128,3	493,8	17244,1		5295	0		4,49	336	3,26
	Guided	90,7	29,4	120,1	4316,1		1329			7,45	325	3,25
run 4b-40	Total	454,5	148,6	603,1	21481,0	35,6	6626		-6,78			
	Unguided	274,5	90,8	365,3	12943,0		3977	0		5,90	331	3,25
	Guided	180,0	57,8	237,8	8538,0		2649			8,04	323	3,22
run 4b-60	Total	452,9	147,6	600,5	21414,9	35,7	6626		-7,19			
	Unguided	183,0	60,4	243,4	8634,4		2649	0		5,87	331	3,26
	Guided	269,9	87,2	357,1	12780,5		3977			8,02	323	3,21
run 4b-100	Total	448,4	150,0	598,4	21162,3	35,4	6624		-7,48	7,48	325	3,19

NETWORK 1	ET	QT	TJT	DT	QNS	Nveh	Pa diverting	Excess cost	Savings	time/veh	dist/veh
run 3	509,4	116,5	625,9	25226,4	40,3	6624				340	3,81
run 4c-1 total	509,2	130,2	639,4	25199,4	39,4	6626	0	2,16	-2,18	347	3,80
unguided	503,7	128,9	632,6	24924,6		6554				340	3,82
guided	5,5	1,3	6,8	274,8		72			0,02		
run 4c-5 total	509,4	135,5	644,9	25210,9	39,1	6629	0	3,04	-3,05	350	3,80
unguided	483,4	128,9	612,3	23901,9		6293					
guided	26,0	6,6	32,6	1309,0		336			-2,76	349	3,90
run 4c-10 total	510,2	137,7	647,9	25265,1	39,0	6639	1	3,51	-3,39	351	3,80
unguided	458,2	123,4	581,6	22655,1		5967					
guided	52,0	14,3	66,3	2610,0		672			-4,65	355	3,88
run 4c-15 total	509,6	154,5	664,1	25241,0	38,0	6629	0	6,10	-5,86	360	3,79
unguided	432,2	130,6	562,8	21354,4		5631					
guided	77,4	23,9	101,3	3886,6		998			-7,50	365	3,89
run 4c-20 total	510,1	143,2	653,3	25311,6	38,7	6624	0	4,38	-4,03	354	3,80
unguided	406,9	113,6	520,5	20123,1		5295					
guided	103,2	29,6	132,8	5188,5		1329			-5,75	360	3,90
run 4c-40 total	511,4	189,2	700,6	25453,2	36,3	6626	0	11,93	-10,28	375	3,80
unguided	305,6	108,7	414,3	15114,5		3977					
guided	205,8	80,5	286,3	10338,7		2649			-14,42	389	3,90
run 4c-60 total	512,5	237,6	750,1	25595,0	34,1	6626	0	19,84	-16,37	396	3,79
unguided	203,3	87,9	291,2	10049,0		2649					
guided	309,2	149,7	458,9	15546,0		3977			-22,15	415	3,91
run 4c-100 total	515,1	362,8	877,9	25910,7	29,5	6624		40,26	-40,26	477	3,91

NETWORK 1		FT	QT	TJT	DT	ONS	Nveh	Pa. diverting	Excess cost	Savings	time/veh	dist/veh
run 5		457,3	265,7	723,0	21567,4	29,8	6624		20,94	-20,94	393	3,26
run 6a-1	Total	458,0	240,8	698,8	21609,1	30,9	6626	0	-3,38			
	Unguided	452,9	239,2	692,1	21362,0		6554			3,22	380	3,26
	Guided	5,1	1,6	6,7	247,1		72			14,72	335	3,43
run 6a-5	Total	458,1	211,7	669,8	21645,9	32,3	6629	0	-7,43			
	Unguided	434,0	204,5	638,5	20462,1		6293			6,97	365	3,25
	Guided	24,1	7,2	31,3	1183,8		336			14,59	335	3,52
run 6a-10	Total	459,8	193,9	653,7	21763,8	33,3	6639	0	-9,79			
	Unguided	411,8	180,0	591,8	19423,3		5967			8,93	357	3,26
	Guided	48,0	13,9	61,9	2340,5		672			15,42	332	3,48
run 6a-15	Total	458,8	173,4	632,2	21727,4	34,4	6624	0	-12,56			
	Unguided	388,5	152,4	540,9	18319,7		5626			11,92	346	3,26
	Guided	70,3	21,0	91,3	3407,7		998			16,18	329	3,41
run 6a-20	Total	458,7	155,6	614,3	21753,9	35,4	6624	0	-15,03			
	Unguided	365,6	129,0	494,6	17253,2		5295			14,42	336	3,26
	Guided	93,1	26,6	119,7	4500,7		1329			17,48	324	3,39
run 6a-40	Total	457,7	147,7	605,4	21701,9	35,8	6626	0	-16,29			
	Unguided	274,8	92,1	366,9	12962,6		3977			15,45	332	3,26
	Guided	182,9	55,6	238,5	8739,3		2649			17,49	324	3,30
run 6a-60	Total	456,7	141,4	598,1	21689,4	36,3	6626	0	-17,30			
	Unguided	182,8	59,4	242,2	8623,3		2649			16,21	329	3,26
	Guided	273,9	82,0	355,9	13066,1		3977			17,99	322	3,29
run 6a-100		452,3	140,0	592,3	21441,5	36,2	6624		-18,08	18,08	322	3,24

NETWORK 1		FT	QT	TJT	DT	ONS	Nveh	Pa. diverting	Excess cost	Savings	time/veh	dist/veh
run 6b-1	Total	458,1	241,3	699,4	21611,8	30,9	6626	0	-3,29		380	3,26
	Unguided	453,0	239,7	692,7	21362,1		6554			3,14	380	3,26
	Guided	5,1	1,6	6,7	249,7		72			14,72	335	3,47
run 6b-5	Total	458,9	210,7	669,6	21688,5	32,4	6629	0	-7,46		365	3,26
	Unguided	434,7	203,5	638,2	20502,0		6293			7,02	365	3,26
	Guided	24,2	7,2	31,4	1186,5		336			14,32	336	3,53
run 6b-10	Total	459,7	196,2	655,9	21757,8	33,2	6639	0	-9,49		358	3,25
	Unguided	411,4	182,0	593,4	19386,2		5967			8,68	358	3,25
	Guided	48,3	14,2	62,5	2371,6		672			14,60	335	3,53
run 6b-15	Total	459,3	170,9	630,2	21774,4	34,5	6629	0	-12,90		345	3,25
	Unguided	388,4	150,6	539,0	18313,2		5631			12,24	345	3,25
	Guided	70,9	20,3	91,2	3461,2		998			16,21	329	3,47
run 6b-20	Total	459,0	166,5	625,5	21771,5	34,8	6624	0	-13,49		343	3,26
	Unguided	365,5	138,7	504,2	17244,0		5295			12,76	343	3,26
	Guided	93,5	27,8	121,3	4527,5		1329			16,38	329	3,41
run 6b-40	Total	458,0	149,5	607,5	21742,7	35,8	6626	0	-16,00		333	3,25
	Unguided	274,5	93,9	368,4	12943,0		3977			15,11	333	3,25
	Guided	183,5	55,6	239,1	8799,7		2649			17,28	325	3,32
run 6b-60	Total	456,2	146,0	602,2	21653,6	36,0	6626	0	-16,73		331	3,26
	Unguided	183,2	60,6	243,8	8640,7		2649			15,65	331	3,26
	Guided	273,0	85,4	358,4	13012,9		3977			17,41	324	3,27
run 6b-100		452,3	143,8	596,1	21458,6	36,0	6624		-17,55	17,55	324	3,24

NETWORK 1		FT	QT	TJT	DT	ONS	Nveh	Pa. diverting	Excess cost	Savings	time/veh	dist/veh
run 5		509,5	126,8	636,3	25238,5	39,7	6624				346	3,81
run 6c-1	total	509,2	129,9	639,1	25199,4	39,4	6626	0	0,44		347	3,80
	unguided	503,7	128,6	632,3	24924,6		6554			-0,46	340	3,82
	guided	5,5	1,3	6,8	274,8		72			1,65		
run 6c-5	total	509,3	135,5	644,8	25208,5	39,1	6629	0	1,34		350	3,80
	unguided	483,3	128,8	612,1	23902,0		6293			-1,33	350	3,89
	guided	26,0	6,7	32,7	1306,5		336			-1,39		
run 6c-10	total	510,2	139,5	649,7	25266,2	38,9	6639	1	2,11		352	3,80
	unguided	458,2	125,0	583,2	22656,2		5967			-1,98	356	3,88
	guided	52,0	14,5	66,5	2610,0		672			-3,25		
run 6c-15	total	509,6	154,5	664,1	25241,0	38,0	6629	0	4,37		360	3,79
	unguided	432,2	130,6	562,8	21354,4		5631			-4,12	365	3,89
	guided	77,4	23,9	101,3	3886,6		998			-5,75		
run 6c-20	total	510,4	135,6	646,0	25345,5	39,2	6624	0	1,52		350	3,80
	unguided	407,1	107,3	514,4	20146,5		5295			-1,13	356	3,91
	guided	103,3	28,3	131,6	5199,0		1329			-3,08		
run 6c-40	total	511,4	189,2	700,6	25453,2	36,3	6626	0	10,11		375	3,80
	unguided	305,6	108,7	414,3	15114,5		3977			-8,48	389	3,90
	guided	205,8	80,5	286,3	10338,7		2649			-12,55		
run 6c-60	total	512,5	237,6	750,1	25595,0	34,1	6626	0	17,88		396	3,79
	unguided	203,3	87,9	291,2	10049,0		2649			-14,47	415	3,91
	guided	309,2	149,7	458,9	15546,0		3977			-20,16		
run 6c-100	total	515,1	362,8	877,9	259910,7	29,5	6624		37,97	-37,97	477	3,91

NETWORK 2		FT	QT	TJT	DT	CNS	Nveh	Pac. diverting	Excess cost	Savings	time/veh	dist/veh
run 1		870,0	1098,8	1968,8	44669,7	22,7	16624				426	2,69
run 2		876,6	1094,9	1971,5	45071,3	22,9	16624		0,14		427	2,71
run 3		876,4	1216,8	2093,2	45015,1	21,5	16624	29	6,32		453	2,71
run 4a-1	Total	877,4	1157,7	2035,1	45093,0	22,2	16612		-2,71			2,71
	Unguided	868,5	1148,1	2016,6	44630,4		16450	11		2,71	441	2,71
	Guided	8,9	9,6	18,5	462,6		162			9,37	411	2,86
run 4a-5	Total	877,0	1170,4	2047,4	45051,3	22,0	16626		-2,20			
	Unguided	833,0	1124,1	1957,1	42772,5		15783	20		1,51	446	2,71
	Guided	44,0	46,3	90,3	2278,8		843			14,92	386	2,70
run 4a-10	Total	878,0	1136,1	2014,1	45085,1	22,4	16628		-3,80			
	Unguided	790,9	1044,4	1835,3	40585,6		14955	20		2,51	442	2,71
	Guided	87,1	91,7	178,8	4499,5		1673			15,10	385	2,69
run 4a-15	Total	877,0	1155,5	2032,5	45056,2	22,2	16626		-2,91			
	Unguided	747,0	1014,8	1761,8	38313,1		14125	25		0,93	449	2,71
	Guided	130,0	140,7	270,7	6743,1		2501			14,03	390	2,70
run 4a-20	Total	875,1	1109,2	1984,3	45006,1	22,7	16624		-5,20			
	Unguided	701,0	908,1	1609,1	35985,5		13282	23		3,78	436	2,71
	Guided	174,1	201,1	375,2	9020,6		3342			10,84	404	2,70
run 4a-40	Total	874,1	1125,1	1999,2	44944,4	22,5	16624		-4,49			
	Unguided	528,6	690,6	1219,2	27079,6		9983	25		3,01	440	2,71
	Guided	345,5	434,5	780,0	17864,8		6641			6,72	423	2,69
run 4a-60	Total	873,0	1129,3	2002,3	44873,6	22,4	16624		-4,34			
	Unguided	352,8	464,7	817,5	18055,7		6641	23		2,24	443	2,72
	Guided	520,2	664,6	1184,8	26817,9		9983			5,74	427	2,69
run 4a-100	Total	870,0	1098,8	1968,8	44669,7	22,7	16624		-5,94	5,94	426	2,69

NETWORK 2		FT	QT	TJT	DT	ONS	Nveh	Pac. diverting	Excess cost	Savings	time/veh	dist/veh
run 5		879,9	1660,7	2540,6	45122,4	17,8	16624		29,04	-29,04	550	2,71
run 6a-1	Total	877,4	1583,7	2461,1	45060,3	18,3	16612	20	-3,06			
	Unguided	868,0	1573,3	2441,3	44583,1		16450			2,96	534	2,71
	Guided	9,4	10,4	19,8	477,2		162			20,08	440	2,95
run 6a-5	Total	879,7	1591,5	2471,2	45151,9	18,3	16626	23	-2,74			
	Unguided	831,9	1530,9	2362,8	42721,7		15783			2,03	539	2,71
	Guided	47,8	60,6	108,4	2430,2		843			15,85	463	2,88
run 6a-10	Total	881,2	1412,1	2293,3	45240,8	19,7	16628	13	-9,76			
	Unguided	787,9	1294,5	2082,4	40482,2		14955			8,87	501	2,71
	Guided	93,3	117,6	210,9	4758,6		1673			17,49	454	2,84
run 6a-15	Total	882,5	1404,7	2287,2	45310,9	19,8	16626	11	-9,98			
	Unguided	745,5	1223,4	1968,9	38286,4		14125			8,78	502	2,71
	Guided	137,0	181,3	318,3	7024,5		2501			18,71	458	2,81
run 6a-20	Total	882,1	1423,3	2305,4	45253,3	19,6	16624	18	-9,26			
	Unguided	701,4	1189,7	1891,1	36001,9		13282			6,84	513	2,71
	Guided	180,7	233,6	414,3	9251,4		3342			18,88	446	2,77
run 6a-40	Total	878,8	1156,7	2035,5	45098,0	22,2	16624	6	-19,88			
	Unguided	527,8	712,2	1240,0	27083,0		9983			18,72	447	2,71
	Guided	351,0	444,5	795,5	18015,0		6641			21,62	431	2,71
run 6a-60	Total	878,5	1154,2	2032,7	45051,0	22,2	16624	3	-19,99			
	Unguided	353,1	476,6	829,7	18111,9		6641			18,25	450	2,73
	Guided	525,4	677,6	1203,0	26939,1		9983			21,15	434	2,70
run 6a-100		872,2	1137,5	2009,7	44685,9	22,2	16616		-20,86	20,86	435	2,69

NETWORK 3		FT	QT	TJT	DT	ONS	Nveh	Pa. diverting	Excess cost	Savings	time/veh	dist/veh
run 1		660,2	401,8	1062,0	30479,6	28,7	18222				210	1,67
run 2		666,9	450,1	1117,0	30778,1	27,6	18222		5,18		221	1,69
run 3		666,8	478,0	1144,8	30776,0	26,9	18222		7,80		226	1,69
run 4a-1	Total	662,4	454,7	1117,1	30571,5	27,4	18071		-1,60			
	Unguided	660,9	453,6	1114,4	30499,5		18039	54		1,67	222	1,69
	Guided	1,5	1,1	2,7	72,0		32			-29,87	304	2,25
run 4a-5	Total	663,9	462,5	1126,4	30640,0	27,2	18129		-1,10			
	Unguided	646,2	451,1	1097,3	29821,0		17666	82		1,13	224	1,69
	Guided	17,7	11,4	29,1	819,0		463			3,26	226	1,77
run 4a-10	Total	664,8	458,5	1123,3	30683,1	27,3	18159		-1,54			
	Unguided	628,7	435,1	1063,7	29006,7		17209	46		1,61	223	1,69
	Guided	36,1	23,4	59,6	1676,4		950			3,44	226	1,76
run 4a-15	Total	663,9	452,0	1115,9	30640,8	27,5	18136		-2,06			
	Unguided	609,5	417,3	1026,9	28120,4		16723	36		2,26	221	1,68
	Guided	54,4	34,7	89,0	2520,4		1413			3,05	227	1,78
run 4a-20	Total	664,0	445,3	1109,3	30647,6	27,6	18148		-2,71			
	Unguided	591,5	398,0	989,5	27283,1		16248	30		3,06	219	1,68
	Guided	72,5	47,3	119,8	3364,5		1900			2,95	227	1,77
run 4a-40	Total	663,1	44,2	1107,3	30605,6	27,6	18153		-2,91			
	Unguided	517,3	-51,7	865,6	23844,5		14350	6		3,99	217	1,66
	Guided	145,8	95,9	241,7	6761,1		3803			2,18	229	1,78
run 4a-60	Total	662,7	433,5	1096,2	30585,5	27,9	18153		-3,88			
	Unguided	444,0	291,3	735,3	20444,2		12436	11		5,89	213	1,64
	Guided	218,7	142,2	360,9	10141,3		5717			2,84	227	1,77
run 4a-100	Total	663,6	425,4	1089,0	30632,6	28,1	18222		-4,87			
	Unguided	296,4	189,9	486,3	13612,1		8633	14		10,34	203	1,58
	Guided	367,2	235,5	602,7	17020,5		9589			3,26	226	1,78

NETWORK 3		FT	QT	TJT	DT	QNS	Nveh	Pa. diverting	Excess cost	Savings	time/veh	dist/veh
run 4b-1	Total	662,3	456,1	1118,4	30563,7	27,3	18071	54	-1,49	1,57	223	1,69
	Unguided	660,7	454,8	1115,5	30491,3		18039			-39,49	326	2,26
	Guided	1,6	1,3	2,9	72,4		32					
run 4b-5	Total	663,8	467,4	1131,2	30636,1	27,1	18129	44	-0,68	0,87	224	1,69
	Unguided	646,1	454,1	1100,2	29814,3		17666			-3,05	241	1,77
	Guided	17,7	13,3	31,0	821,8		463					
run 4b-10	Total	665,4	480,4	1145,8	30706,3	26,8	18159	51	0,43	-0,02	226	1,69
	Unguided	628,7	452,7	1081,4	29007,9		17209			-4,34	244	1,79
	Guided	36,7	27,7	64,4	1698,4		950					
run 4b-15	Total	664,1	468,4	1132,5	30645,2	27,1	18136	25	-0,61	1,30	223	1,68
	Unguided	609,6	427,4	1037,0	28124,8		16723			-4,03	243	1,78
	Guided	54,5	41,0	95,5	2520,4		1413					
run 4b-20	Total	664,3	484,3	1148,6	30652,0	26,7	18148	51	0,74	0,03	226	1,68
	Unguided	591,2	429,3	1020,5	27270,0		16248			-3,77	243	1,78
	Guided	73,1	55,0	128,1	3382,0		1900					
run 4b-40	Total	664,7	519,4	1184,2	30668,7	25,9	18153	48	3,83	-2,37	232	1,66
	Unguided	518,0	404,8	922,9	23878,9		14350			-5,75	247	1,79
	Guided	146,7	114,6	261,3	6789,8		3803					
run 4b-60	Total	664,9	571,4	1236,3	30673,9	24,8	18153	67	8,40	-7,48	243	1,65
	Unguided	444,5	395,2	839,7	20473,9		12436			-6,78	250	1,78
	Guided	220,4	176,2	396,6	10200,0		5717					
run 4b-100	Total	665,4	651,2	1316,6	30694,4	23,3	18222	78	15,01	-18,85	269	1,58
	Unguided	297,0	347,6	644,6	13642,3		8633			-7,87	252	1,78
	Guided	368,4	303,6	672,0	17052,1		9589					

NETWORK 3	FT	QT	TJT	DT	ONS	Nveh	Pa. diverting	Excess cost	Savings	time/veh	dist/veh
run 3_bis	660,0	416,9	1076,9	30460,6	28,3	18024	14	8,05		215	1,69
run 4c-1 Total	654,8	397,9	1052,7	30219,9	28,7	17873	5	-1,42	1,51	212	1,69
Unguided	653,3	396,7	1049,9	30148,2		17841					
Guided	1,5	1,2	2,8	71,7		32			-38,51	315	2,24
run 4c-5 Total	656,3	406,9	1063,1	30287,2	28,5	17931	9	-0,77	1,14	213	1,69
Unguided	638,6	393,3	1031,8	29469,0		17468					
Guided	17,7	13,6	31,3	818,2		463			-7,02	243	1,77
run 4c-10 Total	657,4	415,5	1072,9	30342,1	28,3	17961	1	-0,02	1,23	212	1,68
Unguided	621,1	382,8	1003,9	28662,5		17011					
Guided	36,3	32,7	69,0	1679,6		950			-14,98	261	1,77
run 4c-15 Total	656,8	418,6	1075,4	30313,3	28,2	17938	0	0,34	1,86	211	1,68
Unguided	602,7	366,3	969,0	27805,8		16525					
Guided	54,1	52,3	106,4	2507,5		1413			-19,20	271	1,77
run 4c-20 Total	656,8	437,5	1094,3	30312,6	27,7	17950	1	2,03	1,77	211	1,68
Unguided	583,9	358,1	942,0	26937,3		16050					
Guided	72,9	79,4	152,3	3375,3		1900			-26,89	289	1,78
run 4c-40 Total	657,0	542,6	1199,6	30322,3	25,3	17955	15	11,82	0,44	214	1,66
Unguided	510,1	331,7	841,8	23517,8		14152					
Guided	146,9	210,9	357,8	6804,5		3803			-48,94	339	1,79
run 4c-60 Total	656,6	677,8	1334,5	30306,6	22,7	17955	49	24,40	-0,93	217	1,64
Unguided	435,7	302,2	738,0	20072,7		12238					
Guided	220,9	375,6	596,5	10233,9		5717			-65,17	376	1,79
run 4c-80 Total	657,4	869,6	1527,0	30340,1	19,9	17950	87	42,38	-6,46	229	1,62
Unguided	362,8	294,6	657,4	16694,4		10335					
Guided	294,6	575,0	869,6	13645,7		7615			-80,77	411	1,79
run 4c-100 Total	663,3	1471,5	2135,8	30604,5	14,3	18024	150	98,33	-31,18	282	1,58
Unguided	290,1	370,0	661,1	13326,9		8435					
Guided	373,2	1101,5	1474,7	17277,6		9589			-143,45	554	1,80

NETWORK 3		FT	QT	TJT	DT	ONS	Nveh	Pa. diverting	Excess cost	Savings	time/veh	dist/veh
run 5		668,1	573,7	1241,8	30838,9	24,8	18222	93	16,93		245	1,69
run 6a-1	Total	663,3	551,9	1215,2	30612,7	25,2	18071	85	-1,32	1,37	242	1,69
	Unguided	661,6	550,9	1212,5	30535,0		18039			-15,55	304	2,43
	Guided	1,7	1,0	2,7	77,7		32					
run 6a-5	Total	665,7	570,6	1236,3	30720,0	24,8	18129	98	0,07	-0,16	246	1,69
	Unguided	647,2	558,6	1205,8	29864,3		17666			9,79	237	1,85
	Guided	18,5	12,0	30,5	855,7		463					
run 6a-10	Total	667,1	576,9	1244,0	30788,2	24,7	18159	98	0,52	-0,60	247	1,69
	Unguided	629,6	550,2	1179,8	29050,1		17209			7,45	243	1,83
	Guided	37,5	26,7	64,2	1738,1		950					
run 6a-15	Total	665,9	564,5	1230,4	30730,5	25,0	18136	131	-0,45	0,59	244	1,68
	Unguided	610,4	522,5	1132,9	28161,5		16723			5,50	248	1,82
	Guided	55,5	42,0	97,5	2569,0		1413					
run 6a-20	Total	666,1	551,8	1217,9	30741,6	25,2	18148	93	-1,52	1,62	241	1,68
	Unguided	591,3	498,0	1089,3	27281,1		16248			7,31	244	1,82
	Guided	74,8	53,8	128,6	3460,5		1900					
run 6a-40	Total	666,1	572,6	1238,7	30738,8	24,8	18153	142	0,13	0,25	245	1,67
	Unguided	518,4	457,1	975,5	23896,6		14350			5,22	249	1,80
	Guided	147,7	115,5	263,2	6842,2		3803					
run 6a-60	Total	666,5	546,1	1212,6	30757,2	25,4	18153	146	-1,98	3,53	237	1,65
	Unguided	444,3	373,3	817,6	20463,6		12436			5,38	249	1,80
	Guided	222,2	172,8	395,0	10293,6		5717					
run 6a-100	Total	667,5	547,8	1215,3	30809,6	25,4	18222	110	-2,13	7,62	227	1,58
	Unguided	296,3	247,2	543,5	13609,8		8633			4,06	252	1,79
	Guided	371,2	300,6	671,8	17199,8		9589					

NETWORK 3		FT	QT	TJT	DT	QNS	Nveh	Pa. diverting	Excess cost	Savings	time/veh	dist/veh
run 6b-1	Total	663,4	551,0	1214,4	30620,1	25,2	18071	86	-1,39	1,45	242	1,69
	Unguided	661,7	549,8	1211,5	30543,1		18039,0			-24,11	326	2,41
	Guided	1,7	1,2	2,9	77,0		32					
run 6b-5	Total	664,9	571,0	1235,9	30684,9	24,8	18129	127	0,04	-0,01	245	1,69
	Unguided	646,5	557,5	1204,0	29834,7		17666,0			5,65	248	1,84
	Guided	18,4	13,5	31,9	850,2		463					
run 6b-10	Total	666,1	573,4	1239,5	30742,2	24,8	18159	87	0,16	0,07	245	1,69
	Unguided	628,5	543,5	1172,0	29004,3		17209,0			2,70	256	1,83
	Guided	37,6	29,9	67,5	1737,9		950					
run 6b-15	Total	666,3	599,4	1265,7	30745,6	24,3	18136	136	2,41	-2,22	251	1,68
	Unguided	610,6	554,4	1165,0	28172,0		16723,0			2,40	257	1,82
	Guided	55,7	45,0	100,7	2573,6		1413					
run 6b-20	Total	666,5	611,1	1277,6	30756,1	24,1	18148	128	3,30	-3,04	253	1,68
	Unguided	591,7	549,2	1140,9	27297,6		16248,0			1,47	259	1,82
	Guided	74,8	61,9	136,7	3458,5		1900					
run 6b-40	Total	667,4	646,2	1313,6	30787,8	23,4	18153	172	6,18	-6,29	261	1,67
	Unguided	518,7	520,7	1039,4	23912,1		14350,0			1,26	260	1,81
	Guided	148,7	125,5	274,2	6875,7		3803					
run 6b-60	Total	668,6	702,3	1370,9	30840,8	22,5	18153	216	10,82	-11,78	274	1,65
	Unguided	445,2	502,1	947,3	20506,8		12436,0			-1,47	267	1,81
	Guided	223,4	200,2	423,6	10334,0		5717					
run 6b-100	Total	671,7	861,6	1533,3	30979,3	20,2	18222	216	23,47	-36,95	336	1,58
	Unguided	297,7	508,0	805,7	13681,3		8633,0			-3,91	273	1,80
	Guided	374,0	353,6	727,6	17298,0		9589					