Logistics Research Centre

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Assessment of the Opportunities for Rationalising Road Freight Transport

Future Integrated Transport Programme

Link Research Project (FIT 022)

FINAL REPORT

Researchers:
Professor Alan McKinnon
Dr. Yongli Ge
Mr. David McClelland

Consortium Partners:
Cold Storage and Distribution Federation
Celsius First
Christian Salvesen
Isotrak
Master Foods
Optrak

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EXECUTIVE SUMMARY

This research project has contributed to the government's objective of making freight distribution more sustainable in both economic and environmental terms. Its 'Sustainable Distribution' strategy aims to '*ensure that the future development of the distribution industry does not compromise the future needs of our society, economy and environment*' (DETR, 1999). This can be partly achieved by getting companies to operate their lorries more efficiently by, among other things, reducing empty running, routing them more directly, increasing the vehicle load factors on laden trips and cutting energy consumption. A key element of the Sustainable Distribution strategy has been the Transport KPI initiative. The main aims of this initiative have been to: (i) enable companies to benchmark the efficiency of their road transport operations (ii) estimate average levels of efficiency at both sectoral and sub-sectoral levels and (iii) assess the potential for improving the efficiency of delivery operations.

To achieve these objectives it has been essential for participating companies to measure efficiency on a consistent basis. They have done this by collecting data over the same 48 hour period and recording it in specially constructed Excel workbooks. Synchronising the auditing process in this way has ensured that the fleets were exposed to similar trading conditions and road traffic levels during the survey period. The LRC developed the original transport KPI methodology and ran surveys for the DETR / DTLR / DfT in the food supply chain in 1997, 1998 and 2002. These contracts funded only a limited analysis of the survey data; calculating average KPI values at sectoral and sub-sectoral levels, preparing benchmark reports for participating companies and estimating potential reductions in cost, energy and emissions within several benchmark scenarios. This failed to exploit the full potential of the transport KPI data-base. In particular, no reference was made to the post-code data available for journey origins and destinations. It was recognised that analysis of this spatial data could permit an assessment of the potential for rationalising the distribution of food in the UK. In the previous transport KPI analysis this potential was assessed relative to current industry best practice. Geographical analysis of trip structure has made it possible to compare actual performance against theoretical optima under varying conditions.

The project has developed software tools which can be applied to a transport KPI database to assess the potential economic and environmental benefits of improving the efficiency of vehicle routing and exploiting backloading opportunities. The first set of tools interface the transport KPI data-base with the commercial vehicle routing package, Optrak. Individual trips are reconstructed and the route the vehicle actually followed compared with optimal routes that the vehicles could have followed under varying delivery time constraints. The second set assesses the potential for increasing the level of backloading. They extract relevant data from the Access data-base, reformat it, check it for consistency, geocode it and finally undertake a load matching analysis within various constraints. Additional geocoding software and several modules of the SAS package are used in the course of this analysis.

In recent years there has been a sharp increase in the number of trucks with onboard vehicle tracking systems. These tracking systems are being used primarily to provide transport managers with real time data on vehicle movements and thus improve day-to-day fleet management. Trips records are, nevertheless, being retained and permit detailed retrospective analysis of distribution operations. It was possible that, with further development, the software tools developed to conduct spatial analysis of the transport KPI data base might be adapted for use with these large commercial data-bases. In the later stages of the project, suppliers and users of road telematics systems were surveyed to determine the nature and scale of their data-bases, the extent to which they are currently being 'data-mined' and the demand from fleet managers for more detailed analysis of operational efficiency.

Transport KPI Survey Data
A total of 28 companies decided to participate in the 2002 survey, six of which committed more than one vehicle fleet, allowing them to undertake intra-company as well as inter-company benchmarking. The sample included four of the five largest supermarket chains in the UK. As the focus of the study was the load carrying unit, the activities of rigid vehicles and semi-trailers were surveyed, but not the tractor units of articulated trucks. The 3650 vehicles included in the survey travelled a total of approximately 1.45

million kilometres over the two-day period and delivered the equivalent of just under a quarter of a million pallet-loads. A total of 24,443 journey legs were monitored. Post-code data were provided for 12,364 (50.6%) of these legs. Many of the legs with post-code data, however, lacked a complete set of weight, pallet-load, distance and delivery time data. Comprehensive data were available for only 8995 legs. A broad cross-section of deliveries was monitored at three different levels in the food supply chain: primary (factory to regional distribution centre), secondary (regional distribution centre to supermarket or local wholesale depot) and tertiary (local distribution from wholesale depots to independent retailers and catering outlets). The survey also had national coverage, with sample fleets operating from bases well dispersed across the UK.

For the purposes of both the original benchmarking and the current analysis, fleets were divided into more homogeneous groups, mainly in relation to the level in the supply chain at which deliveries were made.

- Primary distribution between factories and RDCs (all articulated vehicles)
- Secondary distribution to supermarkets and superstores (mainly articulated vehicles)
- Tertiary distribution to small shops and catering outlets (mainly rigid vehicles)
- Mixed distribution to large and small outlets (involving both articulated and rigid vehicles)

The analysis of routing efficiency was applied mainly to fleets involved in tertiary distribution. Their vehicles generally undertake multi-drop deliveries. The analysis of backloading potential, on the other hand, was confined to longer distance, single-drop deliveries at the primary and secondary levels.

Analysis of Routing Efficiency

Procedures were developed which (i) extract relative data from the transport KPI Access data base (ii) reconfigure it in an Excel spreadsheet (iii) input it into the Optrak vehicle routing package and (iv) perform calculations on the outputs of the Optrak modelling to estimate potential cost and emission reductions. At stages (ii) and (iii) in this process checks were made of the availability and validity of post-code data. The Optrak package requires postcodes with at least four digits. Across the fleets sampled, between 5 and 10% of delivery and collection points had missing or anomalous post-codes. As the delivery rounds analysed had an average of ten collection / delivery points, there was a high probability of a route having an inadequate set of post-code data. In an effort to maximise the sample of routes, considerable time was expended checking and, where possible correcting, post-codes. Within the available time it was only possible to check and analyse the routing data for a total of seven fleets. Over the 48 hour survey period they made a total of 469 trips for which adequate post-code data were available.

A comparison was made between the actual distances travelled and transit times, as recorded in the transport KPI survey, and the optimum values that could be achieved under varying conditions. Six scenarios were constructed in which three key scheduling variables were altered: length of the drivers' shift, delivery time window at customers' premises, opening and closing times at these premises. Scenario 1 (the 'base' scenario) used industry standard values typically adopted as defaults in routing packages. Detailed analysis of one company's delivery operation, comprising the distribution of 744 food orders over two days in the south of England revealed that there was significant potential for reducing traffic, cost and emission, though the magnitude of the savings was very sensitive to scheduling constraints.

Analysis of Backloading Opportunities

A previous attempt by Cundill and Hull (1979) to analyse the potential for improving backloading in the UK was reviewed. This study had two major limitations. First, in the absence of information about the scheduling of trips and handling characteristics of the loads they had to over-simplify the load matching procedure and scale-down the number of 'profitable matches' by an arbitrary amount (75%). Second, their analysis was confined to freight movements to and from Swindon and Hull, which were not necessarily representative of the general pattern of road freight transport across the UK. The analysis of backloading potential using transport KPI survey data overcame these limitations.

The first step in the backloading analysis involved finding empty journey legs that could potentially be allocated backloads. Initially the focus was on empty legs with a length of over 100 kilometres. A radius of 50 km around the origin and destination of the empty legs was then used to delimit a search zone for potential loads. Various levels of screening were applied to these potential loads relating to (a) location and direction of freight movement (b) vehicle compatibility (c) vehicle capacity and (d) delivery time window. The geographical information system (GIS) modules in the SAS package were used to store, manipulate, analyse and display this geographically-referenced data. Coding instructions were written in the SAS programming language to integrate spatial and attribute data and conduct the backloading analysis. An interactive query interface was established to enable the user to identify backloading opportunities on a company, zonal or individual trip basis. As distances were modelled on a 'crow-fly' basis, allowance had to be made for estuaries. This was done by routing journeys via strategically located 'way-points'.

Of the 53 fleets (28 companies) which participated in the KPI survey, 29 fleets (13 companies) were selected for backloading analysis, those primarily engaged in longer distance trunking between factories, distribution centres and supermarkets. The final sample was composed of 2957 complete trips comprising 8995 legs with at least time and load information. Within this sample there were 573 empty journey legs longer than 100 kms. By matching the origins and destinations of loads it would have been possible to eliminate approximately a third of these legs (181). Each of these matches would save an average of 220 vehicle kms (after allowing for deviation from the direct return route). Across the sample of 13 companies, empty running would have been reduced by 13.7%. These backloading opportunities were analysed at sectoral, sub-sectoral and individual company levels. For example, sufficient data were provided by one major grocery retailer to assess the extent to which backloads could be generated internally within its transport system. Screening for vehicle compatibility (related mainly to temperature control), vehicle capacity (need to accommodate a backload in full) and scheduling (need for vehicle to return to base within two hours of the actual arrival time) reduced the number of load matches cumulatively by 48, 72 and 47. This meant that only 14 potential load matches met all four sets of backloading criteria, eliminating only 2.4% of all the empty legs longer than 100kms.

Limitations of the Transport KPI Survey Data

The transport KPI survey was designed to collect standardised vehicle operating data that could be used to benchmark the efficiency of companies' road freight deliveries. As routing and backloading analysis was not in the original specification of the survey design, it is hardly surprising that the content and structure of the resulting data-set is not ideally suited to this type of research. If the DfT and its industry partners wish to make the analysis of routing and backloading an explicit objective of future transport KPI surveys it will be necessary to change this specification in several ways. The project reviewed the limitations of the transport KPI data and explained how they might be overcome. The main limitations were:

- *Poor quality of much of the post-code data.*
- *Failure in the trip audit to differentiate drops and collections at an individual location.*
- *Failure to monitor the activities of the tractor unit*: The transport KPI surveys in the food sector have focused attention on the load carrying unit (i.e. rigid vehicles and articulated trailers) This created a problem for the analysis of backloading potential because when assessing potential load matches it is important to know how tractors as well as trailers are scheduled.
- *Lack of data on opening times, time-windows and driver shifts*. In the absence of information about the actual opening times and delivery time windows at collection and delivery points and drivers' hours, hypothetical values had to be used for the various scenarios. The modelling would be much more realistic if companies provided information about the degree of delivery flexibility.
- *No differentiation of temperature-controlled vehicles in the trip audit*: Inferences had to be made about the availability of refrigeration equipment from load data.
- *Number of vehicles deployed on a particular delivery operation*: this is not specified in the trip audit and therefore cannot be compared with the optimum numbers of vehicles determined by the Optrak package
- *Insufficient density of trips*: The effectiveness of the backloading analysis is critically dependent on the number of trips in the data-base. Despite the relatively high level of industry participation in the 2002 transport KPI survey and many thousands of journey legs surveyed, the number of potential load matches only supported detailed analysis at the first level of screening, related to the location of origins and destinations.

Surveys of Suppliers and Users of Vehicle Telematics Systems (VTS)

These surveys examined (i) the potential for vehicle telematics systems to collect operational data required for the calculation of transport KPIs (ii) the nature, formatting, storage and analysis of data currently collected (iii) the interfacing of road telematics databases with other software packages and (iv) the demand from vehicle operators for performance measurement systems. In the proposal it was suggested that telephone and face-to-face interviews would be supplemented by a 'more extensive postal questionnaire survey'. A decision was made to drop the postal questionnaire survey and expand the telephone interview survey. Through personal contact with the companies, it was possible to obtain more information and discuss the technicalities of the service in greater detail. The success of this approach is reflected in the exceptionally high response rate for the survey of suppliers (33 companies: 89% response rate) and above-average response rate for the user survey (32 companies: 39% response rate). In-depth face-to-face interviews were held with four organisations. Questionnaires were designed and piloted for these surveys. Responses were coded and analysed using an Excel spreadsheet.

At present, telematic services are designed mainly to help companies improve time utilisation of vehicle assets, fuel efficiency and driver productivity. The current inability of VTS to monitor vehicle loading either directly through the use of sensors or indirectly through interfacing with other company IT systems is a major constraint on the wider of adoption of the vehicle utilisation measures promoted by the government's transport KPI initiative. Indeed only one of the 33 telematics companies surveyed had the capability of monitoring all the variables required to measure the energy-intensity of a distribution operation. As load data is a key element in the spatial analysis of the transport KPI data, the applicability of the software tools developed by this project to commercial road telematics data-bases is currently limited. All the VTS suppliers surveyed provide retrospective analysis of tracking data, though the nature of this analysis and degree of customisation to client requirements varies widely. A third of the suppliers undertake benchmarking for clients, though in two-thirds of cases this is restricted to intra-company benchmarking. Only fifth of the sample of users claimed to use vehicle telematic data on a routine basis for calculating transport KPIs. There was, nevertheless, strong interest in making more use of this data for efficiency auditing and benchmarking. Three-quarters of the companies believed that more use could be made of tracking data to reduce empty running. The survey also detected disillusionment with this technology among some respondents who felt that several suppliers had 'over-sold' the systems and not provided enough guidance and after-sales support.

It was recognised at the outset that the commercial value of the tool-kit would be greatly enhanced if it could be deployed on a short-term basis to identify opportunities for improved loading. Following discussions with operators of road telematics systems and online freight exchanges, it has been concluded that the tool-kit lacks the functionality and is too closely customised to the transport KPI data to assume this role. Since the FIT proposal was originally prepared, several companies, such as Freight-traders, Teleroute and the Backload.com, have not only developed software capable of matching loads and available vehicle capacity but also created a transactional platform on which backhaul capacity can be traded. Their experience has shown that to provide a commercially viable load matching service it is necessary to handle a very high density trips. Their main problem has been generating the required volume of business rather than refining the software. As software for the real-time monitoring and trading of backhaul capacity has been now been developed and commercialised, with varying degrees of success, there seems little point in adapting our software tools for this purpose.

Deliverables

The main deliverable from this project has been the new set of software tools for retrospective analysis of the operational efficiency of truck fleets using data compiled in transport KPI-type surveys. They supplement the software which has already been developed by the LRC for the averaging and benchmarking of KPI values. Use of these tools permits the assessment of potential efficiency gains against theoretical optima, in contrast to the earlier benchmark analysis which judged this potential against prevailing industry best practice. It is anticipated that the main use of the tools will be to estimate potential cost, energy and emissions savings at an aggregate level, though they could be applied to a single company's transport operation where it supplies sufficient fleet data. The transferability of the tools will be partly constrained by their integration with the Optrak and SAS software packages and by the degree of customisation to the existing transport KPI methodology. Other deliverables include (i) the results of the routing and backloading analyses on which the new software tools were tested and (ii) the results of the surveys of companies supplying and using road telematics systems. The latter results provide a useful insight into the current state of the telematics sector in the UK and the possibility of applying a similar set of software tools to commercial vehicle tracking data bases.

CONTENTS

Acknowledgement

We wish thank all the organisations which have which have contributed to this project. We are particularly grateful to the industrial partners for their support and encouragement throughout. The Cold Storage and Distribution Federation deserve special mention as they have worked closely with the Logistics Research Centre over the past seven years on the transport KPI initiative which has formed the basis of the present project. We are also very grateful to the Department for Transport for funding this project as part of the joint DfT / EPSRC Future Integrated Transport programme. Finally, our thanks also go the numerous suppliers and users of vehicle tracking systems which participated in the interview survey.

Contact Details

Logistics Research Centre
Heriot Watt University
EDINBURGH
UK
EH14 4AS

Tel 0131 451 3850
Fax 0131 451 3498

Website: http//www.sml..hw.ac.uk/logistics

SECTION 1. INTRODUCTION

1.1 TRANSPORT KPI INITIATIVE:

This research project has contributed to the government's objective of making freight distribution more sustainable in both economic and environmental terms. Its 'Sustainable Distribution' strategy aims to '*ensure that the future development of the distribution industry does not compromise the future needs of our society, economy and environment*' (DETR, 1999). This can be partly achieved by getting companies to operate their road freight vehicles more efficiently by, among other things, reducing empty running, routing vehicles more directly, increasing the vehicle load factors on laden trips and cutting energy consumption.

A key element of the Sustainable Distribution strategy has been the Transport KPI initiative. This was instigated in 1997 by several companies belonging to the Cold Storage and Distribution Federation (CSDF) which were concerned about the downward pressure on vehicle load factors at a time when road transport costs were rising. They were keen to explore ways in which they could work together to improve vehicle utilisation. The government provided financial support for the initiative under its Energy Efficiency Best Practice Programme (EEBPP) (now renamed the TransportEnergy Best Practice Programme), recognising that if it was successful it could yield significant savings in fuel and CO2 emissions and reductions in lorry traffic levels.

The main aims of the transport KPI iniative have been to:

- enable companies to benchmark the efficiency of their road transport operations
- estimate average levels of efficiency at both sectoral and sub-sectoral levels
- assess the potential for improving the efficiency of delivery operations

To achieve these objectives it has been essential for participating companies to measure efficiency on a consistent basis. They have done this by collecting data over the same 48 hour period and recording it in specially constructed Excel workbooks. Synchronising the auditing process in this way has ensured that the fleets were exposed to similar trading conditions and road traffic levels during the survey period.

To date, six transport KPI surveys have been undertaken in four sectors, and one is currently underway (Table 1.1). This research project has been based on the results of the survey conducted in the food supply chain in May and October 2002[1]. This survey employed a methodology originally developed by the Logistics Research Centre in 1997 and subsequently refined. The LRC's contracts to run the 1997, 1998 and 2002 transport KPI surveys in the food sector funded only a limited analysis of the survey data. This involved calculating average KPI values at sectoral and sub-sectoral levels, preparing benchmark reports for participating companies and estimating potential reductions in cost, energy and emissions within several benchmark scenarios (McKinnon, 1999; McKinnon, Ge and Leuchars, 2003a and 2003b, Energy Efficiency Best Practice Programme, 1998 and 1999).

Table 1. 1 . *Transport KPI Surveys*

Sector	**Survey Date**
Temperature-controlled food	1997
Food (all temperatures)	1998
Automotive	2001
Food (all temperatures)	2002
Non-food retailing	2002
Road leg of air cargo distribution	2002-3
Pallet-load networks	2004

1.2 SPATIAL ANALYSIS OF TRANSPORT KPI DATA

The earlier analysis failed to exploit the full potential of the transport KPI data-base. In particular, no reference was made to the post-code data available for journey origins and destinations. It was recognised that analysis of this spatial data could permit an assessment of the potential for rationalising the distribution of food in the UK. In the previous transport KPI analysis this potential was assessed relative to current industry best practice. Geographical analysis of trip structure has made it possible to compare actual performance against theoretical optima under varying conditions. The original intention was to assess the potential economic and environmental benefits of rationalising road freight operations in four ways:

- Increasing the backloading of returning delivery vehicles
- Improving the routing of vehicles
- Rescheduling deliveries
- Increasing the degree of load consolidation

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[1] In the original proposal it was indicated that data from the 1998 KPI survey would be analysed. By the time the project actually started in December 2002, this survey had been updated and expanded.

The first two measures have been analysed in detail. The effects of the third measure, delivery rescheduling, have been modelled in relation to vehicle routing options. The sensitivity of journey length, cost and transit time to variations in opening times and delivery time windows have been assessed. It has proved impractical, however, to estimate the opportunities for consolidating loads moving between proximate origins and destinations. Given the variability of load weights and dimensions, temperature-control requirements, vehicle handling systems and scheduling, it is extremely difficult to determine the probability of achieving an acceptable match between two or more partial loads on particular corridors. The research has therefore been confined to the first three rationalisation measures.

To conduct this analysis it has been necessary to develop new software tools. The first set of tools interface the transport KPI data-base with the commercial vehicle routing package, Optrak. These tools require a significant amount of manual input. Individual trips are reconstructed and the route the vehicle actually followed compared with optimal routes that the vehicles would have followed under varying delivery time constraints. The second tool set assesses the potential for increasing the level of backloading. These tools extract relevant data from the Access data-base, reformat it, check it for consistency, geocode it and finally undertake a load matching analysis within various constraints. Additional geocoding software and several modules of the SAS package are used in the course of this analysis.

1.3 ANALYSIS OF ROAD TELEMATICS DATA

In recent years there has been a steep increase in the number of trucks with onboard vehicle tracking systems. These tracking systems are being used primarily to provide transport managers with real time data on vehicle movements and thus improve day-to-day fleet management. Trip records are, nevertheless, being retained and permit detailed retrospective analysis of distribution operations. It was possible that, with further development, the software tools developed to conduct spatial analysis of the transport KPI data base might be adapted for use with these large commercial data-bases. In the later stages of the project, suppliers and users of road telematics systems were surveyed to determine the nature and scale of their data-bases, the extent to which they are currently being 'data-mined' and the demand from fleet managers for more detailed analysis of operational efficiency. While the general analytical procedures developed in this project will be applicable to commercial road telematics data-bases, the actual tools have had to be so closely customised to particular aspects of the transport KPI database that they are unlikely to be directly transferable.

1.4 OBJECTIVES OF THE PROJECT

The project had six objectives:

- To define and specify the requirements for the software tool-kit
- To develop a software tool-kit for use on the 2002 transport KPI database for the food sector
- To apply the tool-kit in an analysis of this database to assess the potential for reducing the economic and environmental costs of road freight transport
- To consider how the tool-kit might have to be adapted to distribution operations in other sectors
- To examine the collection of KPI data by commercial road telematics systems
- To investigate ways of combining the software tool-kit with real-time road freight information systems to identify backloading and load consolidation opportunities on a short-term basis.

Figure 1.1 shows how the research project was organised to achieve these objectives. Details of the management of the project can found in Section 10.

1.5 STRUCTURE OF THE REPORT

The remainder of the report is divided into nine sections:

Section 2 outlines the nature and extent of the 2002 food transport KPI database, the consistency checks that have been undertaken and the classification of fleets into sub-sectors.

Section 3 focuses on the efficiency of vehicle routing. It describes the software developments required to interface the transport KPI database with the Optrak vehicle routing package. The results of the analysis of routing efficiency within varying time constraints are then reported.

Section 4 examines the potential for improving backloading. Previous research on the empty running and backloading of trucks is reviewed. The development of software tools for this part of the analysis is then outlined. Backloading opportunities are assessed at four levels of load-matching.

Section 5 considers the limitations of the transport KPI database for this type of spatial analysis and recommends changes to the methods of data collection and management that would facilitate future modelling of potential efficiency gains.

Section 6 reports the results of two surveys of suppliers and users of vehicle tracking systems. These enquired about the nature of the telematics services, the use currently being made of the transport databases, the software interfaces and future plans for the use of tracking data for KPI measurement.

Section 7 assesses the extent to which the original objectives of the project have been achieved against technical, commercial, financial and other criteria.

Section 8 outlines the main deliverables of the project.

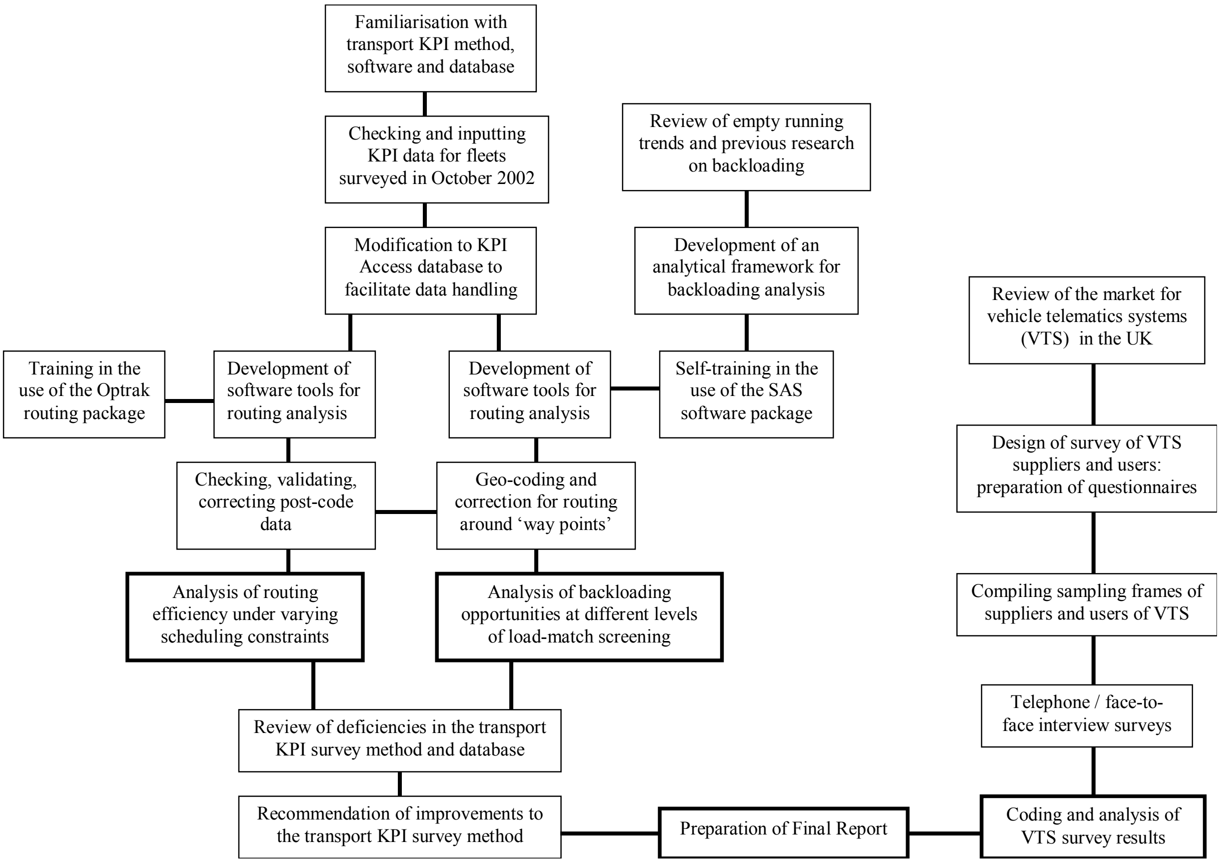
Section 9 addresses the issue of dissemination. It lists papers already prepared and plans for future publications and conference papers.

Section 10 provides details of the management of the project.

Section 11 contains a glossary of terms.

Section 12 comprises seven appendices on various aspects of the project.

Figure I. 1 . *Structure of the Research Project*



SECTION 2. THE TRANSPORT KPI DATA-BASE

2.1 CHOICE OF KPIS

The use of KPIs to monitor the efficiency and effectiveness of logistics has been discussed by the Nevem Workgroup(1989), Caplice and Sheffi (1994 and 1995), Ploos van Amstel and D'hert (1996) and van Donselaar and Sharman (1998). Long lists of possible KPIs have been compiled to assess the performance of many different aspects of a logistical operation. Inter-company benchmarking of logistical KPIs is also well established (Hanman, 1997; Randall, 2003).

The original selection of KPIs for this initiative back in 1997 was restricted in several respects. First, it related solely to the transport function. Second, it excluded any reference to the cost of transport operations. Initial consultations with CSDF members revealed that few companies would be prepared to divulge this information. The KPIs were designed therefore to measure operational, rather than commercial, performance. It has, nevertheless, been possible to convert some of the performance measures into cost estimates using industry standard cost data, such as that published in the *Motor Transport* Cost Tables. Third, unlike many performance measurement systems which are internal to a single business and thus tailored to its requirements, the KPIs adopted for this project had to win acceptance from firms across an business sector. They had also to relate to the wider impact of transport operations on the environment in contrast to many of the traditional metrics which are concerned solely with economic efficiency (McIntyre et al.,1998).

Caplice and Sheffi (1994) have differentiated three types of logistics KPI:

Utilisation indices which measure 'input usage' and are usually expressed as a ratio of the actual input of resources to some normative value.

Productivity indices which measure 'transformational efficiency' and typically take the form of input : output ratios.

Effectiveness indices which measure the 'quality of process output' as a ratio of the actual quality achieved to some norm.

The vehicle audit employed all three types of KPIs, ensuring that the assessment was broadly-based and concerned with both inputs and outputs.

Discussions were held with senior managers of manufacturing, retailing and logistics firms to canvas their opinions on possible KPIs. At a ‘think tank’ session they debated the various options and examined the practical problems they might pose. The derivation of the KPIs was, therefore, a ‘bottom-up’ exercise involving close consultation with industry. The KPIs had to meet several requirements. They had to be:

- defined in clear and unambiguous terms so that they could be easily understood by staff responsible for data collection
- capable of direct and detailed measurement at operational level
- measurable in a consistent manner by all participating companies
- compatible with data recording systems already in place and software packages with which company staff were familiar
- correlated with operating costs and energy consumption
- of direct relevance to the management of the transport operation
- widely acceptable across the industry and of possible application in other sectors.

The deliberations with senior managers led to the establishment of an agreed set of five KPIs. The first three KPIs were essentially ‘utilisation’ measures, the fourth was a ‘productivity’ index and the last assessed the ‘effectiveness’ of the delivery operation:

1. *Vehicle loading*: this was measured by ratio of the actual load carried to the maximum load that could have been carried within with vehicle weight, floorspace and height constraints.

2. *Empty running*: the distance the vehicle travelled empty (excluding the return movement of empty handling equipment, which was separately recorded).

3. *Fuel consumption*: for both motive power and refrigeration equipment.

   The fuel efficiency of the tractor units was expressed on a km-per-litre basis and averaged across the fleet on an annual basis. No attempt was made to estimate fuel consumption during the 48 hour survey period as this was considered impractical. These estimates would, after all, relate to tractor units, whereas the main survey unit was the trailer. The same tractor might haul several different trailers during the survey period. Annual average litres / km figures were obtained for each type of vehicle within each fleet. These were multiplied by the distances travelled during the survey period to obtain estimates of fuel consumption.

The first three KPIs were used to develop a composite measure of energy-intensity. As food is a relatively low density product, loads moved by truck tend to be volume-constrained rather than weight-constrained. It was decided, therefore, to express energy-intensity in terms to pallet-kilometres rather than tonne-kilometres. It was defined as the amount of fuel required to move one pallet one kilometre (excluding fuel consumed by the refrigeration equipment.)

4. *Vehicle time utilisation*: This was measured at hourly intervals over a period for 48 hours for all the trailers surveyed. A record was made of the dominant activity of the trailer over the previous hour. Time was classified into seven activities depending on whether the vehicle was: running on the road, being loaded / unloaded, pre-loaded awaiting departure, awaiting loading / unloading, undergoing maintenance / repair, in driver daily rest period or idle (i.e. empty and stationary).

5. *Deviations from schedule*: This KPI was included because instability in transport schedules can have a bearing on vehicle utilisation as it makes it more difficult for companies to plan backhauls and more complex multiple collection / delivery rounds. Companies were asked to specify the main cause of any delay as being: a problem at collection point (responsibility of the consigning company), a problem at delivery point (receiving company's responsibility), the actions of the company undertaking the delivery ('own company action'), traffic congestion, equipment breakdown or the lack of a driver.

Only data collected for the calculation of the first three KPIs, relating to vehicle fill, empty running and fuel consumption, was used in the present project. The time utilisation data was collected on a separate spreadsheet and was not trip-related. Information on deviations from schedule was trip-related and could have been incorporated into the routing and backloading analysis either for specific trips or as a generalised probability function. Within the project time-frame this has not been possible. Future development of the modelling will try to make allowance for unreliability in the food distribution system.

2.2 SAMPLE OF COMPANIES, FLEETS AND VEHICLES

A questionnaire survey of companies participating in the 1998 audit revealed that on average approximately five days of staff time were required per fleet to set up and implement the internal data collection procedures. This was in addition to the time that company representatives spent attending briefing sessions. As participation in the survey required companies to make a significant resource commitment, the initiative had to be intensively marketed. Promotional activities were organised by the CSDF. A conference, press articles, telephone calls and company visits were used to publicise the survey.

A total of 28 companies decided to participate in the 2002 survey, seven of which committed more than one vehicle fleet, allowing them to undertake intra-company as well as inter-company benchmarking. The sample included four of the five largest supermarket chains in the UK. As the focus of the study was the load carrying unit, the activities of rigid vehicles and semi-trailers were surveyed, but not the tractor units of articulated trucks. The 3650 vehicles included in the survey travelled a total of approximately 1.45 million kilometres over the two-day period and delivered the equivalent of just under a quarter of a million pallet-loads (Table 2.1). The survey monitored just over 13 million tonne-kms of freight movement in the grocery sector over the two-day period.

A total of 24,443 journey legs were monitored. Post-code data were provided for 12,364 (50.6%) of these legs. Table 2.1 shows the proportion of post-codes with varying numbers of digits. Many of the legs with post-code data, however, lacked a complete set of weight, pallet-load, distance and delivery time data. Comprehensive data were available for only 8995 legs. Tables 2.2 and 2.3 shows the distance and transit time profiles for the full sample of journey legs. In the backloading analysis, a distance of 100km was adopted as the minimum leg length required for viable load matching.

Table 2. 1 . *Availability of post-code data*

Total journey legs	24,443	100%
Legs with some post-code data	12,364	50.6%
Legs with full post-code	10,040	41.1%
Legs with 5-digit post-code	1,662	6.8%
Legs with 4-digit post-code	591	2.4%
Legs with 3-digit post-code	71	0.3%

Table 2. 2 . *Distribution of Journey Legs by Length*

Distance (km)	***Number of legs***
<10	6,163
>10	17,760
>20	15,144
>30	13,245
>40	11,479
>50	9,957
>60	8,706
>70	7,566
>80	6,543
>90	5,703
>100	5,050
>150	2,558
>200	1,183
>250	509
>300	178

Table 2. 3 . *Distribution of Journey Legs by Duration*

Duration (hour)	***Number of legs***

A broad cross-section of deliveries was monitored at three different levels in the food supply chain: primary (factory to regional distribution centre), secondary (regional distribution centre to supermarket or local wholesale depot) and tertiary (local distribution from wholesale depots to independent retailers and catering outlets) (Figure 2.1).

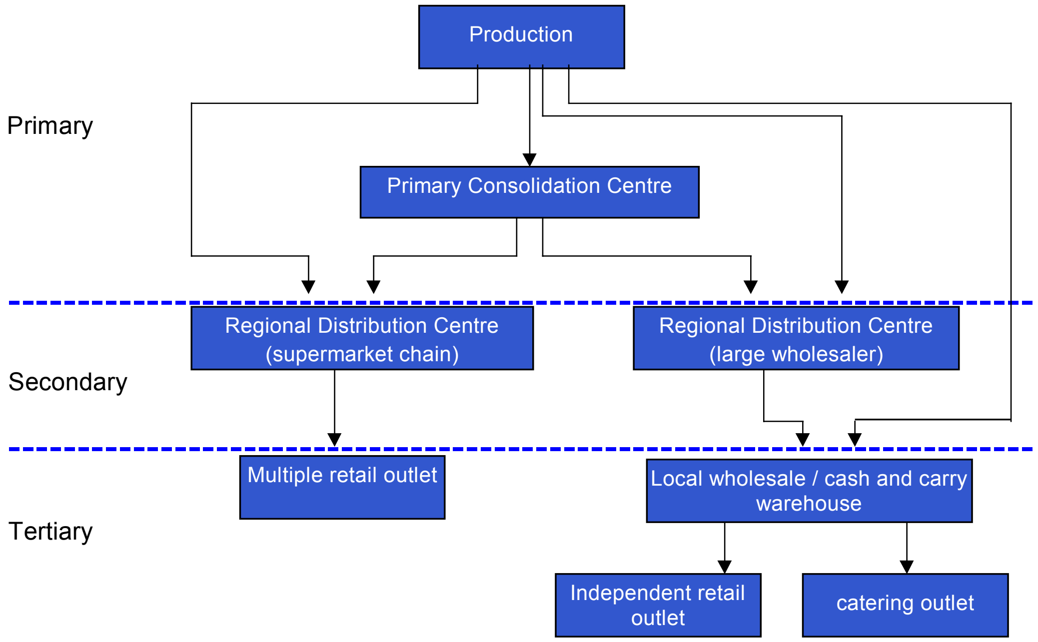


Figure 2.1. *Distribution Channels in the Food Sector*

The survey also had national coverage with sample fleets operating from bases well dispersed across the UK (Figure 2.2).

Table 2. 4 . *Comparison of Key Survey Parameters*

	Transport KPI Survey	**CSRGT[1] 'other foodstuffs' category**
Full loading % by weight	13%	11%
Full loading % by volume	37%	31%
% empty running	19%	22%
Average vehicle lading factor	53%	56%
Average fuel efficiency: (km per litre)		**all road freight operations**
Small rigid (2 axles) < 7.5 tonnes	4.0	4.1
Medium rigid (2 axles) 7.5 - 18 tonnes	3.6	3.7 (7.5-14t) - 3.3 (14 -17t)
Large rigid (> 2 axles) > 18 tonnes	3.1	2.9 (17-25t)
32 tonne articulated vehicle (4 axles)	3.2	3.2 (< 33t)
38-44 tonne articulated vehicle (>4 axles)	2.9	2.9 (> 33t)

1. Continuing Survey of Road Goods Transport

The sample of companies and fleets was not the result of random selection. Care must therefore be exercised in interpreting the aggregate results as these may not be representative of the food supply chain as a whole. An indication of the representativeness of the sample can, nevertheless, be obtained by comparing some of the survey results with corresponding values from the government's Continuing Survey of Road Goods Transport (CSRGT), which is based on a much larger, randomly-generated sample of vehicles. The average values for some of the key parameters are similar (Table 2.4), suggesting that the road transport operations monitored over the two-day period are fairly representative of the general movement of food by road in the UK[2].

Figure 2.2. Locations of the Main Bases of the Sample Fleets

2.3 METHOD OF DATA COLLECTION

Having committed themselves to the survey, companies were asked to assign appropriate staff to the collection and collation of transport data (Figure 2.3). They were invited to three briefing sessions run by the CSDF and LRC at which the data collection process was outlined in detail. Definitions were clarified and advice given on the methods of collecting and recording the information. At these sessions, companies were issued with manuals and CDs containing the standard Excel workbook into which the data was to be entered. It was then the responsibility of companies to decide on the numbers, types and locations of vehicles to be surveyed. Some identified a sample of vehicles at a particular location, while others committed

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[2] It is not possible to disaggregate CSRGT fuel efficiency data by commodity class.

whole fleets based at one or more depots. Transport and logistics managers had also to work out how to manage the data collection process internally. This usually involved the delegation of tasks to supervisors, clerks and drivers and liaison with IT staff.

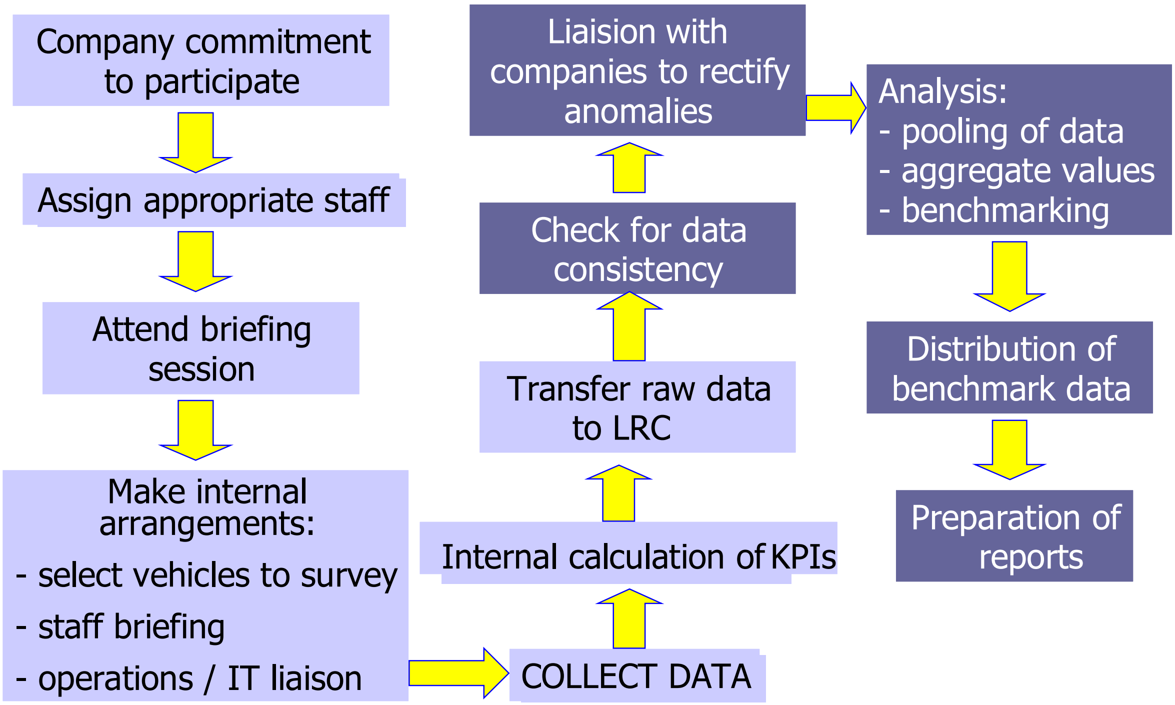


Figure 2.3. *Process of Collecting Transport KPI Data*

Participating companies were asked to enter their operating data into a standard Excel workbook comprising three spreadsheets for:

1. General data on the vehicle fleet
2. Data on all trips performed during the 48 hour period
3. Hourly audit of vehicle activity during this period.

Appendix A contains copies of these spreadsheets.

Once the data was collected companies were able to calculate their KPI values themselves using macros embedded in the Excel workbook. The spreadsheets containing the ‘raw data’ were then returned to the LRC for checking, aggregation and analysis.

Consistency checks were made both at the time of data entry and prior to analysis. The initial check ensured that data fell within acceptable ranges. Once all the data was entered, higher-level checks detected anomalies and missing values. Where these would have significantly affected the analysis the company was contacted in an effort to correct/complete their data-set.

All participating companies were sent benchmark reports for each of their fleets in which their operation efficiency was compared with sectoral and sub-sectoral averages.

2.4 CLASSIFICATION OF THE FLEETS

The sample contained fleets engaged in a diverse range of distribution operations. To improve the validity of the benchmarking it was necessary to split the fleets into more homogeneous groups, mainly in relation to the level in the supply chain at which deliveries were made.

- Primary distribution between factories and RDCs (all articulated vehicles) (P)
- Secondary distribution to supermarkets and superstores (mainly articulated vehicles) (S)
- Tertiary distribution to small independent shops and catering outlets (mainly rigid vehicles) (T)
- Mixed distribution to large and small outlets (involving both articulated and rigid vehicles) (M)

Table 2. 5 . *Classification of Sample Fleets and Vehicles by Sub-Sector*

Category	Code	Supply chain links	Vehicle types	No. of fleets	No. of Vehicles
Primary	P	Factory to RDC	all articulated	9	812
Secondary	S	RDC to supermarket	mainly articulated	21	3097
Tertiary	T	Local depot to small independent retailers and catering outlets	mainly rigid	14	606
Mixed	M	Various	articulated and rigid	9	572

Table 2.5 shows the number of fleets in each category. The fourth category contained mixed fleets engaged in different types of delivery operation. The average KPI values for these mixed fleets partly depend on the balance between trunking and local delivery activities.

The analysis of routing efficiency was applied mainly to fleets involved in tertiary distribution. Their vehicles generally undertake multi-drop deliveries. The sequencing of drops within the delivery rounds is the main determinant of routing efficiency. Most of the road freight movements at the primary and secondary levels of the supply chain are single drop deliveries.

The analysis of backloading potential, on the other hand, was confined to longer distance, single-drop deliveries at the primary and secondary levels. Backloading is generally only economical on longer journey legs (except where the return load can be picked up the delivery point). Furthermore, on multiple-drop rounds empty running is usually confined to the last leg of the journey back to the depot, which is typically fairly short.

SECTION 3. OPTIMISATION OF VEHICLE ROUTING

3.1 METHODOLOGY

The potential for improving the efficiency of fleet operation will be examined by interfacing commercial vehicle routing and scheduling software package Optrak with the KPI 2002 survey in the food sector. Optrak is a computer system which plans efficient vehicle loads and routes. It combines road network data with information on vehicles, customers, orders, depot location and timing to produce a set of trips that makes the best use of available resources.

The main objectives of interfacing Optrak with the KPI 2002 survey database are to see (a) to what extent to routing of vehicles monitored in the 2002 transport KPI survey is sub-optimal and (b) the sensitivity of delivery efficiency to variations in service parameters.

Fleet selection

Only fleets heavily involved in multiple-drop delivery were included in this analysis. These mostly belonged to the tertiary and mixed categories. Fleet selection also took account of the quality of the spatial data provided by the company. As explained in greater detail in Section 5, much of the post-code data was inaccurate. Given the large amount of time required to check the validity of post-codes and eliminate trips containing inaccurate post-code data, priority was given to those fleets which, on the basis of sampling, appeared to have the most accurate post codes. Within the time allocated for this part of the project, the routing efficiency of seven fleets representing was analysed. A range of different distribution systems were selected for this optimization analysis. It included a group of fleets from the same company in the same sector, a group of fleets from the same company but different sub-sector, and a group of fleets within the same sub-sector, but from different companies.

Data preparation

The relevant information in the KPI 2002 survey database was converted into different CSV (Comma Separated Values) files required by Optrak as follows:

- customer.csv
- depot.csv
- driver.csv
- opentime.csv
- order.csv
- product.csv
- vehicle.csv

The required data was extracted from the Access database and stored in separate CSV files in Excel spreadsheets. Within Excel they were formatted for input into Optrak .

Scenario analysis

Seven delivery scenarios were constructed to assess the degree of routing efficiency for a sample of fleets under different operating conditions. These conditions were defined with respect to driver shifts, opening times and delivery time windows.

3.2 FLEET SELECTION

The following three groups of fleets were selected for optimisation using Optrak:

- Same company, same sub-sector (Tertiary Distribution)

The first group of fleets were all within the same company and the same sub-sector. This included two fleets involved in tertiary distribution. A total of 96 valid trips and 847 journey legs (including empty legs) were selected.

- Same company, different sub-sector

The second group of fleets were all within the same company but each from different sub-sector (which involves secondary, tertiary, and mixed distribution). This group was composed of three fleets, with a total of 338 valid trips and 1129 journey legs selected.

- Same sub-sector, different company (Primary temperature controlled distribution)

The third group of fleets was composed of two fleets within the same sub-sector (primary temperature controlled distribution) but from different company. A total of 35 valid trips and 98 journey legs were selected.

3.3 DATA INPUT INTO THE OPTRAK MODEL

Customer data

Optrak defines a customer as a delivery/collection location. Each delivery address needs a unique code. Optrak can use grid reference, postal code, or town name to determine a customer's location. In the models developed for this project, customer locations were determined using postcodes stored in the KPI database.

Orders

An order record contains the order details, such as its reference number, the customer involved, whether it is a delivery or a collection, how much of which product is to be carried and which visiting times apply. This is the header record consisting of general information about an order. The detailed information of each additional part of an order is held in the order parts file that is linked to the orders file.

Drivers

The time drivers spend working and driving is restricted by legislation and labour agreements. The planning of trips takes account of driver availability and no schedule will be produced which infringes regulations controlling driver hours. Driver's work regulations and other constraints include shift length, shift driving, shift work, shift gap, break length, break after driving, breaking after working, etc. Besides, individual driver's preference of working time can be specified in a separate form.

Vehicles

The vehicles file describes the number of vehicles that can be used in the trip schedules, which depot(s) a vehicle belongs to, the maximum weight/volume that can be carried on the vehicle, and cost of operation including distance-related and time-related cost elements. The vehicle cost information is obtained from *Motor Transport's* vehicle cost tables (Anon, 2002).

Load/unload rates

These loading and unloading rates model the loading/unloading process. Loading and unloading times can have a large impact on the quality of routes, especially if loading and unloading take up a large proportion of the working day.

Opening times

Each customer and depot must have a record which specifies opening times on a daily and weekly basis. This allows the optimisation algorithms to schedule trips so that a vehicle arrives at a customer in good time for all loading and unloading to be completed before closing time.

Depots

The depots file contains general information on the depot(s), its location, opening times, vehicle restrictions and load rates.

3.4 KEY FACTORS CONSIDERED

The following key factors included in this optimisation exercise: driving hours, customer demand time window, customer/depot opening time, loading/unloading rate.

3.4.1 key parameters for the base scenario

The base scenario (scenario 1) is established using parameters used in common practice.

Shift length: maximum duration of a shift (11:00) including driving loading/unloading, and break(s).

Shift driving: maximum total driving time in a shift (9:00).

Shift gap: minimum time between the end of one shift and the start of the next (13:00).

Break length: minimum length of a break (0:45).

Break after driving: maximum driving time without taking a break (4:30).

Break after working: maximum working time without taking a break (5:30).

Loading/unloading rate: depot (0:30), customer sites (3 minutes/pallet).

(Consultation with industry patterns indicated that the ratio of loading / unloading time for wooden pallets and roll cages was 4:1. Typically a roll cage would be offloaded in 70 seconds, a wooden pallet in 3 minutes)

Check-in time: customer sites (0:15).

Customer opening time: 06:00 to 18:00.

Depot opening time: 24 hours a day.

Delivery time window: a period of 6 hours before and 4 hours after the scheduled arrival time.

Most of the parameter listed above could be adjusted using the Optrak user interface. Customer delivery time windows, on the other hand, had to be changed within in the Excel CSV file first and then be loaded into the Optrak model.

3.5 SCENARIO ANALYSIS

In this section, the operation of the first group of fleets involved in tertiary distribution will be used to demonstrate how fleets performance can be affected by changes in the key variables. Seven scenarios were constructed for optimisation analysis:

- *Scenario 2*, drivers' hours is extended from 9 to 10 hours.
- *Scenario 3* drivers' hours reduced from 9 to 8 hours.
- *Scenario 4*, a broader customer opening time (6:00-20:00) is used.
- *Scenario 5*, customer opening time is shortened to a period between 08:00 and 16:00.
- *Scenario 6*, a tighter delivery time window is used (an order can be delivered/collected between a period of 3 hours before and 2 hours after the scheduled delivery/collection time).
- *Scenario 7*, a broader delivery time window is used (an order can be delivered/collected between a period of 12 hours before and 8 hours after the scheduled delivery/collection time).

How fleets' performance can be affected by the key factors is tested by comparing the simulation results of scenarios 2 to scenario 7 with the base scenario (scenario 1). The parameters for different scenarios are listed in Appendix B.

3.5.1 Major outputs

The Optrak package generated the following outputs:

- Number of unrouted orders:
- General information--number of vehicles used, trips, shifts
- Vehicle efficiency--average deliveries/collections per trip
- Time utilization--travelling, waiting, loading
- Cost--mileage cost and time cost

Apart from the above outputs from Optrak, empty mileage and time cost can also be calculated. This was done outside the Optrak model in an Excel spreadsheet, using Optrak outputs and cost information obtained Motor Transport's vehicle operating cost tables.

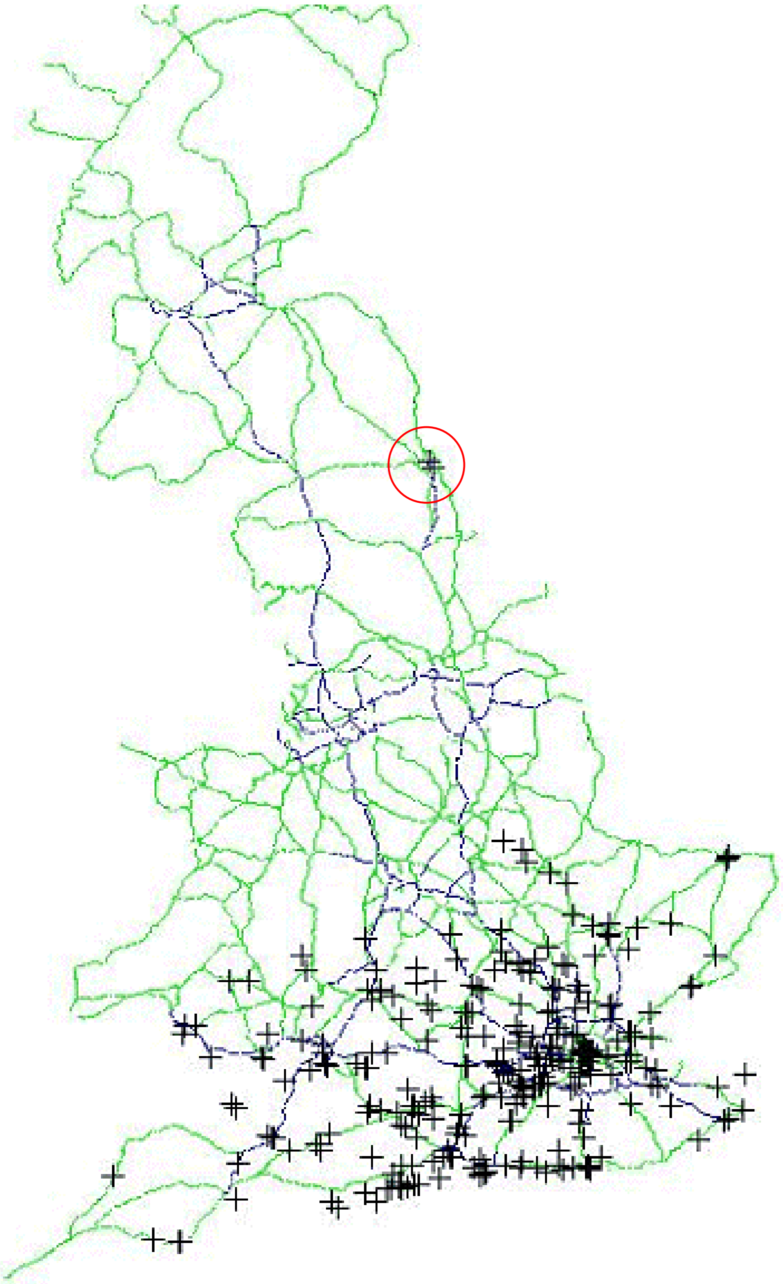


Figure 3.1. *Optrak customer location graph*

Unrouted orders

In each scenario, some orders were unrouted. This is likely to be the result primarily of:

- inaccurate postcodes;
- postcode approximation;
- tighter opening time window than applied in practice;
- tighter time window than applied in practice

Inaccurate post-coding is one of the major causes for unrouted orders, as illustrated by Figure 3.1, an Optrak customer location map. On this map, two customer locations are marked by a red circle. These two orders could not be scheduled into any route using Optrak under the constraints explained above because they are too far from the depots. Further checking of the original database confirmed that the post-codes of these two orders were not properly recorded.

Another reason for orders not being incorporated into routes is also related to a lack of precision in the spatial data. The version of Optrak provided for research purposes only allows the use of post-codes with 4 or more digits. A significant number of post-codes did not meet this requirement.

The use of tighter opening time windows, and/or delivery time windows in some scenarios than actually applied during the transport KPI survey can also result in some orders being unrouted.

It has been estimated that, depending on the quality of the previous manual route planning, computerised vehicle routing and scheduling packages can cut transport cost and distance travelled by between 5 and 10 percent (Eibl, 1996; Freight Transport Association, 2000)

Table 3. 1 . *Vehicle Cost Table (Motor Transport, May 2002)*

Vehicle class	Avg. of Kms Per Litre (km/litre)	Cost Per Km (£/km)	Cost Per Hour (£/hour)
32-semi	3.2	0.224	29.17
38-semi	2.9	0.244	32.08
City-semi	3.2	0.225	26.75
Large rigid	3.1	0.234	23.7
Medium rigid	3.6	0.200	21.58
Small rigid	4.0	0.179	18.25

Table 3.1 shows the operating cost values that were used to estimate the distance- and time-related cost savings accruing from the optimisation of routing within the various scenarios.

Optimisation has been defined purely in terms of the minimisation of total transport costs. These transport costs have been divided into three categories:

Running costs: distance-related costs associated with fuel, tyres and vehicle maintenance.

Labour costs: driver's wage costs plus national insurance contributions expressed on an hourly basis.

Standing costs: annual costs of vehicle depreciation, insurance and licensing divided by 112.5 to cover the two days of the KPI survey. (According to the Motor Transport cost tables, rigid vehicles are operated for an average of 225 days per annum.) These costs are multiplied by the number of vehicles required for each delivery scenario.

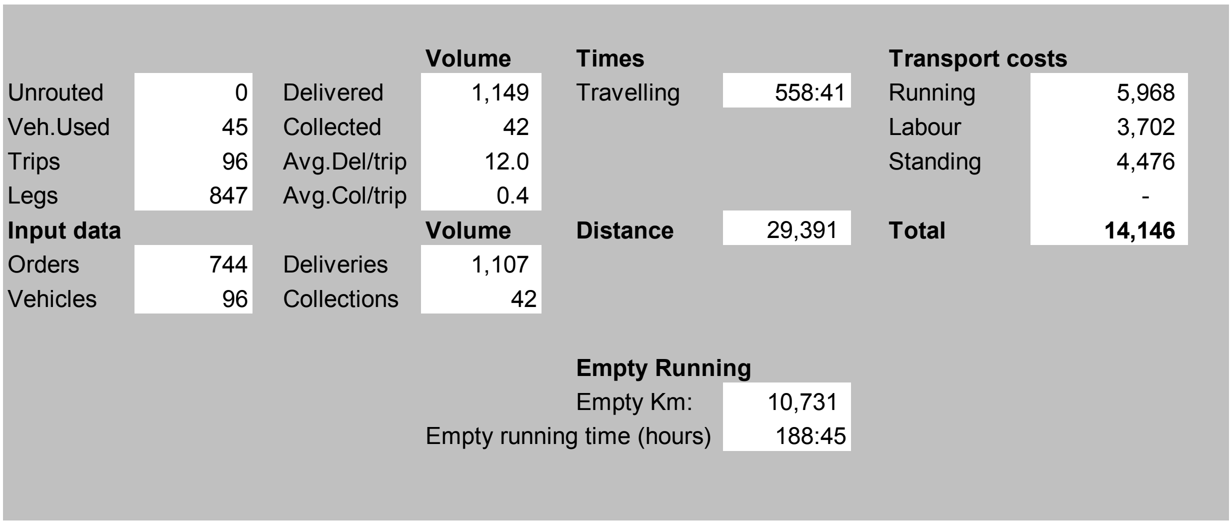
3.5.2 Results of the Routing Analysis

Scenario 0 (Original situation)

The figures of the actual delivery operation were obtained from the 2002 KPI data base and costed using the data in Table 3.1.

In Table 3.2, it is shown that there are 744 orders with valid information recorded in the database. These orders are composed of 42 pallets of collections and 1,107 pallets of deliveries over the two-day period for the sample fleets involved in tertiary distribution. These customer requirements were achieved using 96 trips. These trips are mostly multiple drops/collections rounds, with an average of about 9 journey legs per trip.

Table 3. 2 . *Operating and Cost Parameters for the Actual Delivery Operation*



			Volume	**Times**		**Transport costs**	
Unrouted	0	Delivered	1,149	Travelling	558:41	Running	5,968
Veh.Used	45	Collected	42			Labour	3,702
Trips	96	Avg.Del/trip	12.0			Standing	4,476
Legs	847	Avg.Col/trip	0.4				-
Input data			**Volume**	**Distance**	29,391	**Total**	**14,146**
Orders	744	Deliveries	1,107				
Vehicles	96	Collections	42				
				Empty Running			
				Empty Km:	10,731		
				Empty running time (hours)	188:45		

(Note: As discussion in Section 5, the transport KPI trip audit does not specify the number of vehicles deployed on a particular delivery operation. The figure of 45 vehicles has been estimated on the basis of the average ratio of vehicles to delivery times for the seven scenarios modelled using the Optrak package.)

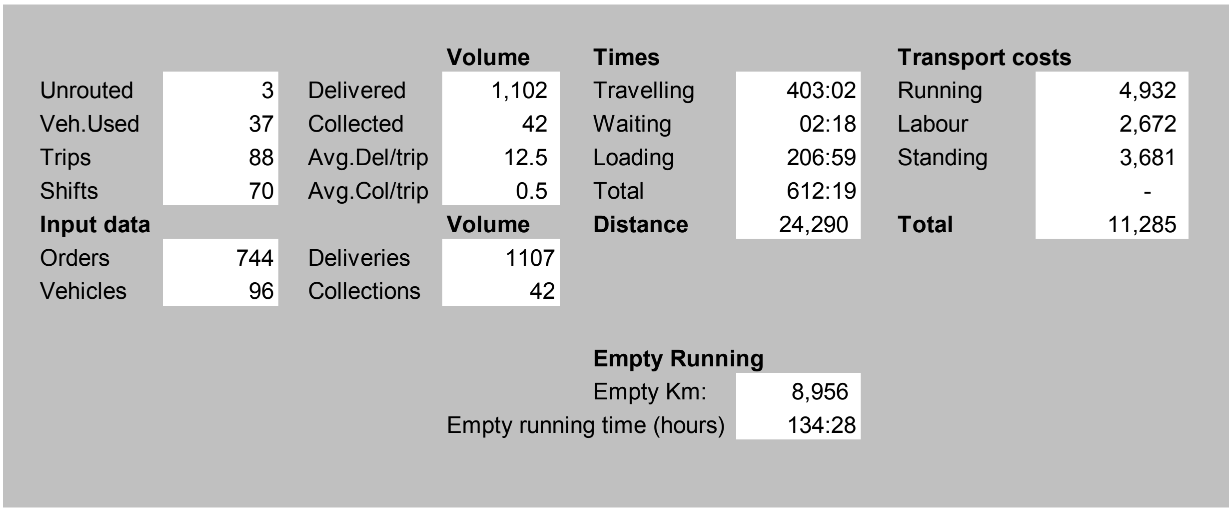
On average, 12 pallets are delivered on each trip whereas only 0.4 pallets are collected. It is also shown that vehicles travelled a total of 29,391 kilometres in making these deliveries and collections, and spent 558 hours on the road. More than a third of the distance travelled was empty running (10,731 kms). The total empty running cost was £6,711, which was more than a third of the total transport cost (£19,408).

Apparently there is large potential for these fleets to improve their transport efficiency. Whether this can be achieved using optimisation software and the relaxation of scheduling constraints is tested in the following scenarios.

Scenario 1 (Base Scenario)

Using industry standard parameters, we can establish the base scenario. As explained previously, in the base scenario, the driving time is assumed to be 9 hours, and the opening time is assumed to be between 6:00 and 18:00. The delivery time window is assumed to be a period between 6 hours before and 4 hours after the scheduled arrival time. By comparing the simulation results of the other scenarios from 2 to 7 with this scenario, it will be shown how fleets' performance can be affected by changes in scheduling constraints.

Table 3. 3 . *Modelling Results for the Base Scenario (Scenario 1)*



			Volume	**Times**		**Transport costs**	
Unrouted	3	Delivered	1,102	Travelling	403:02	Running	4,932
Veh.Used	37	Collected	42	Waiting	02:18	Labour	2,672
Trips	88	Avg.Del/trip	12.5	Loading	206:59	Standing	3,681
Shifts	70	Avg.Col/trip	0.5	Total	612:19		-
Input data			**Volume**	**Distance**	24,290	**Total**	11,285
Orders	744	Deliveries	1107				
Vehicles	96	Collections	42				
				Empty Running			
				Empty Km:	8,956		
			Empty running time (hours)		134:28		

It is shown in Table 3.3 that there are 3 unrouted orders (including 2 orders with wrong postcodes). Altogether, 88 trips and (37 vehicles) are used in this scenario. Compared with the actual situation, this saved 8 trips. Transport cost was reduced from £19,408 to £16,351, a 16% reduction. It is worth noting that a 56% reduction in total empty running cost was also achieved.

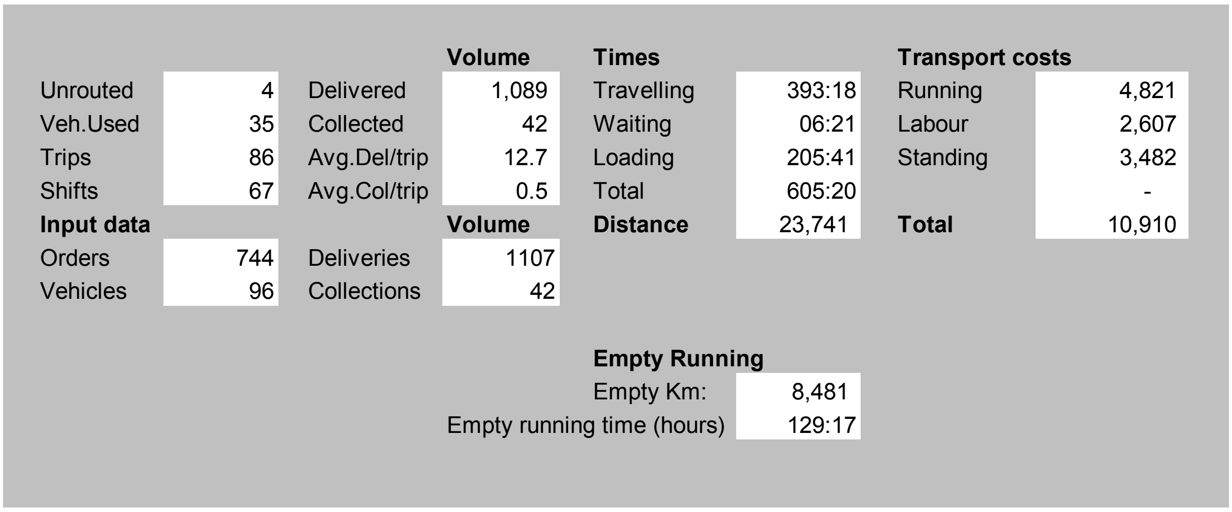
The distribution of optimised trips in the Base Scenario can be mapped using Optrak's trip path option (see Figure C.1 in Appendix C). Each driver's work for the scheduling period can also be displayed as bar chart using Optrak's trip histogram function as shown in Figure C.2 in Appendix C.

Scenario 2

By extending the driving hour by 1 hour, it is expected that some trips can be saved and the total transport cost can be reduced. This is confirmed by the simulation results of scenario 2 (Table 3.4).

Transport cost is further reduced to £16,068. Compared with the optimised base scenario, a 2% reduction in transport cost and a 5% reduction in empty running cost are possible.

Table 3. 4 . *Modelling Results for Scenario 2*



			Volume	**Times**		**Transport costs**	
Unrouted	4	Delivered	1,089	Travelling	393:18	Running	4,821
Veh.Used	35	Collected	42	Waiting	06:21	Labour	2,607
Trips	86	Avg.Del/trip	12.7	Loading	205:41	Standing	3,482
Shifts	67	Avg.Col/trip	0.5	Total	605:20		-
Input data			**Volume**	**Distance**	23,741	**Total**	10,910
Orders	744	Deliveries	1107				
Vehicles	96	Collections	42				
				Empty Running			
				Empty Km:	8,481		
				Empty running time (hours)	129:17		

Scenario 3

Scenario 3 is characterised by shorter drivers' shifts. As shown in the optimised results (Table 3.5), shorter driving time leads to increased an number of unrouted orders, the number of vehicle used and trip numbers. It also leads to a significant increase (by 12% compared with the base scenario) in distance run empty.

Table 3. 5 . *Modelling Results for Scenario 3*

			Volume	**Times**		**Transport costs**	
Unrouted	2	Delivered	1,105	Travelling	386:33	Running	4,711
Veh.Used	34	Collected	42	Waiting	04:04	Labour	2,562
Trips	84	Avg.Del/trip	13	Loading	206:24	Standing	3,382
Shifts	66	Avg.Col/trip	1	Total	597:02		-
Input data			**Volume**	**Distance**	23,200	**Total**	10,655
Orders	744	Deliveries	1107				
Vehicles	96	Collections	42				
				Empty Running			
				Empty Km:	8,286		
				Empty running time (hours)	126:38		

Scenario 4

One objective of the vehicle routing software is to route as many orders as possible. It is expected that more orders can be routed by extending customers' opening time. This is tested in scenario 4, where every other assumption remains the same except that the customer's opening time is extended by 2 hours (from 18:00 in the base scenario to 20:00 in this scenario).

Compared with the base scenario, we can see that using the same number of vehicles (with two additional trips though) one more order could be routed (Table 3.6), although this is at the expense of slightly higher transport cost than in scenario 1.

Table 3. 6 . *Modelling Results for Scenario 4*

			Volume	**Times**		**Transport costs**	
Unrouted	6	Delivered	1,100	Travelling	426:19	Running	5,273
Veh.Used	42	Collected	42	Waiting	04:08	Labour	2,826
Trips	89	Avg.Del/trip	12	Loading	206:38	Standing	4,178
Shifts	79	Avg.Col/trip	0	Total	637:05		-
Input data			**Volume**	**Distance**	25,966	Total	12,277
Orders	744	Deliveries	1,107				
Vehicles	96	Collections	42				
				Empty Running			
				Empty Km:	10,009		
				Empty running time (hours)	151:28		

Scenario 5

In scenario 5, where a shorter customer opening time was assumed, the number of unrouted orders increased from 3 to 5 compared with the base scenario. At the same time, both transport cost and empty running were increased (Table 3.7). A 1% increase in total transport cost and a 7% increase in empty running cost are incurred.

Table 3. 7 . *Modelling Results for Scenario 5*

			Volume	**Times**		**Transport costs**	
Unrouted	2	Delivered	1,105	Travelling	404:39	Running	4,967
Veh.Used	37	Collected	42	Waiting	06:33	Labour	2,681
Trips	90	Avg.Del/trip	12	Loading	207:39	Standing	3,681
Shifts	70	Avg.Col/trip	0.5	Total	618:51		-
Input data			**Volume**	**Distance**	24,459	**Total**	11,329
Orders	744	Deliveries	1107				
Vehicles	96	Collections	42				
				Empty Running			
				Empty Km:	9,499		
				Empty running time (hours)	142:14		

Scenario 6

In scenario 6, transport cost increases as delivery time windows narrow. The narrow time window not only leads to increased number of unrouted orders (from 3 unrouted orders in the base scenario to 9 unrouted orders in this scenario), but also results in increases in the number of trips, vehicles used and empty running (Table 3.8).

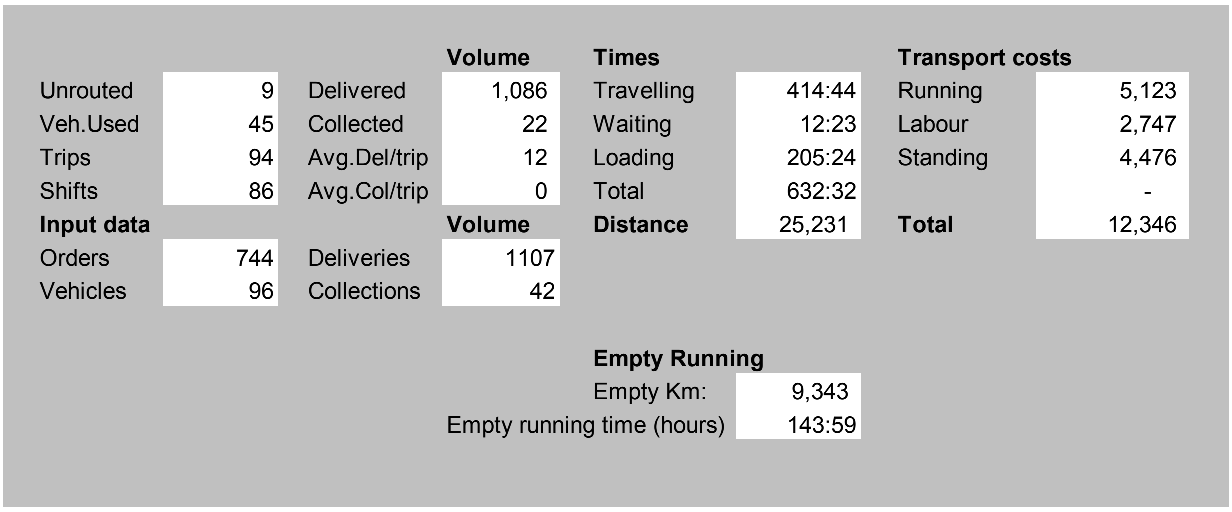
Table 3. 8 . *Modelling Results for Scenario 6*

			Volume	**Times**		**Transport costs**	
Unrouted	5	Delivered	1,090	Travelling	414:51	Running	5,125
Veh.Used	43	Collected	42	Waiting	00:12	Labour	2,748
Trips	93	Avg.Del/trip	12	Loading	207:04	Standing	4,277
Shifts	82	Avg.Col/trip	0	Total	622:07		-
Input data			**Volume**	**Distance**	25,239	**Total**	12,150
Orders	744	Deliveries	1107				
Vehicles	96	Collections	42				
				Empty Running			
				Empty Km:	9,488		
				Empty running time (hours)	145:15		

Scenario 7

In scenario 7 where a broader ordering time window is assumed, optimisation demonstrate that cost decreases as the customer delivery time windows are relaxed (Table 3.9). It is also shown that, except for two wrongly recorded orders that are too far from the depots, all other orders are routed.

Table 3. 9 . *Modelling Results for Scenario 7*



			Volume	**Times**		**Transport costs**	
Unrouted	9	Delivered	1,086	Travelling	414:44	Running	5,123
Veh.Used	45	Collected	22	Waiting	12:23	Labour	2,747
Trips	94	Avg.Del/trip	12	Loading	205:24	Standing	4,476
Shifts	86	Avg.Col/trip	0	Total	632:32		-
Input data			**Volume**	**Distance**	25,231	**Total**	12,346
Orders	744	Deliveries	1107				
Vehicles	96	Collections	42				
				Empty Running			
				Empty Km:	9,343		
				Empty running time (hours)	143:59		

As shown in Table 3.9, the number of trips used is reduced from 88 to 84 compared with the base scenario. At the same time, total transport cost is reduced by 19% compared with the actual delivery operation, and by 4% compared with the base scenario. A 7% reduction in empty running is achieved in this scenario compared with the base scenario.

3.5.3 Benefits of More Efficient Vehicle Routing

It is evident that the actual pattern of delivery observed during the transport KPI survey for the sample fleets was sub-optimal. The degree of sub-optimality is difficult to determine as the KPI survey did not collect any information about opening times, delivery time windows or driver shifts. The analysis has shown, however, that if deliveries had been optimised within a realistic range of scheduling constraints, substantial reductions in vehicle-kms, empty running, transit time and vehicle numbers could have been achieved (Figure 3.2). This would have translated into significant economic cost savings and environmental benefits (Figure 3.3).

To secure much of this benefit, however, changes in company behaviour would be required. Industrial partners in the research project have argued that to obtain the estimated transport cost savings it will often be necessary to change working practices, rebalance logistical cost trade-offs and renegotiate delivery arrangements with suppliers and customers. Data collected in the transport KPI surveys offer little insight into the nature and magnitude of the necessary behavioural change. Several recent studies have examined how companies can pursue 'transport optimisation' (ECR Europe 2000; ECR UK, 2003) , though they have not investigated in detail the practical constraints that have to be overcome.

Figure 3.2. *Comparison of Key Parameters for Delivery Scenarios (S0-S7):*

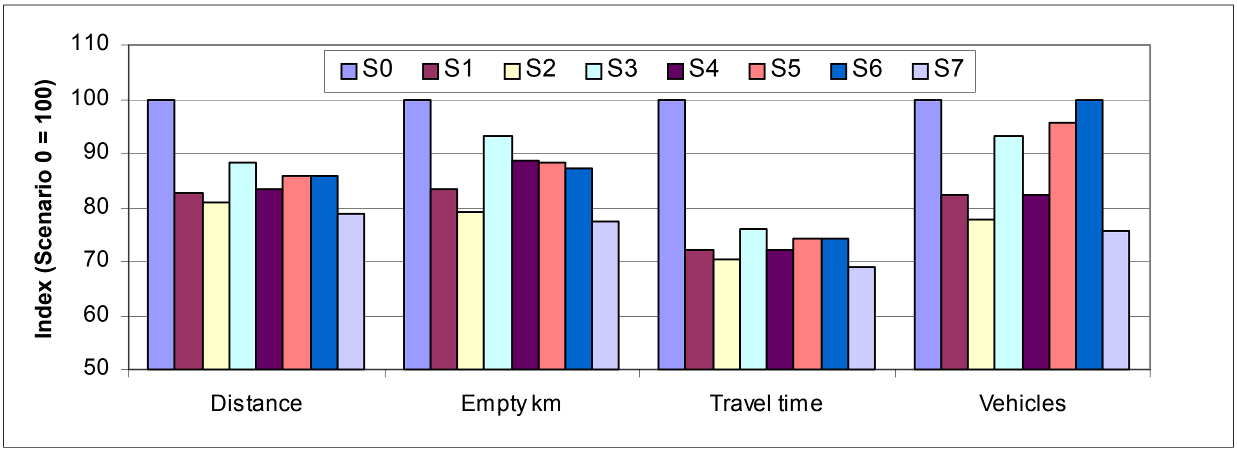
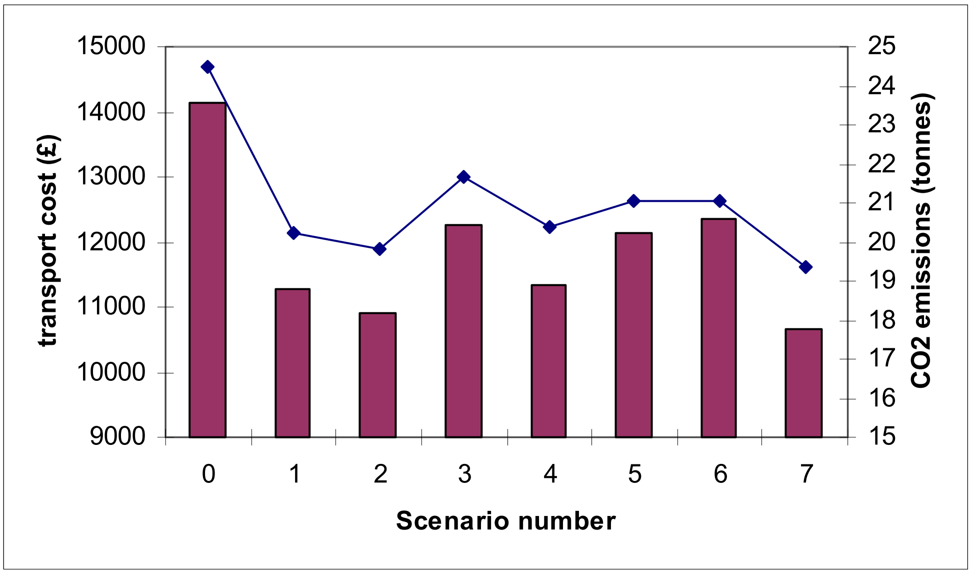


Figure 3.3. *Transport Costs and CO_2 Emissions for Delivery Scenarios*



Scenario 0: actual delivery operation monitored by transport KPI survey
Scenario 1: (Base) delivery parameters defined in Section 3.4.1
Scenario 2: maximum driver's hours extended from 9 to 10 hours
Scenario 3: maximum driver's hours shortened to 8 hours
Scenario 4: customer opening time extended to 6am –8pm
Scenario 5: customer opening time shortened to 6am-4pm
Scenario 6: time window narrowed from 6 to 3 hours before and 4 to 2 hours after scheduled arrival time
Scenario 7: time window widened to 12 hours before and 8 hours after scheduled time

SECTION 4. BACKLOADING ANALYSIS

4.1 EMPTY RUNNING TREND IN THE UK

The proportion of truck-kms run empty has declined over the past 30 years from 33.7% in 1973 to 26.5% in 2002 (Figure 4.1). This reduction in empty kms will have yielded large economic and environmental benefits. If the percentage of empty running had remained at its 1974 level, road haulage costs in 2002 would have been £1.3 bn higher and an extra 1.05 million of tonnes of CO2 would have been emitted into the atmosphere by lorries[3]. It is uncertain how long this beneficial trend will continue and at what level it is likely to stabilise. A survey of a panel of experts undertaken by Browne and Allen (1997) suggested that the level of empty running would decline to 24% by 2005. It appears that this panel largely extrapolated the past trend in empty running. Extrapolating on the basis of more recent data, for the period between 1995 and 2003, suggests that by 2010 lorries in the UK will be running 23.2% of their annual kilometres empty. This reduction, coincidentally, would yield a similar reduction in CO_2 emissions as the freight modal shift required to achieve the government's objective of increasing rail tonne-kms by 80% by 2010. Extrapolatory forecasting of the empty running trend is very risky, however, particularly as factors causing this trend may change.

An attempt has been made to explain the decline in empty running in the UK (McKinnon, 1996). This identified seven possible factors and used available statistics to assess their likely impact on the level of empty running. In the course of the present project, this analysis has been updated. The factors were as follows:

1. Outsourcing of road haulage operations: it has been suggested that third-party haulage companies achieve higher levels of backloading than own account operators. Although the latter have had the freedom to 'carry for others' since the 1970s and many exercise this freedom by possessing a 'standard' license, it is felt that they have a more limited knowledge of the haulage market and hence more difficulty in finding return loads. If this were so, the substantial shift in the division of road freight traffic from own account to third party operators over the past thirty years would have contributed to the decline in empty running. CSRGT

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[3] This calculation assumes that the decline in empty running has not been offset by a decline in the load factors of laden vehicles. CSRGT data for the period since 1985 indicates that lading factors have remained fairly stable, suggesting that offsetting effect on vehicle utilisation will have been marginal.

data, however, indicate that the initial premise is flawed. While in 1983 own account operators had a marginally higher empty running level than hire and reward hauliers, this level has declined more steeply over the past 20 years and now fallen below that of road hauliers (Figure 4.2). The major growth in the outsourcing of road transport is therefore unlikely to have had much impact on the overall level of empty running.

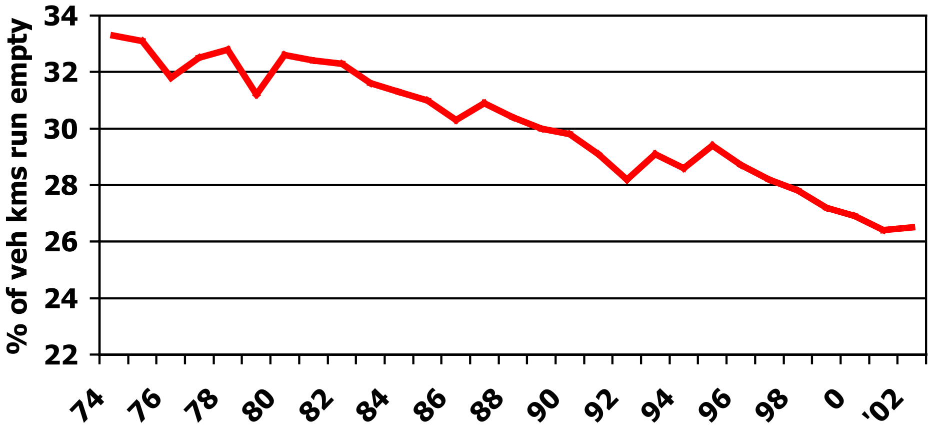

Figure 4.1. *Proportion of Lorry-kms Run Empty: UK*

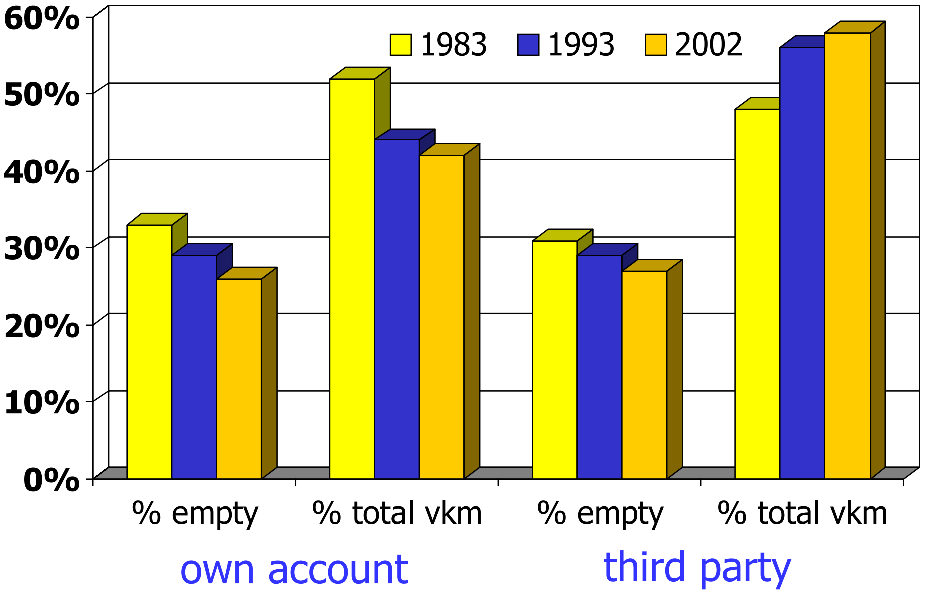

Figure 4.2. *Empty Running and Outsourcing Trends*

2. Greater balancing of inter-regional flows: much empty running is the result of geographical imbalances in traffic flows. An Inter-regional Traffic Imbalance (IRTI) Index was devised to measure the extent to which inter-regional road freight flows in the UK were unbalanced:

$$\text{IRTI} = \Sigma_i \left| I_i - O_i \right| \ / \ \Sigma_i \left| I_i \right|$$

Where I and O denote, respectively, the inward and outward flows of road freight into and out of region i.

Using CSRGT data, index values of 0.149 and 0.156 were calculated for, respectively, 1983 and 2003 (Central Statistical Office, 1984; Department for Transport, 2004). This suggests that the degree of inter-regional traffic imbalance has shown a slight increase over the past twenty years. Over the same period, the proportion of road freight moving inter-regionally increased from 21.8% to 29.7%, accentuating the effects of the growing inter-regional traffic imbalance. These changes in the geographical pattern of road freight movement have not been analysed in detail though they are likely to have been the result of three inter-related processes: wider sourcing of commodities, centralisation of production and inventory and greater regional specialisation (McKinnon and Woodburn, 1996). Other things being equal, these trends in the pattern of freight flow will have made it more difficult for companies to find back-loads. It should be noted, however, that the IRTI index is solely weight-based and takes no account of the cubic volumes of freight moving in each direction. The main government survey of road freight flows, upon which this analysis is based, does not collect volumetric data.

3. Increase in the average length of haul: The longer the journey, the greater will be the incentive to find a return load. Previous regression analysis in the UK established the following relationship between trip length and the probability of a vehicle running empty (McKinnon, 1996):

$$P_e = 0.448 - 0.0008\,t \quad (r^2 = 0.72)$$

Where P_e is the probability of a journey leg being run empty and t the leg length. Applying this formula to the increase in the average length of haul for road freight in UK between 1973 and 2003 (from 54 km to 92 km) suggests that the lengthening of hauls was responsible for around 40% of the decline in empty running over this period.

4. Change in trip structure: On multiple drop rounds only the last leg is likely to be empty and this often represents a small proportion of the total distance travelled. As the percentage of multiple drop rounds and average number of drops per trip has been increasing, this change in trip structure is likely to have had the effect of depressing the level of empty running

5. Growth of reverse logistics: In many supply chains, there has been a strengthening return flow of packaging waste, handling equipment and product. This is mainly result of the following developments:

- EU and UK directives requiring more recycling of packaging waste
- Increased use of reusable handling equipment
- Retrieval of end-of-life products and components for refurbishment and remanufacturing (increasingly in accordance with EU directives)
- Growth in the return of products for servicing and repair
- Growth of home shopping (typically 25-30% of merchandise is returned)
- Return / redistribution of 'liability inventory'(i.e. slow moving ranges) from stores

These trends are generating more return loads and cutting empty running. (In the KPI survey, empty running is distinguished from returning with empty packaging and handling equipment.)

6. Increased use of load matching services: in addition to traditional load matching agencies, which have relied on telephone and fax communications, new online freight exchanges have emerged over the past 5-6 years, providing both web-enabled tendering and online auctions for road haulage services (Rowland, 2003). This is making it easier to match loads with available vehicle capacity. No attempt has yet been made to quantify the net effect of these services on empty running.

7. Adoption of new management initiatives, such as *supplier collection / onward delivery* (EEBPP, 1998) and *factory gate pricing* (Finegan, 2002; Aujla, Hainsworth and Patel, 2003) in the retail grocery sector. The large UK supermarket chains have been assuming greater responsibility for inbound flows of supplies into their RDCs increasing the use of their shop delivery fleets for the collection of supplies. This achieves more balanced loading and cuts empty running.

In summary, the reduction in empty running appears to be the result mainly of factors 3-7, all of which are likely to continue for the foreseeable future and prolong the downward trend in empty running. Several other developments, however, may counteract their effects. First, worsening traffic congestion will reduce delivery reliability, gradually undermining the confidence in delivery schedules that transport managers require to exploit backloading opportunities. Second the working time directive, coupled with the worsening driver shortage, will reduce the slack in companies' delivery schedules, making it more difficult to incorporate backhauls.

It is also widely acknowledged that the downward trend in empty running will stabilise well above zero. There will remain a substantial amount of empty running because of various constraints:

Priority given to the outbound delivery service: many companies prefer not to risk jeopardising the quality of the outbound delivery to customers. In a survey of company attitudes to backloading conducted this was identified as the main constraint (McKinnon, 1996) (Figure 4.3).

Unreliability of collection and delivery operations: the risk of backloading operations being delayed (and thus disrupting later outbound trips) can be quite high. The 2002 food transport KPI survey, for example, have revealed that around 29% journey legs are subject to a delay. These delays averaged 45 minutes. The survey data also permitted an analysis of the frequency and duration of delays at different types of collection and delivery point, where a large proportion of food backloads originate. Journey legs starting at one of the three main collection points, factories, RDCs and primary consolidation centres, had, respectively, a 42%, 36% and 30% probability of being delayed, with these delays averaging 35-45 minutes (Figure 4.4).

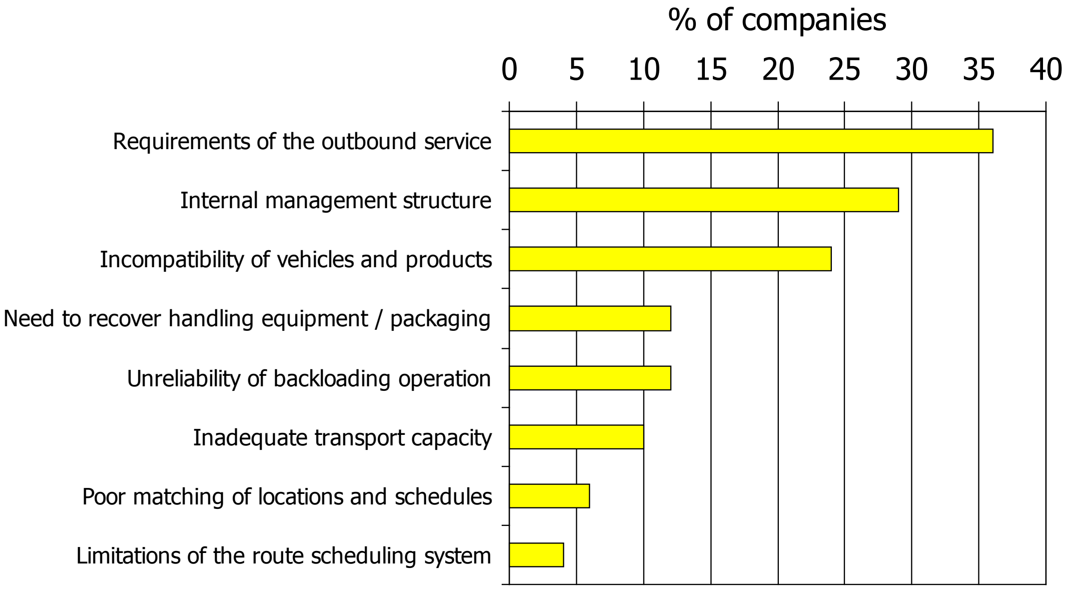

Figure 4.3. *Factors Constraining Backloading: Results of Company Survey*

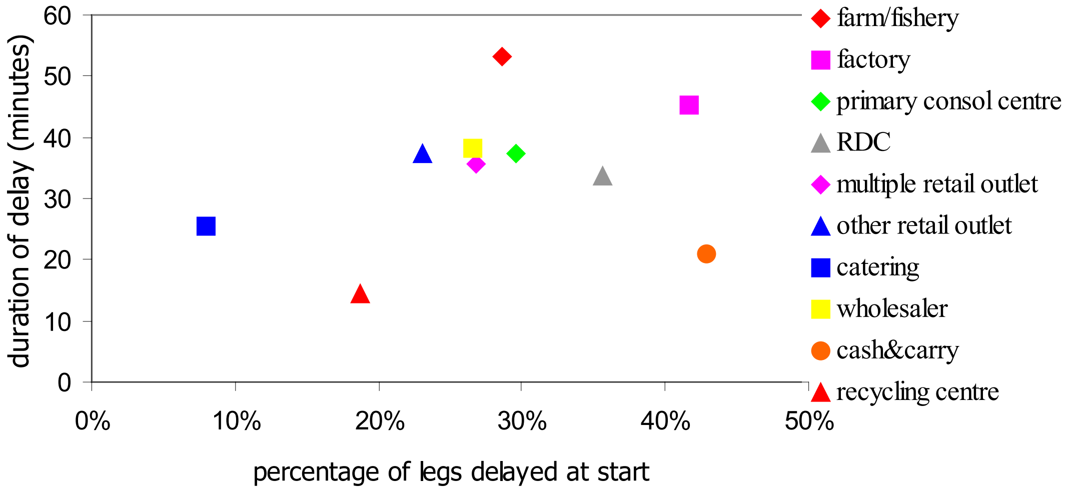

Figure 4.4. *Frequency and Duration of Delays at Collection Points*

- Inadequate knowledge of available loads: many possible matches of available vehicle capacity with suitable loads are missed because of a lack of transparency in the road haulage market. The growth of load matching agencies and online freight exchanges is helping to overcome this constraint.

- Lack of co-ordination between purchasing and transport / logistics departments: it is likely that more backloading opportunities would be realised if the physical movement of products was discussed as part of the trade negotiation between companies.

- Incompatibility of vehicles and products: often the vehicle available to collect a backload fails to meet that handling characteristics of the available load.

- Trip length too short for viable backloading operation: For example, 38% of the tonnage of 'other foodstuffs' transported by road travels a distance of less than 100 km (60 miles) (DfT, 2003)

4.1.1 Empty Running in the Food Supply Chain

According to the CSRGT, empty running in the 'other foodstuffs' category was approximately 5% lower than the all-commodity average in 2002 (Department for Transport, 2003). This may be partly related to the fact that the average length of haul for this commodity class is above average. Figure 4.5 shows how across the NST commodity classes, there is weak inverse relationship between average length of haul and the level of empty running. The proportion of empty mileage may also be lower in the food sector because of the high proportion of supplies distributed in multiple drop rounds, the strong reverse flows of empty handling equipment and packaging material particularly from supermarkets) and the backloading initiatives of the major grocery retailers (Patel, 2002). Over the past 7 years, empty running has declined at a similar rate in the 'other foodstuffs' category as for all commodities (Figure 4.5).

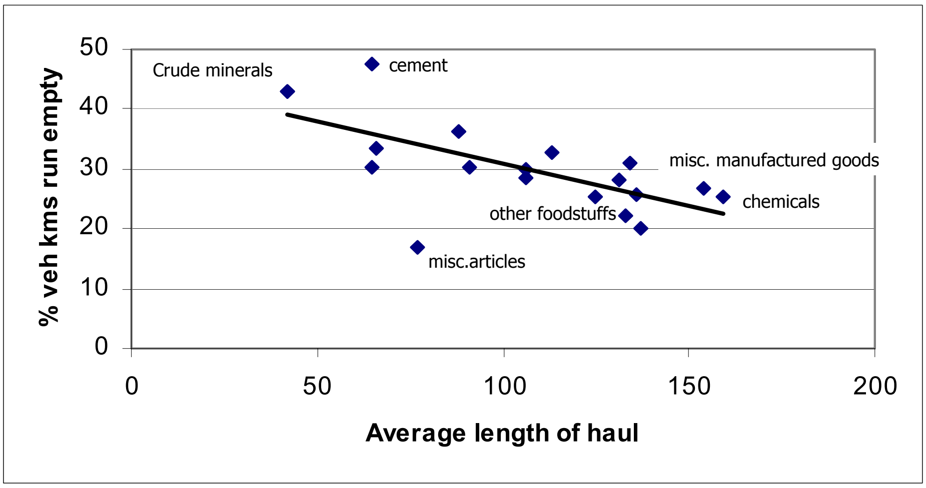

Figure 4.5. *Relationship between Length of Haul and Empty Running by Commodity Group*

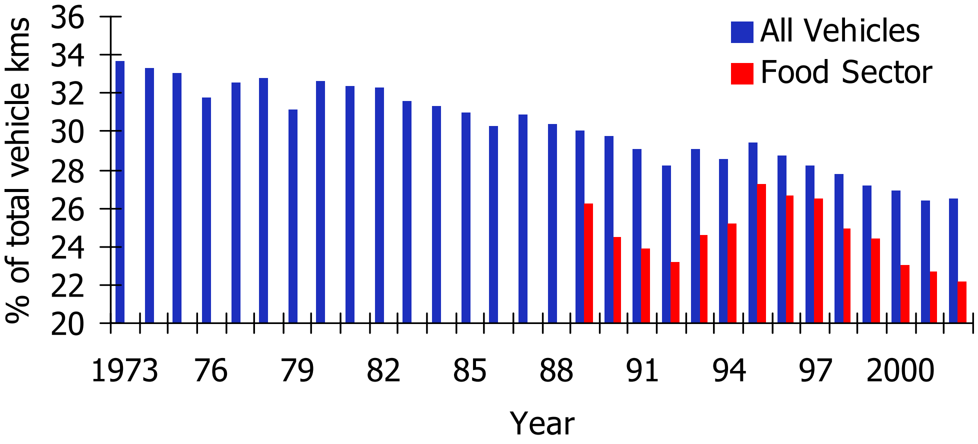

Figure 4.6. *Comparison of Empty Running Trends for all Commodities and 'Other Foodstuffs' Category*

The average level of empty running among the fleets monitored in the 2002 transport KPI survey was slightly below the CSRGT estimate for the 'other foodstuffs' category. Of the 1.45 million kilometres travelled by the sample vehicles over the 48 hour period, 0.28 million were run empty - approximately 19% of the total. There were, nevertheless, wide variations around the mean value (Table 4.1). The fleet averages for empty running were particularly sensitive to the mix of trip types undertaken. Where there was a large proportion of multiple-drop trips, the average figure for empty running tended to be lower. This partly explains the wide variation in the proportion of empty running across the 53 fleets surveyed.

Table 4. 1 . *Variations in the Level of Empty Running by Fleet*

% of vehicle-kms run empty	% of fleets
0-10	31%
11-20	13%
21-30	33%
31-40	19%
41-50	4%

Even fleets engaged in a similar pattern of delivery, however, can have markedly different levels of empty running. In some cases, this can be explained by differences in the types of handling equipment used and the manner in which it is returned. The return of roll cages from supermarkets, for instance, was classed as 'running with returns' rather than empty running, as it represented an essential stage in the distribution process and limited the opportunity to pick up a back load. A vehicle carrying only its usual complement of wooden pallets, on the other hand, was deemed to be empty as it could be backloaded with product. Some fleets achieving very low levels of empty running handled heavy flows of 'returns'. When allowance was made for these operational differences, however, there remained significant variations in the level of empty running, suggesting that some companies could do more to find back loads.

The main purpose of this part of the project was to assess the potential for reducing empty running by analysing the missed opportunities at company and sectoral levels for collecting backloads.

4.1.1.1 Previous Research

This was not the first attempt in the UK to estimate potential reductions in empty running. Cundill and Hull (1979) used road freight data collected in the course of urban freight studies in Hull and Swindon to undertake an analysis of possible 'destination and origin matching' on journeys to and from these two towns (Figure 4.7). They excluded trips shorter than 50 km and confined their attention to standard 'platform and box-bodied' vehicles which could handle a broad range of consignments.

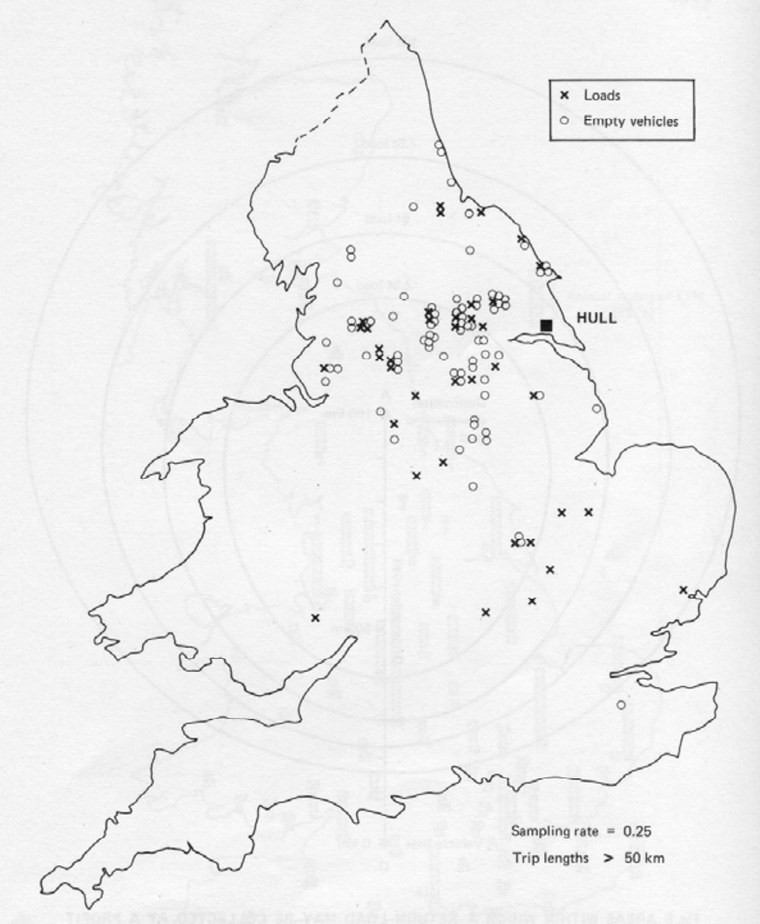

Figure 4.7. *Matching of Available Loads and Empty Vehicles on Trips to and from Hull*

Using industry standard data on vehicle operating costs and haulage rates they were able to determine the profitability of diverting a vehicle from its direct return route to collect an available load. The search area for profitable loads formed an eliptical shape around this return route and allowed for the possibility of a vehicle initially travelling beyond the destination point to obtain a backload. Cundill and Hull acknowledged that their model took no account of the scheduling of deliveries ('urgency'), the handling characteristics of the products ('fragility') and the possible 'incompatibility' of vehicles and loads. As they had no data on these constraints, they arbitrarily scaled down their estimate of 'profitable matches' by 75% to make it more realistic. As this was not based on any empirical evidence, it seriously undermined credibility in the estimate of potential savings in empty running. This deflated estimate was, nevertheless, grossed up to a UK level to indicate the general potential for reducing empty running. It was indicated that an extra 660,000 profitable load matches could be achieved annually, each one saving 235 vehicle-kms. The resulting saving of 155 empty vehicle-kms per annum was equivalent to 3.5% of total empty running in 1978. This would have brought the empty running level down from 33% to 32% of lorry kms.

This study had three major limitations. First, in the absence of information about the scheduling of trips and handling characteristics of the loads the researchers had to over-simplify the load matching procedure and scale-down the calculated benefits by an arbitrary amount. Second, the analysis was confined to lorry journeys to and from two towns. It was not know how representative freight movements to and from these towns would be of the general pattern of road freight transport across the UK, in particular in terms of directional imbalances and average trip length. Third, the modelling of road haulage rates was based on national average figures and took no account of the fact that backhaul rates are typically below average and often barely cover marginal costs.

The analysis of backloading potential using transport KPI survey data overcomes several of these limitations. First, the availability of data on delivery schedules and load characteristics permits more complex and realistic modelling of load-matching opportunities and removes the need to deflate estimates by an arbitrary amount. Second, the KPI survey data relate to a much more geographically dispersed pattern of flow. It therefore provides a sounder basis for generalising about opportunities for backloading at a national level. On the other hand, the KPI data relate to single commodity group unlike the Cundill and Hull analysis which was essentially cross-sectoral. Any generalisation on the basis of the current study applies solely to the grocery supply chain. Also, the present analysis also has no commercial dimension as no data was requested from the participating companies on road haulage rates and costs.

4.2 METHODOLOGY USED IN THE PRESENT STUDY

The potential for backloading was analysed with the use of an interactive GIS (Geographical Information System) system tool. The GIS system was developed using a commercial software package, SAS/GIS (SAS Institute Inc., 1995).

Using this system it was possible to construct maps showing the participating companies' current road freight operations. The first step in the backloading analysis was to find the empty legs that could potentially be allocated backloads. Initially the focus was on empty legs with a length of over 100 kms. A radius of 50 km around the origin and destination of the empty legs was then used to delimit a search zone for potential loads. Various levels of screening were then applied to these potential loads relating to (a) location and direction of freight movement (b) vehicle compatibility (c) vehicle capacity and (d) delivery time window. Backloading potential was assessed using several levels of load screening and delivery scenarios. Potential economic and environmental benefits were estimated based on relevant data on vehicle operating costs and CO_2 emissions.

Software development

Geographical Information Systems (GIS) enable storage, manipulation, analysis and display of geographically referenced data. A geo-coding tool was used to convert the post-codes stored in the Access database into the National Grid Reference system used in the UK. The Eastings and Northings obtained through the geo-coding procedure were used for locate collection and delivery points. All relevant information is retrieved from the Access database and stored in CSV format. These files are imported into SAS with coding instructions written in SAS programming language. The spatial data was integrated with the attribute data using SAS/GIS. Algorithms were developed to interactively interrogate the KPI survey database and assess the backloading potential at different levels of load screening.

A geographic information system is a tool for organising and analysing data that can be referenced spatially—that is, data that can be tied to physical locations. The value of GIS lies in the ability to integrate disparate sets of data, visualise them in the form of maps and, on this basis, perform interactive analysis. The GIS developed for the KPI 2002 survey in the food sector enables interaction with the data by selecting features and performing actions based on those selections.

GIS contains two basic types of data: spatial data expressed in co-ordinate form and attribute data associated, in this case, with collection and delivery points, loads and trips. Figure 4.8 shows the framework for the development of the GIS framework for the backloading analysis. The database of the 2002 KPI survey contains not only attribute data of detailed trips and vehicle activities in the 48-hour period, it also recorded spatial information in the form of post-codes. These postcodes were converted into Eastings and Northings of National Grid Reference using the Code-Point database (a part of the Digimap package). The Eastings and Northings can also be converted into Longitude/Latitude using Excel Macro.

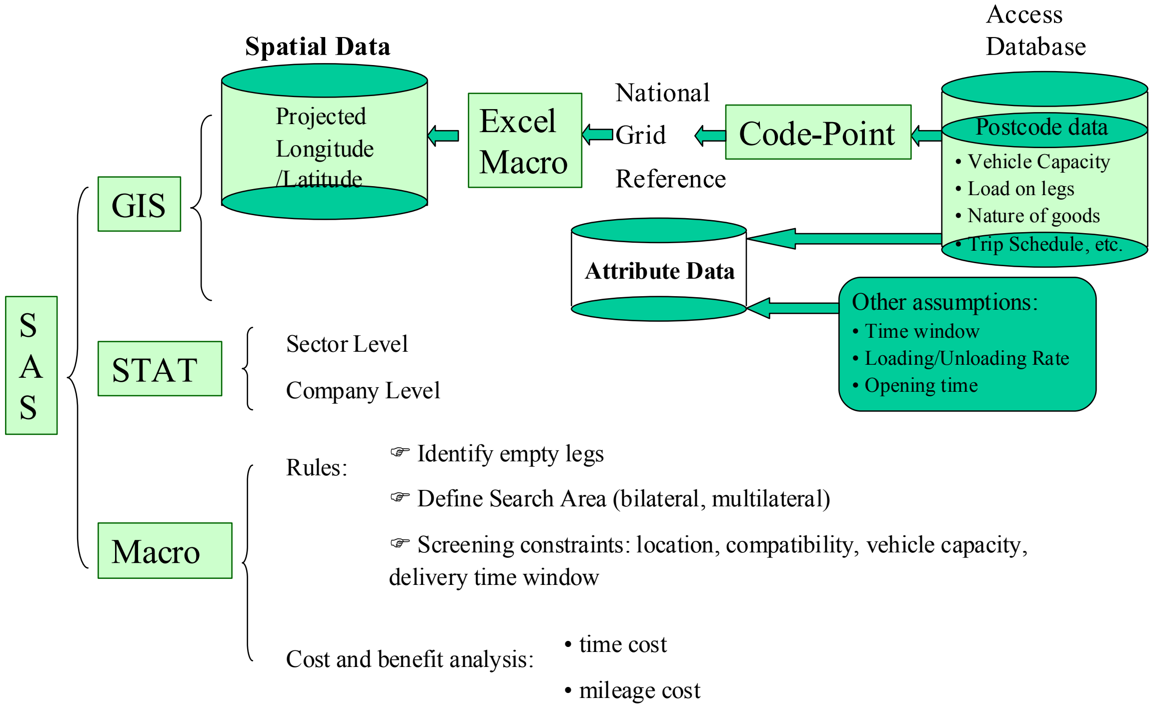

Figure 4.8. *Framework for the development of GIS for backloading analysis*

The GIS integrated the spatial data and attribute data. Based on the GIS system and the algorithms developed, various scenarios were constructed allowing for different levels of load screening.

Fleet selection

All fleets with valid post-code, load data (in pallet units) and time information were included in the backloading analysis.

Assumptions and Rules

Following discussions with industrial partners, assumptions were made about vehicle compatibility, vehicle capacity and delivery time windows. Rules were also defined for the different levels of screening. These were all integrated into the interactive interface of the GIS.

Reductions in empty running, CO_2 emissions, and fuel cost

The net reduction in empty running was calculated by subtracting any additional deviation mileage from the total saving in empty kms. This net reduction in vehicle-km was converted into reductions in CO_2 emissions and fuel cost based on standard ratios.

4.3 FLEET SELECTION

The selection of fleets and trips for the backloading analysis took account of the quality of the spatial information provided. Of the total 24,443 journey legs stored in the database, just over a half (12,364 legs) had postcode information. These postcodes were geocoded using the Ordinance Survey's Code-Point database (Ordnance Survey, 2002), which has 1644036 full UK postcodes (excluding Northern Ireland). Of all journey legs having postcode information, 10040 were geocoded using the full postcode, 1662 journey legs using the first 5 digits postcode, 591 journey legs using the first 4 digits postcode, and 71 journey legs using the first 3 digits postcode.

Most opportunities for backloading exist among trips with fewer than five journey legs. Fleets mainly engaged in multiple-drop operations (with five or more journey legs) were therefore excluded from the sample. Of the 53 fleets (27 companies) which participated in the survey, 29 fleets (13 companies) are selected for backloading analysis. The final sample was composed of 2957 complete trips comprising 8995 legs with at least time and load information. The trips in the sample had an average of three journey legs.

4.4 GIS DEVELOPED FOR BACKLOADING ANALYSIS

As mentioned above, a GIS is mainly composed of: spatial data and attribute data. The integration of these two types of data in the GIS is fundamental to the backloading analysis.

Spatial data

Because some of the post-code data in the KPI database was of poor quality, several levels of geo-coding are required to ensure that the post-code entered into SAS/GIS was as accurate as possible. Most of the postcodes (81% of journey legs with postcode information) had been geocoded with full post-code. Post-codes for which there was no match in the Code Point database were converted into Eastings and Northings using a centre of gravity approximation. The trip patterns of the sample fleets are displayed in Figure D.1 in Appendix D.

Attribute data

The other relevant information is retrieved from the Access database and stored in CSV format. This includes vehicle data, composition of trips and information about loads and delivery time windows. These files were imported into SAS using codes written in SAS programming language. The spatial data is then integrated with the attribute data using the interface provided in SAS/GIS.

4.4.1 Features of the Food Transport GIS

The interface of the GIS for backloading analysis is shown in Figure 4.9. This shares common features with other applications developed in windows environment, such as object(s) selection, enlargement, and drag and move. It also has all the common features of a GIS, such as showing location and distance, and providing feedback on selected areas or lines (i.e. journey legs in this case).

As shown in Figure 4.9, trips of different companies are displayed in different colours. Each company's distribution network can also be displayed separately by clicking in the corresponding check boxes at the top.

An interactive query interface is also available so that journey legs or trips of certain types (for example, of a specific company or over a certain distance) can be selected. Various actions relating to different levels of screening can then be taken for selected journey legs, as shown in Figure E.2 in Appendix E. The screening results are stored in table format and can be subject to further analysis if required.

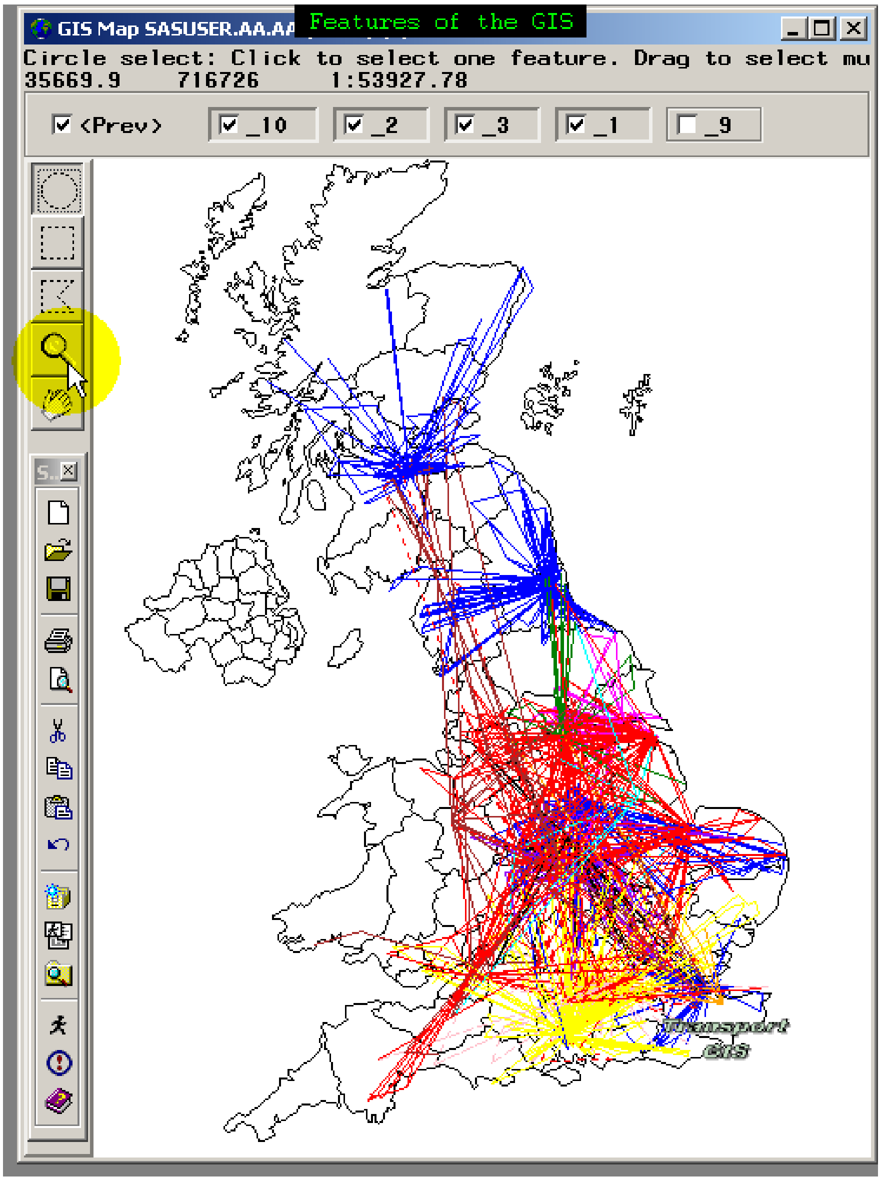

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Figure 4.9. *Features of the GIS*

4.4.2 Screening of Potential Backloads

Screening was undertaken at four levels: location / distance, vehicle compatibility, capacity, and delivery time window.

Location and distance

The assessment of backloading potential is not only constrained by the distance between the original collection and delivery points, but also by the extent to which vehicles must deviate from the direct return route.

Two measures were taken to improve the accuracy of the distance measurement:

(a) The straight line ('crow-fly') distances used in this analysis were converted into approximate road network distances using a standard wiggle factor of 1.28.

(b) Allowance was made for major geographical barriers, such as rivers, estuaries and mountains (Table 4.2). Movements between twelve zones affected by these barriers were routed via eleven 'way points' to prevent, for example, the routing of a vehicle across the Wash. (This method was previously applied by a member of LRC research team for an online backloading service called the *backload.com*). Most of the parameters have been tested previously in practice with reasonably high accuracy. A graphical representation of the estuary zones and way points is shown in Figure D.3 in Appendix D. This system ensures, for example, that traffic moving between the Lothians and Fife passes a waypoint at the Forth Bridge.

Table 4. 2 . *Estuary Zones and Way Points*

Way Points	ID	Major Routes	Estuary Zones
Dartford river crossing	WP1	M25	Kent↔East Anglia
Sleaford	WP2	A17	East Anglia↔ Lincolnshire
Humber bridge	WP3	A15	Lincolnshire↔East Yorkshire
Tyne Tunnel	WP4	A17	East Yorkshire↔Borders East
Forth Road Bridge	WP5	A90	Borders East↔Fife
Tay Road Bridge	WP6	A92	Fife↔Grampian
Inverness	WP7	A9	Grampian↔Highland
Glasgow	WP8	M74	Highland↔Strathclyde
Gretna	WP9	M74	Strathclyde↔North West
Warrington	WP10	M6	North West↔Wales
Severn river crossing	WP11	M48/M4	Wales↔South West

A future refinement of the backloading analysis could be the linking of a road network database to the GIS to provide more accurate distance measurements.

Vehicle Compatibility

Previous research (McKinnon, 1996) has shown that the incompatibility of upstream and downstream flows can severely limit the scope for backhaulage, particularly for firms in process industries. The impact of vehicle incompatibility on back haulage in the food sector has not, however, been explored. In the food sector, whether a vehicle can take a load or not is first of all restricted by its temperature-control capabilities. Secondly, the temperature range of a compartment and the time required to vary its temperature in order to meet the requirements of different products is another limiting factor, affecting the compatibility of a vehicle with potential backloads.

Vehicle Capacity

Vehicle capacity is another important factor that determines whether a vehicle can pick up a back load. A simplifying assumption has been made in this modelling exercise that a backload will only be collected where there is sufficient capacity in the empty vehicle to carry the full load. In a future version of the model it may be possible to relax this assumption and allow the collection of part loads.

Delivery Time Window

The prime objective of transport management is to meet requirements for fast and reliable outbound delivery to customers. Any delay in the return of delivery vehicles and its cumulative effect can compromise this objective. At corporate level, the benefits of return loading are often considered to be relatively minor when set against the marketing advantages of gaining and maintaining a reputation for on-time delivery. It can be important therefore to accommodate any backloading within existing schedules and ensure that vehicles are returned in time for their next outbound delivery. As the KPI database contains information on the timing of follow-on trips, it is possible to check whether backload opportunities could be realised within scheduling constraints.

4.5 BACKLOADING ANALYSIS

4.5.1 Location Screening

As mentioned earlier, in the backloading analysis only trips with empty legs over 100 kms were included in the analysis. The software tools allow the user to vary this threshhold distance. 573 empty legs (as shown in Figure 4.10) met this criterion across the fleets of the thirteen companies in the sample.

The search areas were defined as cycles centred at the origin and destination of an empty leg with a radius of 50 kilometres. The distance between a potential load's start and finish points, or the empty running distance of the potential load, also had to be over 1/3 of the distance of the empty leg.

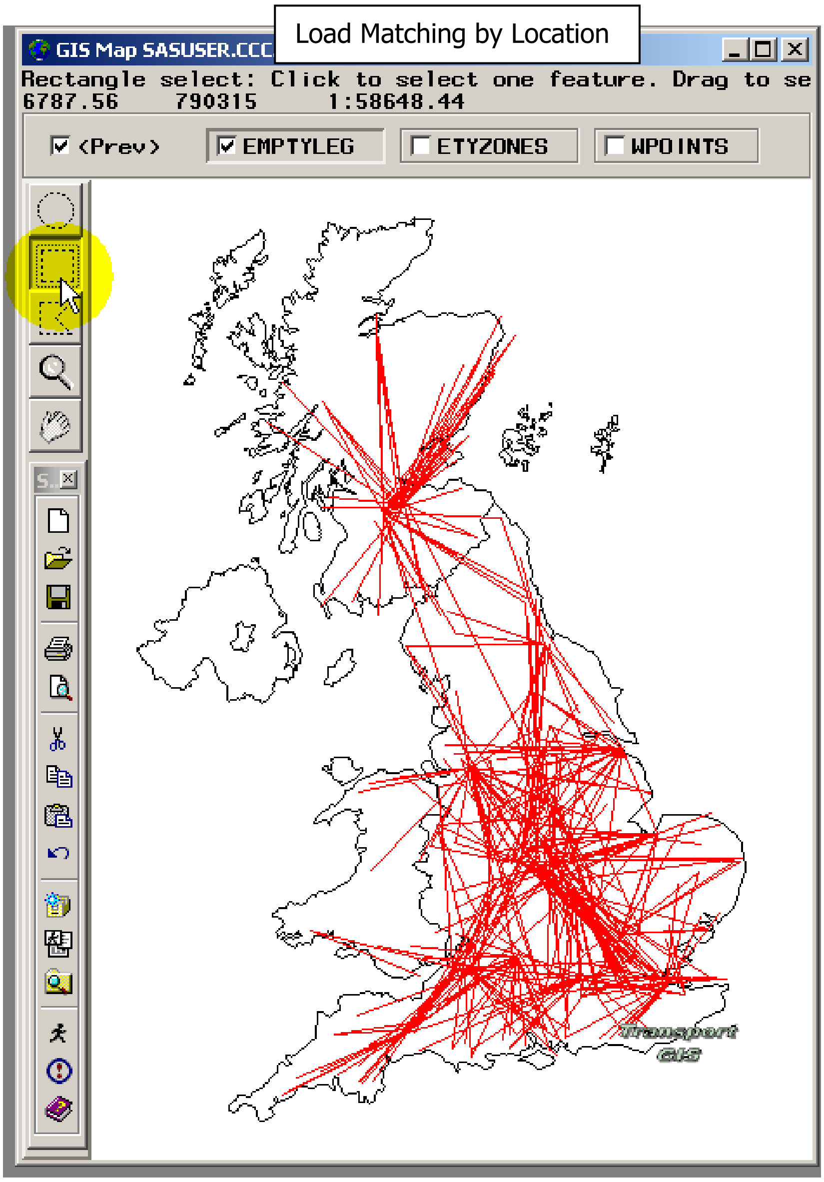

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Figure 4.10. *Empty Legs Selected for Backloading Analysis*

The results of an interactive backloading analysis based on a selected sample of empty legs are shown in Table E.1 in Appendix E. Detailed information about the matched cases is stored in separate tables.

Of the 573 empty legs over 100 km, 229 have potential load matches based on the location and direction of the freight movement. However, there are some conflicts among these matches. Some of the potential loads are matched to more than one empty leg, while some empty legs are matched with more than one load. Roughly a third (181) of the empty legs could be allocated unique loads.

4.5.1.1 Backloading opportunities at sub-sector level

Table 4.3 shows that of the total 2957 trips selected for backloading analysis, over three quarters were at the secondary distribution level. There are clear distinctions in terms of average journey distance. Primary distribution has the longest average distance of 116 km per journey leg. Mixed distribution and secondary distribution have similar average distances in the sample (around 80km), while tertiary distribution has the shortest average distance of just about 50 kilometres.

Table 4. 3 . *Sample statistics at sub-sector level*

sector	average distance per leg (km)	number of legs	number of trips	
M	80.9	181	63	2.1%
P	116.0	814	293	9.9%
S	82.7	6,953	2,298	77.7%
T	49.9	1,046	303	10.2%

Table 4. 4 . *Backloading opportunities at sub-sector level*

Frequency		**Matched Loads**					
		M	**P**	**S**	**T**	**Total**	
Empty Legs	**M**			1		1	0.6%
	P	1	23	24		48	26.5%
	S		22	99	3	124	68.5%
	T		2	6		8	4.4%
	Total	1	47	130	3	181	
		0.6%	26.0%	71.8%	1.7%		100.0%

Table 4.4 shows the opportunities of backloading at sub-sector level based on location screening. Most of the backloading opportunities are arise from primary and secondary distribution. Over two-thirds of them are within the same sub-sector. Secondary distribution provides about 50% of the backloading opportunities for primary distribution and obtains about 18% of its backloading opportunities from primary distribution. Other matches (about one-third of the total) are between other pairs of sectors. In the sample, the backhaul opportunities for the mixed and tertiary distribution account for only 5% of the total.

4.5.1.2 Backloading opportunities at company level

Sample statistics at company level are shown in Table F.1 in Appendix F. The sample is largely skewed by one company, which accounts for a large proportion of the sample of empty legs for backloading analysis. (12 of the fifteen fleets which this company committed to the 2003 KPI survey were included in the backloading analysis.) This company has an extensive distribution network across the UK. Analysis of its KPI data reveals the extent to which backloads can be generated internally within a large companies' distribution systems.

As shown in Table 4.5, there are wide variations of backloading opportunities among the thirteen sample companies in terms of both the number of backloads carried and provided. The dominant company could have obtained 71 matched loads internally, accounting for about 40% of the total backloading opportunities. This company attracted 35% potential backloads from other companies. It provided 32 backloads for other companies' transport operations.

4.5.1.3 Backloading opportunities within a company's operation

The internal opportunities for backloading were examined in detail for the company with twelve fleets in the sample. As shown is Table 4.6, a third of the backhaul opportunities were within these fleets, the remainder between fleets.

Backloading opportunities were not proportional to the size of fleets in the sample. They are much more closely related to the geographical distribution of the company's warehouses. The biggest fleet in the sample, fleet9_3, could have found more loads than other fleets; it is also the biggest generator of loads for other fleets. However, fleet9_12 with only 3% of trips in the sample could have obtained 18% of the loads. It is also shown that there is strong connection between fleets based at particular pairs of depots. The existence of such bonds between these fleets is mainly due to the close proximity of their vehicle base.

Interactive Analysis

The GIS interface allows the user interactively to search for backloading opportunities within particular areas, for particular fleets or companies and or even for individual empty legs. The screening results are stored in separate tables that can be displayed in table or form format as shown in Table F.1 and F.2 in Appendix F.

Table 4. 5 . *Backloading opportunities at company level*

Frequency		Matched Loads										
		1	3	4	6	8	9	10	11	12	13	Total
Empty Legs	1						4		1	1	2	8
	3	1	14			1	13	1	1	1	1	33
	4						3					3
	5						1					1
	6										1	1
	8		1				4	1				6
	9	2	13	3		4	71	1	2	1	12	109
	10		1			1	1	1				4
	11		1				2					3
	12		1				1			2		4
	13	1	1		1		3			1	2	9
	Total	4	32	3	1	6	103	4	4	6	18	181

Table 4. 6 . *Backloading opportunities within a company's operation*

Frequency		**Matched Loads**										
		9_1	9_10	9_11	9_12	9_2	9_3	9_4	9_5	9_8	9_9	Total
Empty Legs	9_1	1										1
	9_10		3								3	6
	9_11			2						1		3
	9_12				4			9				13
	9_2						7					7
	9_3					6	7		1			14
	9_4				5							5
	9_5		1				1		4		1	7
	9_6							1			1	2
	9_8			4								4
	9_9		3					1	1	2	2	9
	Total	1	7	6	9	6	15	11	6	3	7	71

4.5.2 Vehicle compatibility screening

Assumptions about vehicle compatibility

The following are the main factors affecting vehicle compatibility: the number of compartments, temperature ranges and the cost and time required to change from one temperature to another in order to meet customer requirements. The industrial partners provided advice on the rules applied for compatibility screening. In the transport KPI data base food products are classified into three temperature categories: ambient, chilled, or ambient. As explained more fully in Section 5, one of the limitations of the KPI survey was its failure record in the trip audit whether or not a vehicle was refrigerated and how many temperature control compartments it had. A vehicle's ability to carry chilled or frozen product was inferred from the nature of the load carried on earlier journey legs.

If one type of products (frozen, chilled, or ambient) was recorded on an earlier leg, it was assumed that there was one compartment on the vehicle capable of carrying products at that temperature. If the vehicle carried ambient product, it was assumed that there was no temperature-control equipment installed and so only ambient backloads could be assigned. If, on the other hand, the vehicle had previously carried chilled or frozen product, it could be used to carry an ambient, frozen or chilled backload. No mixing of the different categories of product was permitted.

If two types (in terms of temperature requirement) of products had been recorded on an earlier leg, it was assumed that there were two compartments on the vehicle. It was assumed, in this case, that the vehicle could be used to carry any combination of two different types of products. In cases where three types (in terms of temperature requirement) of products had been recorded on a previous leg, a backload comprising three types of product was permitted.

Screening Results

Of the 181 matched loads that met the location / direction criterion, 48 matches (26.5%) were constrained by vehicle compatibility and thus eliminated. This left 133 potential matches, accounting for about 23% of the sample of empty legs over 100 kilometres.

4.5.3 Vehicle capacity screening

Assumptions about vehicle capacity

It is assumed that for a vehicle to be able to take a backload, it must have adequate capacity to accommodate the entire load, thus eliminating a loaded journey. Capacity was measured in volume terms by the number of pallets that could be carried.

Screening Results

Screening results shows that of the 133 matched cases from the previous two levels of screening based on location / direction and vehicle compatibility, 72 matches (54%) were constrained by vehicle capacity and therefore eliminated. The remaining 61 potential load matches accounted for about 10.6% of the sample of empty legs over 100 kilometres.

4.5.4 Time screening

The fourth level of screening took account of scheduling constraints.

Assumptions about time window of outward loads

Tight scheduling of the next outbound delivery often prevents a vehicle from collecting a return load. In the KPI 2002 database, data is available on the time all empty vehicles arrived at their destination. It was assumed that this scheduled return time could be relaxed by a maximum of 2 hours. At the fourth level of screening, the collection of a backload was considered feasible if a vehicle could deviate from its direct return route, pick up and deliver the load and return to its base within 2 hours of the time it actually arrived there during the KPI survey.

Screening Results

Of the 61 load matches surviving the three previous levels of screening based on location / direction, vehicle compatibility and vehicle capacity, 47 matches (77%) were constrained by the delivery schedule and therefore are eliminated. This left only 14 potential load matches accounting for about 2.4% of the sample of empty legs over 100 kilometres.

4.6 POTENTIAL SAVINGS

One objective of the backloading analysis was to estimate the potential savings in empty mileage, fuel consumption, emissions and cost that would accrue from improved backloading. The estimates presented in Table 4.7 relate only to load matches achieved at the highest level of screening, relating to location and direction. They shows that the average length of the matched empty legs is 140 kilometres, whilst the average length of corresponding empty legs in the opposite direction is 128 kilometres. On average, a vehicle needs to deviate a total of 48 kilometres in order to pickup and deliver a backload. Therefore, on average, if load matching can be achieved the average net reduction in empty running is 220 kilometres per match.

Further calculation reveals that, across the food distribution operations of the thirteen companies in the sample, it would be possible to reduce empty running by 39,820 km (13.7% of the total empty running in the sample). This would cut fuel consumption by 12,444 litres (worth £9,457 at fuel prices prevailing at the time of the survey) and CO_2 emissions by 33.1 tonnes.

Table 4. 7 . *Potential savings in empty mileage, fuel consumption, emissions and cost (based on location screening)*

Reductions in empty running, fuel consumption, emissions and cost for sample fleets over 2 day period		
Number of unique matches		181
Average length of matched empty legs	Km	140
Average length of empty legs in reverse direction	Km	128
Average deviation distance	Km	48
Average reduction in empty running per match	Km	220
Total reduction in empty running	Km	39,820
% of total empty running for sample fleets	%	
Reduction in fuel consumed	Litres	12,444
% of total fuel consumption	%	
Fuel cost saving	£	9,457
Reduction in CO2 emissions	Tonne	33.1

SECTION 5. LIMITATIONS OF THE TRANSPORT KPI SURVEY DATA

The analysis of routing efficiency and backloading potential used data that was not specifically collected for this purpose. As explained in Section 1, the survey was designed to collect standardised vehicle operating data that could be used to benchmark the efficiency of companies' road freight deliveries. The inclusion of post-code data on trip origins and destination, upon which the spatial analysis of routing and backloading is based, was originally intended merely to provide validation of trip lengths or offer an alternative means of calculating these lengths where a company had failed to enter distance data into the trip audit spreadsheet.

As routing and backloading analysis was not in the original specification of the transport KPI survey design, it is hardly surprising that the content and structure of the resulting data-set is not ideally suited to this type of research. If the DfT and its industry partners wish to make the analysis of routing and backloading an explicit objective of future transport KPI surveys it will be necessary to change this specification in several ways.

In this section, we examine the limitations of the transport KPI data and explain how they might be overcome. The main limitations were as follows:

5.1 QUALITY OF THE POST-CODE DATA

Table 2.1 shows the proportion of journey legs for which various levels of post-code data were provided. To give the analysis an adequate degree of geographical resolution, it is necessary to have at least five digit post-codes, particularly in suburban and rural areas. Approximately 48% of journey legs met this requirement.

Consistency checks on the post-code data, however, revealed numerous anomalies. These were partly detected by comparing the calculated leg length based on post-code data with the distance entered in the spreadsheet. Mapping trips also revealed a significant number of anomalies. Some post-codes were simply invalid. Overall between 5 and 10% of post-codes contained an error. These anomalies are likely to have been the result of mistakes in the manual input of data by companies or in the customer data files from which post-code data were extracted. Correcting these anomalies proved a very time-consuming process and restricted the number of fleets that could be subjected to the routing efficiency analysis.

Apart from a general exhortation to companies to check the accuracy of post-code data more thoroughly, there is little that the survey organisers can do to improve this situation. The growth of vehicle tracking, however, is likely to increase the accuracy of geographical referencing. An increasing proportion of KPI data, particularly on vehicle positioning, will be captured from road telematic data-bases, avoiding the need for manual data entry or interfacing with customer data files.

This will also facilitate the supply of post-code data. Discussions with participating companies have revealed that assembling this data can be one of the most demanding parts of the data collection process. By imposing an additional burden on companies it may be deterring some from participating. In the interests of maximising the sample size and thus expanding the benchmark group, a case could be made for removing post-codes from the survey or at least making them optional. This would greatly constrain any future use of the software tools developed in this project and any repetition of the routing and backloading analysis.

5.2 DIFFERENTIATION OF DROPS AND COLLECTIONS

In the transport KPI survey, journey legs are defined by a change in 'load status' at origin and destination. In the trip audit spreadsheet, the change in load status is simply recorded as a change in the number of pallets and payload weight. In most cases the change in load status will result from goods being either loaded or off-loaded. At some locations, however, both a delivery and a collection occur. At supermarkets, for example, fresh supplies can be dropped and some returned product picked up for return to the RDC. If 20 pallet-loads were delivered and 3 pallet-loads collected, the change in load status would be recorded as 17 pallets with no specific reference made to the fact that a load was being collected. (The return of handling equipment and packaging waste is separately itemised). This failure to differentiate deliveries and collections makes it difficult to estimate accurately the current level of vehicle backloading.

It would require only a small modification to the trip audit spreadsheet to collect separate information about deliveries and collection.

5.3 MONITORING OF TRACTOR USAGE

The transport KPI surveys in the food sector have focused attention on the load carrying unit. This means that in the case of articulated vehicles, only the activities of trailers are recorded. No reference is made to tractor units. This creates a problem for the analysis of backloading potential because when assessing potential load matches it is important to know how tractors as well as trailers are scheduled. The time available to pick up a backload is usually influenced more strongly by the utilisation of the tractor than that of the trailer. The tractor, after all, is the more expensive asset and, combined with the driver, the unit with by far the highest time-related costs. The screening of backloading opportunities with respect to scheduling constraints could, therefore, be undertaken much more realistically if the use of tractor units, as well as trailers, was monitored.

The KPI surveys in the automotive and non-food retailing sectors monitored both tractor and trailer usage. Code numbers were used to identify tractors and trailers on every journey leg. This appears to have worked quite effectively, though problems did arise when tractors were allocated to trailers outside the sample fleet and undertook trips that were excluded from the survey. With further refinement, the transport KPI methodology could provide a more comprehensive record of the activities of tractor units.

5.4 OPENING TIMES, TIME-WINDOWS AND DRIVER SHIFTS.

In the analysis of route optimisation, several scenarios were constructed to illustrate the effects of relaxing time constraints on delivery efficiency. In the absence of information about the actual opening times and delivery time windows at collection and delivery points and drivers' hours, hypothetical values had to be used for the various scenarios. The modelling would be much more realistic if companies provided information about the degree of delivery flexibility. It would be too much to expect respondents to define the delivery time-windows for every collection and delivery point. When completing the trip audit spreadsheet, they are currently asked to specify the scheduled arrival time. This could be changed to the earliest and latest arrival time that would be acceptable to the companies concerned. Allowance could also by made for the driver's shift patterns and legal driving hours. This would require only a modest adjustment to the spreadsheet, but significantly increase the data collection burden on companies. It is uncertain, too, if the staff entering the data would be able to judge the 'acceptable' degree of variability in delivery schedules.

5.5 DIFFERENTIATION OF TEMPERATURE-CONTROLLED VEHICLES

As currently constructed, the trip audit spreadsheet does not indicate if a trailer is refrigerated or compartmentalised for the distribution of loads at different temperatures on the same trip. Inferences can be made about refrigeration from load data. On each journey leg the number of ambient, chilled and frozen pallets is recorded. It is possible, however, that an ambient load might be carried in refrigerated vehicle, or that a vehicle carrying only, say, 12 pallets of frozen food has an empty chilled compartment. The situation is complicated by the length of time it takes to reduce the on-board temperature to the levels required to load frozen or chilled consignments. As a high proportion of road deliveries of food products in the UK are temperature-controlled, full account must be taken of vehicles' refrigeration capabilities when modelling backloading opportunities in this sector. More detailed specification of vehicle type is therefore required in the audit of trips.

5.6 NUMBER OF VEHICLES DEPLOYED ON A PARTICULAR DELIVERY OPERATION

Among the general fleet data collected in the first spreadsheet is information about the numbers and types of vehicle included in the survey. In the trip audit spreadsheet, however, no indication is given of the total number of vehicles deployed on a particular part of the delivery operation. This makes it impossible to compare the actual numbers of vehicles used to the optimum number of vehicles estimated by Optrak. This could be rectified by a minor redesign of the trip audit spreadsheet.

5.7 INSUFFICIENT DENSITY OF TRIPS

The effectiveness of the backloading analysis is critically dependent on the number of trips in the data-base. As discussed in the previous section, despite the relatively high level of industry participation in the 2002 transport KPI survey and many thousands of journey legs surveyed, the number of potential load matches only supported detailed analysis at the first level of screening, related to the location of origins and destinations. Extending the analysis to the lower levels of screening would require an order of magnitude increase in the trip density. One way in which this might be achieved would be to run several transport KPI surveys in different sectors simultaneously over the same two day period. This would also permit an analysis of cross-sectoral backloading opportunities.

Analysis of backloading potential on a sectoral basis may be justified in the case of the food industry because much of the distribution requires temperature-control. In other sectors, greater use is made of standard, non-refrigerated vehicles which could carry a broad range of commodities. For these sectors, it would make sense to pool trip data to achieve a wider assessment of backloading opportunities.

At present, only the transport KPI data-bases allow this type of analysis. By intensively surveying a large sample of vehicles over a very short time period, they achieve a much higher density of trips than the CSRGT. CSRGT surveys approximately 360 lorries at any given time, whereas the 2002 food KPI survey monitored the activities of almost 3600 vehicles over two days. The latter survey also collected information about the scheduling of trips, something which is excluded from CSRGT. It has been proposed that the questionnaire data collected by CSRGT could be supplemented by vehicle tracking data. This would offer a means of monitoring vehicle scheduling as well as increasing the sample size. It would, however, require a ten-fold increase in this sample size to offer a similar trip density to that achieved by the 2002 food KPI survey and several times this increase if several sets of KPI data from different sectors were combined. It is worth noting, however, that the future development paths of the CSRGT and transport KPI surveys may ultimately converge (Figure 5.1).

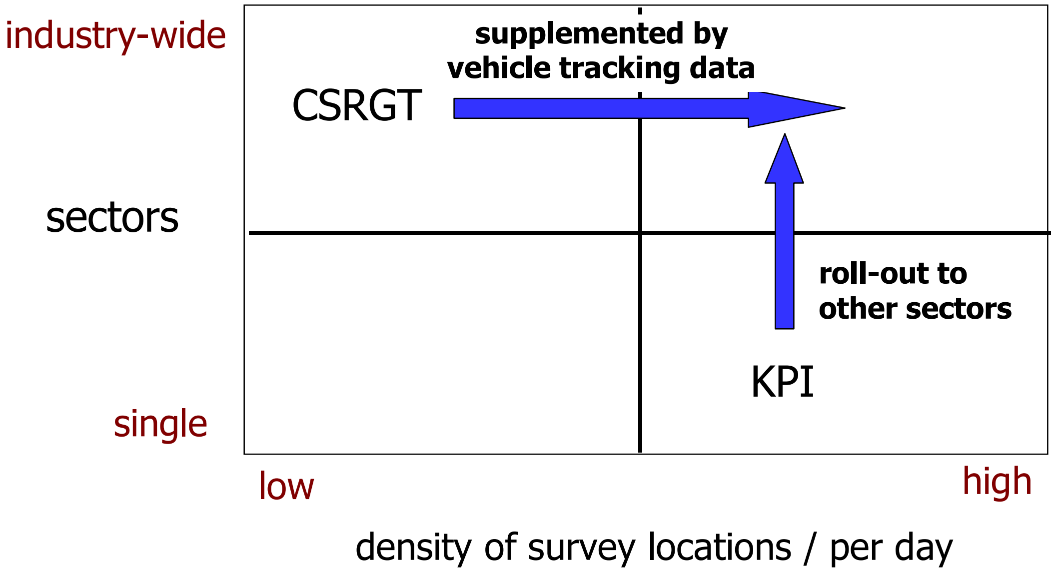


Figure 5. 1 . *Possible Development Paths for CSRGT and KPI Surveys*

SECTION 6. ASSESSING THE POTENTIAL FOR VEHICLE TELEMATICS SYSTEMS TO PRODUCE KEY PERFORMANCE INDICATORS

6.1 INTRODUCTION

The purpose of this part of the research was to examine the potential for Vehicle Telematics Systems (VTS) to provide accurate data that can be used to derive specific Key Performance Indicators (KPI's), in line with those used in the 2002 food transport KPI survey.

Those KPI's were: -

- Vehicle capacity utilisation
- Empty Running
- Time utilisation
- Deviation from schedule
- Fuel efficiency and energy intensity

Vehicle tracking systems will be required to provide information on ten factors to allow the calculation of these five KPI's.

Information on the following factors is required: -

- Vehicle capacity (weight)
- Vehicle capacity (volume/floorspace)
- Length of leg
- Length of trip (a combination of legs)
- Planned route/timings
- Actual route travelled
- Start/end times for each leg/trip/period of activity/inactivity (and reason)
- Weight/volume of goods carried at all times
- Fuel consumed
- Total distance travelled

It was also of importance to establish the nature of the data handling process and the methods employed to transfer data between the VTS and external software systems.

6.2 METHODOLOGY

The collection of primary data involved telephone interview surveys of samples of providers and users of VTS. These were supplemented by several face to face interviews to gain a deeper insight in the supply and demand for VTS services.

6.2.1 Population and Sample

1. Suppliers of Vehicle Telematics Systems

Given the relatively small number of VTS suppliers in the UK, it was decided to approach the entire population of companies, removing the need for sampling. Contact details for these suppliers were obtained from the Transport Energy Best Practice 'Telematics Guide'. Further research into potential respondents was carried out using the Internet and relevant trade publications.

The population was finally established at 47 potential suppliers. This figure is in a constant state of flux due to the volatility of the marketplace. In recent months there have seen several mergers, some new business start-ups and some suppliers who have ceased to trade. 33 suppliers took part in the survey. 10 of the companies contacted are not directly involved in the UK market. These suppliers either did not have a UK sales office, were equipment manufacturers whose route to market was through resellers, or who did not offer a VTS service relevant to the present study. Four suppliers failed to respond despite numerous contact attempts. The overall response rate from relevant suppliers was 89.2%. This was very high for a survey of this type and reflects the high level of interest in research of this type in the VTS sector.

Each supplier was investigated using the Internet. A subjective ranking was established based on the information contained within each supplier's website. At this stage, suppliers identified as not being directly involved in relevant VTS activities were excluded from the survey. A contact database was set up for the remaining companies in order to manage the telephone survey.

6.2.2 Questionnaire

A questionnaire was constructed which addressed the following issues:

- the level of technical sophistication
- data handling processes
- ability to provide data required for KPI analysis
- interfacing with 3rd party software systems
- methods of data analysis
- KPIs currently calculated
- benchmarking services

The questionnaire was piloted in several ways:

Timed face-to-face question and answer sessions with staff in the LRC

Simulation of telephone survey in typical conditions with a spokesman from Isotrak.

Feedback from Isotrak after an internal review of the questionnaire.

A copy of the questionnaire can be found in Appendix G.

2. Users of Vehicle Telematics Systems

Within the road freight sector, the population of potential users of VTS comprises in excess of 100,000 businesses. These are companies that hold an Operators Licence that enables them to operate vehicles in excess of 3.5 tonnes gross vehicle weight for either hire or reward or in connection with a trade or business. Approximately 88% of Operator Licence holders operate fewer than 5 vehicles, this probably being the lower limit for profitable use of a VTS. This leaves approximately 12,500 businesses for which the installation of VTS could be commercially justified. Given such a large population, and limited resources available to carry out the survey, it was decided that stratified sampling based on fleet size and the number of fleets in each size band would be attempted.

It is difficult to determine in advance which companies' fleets are fitted with VTS. The only reliable source of such information was the testimonial sections of each supplier's website. It was not deemed appropriate to approach suppliers directly to ask about their customer base, partly as this could produce biased results.

Ultimately a sample of 81 companies using VTS were contacted, 32 of which agreed to take part in the survey (39.5%). This is a significantly lower response rate than that for suppliers, and can be attributed mainly to the difficulty of identifying the correct individuals with the companies and respondents lacking the time to participate.

6.2.3 Questionnaire

The development of the questionnaire for users was broadly similar to that for the suppliers. It was of interest to establish a fleet profile and to determine whether this influenced the choice of VTS supplier. Of particular interest was the use being made of the VTS to derive KPI s and the use of these KPIs for benchmarking purposes.

The Questionnaire for users of VTS is found in Appendix H.

6.2.4 Collection of Data Sections 1 & 2

Telephone survey scripts were prepared to ensure accuracy and consistency during the telephone survey. This included an introductory section that outlined the reasons for the survey. A separate questionnaire was printed for each respondent and their answers noted during the telephone conversation.

After each interview the responses were transferred to an MS Excel spreadsheet. Any additional comments were noted alongside with the respondent's answers to specific questions. Most of the interviews with semi-structured which answers to the pre-prepared questions supplemented by additional points raised by the respondent.

The interview data was collated into one Excel file in which the analysis was carried out. The results of the analysis are summarised in the following section.

6.3 ANALYSIS AND INTERPRETATION OF THE RESULTS

6.3.1 1. Suppliers of Vehicle Telematics Systems

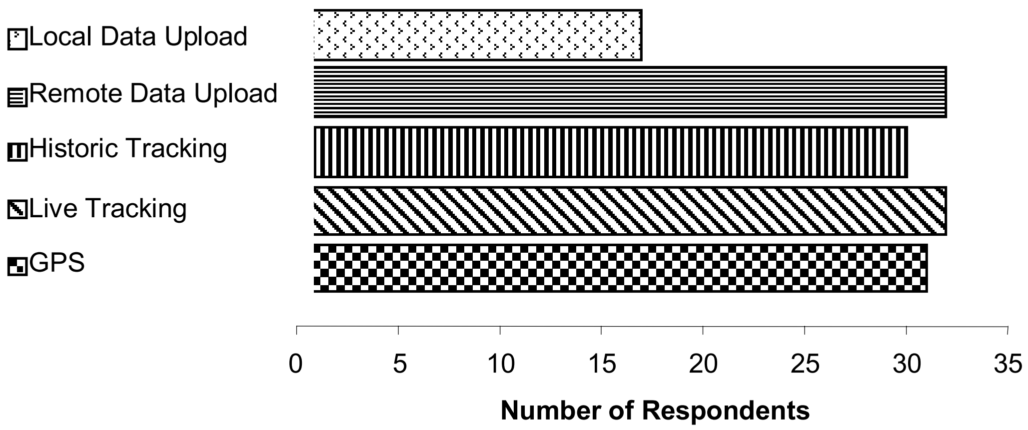


Figure 6. 1 . *Basic Service Offering*

The basic service offering relates to the functionality of the VTS. The majority of systems surveyed use the Global Positioning System (GPS) for locating the vehicle (Figure 6.1). Only one company employs a different method that uses an independent network of beacons that are used both to triangulate the vehicle's position and to provide a communications medium.

The potential to track a vehicle's position in a live environment (i.e. while the vehicle is running on the road) is critical for some user applications. In addition, in order to enable KPI monitoring it is necessary to have a continuous record of vehicle movement. Historic tracking of the vehicle (the so-called 'snail-trail') is therefore vital. This however requires the uploading of a large volume of data from each vehicle, and can substantially increase communications costs. While all systems allow for the remote uploading of data, only 17 (52%) of them allow for local data uploading at the vehicles base, making use of a local data connection (cable or local area network).

There is no particular advantage in the ability to derive KPI values in a live environment. This can be done retrospectively. The upload of the large amounts of tracking data required for the calculation of KPIs can, therefore, be delayed until it is economical to do so.

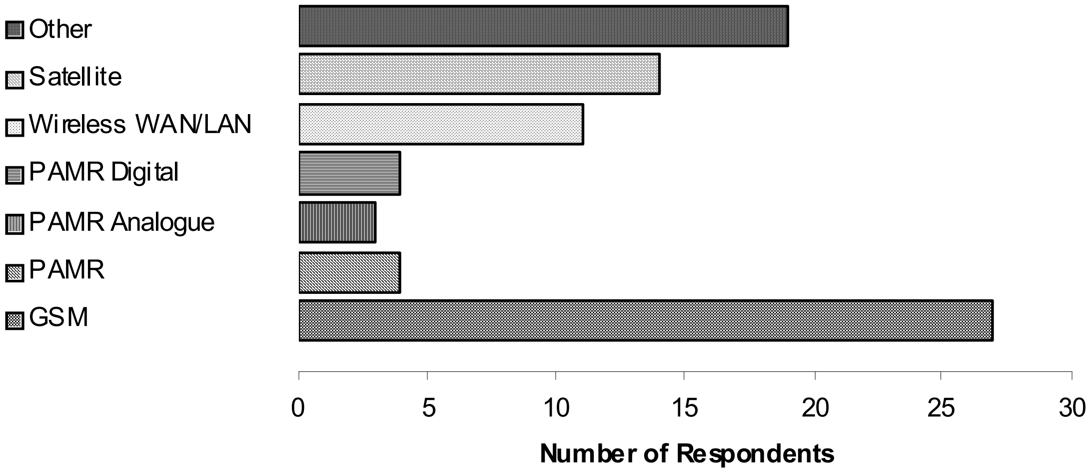


Figure 6. 2 . Communications Capability

The different methods of communication between the vehicle and its base will result in different running costs (Figure 6.2). The most popular method (use by 27 suppliers) uses the GSM telephone network, however this is expensive for large data transfers. There are 19 suppliers which now offer the newer GPRS network, and this allows for larger amounts of data transfer for a relatively low monthly cost (from £1 per megabyte per month)

Several suppliers offer the ability to tailor the communications medium to the specific needs of the customer. Fourteen offer the customer the opportunity to use satellite networks for communications purposes, however this can be expensive, depending on the data transferred.

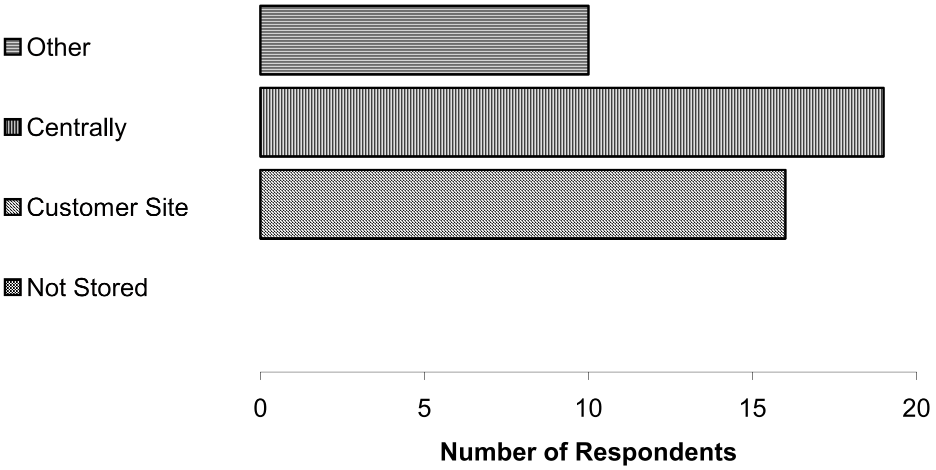


Figure 6. 3 . Data Storage

Data must be stored in order to make it available at a later date for processing and interpretation (Figure 6.3). The method and location of data storage has an impact on its accessibility for subsequent analysis. Inconsistencies emerged in suppliers' responses to questions about data storage. 21 of the suppliers (68%) claimed that they store the data at the customer's site, while 24 (78%) indicated that the customers directly transferred the data from their vehicles to their sites. There seems to be some confusion on this issue.

Another inconsistency arose on the centralisation of data storage (Figure 6.4). 24 companies (78%) claim to store the data centrally, while 26 (84%) claim to be able to make it available via a web-based bureau. In order to do this it would be necessary to have the data stored centrally.

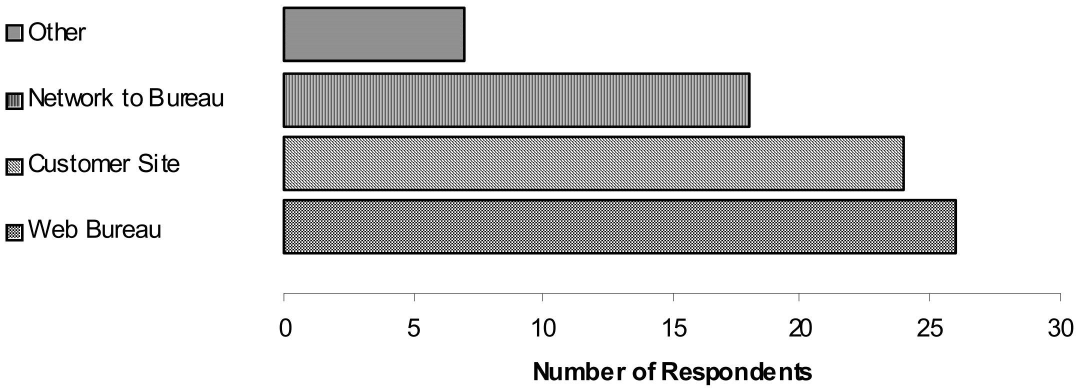


Figure 6. 4 . *Data Access*

It is apparent that the data is reliably stored in some location other than on the vehicle for the majority of systems. One can assume therefore that in all cases any data collected is available for the derivation of KPI's.

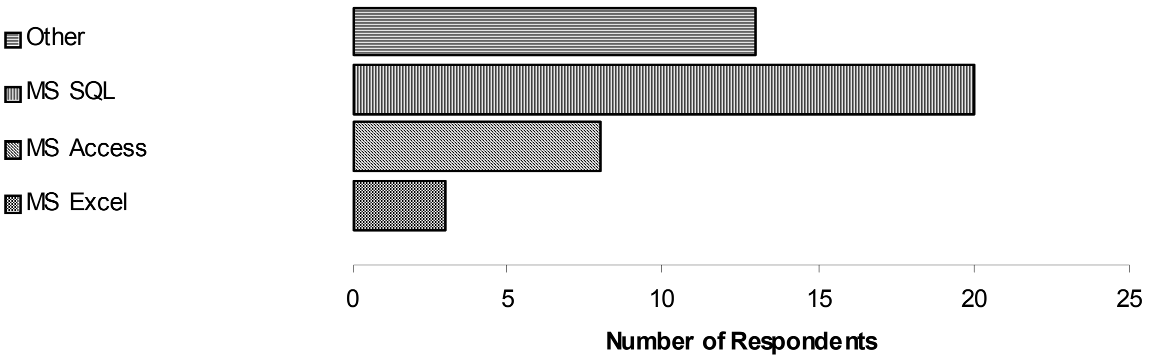


Figure 6. 5 . *Database Type*

In every case, the databases used conform to standard formats, requiring no specialised hardware to run (Figure 6.5) . Four companies offer the ability to use Enterprise Resource Planning (ERP) software databases, such as SAP or Oracle, whilst two use their own proprietary database systems for security reasons.

Twenty-eight (85%) of the suppliers offer the means of downloading raw data in the standard Comma Separated Value (CSV) format. Three-quarters of the companies surveyed also support other forms of data download into other software packages. It should be noted that two suppliers indicated that printed reports were the supported method of data export. This would be acceptable if the reports could be customised to produce the relevant KPI's. In summary, considerable flexibility exists for the export of raw VTS data to standard software programmes for manipulation and processing.

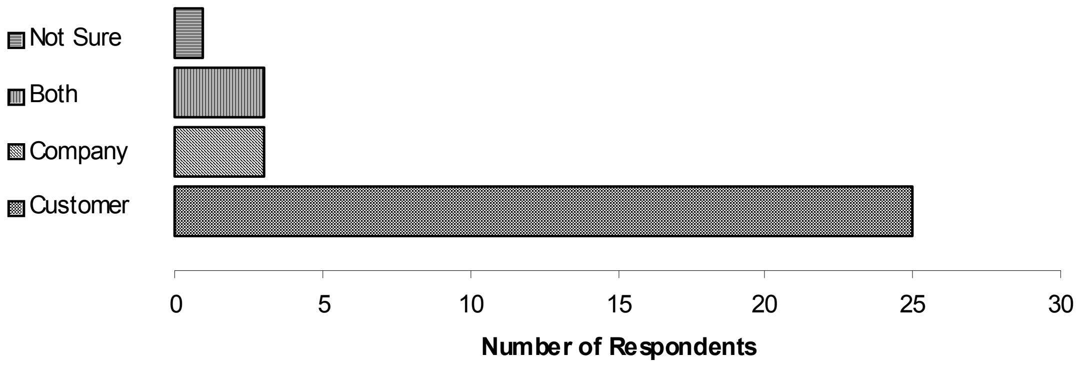


Figure 6. 6 . *Data Ownership*

The issue of data ownership, whilst not directly affecting the derivation of KPI's, is nonetheless relevant. 25 suppliers (81%) said that the customer owns the data, whereas 3 (10%) said they did and 3 thought that it was owned jointly (Figure 6.6). There is however another possibility – that the owner of the goods being carried has a stake in ownership. This will perhaps depend on the nature of the relationship between carrier and consignor, and whether the consignor was influential in the carrier's decision to invest in a VTS.

Tables 5.1 and 5.2 display the range of specific data values that are required in order to derive the five KPIs used in the 2002 transport KPI survey. 18 suppliers (58%) claimed to record sufficient data to derive these KPI's, in some cases through adding data obtained from an interfaced routing and scheduling software system. In analysing the survey responses, however, it is apparent that several suppliers require the use of additional devices in order to derive load weight and/or volume information. Whilst this may be technically possible, it is unlikely that many customers would be prepared to bear the additional capital cost of installing load sensors in each vehicle.

Only 9 suppliers (29%) linked their VTS to the vehicle's CANBUS system to record information from the vehicle management system. This would include data such as engine hours and idle time, fuel consumption, over-revving, gear changes and more. It is possible to derive fuel consumption by other means, using a fuel flow meter for example, or by analysing fuel drawn compared with distance driven. The additional expense of a fuel flow meter is, again, not one that is common amongst users of VTS.

Clearly, the majority of suppliers rely on the use of additional sensors to determine vehicle telemetry data and this is 'customisable' by the user at additional expense. At present, therefore, that the majority of VTS suppliers fall well short of providing the necessary data to calculate the five KPIs.

All the VTS suppliers are able to collect core data on vehicle movement, position, speed and direction of travel, derived from GSP. The GPS receiver is in effect an external sensor linked to the VTS. Its functionality determines the available data. All 31 suppliers claim to be able to determine the start and finish points for each leg, the time, date and position of each event. These are recorded automatically by the system (Figure 6.7). This is vital in order to determine 4 of the 5 KPI's listed above.

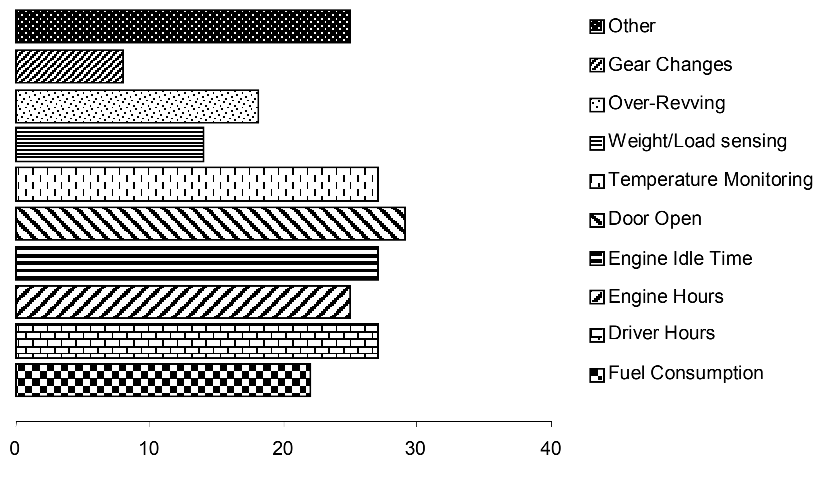


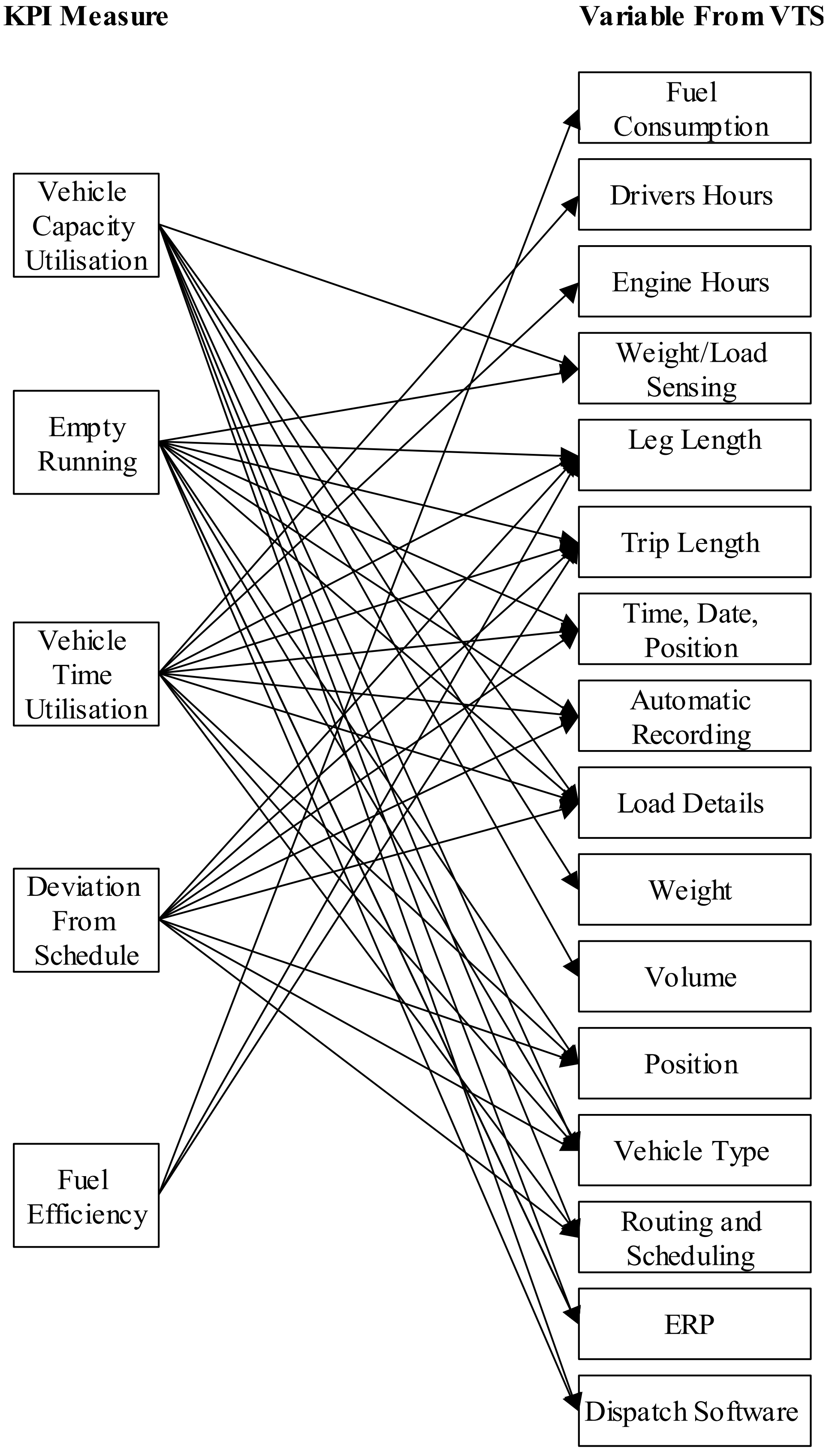
***Figure 6. 7 .** Vehicle Telemetry Data Collected*

Table 5. 1 . *KPI’s derived from telematics data*

KPI	Capacity Utilisation	Empty Running	Time Utilisation	Deviation From Schedule	Fuel Efficiency
Factors Required	**4**	**8**	**10**	**8**	**2**
Company 1	*(1)*	*(6)*	*(8)*	*(7)*	**2**
Company 2	*(2)*	*(6)*	**10**	**8**	**2**
Company 3	*(1)*	*(6)*	*(8)*	*(6)*	*(1)*
Company 4	*(1)*	*(5)*	*(5)*	*(5)*	**2**
Company 5	*(1)*	*(6)*	*(9)*	*(7)*	*(0)*
Company 6	*(1)*	*(5)*	*(6)*	*(5)*	**2**
Company 7	*(0)*	*(5)*	*(7)*	*(5)*	**2**
Company 8	*(1)*	*(6)*	*(9)*	*(7)*	*(1)*
Company 9	*(1)*	*(6)*	*(9)*	*(7)*	**2**
Company 10	*(2)*	*(6)*	*(9)*	*(7)*	**2**
Company 11	*(1)*	*(6)*	*(9)*	*(7)*	*(1)*
Company 12	*(1)*	*(6)*	*(8)*	*(7)*	*(1)*
Company 13	*(1)*	*(6)*	*(6)*	*(6)*	*(1)*
Company 14	*(2)*	*(5)*	*(7)*	*(5)*	*(1)*
Company 15	*(2)*	*(7)*	*(9)*	*(7)*	**2**
Company 16	*(1)*	*(6)*	*(9)*	*(7)*	*(0)*
Company 17	*(0)*	*(4)*	*(5)*	*(5)*	*(1)*
Company 18	*(2)*	*(6)*	*(7)*	*(7)*	**2**
Company 19	*(1)*	*(5)*	*(7)*	*(6)*	*(1)*
Company 20	*(2)*	*(7)*	*(9)*	*(7)*	**2**
Company 21	*(1)*	*(6)*	*(9)*	*(7)*	*(1)*
Company 22	*(1)*	*(6)*	*(9)*	*(7)*	**2**
Company 23	*(3)*	*(7)*	**10**	**8**	**2**
Company 24	*(2)*	*(7)*	*(9)*	*(7)*	**2**
Company 25	*(2)*	*(6)*	**10**	**8**	**2**
Company 26	*(2)*	*(7)*	*(9)*	*(7)*	**2**
Company 27	*(2)*	*(7)*	**10**	**8**	**2**
Company 28	*(3)*	*(7)*	**10**	**8**	**2**
Company 29	**4**	**8**	**10**	**8**	**2**
Company 30	*(3)*	*(7)*	**10**	**8**	**2**
Company 31	*(1)*	*(6)*	*(8)*	*(6)*	**2**
Company 32	*(3)*	*(7)*	*(9)*	*(7)*	**2**
All KPI's Available	**1**	**1**	**7**	**7**	**21**
All KPI's Claimed	**7**	**13**	**23**	**18**	**18**

Bolded numbers indicate full set of variables for the KPI. Figures in brackets show the number of variables that can be monitored where this is less than the full set.

Table 5. 2 . *Variables required to derive KPIs*



Again, all suppliers have data regarding the position of the vehicle using x-y co-ordinates, which is the most readily used geo-coding format for this data (Figure 6.8). 29 companies (94%) store data relating to the vehicle itself (model, load capacity, body type). Whilst this is acceptable for rigid vehicles, it does not necessarily allow for the varying types of trailer that a tractor unit may haul during daily operation. A link to external data is needed to determine which trailer type is being used. This will be discussed in more depth in Section 6.3.2.

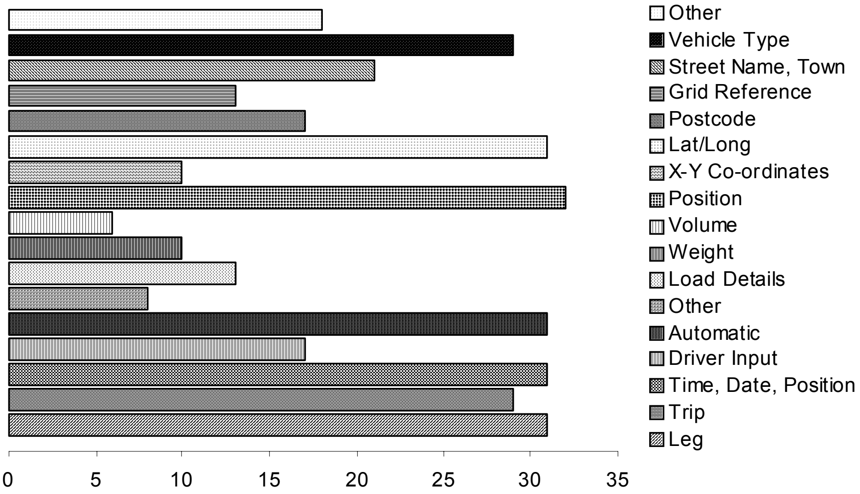


Figure 6. 8 *. Stored Data Contents*

The ability to determine the weight and/or volume of load is fundamental to the calculation of several of the KPI values: vehicle capacity utilisation, empty running and energy intensity.

Although not directly collected by the VTS suppliers, this data may be available from other sources. It is often contained in other transport management software packages, particularly those relating to routing and scheduling.

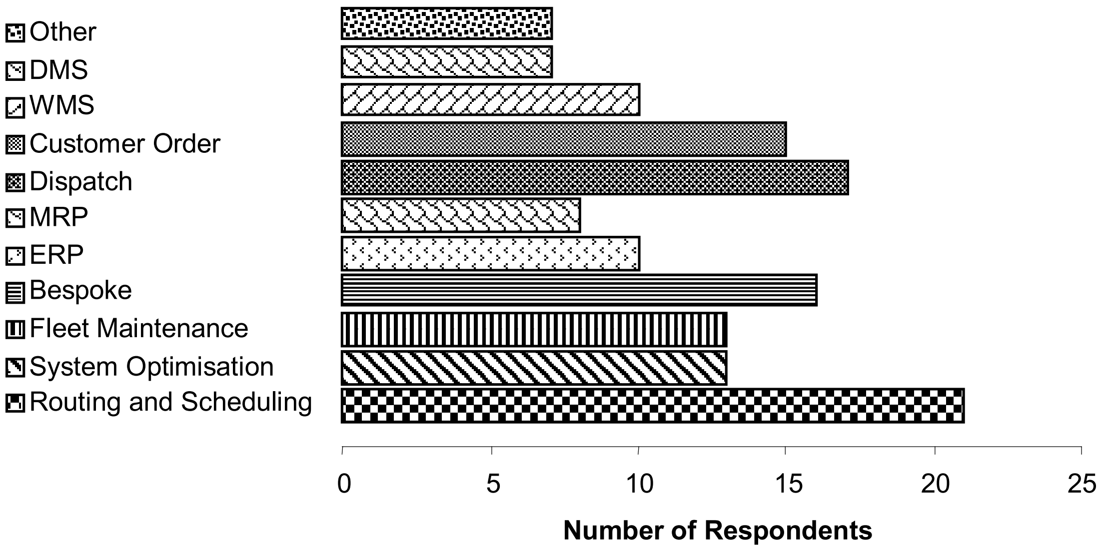


Figure 6. 9 . *Software Interfacing*

21 suppliers (68%) said that their VTS system could interface with other commercially available routing and scheduling software packages (Figure 6.9). (One supplier thought that 'Autoroute Express' was a routing and scheduling package!) Data relating to load weight and volume may also be contained within other software systems some of which can be interfaced with VTS (Figure 6.10).

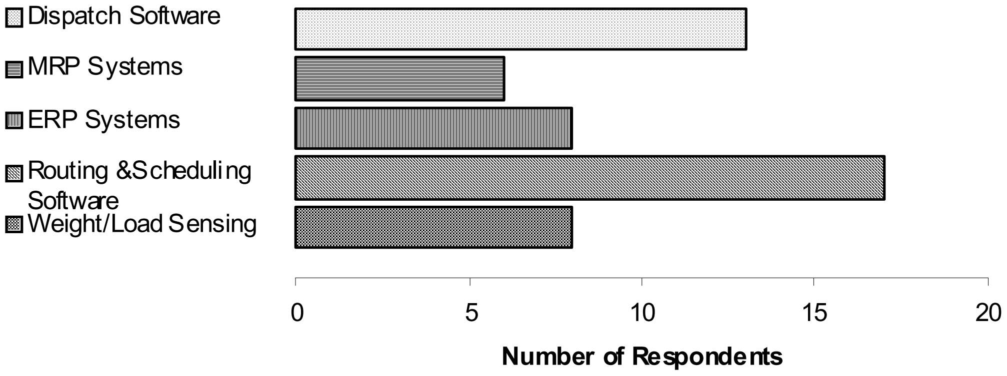


Figure 6. 10 . *Ability to Determine Load Weight and Volume*

It may also be possible to determine which trailer is assigned to a tractor unit using the data provided by one of these software systems. This too would enable the derivation of the KPI's.

The KPI measures derived from the data held by VTS suppliers differ in a number of respects from the KPIs calculated by the 2002 KPI survey. When asked what KPI values are currently calculated for / by customers on the basis of VTS data, companies identified the following:

- Time on site.
- Speeds: - average, maximum.
- Trips/day/week.
- Idle time.
- Response Times.
- Proof of Location.
- Driver based reports.
- Total work hours.
- Overspeed.
- Mileage/hours utilisation.
- Harsh braking.

While these KPI's may be relevant to particular operations, they do not provide a complete and measurable picture of vehicle asset utilisation. Several of these indices can be combined to assess driver performance in terms of fuel efficiency. None of the currently available VTS services, however, permit the calculation of energy intensity values, which are influenced at least as much by the loading of the vehicle as by fuel efficiency.

Of the KPIs monitored in the 2002 KPI's, vehicle time utilisation was the one that the largest number of VTS suppliers measure (74%). Of these, 16 (52%) were able to differentiate between tractor and trailer time utilisation (Figure 6.11). In the 2002 food KPI study, time utilisation related to that of the trailer, not the tractor unit. Whilst trailer tracking devices are available, they are certainly not as widespread as those fitted to tractor units. VTS can detect whether a trailer is connected to a tractor, but at present cannot identify which trailer is connected.

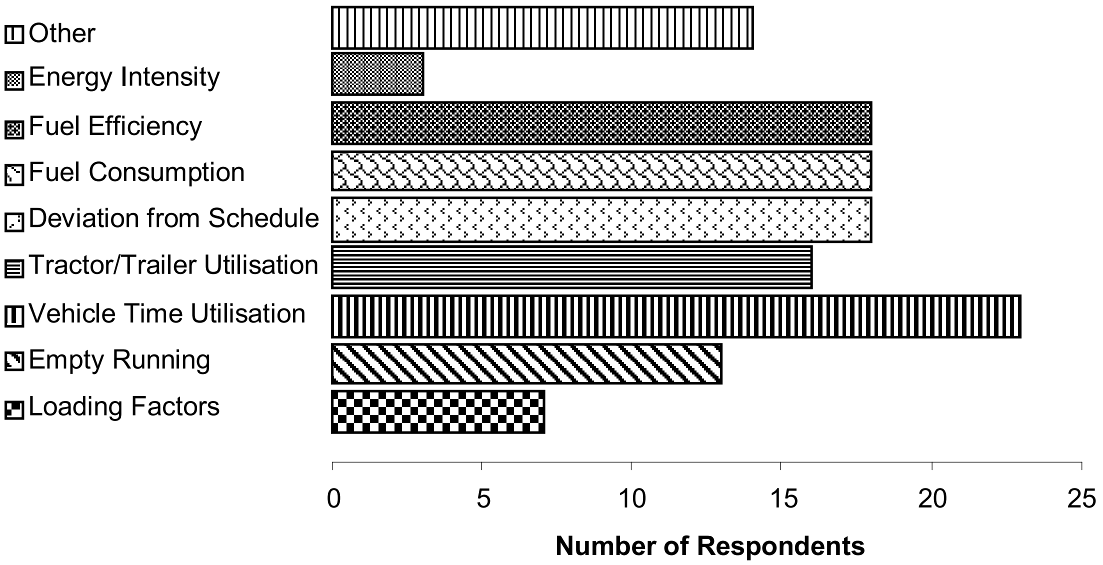


Figure 6. 11 . *KPI Measures*

The relevance of differentiating between tractor and trailer time utilisation will depend on the nature of the operation (loading/unloading times, idle time, trailer loaded waiting to depart, etc), and the ratio of trailers to tractor units (the ‘articulation ratio’). For example, a company operating a small fleet with an articulation ratio of 1.1:1 trailers: tractor units will have little need to differentiate between tractor and trailer time utilisation. On the other hand, a large supermarket chain with a ratio 3:1 would have a much greater need for this service.

Relatively few suppliers (23%) were able to provide vehicle capacity utilisation data (referred to as ‘loading factors’ in the Figure 6.11). Fuel consumption and deviation from schedule scored fairly well with 18 suppliers able to provide these KPI’s. Only 3 (10%) were able to provide the energy intensity estimates, reflecting most companies inability to monitor vehicle loading.

The customisation, analysis and benchmarking of the KPI’s is critical to ensure meaningful management reporting and response. All the suppliers claimed to perform retrospective analysis of the data as part of their service, through reporting procedures set up at installation. Only three suppliers (10%) said that the retrospective analysis was not perceived as being valued by the customer.

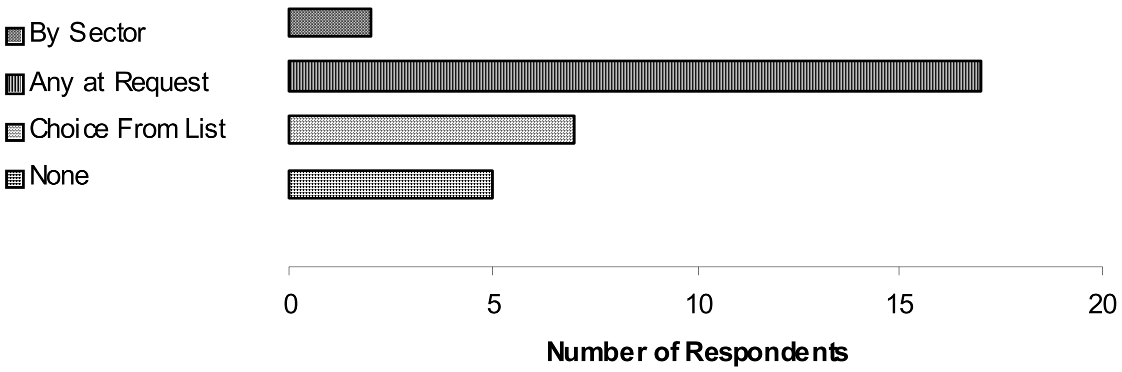


Figure 6. 12 . *KPI Customisation*

Seventeen of VTS suppliers (55%) claim that they can provide any KPI by customer request (Figure 6.12). One must question whether this response is based on the desire to give the answer perceived to be the best, and not necessarily a true reflection of what companies are capable of providing. Five suppliers do not offer any KPI customisation.

Nine out of ten of the suppliers claimed to be 'proactive in identifying potential efficiency improvements' (Figure 6.13). There is however little data to support this claim. Eleven (35%) offer a benchmarking service. Eight of them restrict this to an internal comparison of individual companies' transport operations. The other three offer an 'external' benchmarking service that encompasses all fleets. This may, nevertheless, be limited value as the all-fleet averages are unlikely to be meaningful comparators for a particular company's transport operation.

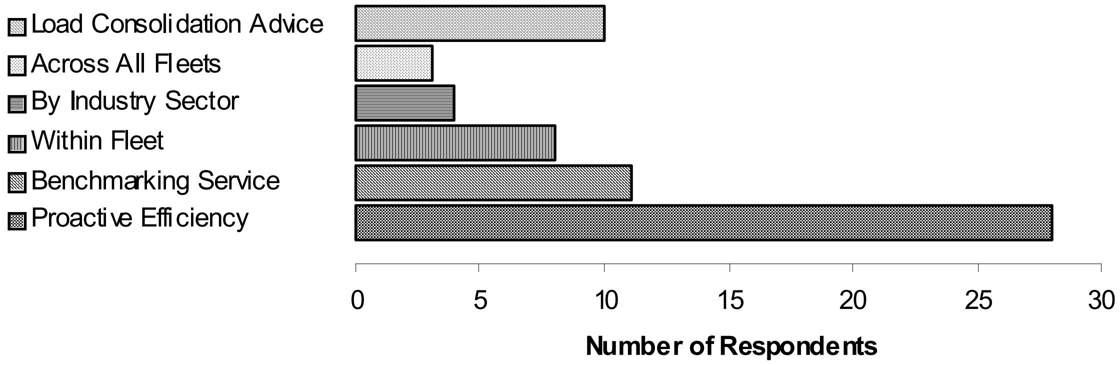


Figure 6. 13 . *Benchmarking Services*

The ability to determine KPI's from the data contained within VTS depends on the extent of integration with other software packages. VTS contain much of the necessary data; however there is little evidence to suggest that suppliers are able to deliver, or even aware of, the 5 KPI's monitored in the 2002 survey (and the other TransportEnergy-sponsored KPI surveys).

Overall, the survey found that there are 4579 fleets fitted with vehicle telematics systems comprising a total of 127,555 vehicles. On the basis of the survey data, it is not possible to disaggregate these fleet and vehicle totals by vehicle type. Some suppliers operate in several market segments within the UK and have installed VTS in a range of vehicles, including cars, vans, taxis, emergency services and security vehicles, airport ground support equipment as well as trucks over 3.5 tonnes gross weight.

6.3.2 Users of Vehicle Tracking Suppliers

Figure 6.14 shows the composition of the sample of VTS users, split into four categories: own account, small hauliers (less than 140 vehicles), large hauliers (more than 140 vehicles) and Third Party Logistics providers. (The figure of 140 vehicles was adopted by Peters et al in their European Survey of VTS to divide hauliers into 'small' and 'large' categories). Overall, 58% of the respondents operated fewer than 50 trucks, 19% between 50 and 140 and 23% over 140.

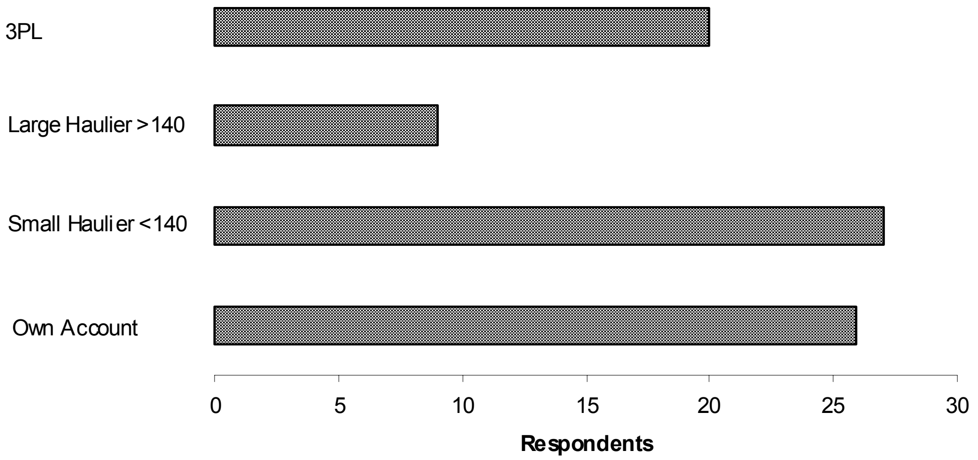


Figure 6. 14 . *Composition of the Sample of VTS Users*

Figures 6.15 depicts the breakdown of respondents by total size of fleet operated.

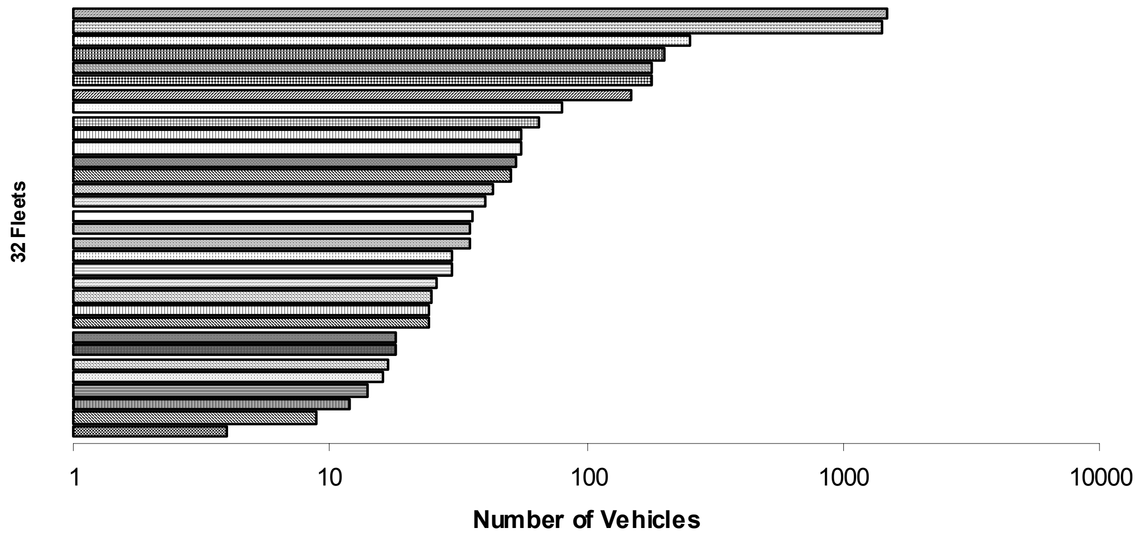


Figure 6. 15 . *Numbers of Vehicles Operated by Sample of VTS Users*

Figure 6.16 shows the number of user responses disaggregated by VTS supplier. Altogether ten VTS suppliers were used by companies in the sample. A disproportionately large number of users employ one of the suppliers. Figure 6.17 shows the number of vehicles fitted with VTS by three of the main suppliers; the 'others' group comprising the remainder of suppliers.

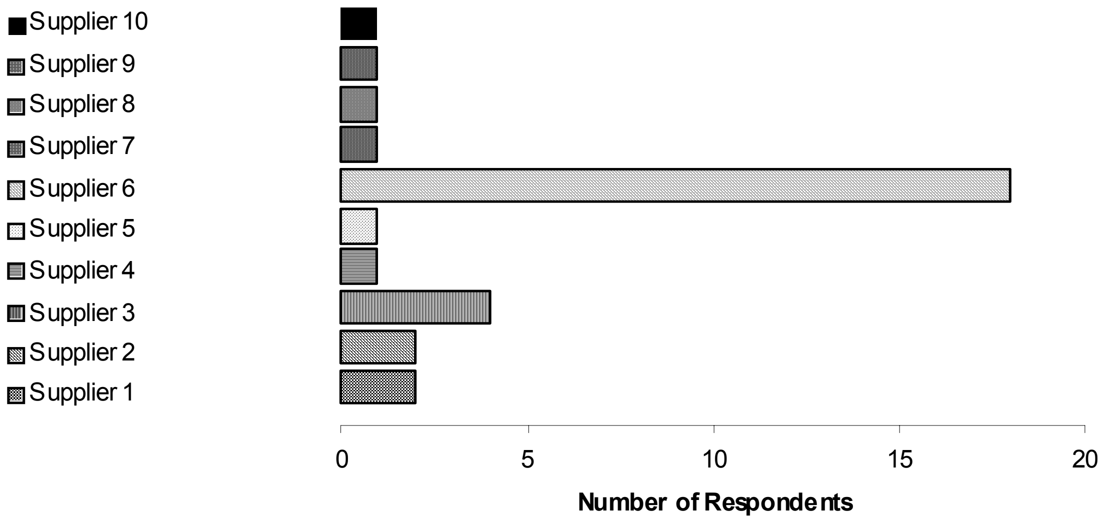


Figure 6. 16 . *VTS Suppliers Employed by Sample of Users*

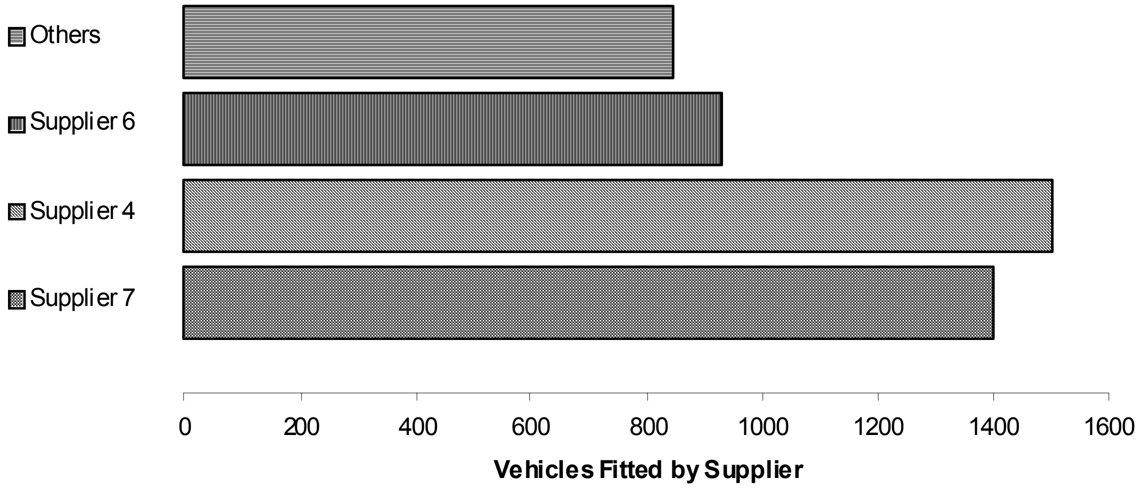


Figure 6. 17 . *Nos. of Vehicles Equipped with VTS Equipment by Particular Suppliers*

User companies were asked to describe main type of distribution activity (Figure 6.18). Several companies are active in more than one type of operation. No single type of operation was particularly dominant. Multi-drop, primary and secondary distribution and general haulage were all well represented in the sample.

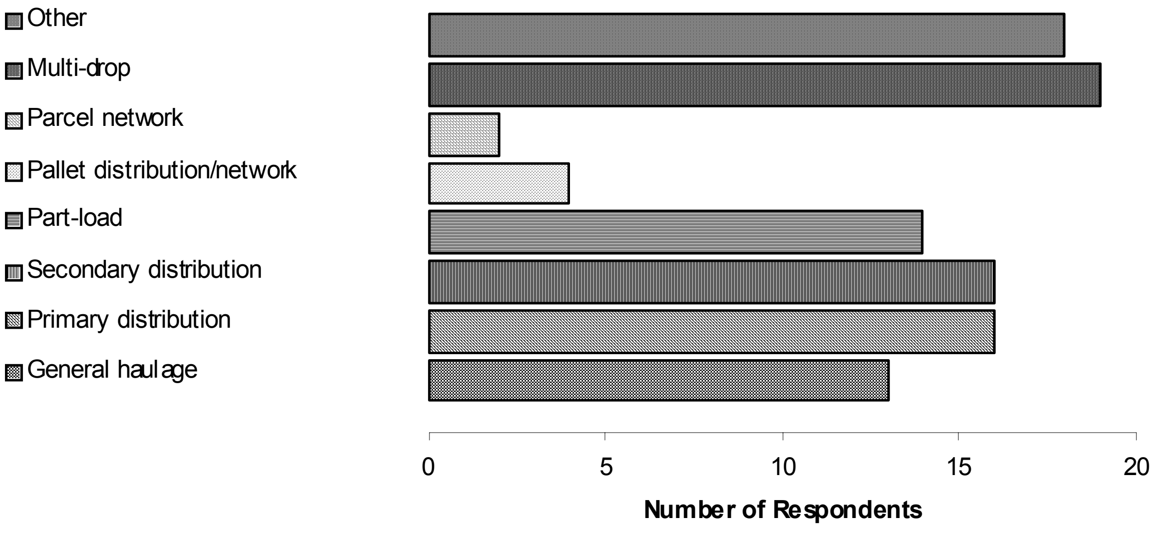


Figure 6. 18 . *Main Types of Distribution Operation for Sample Companies*

More than half of respondents have equipped their entire fleet with VTS (18 companies) (Figure 6.19). Three companies have equipped less than 50% of the fleet, the remaining 11 having more than 50%.

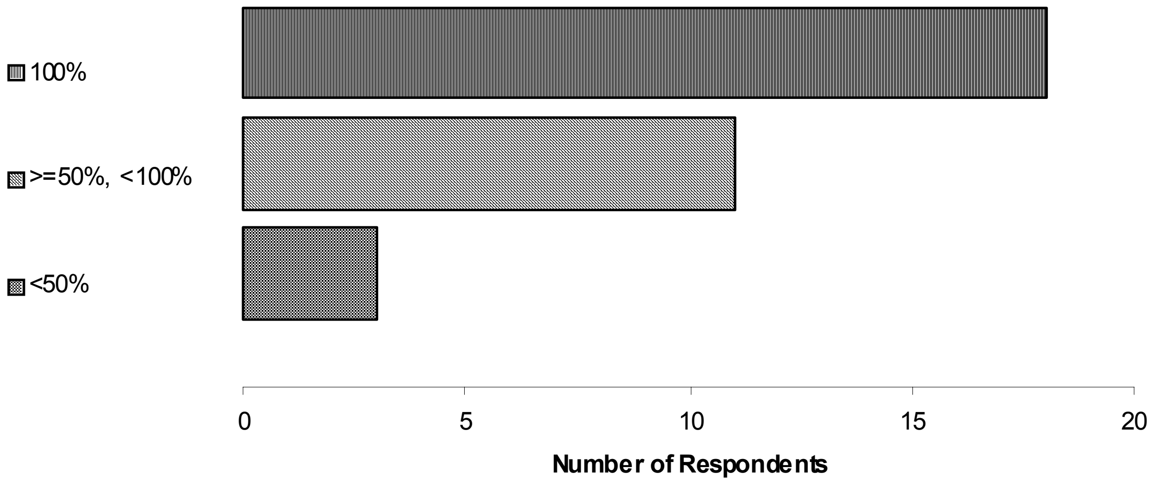


Figure 6. 19 . *Proportion of Fleet Equipped with VTS*

The survey explored the main ways in which companies segmented their fleets for purpose of vehicle telematics (Figure 6.20). The most significant differentiator was the operational role of the vehicles. Some types of operation may require less control, or the return on investment in VTS is seen to be lower for certain types of operation. Of the respondents stating ‘other’ as the choice for fleet segmentation, the main reasons given related to the fleet replacement policy. Companies were unwilling to fit VTS to vehicles that were about to be replaced (though no timescales were stated). One own account operator had recently purchased a separate company and had not yet integrated its vehicles into the central VTS management processes, though this was to be implemented in the near future.

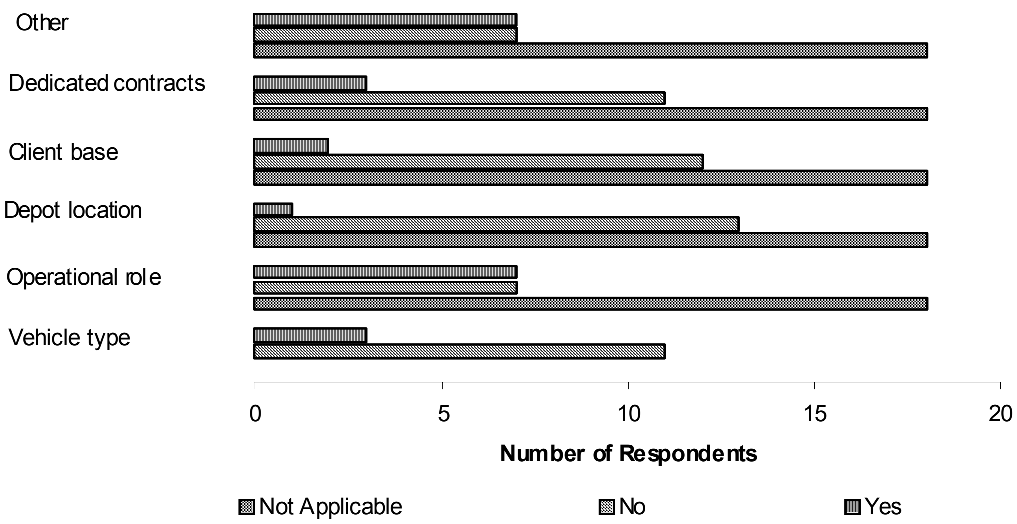


Figure 6. 20 . *Segmentation of Fleets for VTS Purposes*

Users were asked their opinions on whether the operation of a mixed fleet (in terms of vehicle make) affected their purchasing decision when seeking to implement a VTS. Users were largely unaware of the systems offered by vehicle manufacturers. In only one case did the operation of a mixed fleet affect choice of VTS supplier, the reason given that a system was required that could operate across a variety of vehicle makes. (72% of the companies surveyed operate a mixed fleet.)

The motivation for a company to invest in VTS was examined. Respondents were asked to state the primary reason for implementing a VTS. Their answer was fitted into one of 7 categories: -

- Fuel savings
- Driver hours control
- Proof of delivery
- Support for demurrage charges
- Reduce communications costs
- Improve delivery reliability
- Improve fleet availability through greater asset visibility

When asked, unprompted, about their motives for investing in VTS, fleet availability had the highest number of responses, followed by driver's hours control and fuel savings (Figure 6.21). When prompted on possible motives, the response was much higher for each (Figure 6.22). Two categories (proof of delivery and demurrage charging), which had scored zero initially, received positive responses from 17 and 16 companies respectively.

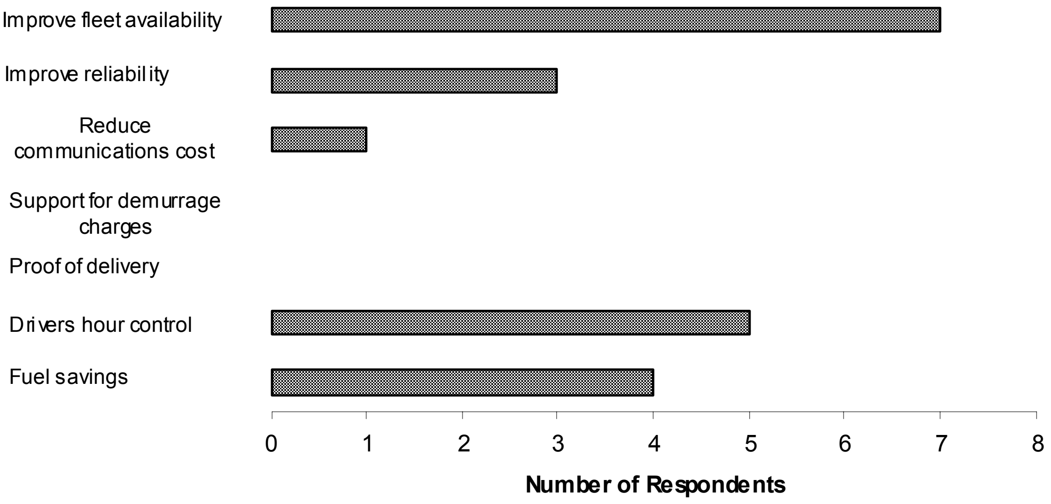


Figure 6. 21 . *Reasons for Implementing VTS – unprompted responses*

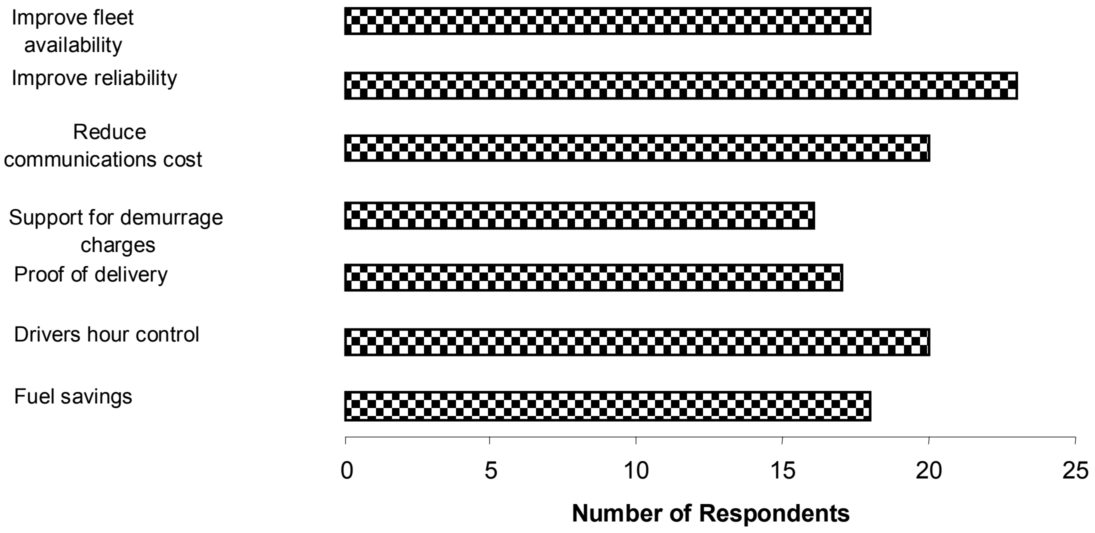


Figure 6. 22 . *Reasons for Implementing VTS – unprompted responses*

A quarter of respondents said that customers insisted on the implementation of a VTS, though none of their customers specified the choice of supplier. This suggests that the reason for insisting on VTS was not to integrate with the customer's existing systems, but rather for general operational reasons of load security and delivery time updating.

Users were asked about any support provided by their VTS supplier on the derivation and benchmarking of KPIs. Twenty companies confirmed that their supplier had given advice on the retrospective analysis of the data, however the extent of that advice was, in general, limited. Only 13 companies expressed a desire to have greater support from their VTS supplier on performance measurement (Figure 6.23). These responses can be related to those of the suppliers on the subject of KPI analysis and benchmarking discussed in the previous section. Most companies surveyed do not routinely perform any KPI analysis of the data from VTS; only seven of the companies surveyed regularly analyse their VTS data.

Approximately two-thirds of the companies (26) were positive about the potential for VTS to reduce empty running and improve load consolidation. Three companies indicated that they would like to see services offered by their VTS supplier to help achieve this (Figure 6.24).

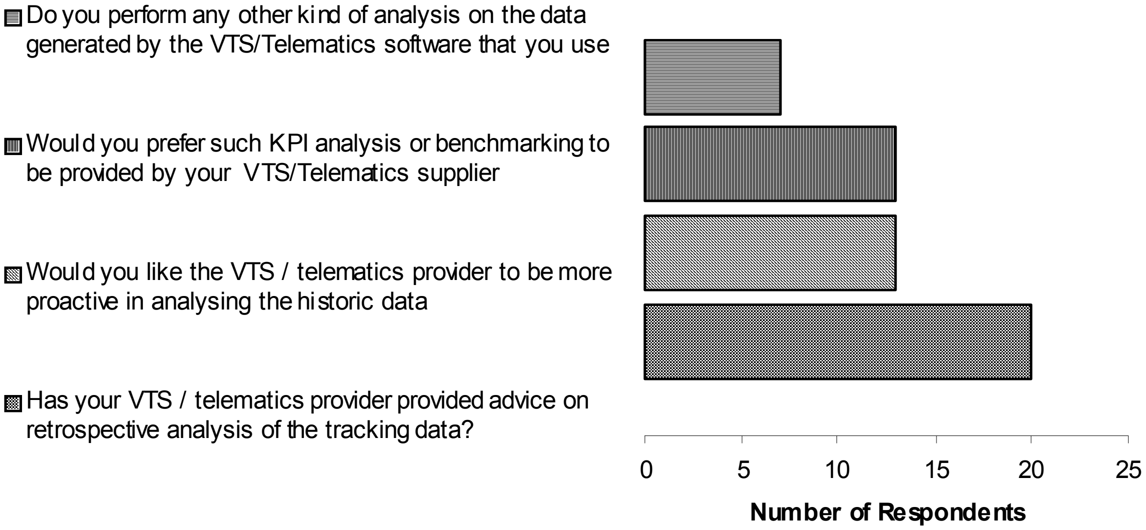


Figure 6. 23 . *Use of VTS for KPI Analysis*

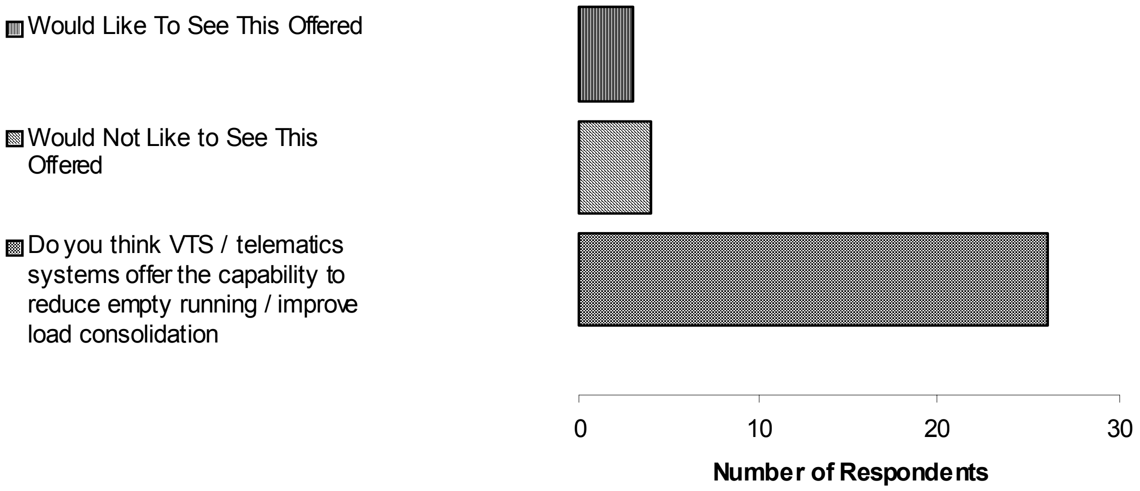


Figure 6. 24 . *Possible Use of VTS to Assist Backloading and Load Consolidation*

Twenty-one companies use their VTS to produce KPI's for management monitoring and reporting. Eight do this on a weekly basis, seven on a monthly basis and the remainder on an ad-hoc basis. Two companies analyse KPI's on a daily basis.

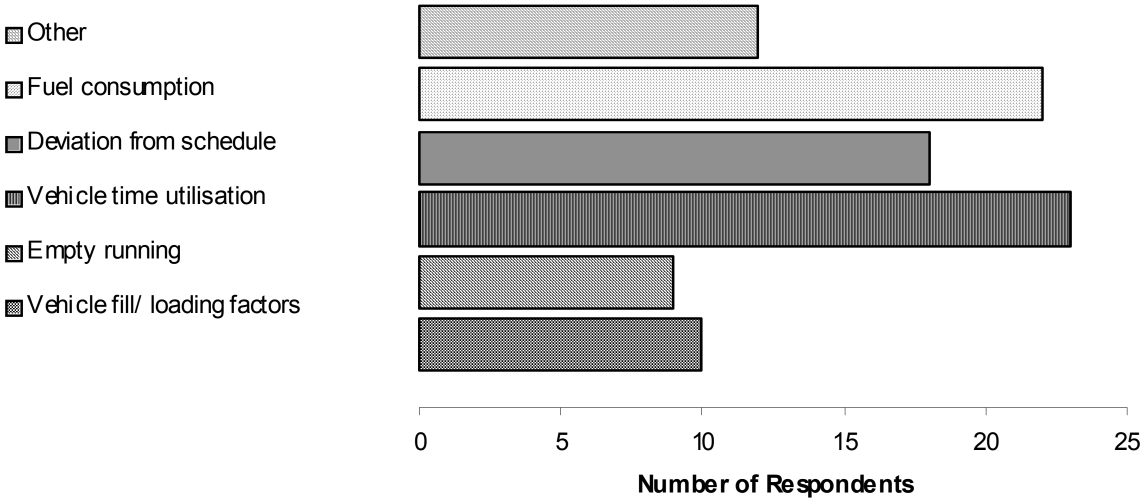


Figure 6. 25 . *Use of VTS Data to Calculate the Five Sets of KPIs*

Very few of the companies calculate all five KPI's used in the 2002 food KPI survey (Figure 6.25). The most commonly used of these KPIs is Vehicle Time Utilisation, used by 63% of the companies (23). This was also the most widely used of the five KPIs among the VTS suppliers. Deviation from schedule and fuel efficiency were also quite widely used, by respectively 23 and 18 of the respondents. None of the companies calculated energy-intensity. The lack of use of the Government Transport KPI scheme for benchmarking shows a general ignorance of it. Only around 20% of the managers of user companies had any knowledge of the government's transport KPI initiative (Figure 6.26).

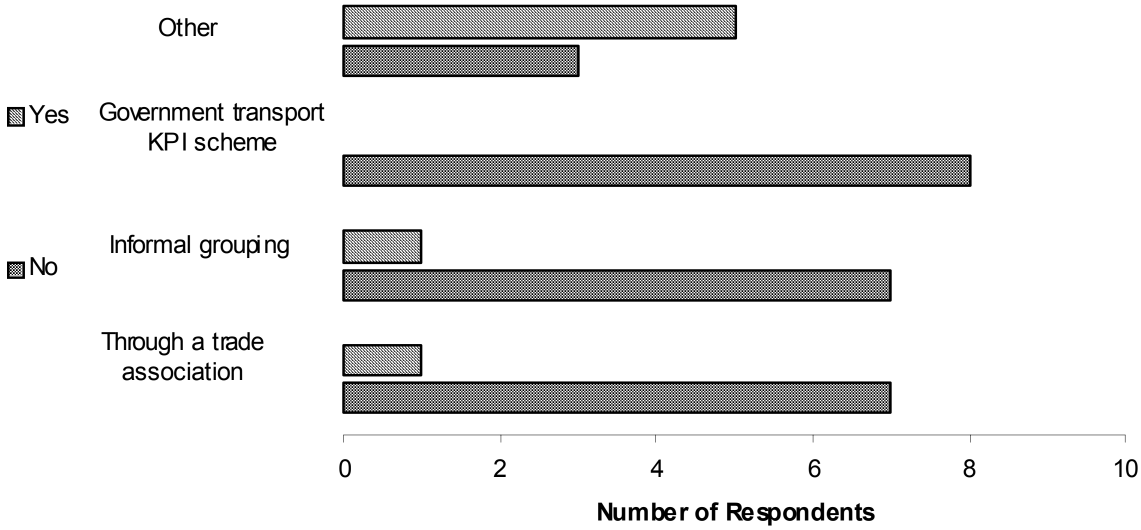


Figure 6. 26 . *Use of Various Transport Benchmarking Networks*

Although many companies were positive about using VTS to reduce empty running (Figure 6.24), only a quarter actually used it for this purpose. Ten users (29%) said they measured vehicle fill/loading factors though this was very difficult to derive from VTS as discussed earlier. Seven own-account operators and three road haulage companies supplying blue-chip customers dominated this response.

The most widely used of the other KPIs relate to driving style and driver hours. One company (a leading retailer) quoted an extensive list of KPI's that they used to measure performance. Only one company had developed a KPI to monitor use of the VTS, the percentage of deliveries confirmed by the VTS system.

In just over half the companies (19), benchmarking was confined to internal comparisons of fleet performance. This may be sensible given the difficulty of finding well matched comparator operations. The very limited amount of external benchmarking was considered to be of a poor quality. One company used a trade association for this purpose and another (a 3PL) an informal grouping. The remainder (5 companies) used manufacturer's cost tables, customer league tables and ad-hoc arrangements of a transient nature.

6.4 CONCLUSION

There are now many suppliers and users of VTS in the road freight sector. The main focus appears to be on vehicle time utilisation, at least from the suppliers' point of view. Users, understandably, focus on the main cost drivers for the operation of the vehicle – fuel consumption and drivers hours.

There is an overall ignorance of the benefits that may be derived from the use of the KPI's advocated by the government's KPI initiative. VTS suppliers could play a useful role in promoting the benefits of KPI analysis and benchmarking, though for most of those surveyed this was not being given a high priority.

The current inability of VTS to monitor vehicle loading either directly through the use of sensors or indirectly through interfacing with other company IT systems is a major constraint on the wider of adoption of the performance measures used in the government's transport KPI initiative, particularly the energy-intensity index.

SECTION 7. ACHIEVEMENT OF OBJECTIVES

Each of the original objectives will restated and an assessment of the extent to which they have been achieved.

Objective 1: To define and specify the requirements for a software tool-kit

In consultation with the industrial partners, we determined what aspects of road freight rationalisation could be modelled using the available KPI database. Within the limited range of parameters available, we tried to keep the modelling as realistic as possible. A decision was made to focus on the efficiency of multiple drop rounds and opportunities for backloading. An original proposal to examine the potential for consolidating part-loads was abandoned as being impractical. The tools had to be able to use the KPI survey data to optimise vehicle routing with different delivery scenarios and to measure backloading potential at levels of load screening.

The new research associate appointed to work on the project conducted an audit of the existing KPI software, comprising the Excel work book, Access data-base and several thousand lines of Visual Basic programming. This led to several modifications to improve consistency and facilitate the manipulation and extraction of data.

He also had responsibility for inputting KPI survey data from several participants in the 2002 survey, who submitted their data late. This helped to familiarise him with the data collection process and existing software. This task was not anticipated in the original proposal as at that time the intention was to use the 1998 data-base which was already complete.

Objective 2: To develop a software tool-kit for use on the 2002 transport KPI database for the food sector.

It was recognised that the tool-kit would have to include proprietary software packages. In the case of the routing analysis, the Optrak package was used while for the assessment of backloading potential SAS and Code-point were used. The research associate was given training in the use of the Optrak package and took a self-training programme on SAS. He successfully interfaced these packages with the transport KPI database. He prepared the visual basic macros required to manipulate the raw data, perform consistency checks, undertake initial processing of some variables and input relevant values into the proprietary packages. Routines have been developed for varying key parameters, such as delivery time windows and driving time for the routing analysis and different levels of load matching for the backloading analysis. The latter analysis has required the creation of a interactive query interface using the GIS modules in SAS. Procedures have also been established to output the results of the analyses in tables and graphics.

This work has effectively supplemented the original transport KPI software with powerful analytical tools and meets one of the core objectives of the project. I

Objective 3: To apply the tool-kit in an analysis of this database to assess the potential for reducing the economic and environmental costs of road freight transport

In the original proposal it was stated the tool-kit would be applied in a full analysis of the transport KPI database to:

(a) test its functionality

(b) provide a general indication of the scope for road freight rationalisation.

The first goal was successfully achieved. It was demonstrated that the software tools did work well and produced the desired outputs. The main outputs were estimates of potential reductions in vehicle-kms. These were converted into reductions in operating cost, energy consumption and emissions using standard ratios.

The second goal proved over-ambitious. Within the available time, the routing analysis was applied to only seven of the fleets. As this analysis related to multiple drop rounds, it would not have been appropriate to apply it to most of the fleets engaged in primary and secondary distribution. More of the tertiary fleets could have been analysed had it not taken so long to correct post-code anomalies and other inconsistencies in the company data. The consistency checks embedded within the KPI software were designed to ensure consistency of the benchmark data, but not to check the validity of the post-code data. The quality of the spatial data was found to be poorer than expected and required more time for checking and correction.

The analysis of backloading opportunities was less seriously affected by deficiencies in the post-coding of journey legs as it related to the longer-distance primary and secondary movements which in most cases were direct single-drop deliveries. It was applied to all the journey legs of over 100 km for which five or six-digit post-codes were available. This sample size was, nevertheless, only large enough to screen potential load matches on the basis of locational criteria. The sample (i.e. density of trips) would have had to be much larger to undertake more realistic screening against other criteria, particularly delivery scheduling.

Because of the limited quantity and quality of the spatial data, the analysis was not as extensive as originally expected and the results less generalisable. The analysis should, therefore, be seen as an illustration of the what geographical analysis of a transport KPI data-base can achieve, rather than the source of accurate estimates of the potential of improving the sustainability of food distribution in the UK.

Objective 4: To consider how the tool-kit might have to be adapted to distribution operations in other sectors

The software tools which manipulate the raw survey data and prepare it for inputting into the supporting packages (Optrak, Code Point and SAS) have been customised to the transport KPI database. Transport KPI audits in other sectors which adopt a similar database structure should be able to apply the tools without much difficulty. The collection and collation of data in the automotive (McKinnon and Leuchars, 2002) and non-food retail KPI surveys (The Logistics Business, 2003), for example, broadly conformed to those of the food KPI survey and so would be amenable to similar analysis. Differences in the specification of these surveys, made in response to industry consultation, would nevertheless require modifications to the survey. Both the automotive and non-food retailing surveys, for example, monitored the operation of tractor units. The software could be refined to include a new set of scheduling constraints related to the movement of tractor units. Overall the automotive KPI data-base generated by the pilot survey in 2001 offers little scope for spatial modelling, partly because of the very small sample size, but also because very little leg-specific data was collected for trips comprising four or more legs.

The tools are sufficiently generic to accommodate most types of trip, vehicle, handling equipment and scheduling, so long as the standard KPI definitions of journey leg and consignment are adopted.

Objective 5: To examine the collection of KPI data by commercial road telematics systems

Two surveys were undertaken of suppliers and users of vehicle tracking services. In the proposal it was suggested telephone and face-to-face interviews would be supplemented by a 'more extensive postal questionnaire survey'. A decision was made to drop the postal questionnaire survey and expand the telephone interview survey. Through personal contact with the companies, it was possible to obtain more information and discuss the technicalities of the service in greater detail. The success of this approach is reflected in the exceptionally high response rate for the survey of suppliers (89%) and above-average response rate for the user survey (39%). In-depth face-to-face interviews were held with four organisations. Questionnaires were designed and piloted for these surveys. Responses were coded and analysed using an Excel spreadsheet.

Overall, these surveys provided answers to the key questions about the magnitude and structure of companies' existing trip databases, the analysis currently undertaken on these databases, interfacing with other software packages and companies' demand for KPI monitoring. They have revealed that the main constraint on the use of existing road telematics systems for KPI measurement is their failure to collect data on the size, weight and composition of vehicle loads. As load data is a key element in the spatial analysis of the transport KPI data, the applicability of the software tools to commercial road telematics data-bases is currently limited.

Objective 6: To investigate ways of combining the software tool-kit with real-time road freight information systems to identify backloading and load consolidation opportunities on a short-term basis

It was recognised at the outset that the commercial value of the tool-kit would be greatly enhanced if it could be deployed on a short-term basis to identify opportunities for improved loading. Following discussions with operators of road telematics systems and online freight exchanges, it has been concluded that the tool-kit lacks the functionality and is too closely customised to the transport KPI data to assume this role. Since the FIT proposal was originally submitted, several companies have established online exchanges for the trading of backload capacity. Their experience has shown that to provide a commercially viable load matching service it is necessary to handle a very high density trips. Companies such as Routel, Elogistics, Easy-to-ship and the Backload.com have not only developed software capable of matching loads and available vehicle capacity but also created a transactional system within which backhaul capacity can be traded. Their main problem has been generating the required volume of business rather than refining the software. As software for the real-time monitoring and trading of backhaul capacity has been now been developed and commercialised, with varying degrees of success, there seems little point in adapting our software tools for this purpose. They are essentially designed for retrospective analysis of the operational efficiency of truck fleets using data compiled in transport KPI-type surveys.

SECTION 8. DELIVERABLES

The main deliverable from this project has been the new set of software tools than can be used to subject transport KPI databases to much more detailed analysis. They supplement the software which has already been developed by the LRC for the averaging and benchmarking of KPI values. Use of these tools permits assessment of potential efficiency gains against theoretical optima, in contrast to the earlier benchmark analysis which judge this potential against prevailing industry best practice.

It is anticipated that the main use of the tools will be to estimate potential cost, energy and emissions savings as an aggregate level, though they could be applied to single company's transport operation where it supplies sufficient fleet data.

The transferability of the tools will be partly constrained by their integration with the Optrak and SAS software packages and by the degree of customisation to the existing transport KPI methodology.

Other deliverables include:

The results of the routing and backloading analyses which used the new software tools. As explained in section 7, however, the extent to which these results can be generalised is limited, given the size and composition of the sample of fleets analysed.

The results of the surveys of companies supplying and using road telematics systems. This provides a useful insight into the current state of the telematics sector in the UK and possibility of applying a similar set of software tools to commercial vehicle tracking data bases.

SECTION 9. DISSEMINATION

To date two papers reporting results of the project have already been published:

McKinnon, A.C., Ge.Y. and Leuchars, D. (2003) ‘Running on Empty’ *ECR Journal*, 3, 1, pp. 73-83.

McKinnon, A.C. and Ge.Y (2003) ‘Use of a Synchronised Vehicle Audit to Determine Opportunities for Improving Transport Efficiency in a Supply Chain’ *Logistics Research Network 2003 Conference Proceedings* (ed. Menachov, D. et al), Institute of Logistics and Transport.

An revised and substantially extended version of this conference paper has been submitted to the *International Journal of Logistics: Research and Applications*.

Reference has also been made to the project in presentations made by Prof. McKinnon to:

- ‘Scenarios for Freight Transport’ workshop organised by *IPTS and the Danish Virtual Centre for Logistics and Freight Transport* in Seville in May 2003.
- European Logistics Association annual conference in Rome in June 2003
- US Council for Logistics Management annual conference in Chicago in September 2003.

A presentation based on the backloading analysis and entitled ‘Eliminate those Empty Miles’ was delivered by Prof. McKinnon at the Motor Transport ‘Tolling and Telematics’ conference in Beaconsfield in November 2003.

Three future journal papers are planned which discuss the results of:

- the analysis of route optimisation within varying delivery constraints
- the assessment of backloading opportunities
- the surveys of road telematics suppliers and users.

A copy of this report is available for downloading from the LRC website (http://www.sml.hw.ac.uk/logistics).

SECTION 10. MANAGEMENT OF THE PROJECT

A 'kick-off' meeting for the project was held at the DTLR offices in London in January 2001 though it did not officially start until December 2002. This delay was partly attributable to protracted negotiations over the collaborative agreement and the time taken to recruit a research associate for the project. It actually proved beneficial because during the intervening period the LRC carried out, for the government's TransportEnergy Programme, the 2002 transport KPI survey creating a much larger and more up-to-date database for the project to analyse.

The six partner organisations have made a valuable contribution to the project. Most of this contribution has been 'in kind' through participation in four quarterly meetings and provision of advice on various issues. In addition, Optrak has granted use of their software package and provided the research associate, Dr. Ge, with training in its use; Isotrak has given extra support with the survey of telematics suppliers and users, as well hosting the four quarterly meetings at its head office; Christian Salvesen and Celsius First (formerly Frigoscandia) have also made a financial contribution to the project. John Hutchings, chief executive of the Cold Storage and Distribution Federation, has co-ordinated the industrial input into the project and chaired the quarterly meetings. Day-to-day management of the project at Heriot-Watt University has been the responsibility of Professor Alan McKinnon.

The main research associate on the project, Dr. Yongli Ge, has undertaken a range of tasks, including:

- familiarisation with the existing KPI database and software
- completion of the data collection and analysis tasks associated with the 2002 KPI survey
- consistency checking / post-code validation and correction
- development of the software tools
- training in the use of the Optrak and SAS packages
- application of the software tools in the analysis of route optimisation and backloading
- liaison with partners and presentations
- presentations to quarterly meetings and participation in conferences

The surveys of VTS suppliers and users was undertaken by Mr. David McClelland.

SECTION 11. GLOSSARY

Articulation ratio: ratio of trailers to tractor units in an articulated vehicle fleet

Backload: consignment carried on the return journey that a vehicle makes back to its starting location or base.

CANBUS: electrical wiring network within a truck

CSRGT: Continuing Survey of Road Goods Transport (main UK government survey of road freight movements)

CSV: comma separated variable (most common type of database formating)

Demurrage: charge imposed by a carrier for the additional time that a vehicle has to spend at a collection or delivery point as a result of a delay in loading / unloading.

Deviation mileage: the additional distance that a vehicle must travel to collect and / or deliver a backload.

ERP: Enterprise Resource Planning (integrated software system for managing a range of business processes, including order fulfilment)

GIS: Geographical information system

Hire and reward fleet: vehicle fleet owned and operated by a company whose main business is road haulage.

KPI: Key Performance Indicator

Leg: section of a journey (or trip) between two points at which the loading of the vehicle changes.

Load factor: ratio of the actual vehicle load to the maximum that could have been carried, expressed in either weight or volume terms.

Load matching: the assignment of loads to empty vehicle capacity, usually within limiting conditions

MRP: Materials Requirements Planning (software system for managing the replenishment of inventory in a manufacturing operation)

Own account fleet: vehicle fleet owned and operated by a company whose main activity is not transport (e.g. manufacturer or retailer)

Primary Distribution: movement of products between factories and regional distribution centres

RDC: Regional Distribution Centre

Search radius: radius of the circles around the leg origin or destination within which a search is made for suitable backloads.

Secondary Distribution: movement of products between distribution centres and supermarkets
Telematics: 'the integration of wireless communications, vehicle monitoring systems and location devices' (source: roadtripamerica.com)

Tertiary Distribution: localised delivery of products to small independent retailers and catering outlets, mainly from wholesale depots

Third party logistics (3PL) provider: a company that can be contracted to provide a range of logistical services either individually or in combination

Time window: time period within which the delivery is timetabled to arrive

VTS: Vehicle Telematics Systems

Way-point: strategic location at the head of an estuary or bay through which the backloading model routes vehicles to prevent them following straight 'crowfly' routes across bodies of water.

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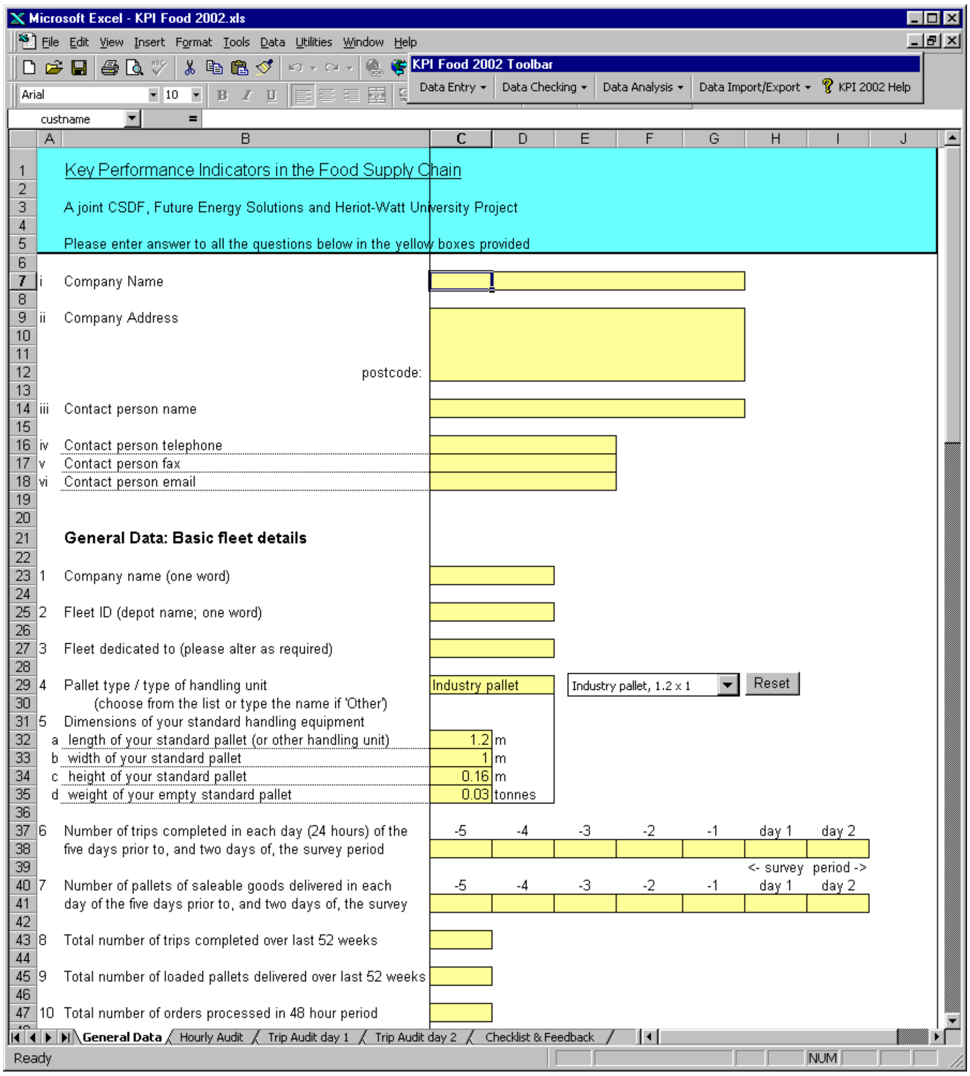
SECTION 12. APPENDICES

Appendix A. COPIES OF TRANSPORT KPI SPREADSHEETS

Table A. 1 . General data worksheet 1



Key Performance Indicators in the Food Supply Chain

A joint CSDF, Future Energy Solutions and Heriot-Watt University Project

Please enter answer to all the questions below in the yellow boxes provided

i Company Name

ii Company Address

postcode:

iii Contact person name

iv Contact person telephone

v Contact person fax

vi Contact person email

General Data: Basic fleet details

1 Company name (one word)

2 Fleet ID (depot name; one word)

3 Fleet dedicated to (please alter as required)

4 Pallet type / type of handling unit: Industry pallet [Industry pallet, 1.2 x 1] [Reset]
(choose from the list or type the name if 'Other')

5 Dimensions of your standard handling equipment

a length of your standard pallet (or other handling unit) 1.2 m

b width of your standard pallet 1 m

c height of your standard pallet 0.16 m

d weight of your empty standard pallet 0.03 tonnes

6 Number of trips completed in each day (24 hours) of the five days prior to, and two days of, the survey period: -5 -4 -3 -2 -1 day 1 day 2

<- survey period ->

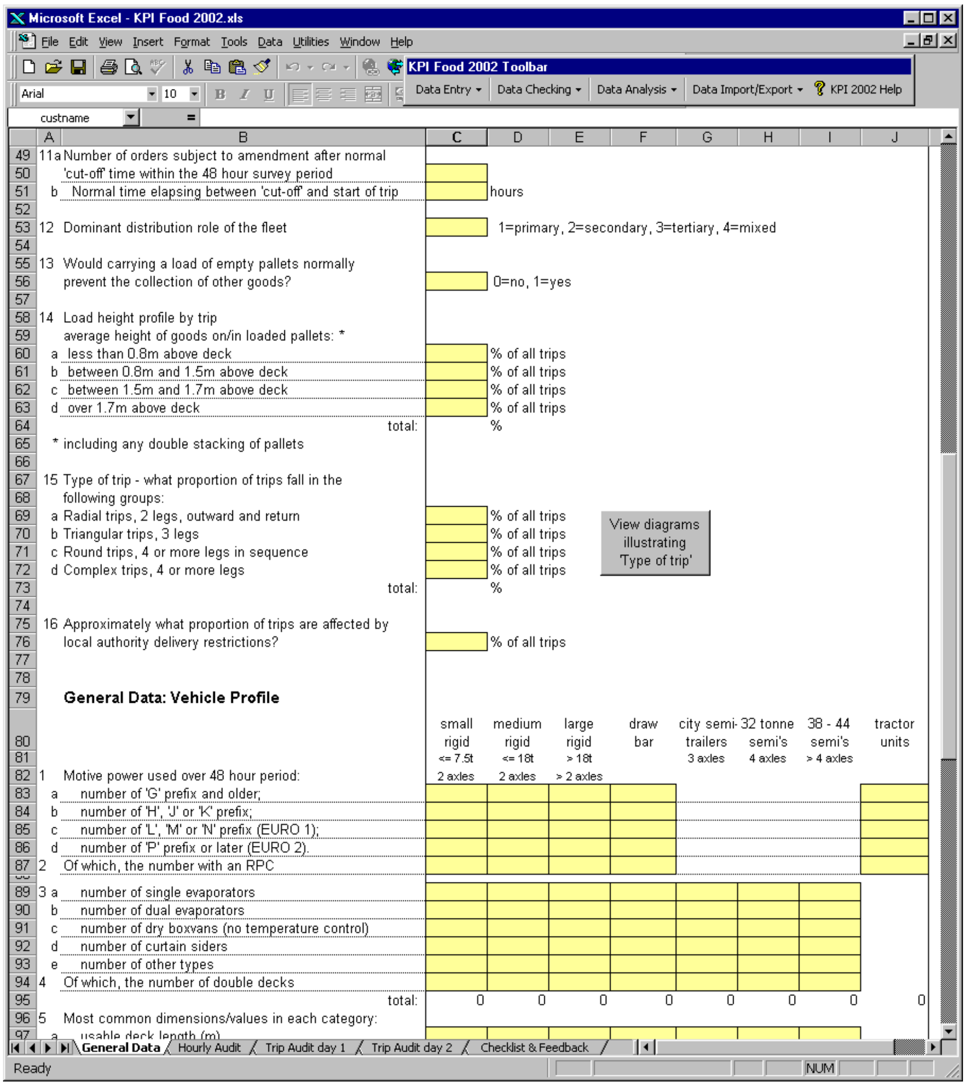
7 Number of pallets of saleable goods delivered in each day of the five days prior to, and two days of, the survey: -5 -4 -3 -2 -1 day 1 day 2

8 Total number of trips completed over last 52 weeks

9 Total number of loaded pallets delivered over last 52 weeks

10 Total number of orders processed in 48 hour period

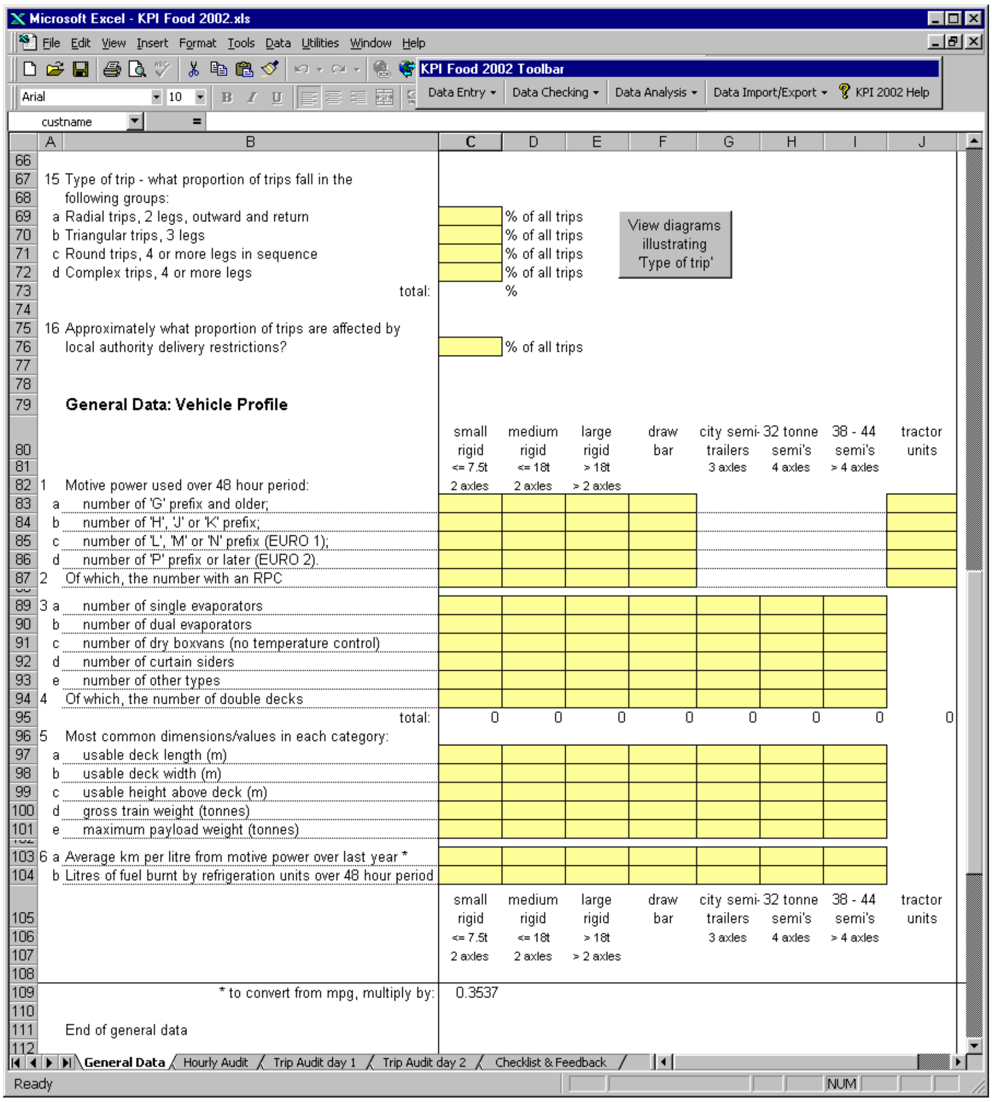
Table A. 2 . *General data worksheet 2*



49 11 a Number of orders subject to amendment after normal
50 'cut-off' time within the 48 hour survey period
51 b Normal time elapsing between 'cut-off' and start of trip hours
52
53 12 Dominant distribution role of the fleet 1=primary, 2=secondary, 3=tertiary, 4=mixed
54
55 13 Would carrying a load of empty pallets normally
56 prevent the collection of other goods? 0=no, 1=yes
57
58 14 Load height profile by trip
59 average height of goods on/in loaded pallets: *
60 a less than 0.8m above deck % of all trips
61 b between 0.8m and 1.5m above deck % of all trips
62 c between 1.5m and 1.7m above deck % of all trips
63 d over 1.7m above deck % of all trips
64 total: %
65 * including any double stacking of pallets
66
67 15 Type of trip - what proportion of trips fall in the
68 following groups:
69 a Radial trips, 2 legs, outward and return % of all trips
70 b Triangular trips, 3 legs % of all trips
71 c Round trips, 4 or more legs in sequence % of all trips
72 d Complex trips, 4 or more legs % of all trips
73 total: %
74
75 16 Approximately what proportion of trips are affected by
76 local authority delivery restrictions? % of all trips
77
78
79 **General Data: Vehicle Profile**

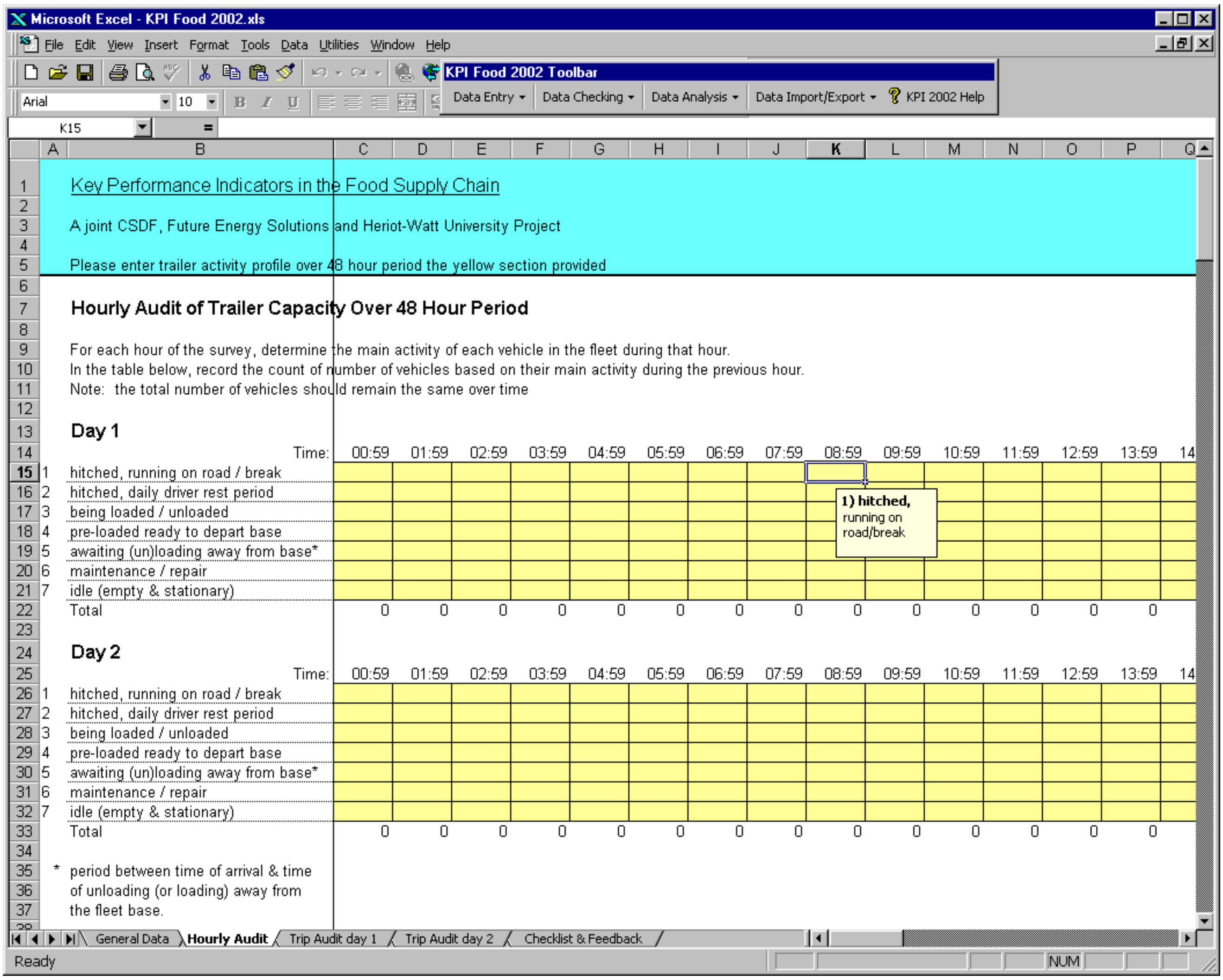
		small rigid <= 7.5t 2 axles	medium rigid <= 18t 2 axles	large rigid > 18t > 2 axles	draw bar	city semi-trailers 3 axles	32 tonne semi's 4 axles	38 - 44 semi's > 4 axles	tractor units
82	1 Motive power used over 48 hour period:								
83	a number of 'G' prefix and older;								
84	b number of 'H', 'J' or 'K' prefix;								
85	c number of 'L', 'M' or 'N' prefix (EURO 1);								
86	d number of 'P' prefix or later (EURO 2).								
87	2 Of which, the number with an RPC								
89	3 a number of single evaporators								
90	b number of dual evaporators								
91	c number of dry boxvans (no temperature control)								
92	d number of curtain siders								
93	e number of other types								
94	4 Of which, the number of double decks								
95	total:	0	0	0	0	0	0	0	0
96	5 Most common dimensions/values in each category:								
97	a usable deck length (m)								

Table A. 3 . *General data worksheet 3*



	A	B	C	D	E	F	G	H	I	J
66										
67	15	Type of trip - what proportion of trips fall in the								
68		following groups:								
69	a	Radial trips, 2 legs, outward and return		% of all trips						
70	b	Triangular trips, 3 legs		% of all trips						
71	c	Round trips, 4 or more legs in sequence		% of all trips						
72	d	Complex trips, 4 or more legs		% of all trips						
73		total:		%						
74										
75	16	Approximately what proportion of trips are affected by								
76		local authority delivery restrictions?		% of all trips						
77										
78										
79		**General Data: Vehicle Profile**								
80			small rigid	medium rigid	large rigid	draw bar	city semi-trailers	32 tonne semi's	38 - 44 semi's	tractor units
81			<= 7.5t	<= 18t	> 18t		3 axles	4 axles	> 4 axles	
82	1	Motive power used over 48 hour period:	2 axles	2 axles	> 2 axles					
83	a	number of 'G' prefix and older;								
84	b	number of 'H', 'J' or 'K' prefix;								
85	c	number of 'L', 'M' or 'N' prefix (EURO 1);								
86	d	number of 'P' prefix or later (EURO 2).								
87	2	Of which, the number with an RPC								
89	3 a	number of single evaporators								
90	b	number of dual evaporators								
91	c	number of dry boxvans (no temperature control)								
92	d	number of curtain siders								
93	e	number of other types								
94	4	Of which, the number of double decks								
95		total:	0	0	0	0	0	0	0	0
96	5	Most common dimensions/values in each category:								
97	a	usable deck length (m)								
98	b	usable deck width (m)								
99	c	usable height above deck (m)								
100	d	gross train weight (tonnes)								
101	e	maximum payload weight (tonnes)								
103	6 a	Average km per litre from motive power over last year *								
104	b	Litres of fuel burnt by refrigeration units over 48 hour period								
105			small rigid	medium rigid	large rigid	draw bar	city semi-trailers	32 tonne semi's	38 - 44 semi's	tractor units
106			<= 7.5t	<= 18t	> 18t		3 axles	4 axles	> 4 axles	
107			2 axles	2 axles	> 2 axles					
108										
109		* to convert from mpg, multiply by:	0.3537							
110										
111		End of general data								
112										

Table A. 4 . *Hourly audit worksheet 4*



Key Performance Indicators in the Food Supply Chain

A joint CSDF, Future Energy Solutions and Heriot-Watt University Project

Please enter trailer activity profile over 48 hour period the yellow section provided

Hourly Audit of Trailer Capacity Over 48 Hour Period

For each hour of the survey, determine the main activity of each vehicle in the fleet during that hour.
In the table below, record the count of number of vehicles based on their main activity during the previous hour.
Note: the total number of vehicles should remain the same over time

Day 1

	Time:	00:59	01:59	02:59	03:59	04:59	05:59	06:59	07:59	08:59	09:59	10:59	11:59	12:59	13:59	14
1	hitched, running on road / break															
2	hitched, daily driver rest period															
3	being loaded / unloaded															
4	pre-loaded ready to depart base															
5	awaiting (un)loading away from base*															
6	maintenance / repair															
7	idle (empty & stationary)															
	Total	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

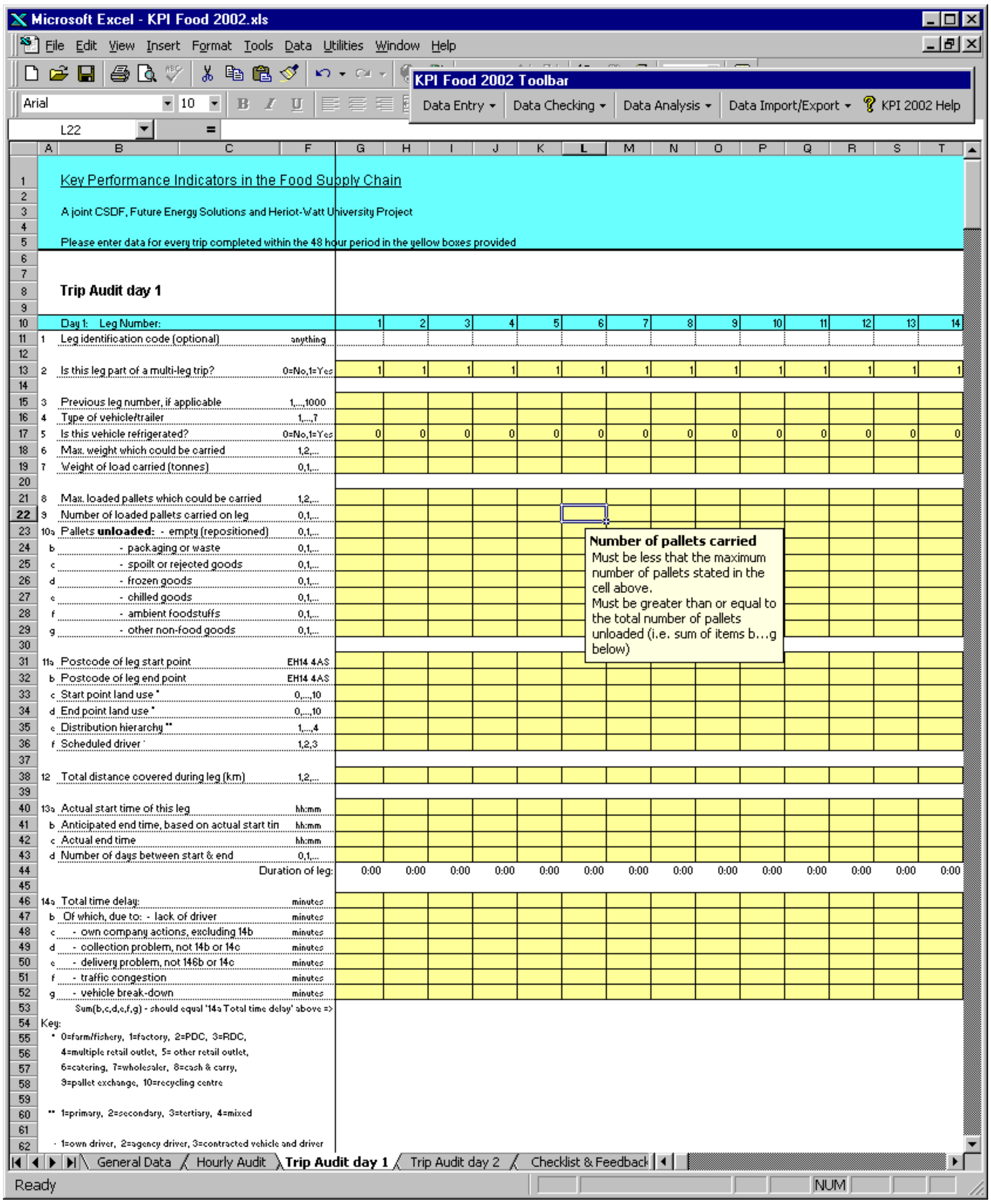
1) hitched,
running on
road/break

Day 2

	Time:	00:59	01:59	02:59	03:59	04:59	05:59	06:59	07:59	08:59	09:59	10:59	11:59	12:59	13:59	14
1	hitched, running on road / break															
2	hitched, daily driver rest period															
3	being loaded / unloaded															
4	pre-loaded ready to depart base															
5	awaiting (un)loading away from base*															
6	maintenance / repair															
7	idle (empty & stationary)															
	Total	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

* period between time of arrival & time of unloading (or loading) away from the fleet base.

Table A. 5 . *Trip audit worksheet 5*



	A	B	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1		Key Performance Indicators in the Food Supply Chain															
2																	
3		A joint CSDF, Future Energy Solutions and Heriot-Watt University Project															
4																	
5		Please enter data for every trip completed within the 48 hour period in the yellow boxes provided															
6																	
7																	
8		**Trip Audit day 1**															
9																	
10		Day 1: Leg Number:		1	2	3	4	5	6	7	8	9	10	11	12	13	14
11	1	Leg identification code (optional)	anything														
12																	
13	2	Is this leg part of a multi-leg trip?	0=No,1=Yes	1	1	1	1	1	1	1	1	1	1	1	1	1	1
14																	
15	3	Previous leg number, if applicable	1,...,1000														
16	4	Type of vehicle/trailer	1,...,7														
17	5	Is this vehicle refrigerated?	0=No,1=Yes	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	6	Max. weight which could be carried	1,2,...														
19	7	Weight of load carried (tonnes)	0,1,...														
20																	
21	8	Max. loaded pallets which could be carried	1,2,...														
22	9	Number of loaded pallets carried on leg	0,1,...														
23	10a	Pallets **unloaded:** - empty (repositioned)	0,1,...														
24	b	- packaging or waste	0,1,...														
25	c	- spoilt or rejected goods	0,1,...														
26	d	- frozen goods	0,1,...														
27	e	- chilled goods	0,1,...														
28	f	- ambient foodstuffs	0,1,...														
29	g	- other non-food goods	0,1,...														
30																	
31	11a	Postcode of leg start point	EH14 4AS														
32	b	Postcode of leg end point	EH14 4AS														
33	c	Start point land use *	0,...,10														
34	d	End point land use *	0,...,10														
35	e	Distribution hierarchy **	1,...,4														
36	f	Scheduled driver `	1,2,3														
37																	
38	12	Total distance covered during leg (km)	1,2,...														
39																	
40	13a	Actual start time of this leg	hh:mm														
41	b	Anticipated end time, based on actual start tin	hh:mm														
42	c	Actual end time	hh:mm														
43	d	Number of days between start & end	0,1,...														
44			Duration of leg:	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00
45																	
46	14a	Total time delay:	minutes														
47	b	Of which, due to: - lack of driver	minutes														
48	c	- own company actions, excluding 14b	minutes														
49	d	- collection problem, not 14b or 14c	minutes														
50	e	- delivery problem, not 146b or 14c	minutes														
51	f	- traffic congestion	minutes														
52	g	- vehicle break-down	minutes														
53		Sum(b,c,d,e,f,g) - should equal '14a Total time delay' above =>															
54	Key:																
55	*	0=farm/fishery, 1=factory, 2=PDC, 3=RDC,															
56		4=multiple retail outlet, 5= other retail outlet,															
57		6=catering, 7=wholesaler, 8=cash & carry,															
58		9=pallet exchange, 10=recycling centre															
59																	
60	**	1=primary, 2=secondary, 3=tertiary, 4=mixed															
61																	
62	`	1=own driver, 2=agency driver, 3=contracted vehicle and driver															

Number of pallets carried
Must be less that the maximum number of pallets stated in the cell above.
Must be greater than or equal to the total number of pallets unloaded (i.e. sum of items b…g below)

Appendix B. PARAMETERS FOR DIFFERENT SCENARIOS

A. Tertiary Distribution (Two fleets of company A):

Table A. 6 . *Parameters of different scenarios for tertiary distribution (shaded cells show changes in parameter values)*

		Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
Driver	Driver hour	4:00-22:00	4:00-22:00	4:00-22:00	4:00-22:00	4:00-22:00	4:00-22:00	4:00-22:00
	Length (hh:mm)	11:00	12:00	10:00	11:00	11:00	11:00	11:00
	Driving (hh:mm)	9:00	10:00	8:00	9:00	9:00	9:00	9:00
	Working (hh:mm)	11:00	12:00	10:00	11:00	11:00	11:00	11:00
	Gap (hh:mm)	13:00	13:00	13:00	13:00	13:00	13:00	13:00
Break:	Working (hh:mm)	0:45	0:45	0:45	0:45	0:45	0:45	0:45
	After driving (hh:mm)	4:30	4:30	4:30	4:30	4:30	4:30	4:30
	After working (hh:mm)	5:30	5:30	5:30	5:30	5:30	5:30	5:30
Load in time windows		Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mix Delivery/Collections		Yes	Yes	Yes	Yes	Yes	Yes	Yes
Customer opening time		6:00-18:00	6:00-18:00	6:00-20:00	6:00-20:00	8:00-16:00	6:00-18:00	6:00-18:00
Depot opening time		4:00-22:00	4:00-22:00	4:00-22:00	4:00-22:00	4:00-22:00	4:00-22:00	4:00-22:00
Check in time (hh:mm)		0:10	0:10	0:10	0:10	0:10	0:10	0:10
Order	Earliest	- 6:00	- 6:00	- 6:00	- 6:00	- 6:00	- 3:00	- 12:00
	Latest	+ 4:00	+ 4:00	+ 4:00	+ 4:00	+ 4:00	+ 2:00	+8:00

B. Three fleets (Secondary, Tertiary and Mixed Distribution) of Company B:

Table A. 7 . *Parameters of different scenarios of fleets within the same company (shaded cells show changes in parameters)*

		Scenario 1	Scenario 2	Scenario 4	Scenario 5	Scenario 6	Scenario 7
Driver	Driver hour	4:00-22:00	4:00-22:00	4:00-22:00	4:00-22:00	4:00-22:00	4:00-22:00
	Length (hh:mm)	11:00	12:00	11:00	11:00	11:00	11:00
	Driving (hh:mm)	9:00	10:00	9:00	9:00	9:00	9:00
	Working (hh:mm)	11:00	12:00	11:00	11:00	11:00	11:00
	Gap (hh:mm)	13:00	13:00	13:00	13:00	13:00	13:00
Break	Working (hh:mm)	0:45	0:45	0:45	0:45	0:45	0:45
	After driving (hh:mm)	4:30	4:30	4:30	4:30	4:30	4:30
	After working (hh:mm)	5:30	5:30	5:30	5:30	5:30	5:30
Load in time windows		Yes	Yes	Yes	Yes	Yes	Yes
Mix Delivery/Collections		Yes	Yes	Yes	Yes	Yes	Yes
Customer opening time		6:00-18:00	6:00-18:00	6:00-20:00	0:00-24:00	6:00-18:00	6:00-18:00
Depot opening time		0:00-24:00	0:00-24:00	0:00-24:00	0:00-24:00	0:00-24:00	0:00-24:00
Check in time (hh:mm)		0:10	0:10	0:10	0:10	0:10	0:10
Order	Earliest	- 6:00	- 6:00	- 6:00	- 6:00	- 3:00	- 12:00
	Latest	+ 4:00	+ 4:00	+ 4:00	+ 4:00	+ 2:00	+8:00

C. Same sub-sector, different company (Primary temperature controlled distribution)

Table A. 8 . *Parameters of different scenarios for fleets within the same sub-sector*

		Scenario 1	Scenario 2	Scenario 4	Scenario 5	Scenario 6	Scenario 7
Driver	Driver hour	4:00-22:00	4:00-22:00	4:00-22:00	4:00-22:00	4:00-22:00	4:00-22:00
	Length (hh:mm)	11:00	12:00	11:00	11:00	11:00	11:00
	Driving (hh:mm)	9:00	10:00	9:00	9:00	9:00	9:00
	Working (hh:mm)	11:00	12:00	11:00	11:00	11:00	11:00
	Gap (hh:mm)	13:00	13:00	13:00	13:00	13:00	13:00
Break:	Working (hh:mm)	0:45	0:45	0:45	0:45	0:45	0:45
	After driving (hh:mm)	4:30	4:30	4:30	4:30	4:30	4:30
	After working (hh:mm)	5:30	5:30	5:30	5:30	5:30	5:30
Load in time windows		Yes	Yes	Yes	Yes	Yes	Yes
Mix Delivery/Collections		Yes	Yes	Yes	Yes	Yes	Yes
Customer opening time		6:00-18:00	6:00-18:00	6:00-20:00	0:00-24:00	6:00-18:00	6:00-18:00
Depot opening time		0:00-24:00	0:00-24:00	0:00-24:00	0:00-24:00	0:00-24:00	0:00-24:00
Check in time (hh:mm)		0:10	0:10	0:10	0:10	0:10	0:10
Order	Earliest	- 6:00	- 6:00	- 6:00	- 6:00	- 3:00	- 12:00
	Latest	+ 4:00	+ 4:00	+ 4:00	+ 4:00	+ 2:00	+8:00

Appendix C. RESULTS OF VEHICLE ROUTING AND SCHEDULING ANALYSIS

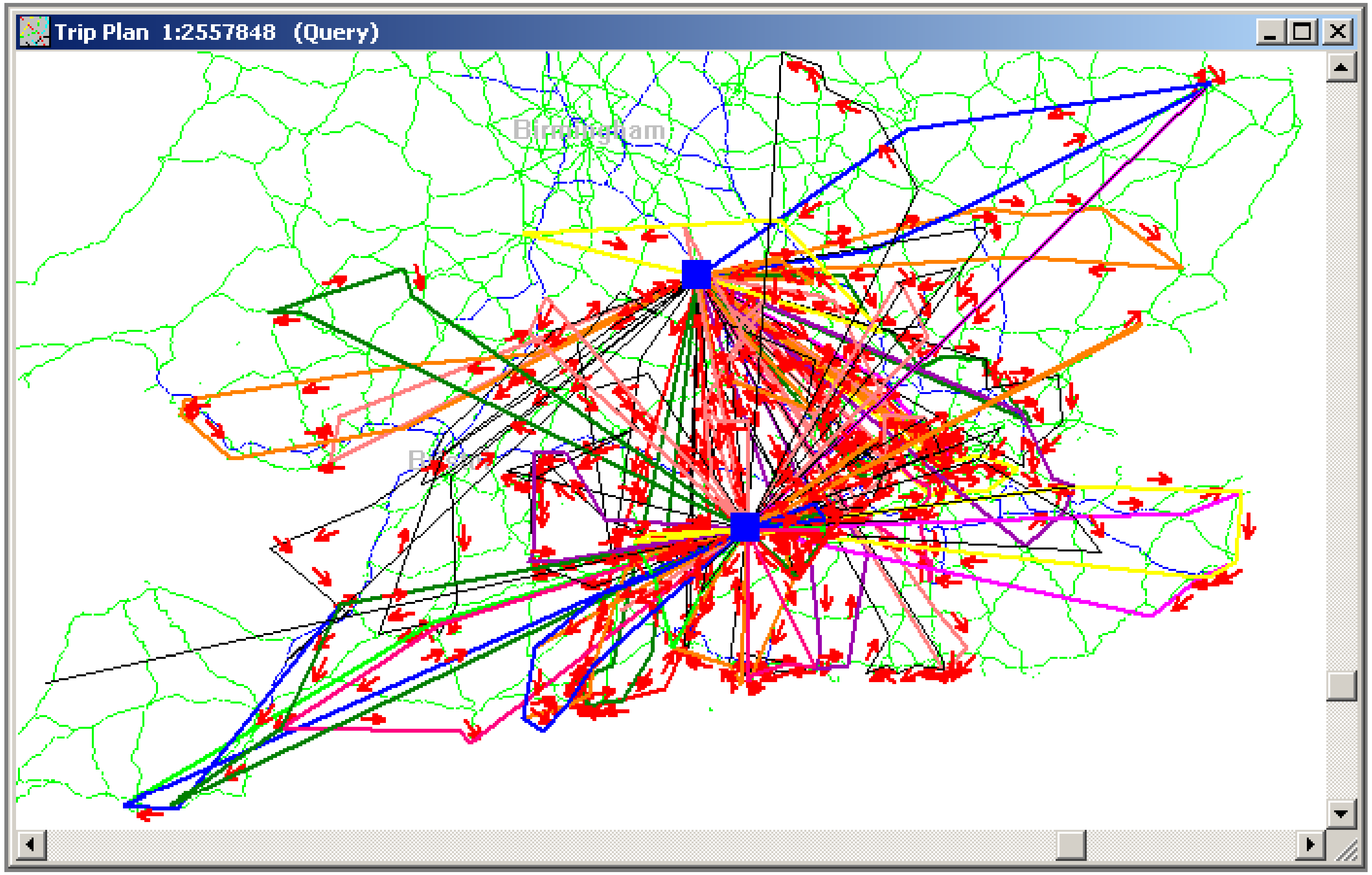


Figure C. 1 . *Distribution of trips for company A's two fleets (Base Scenario)*

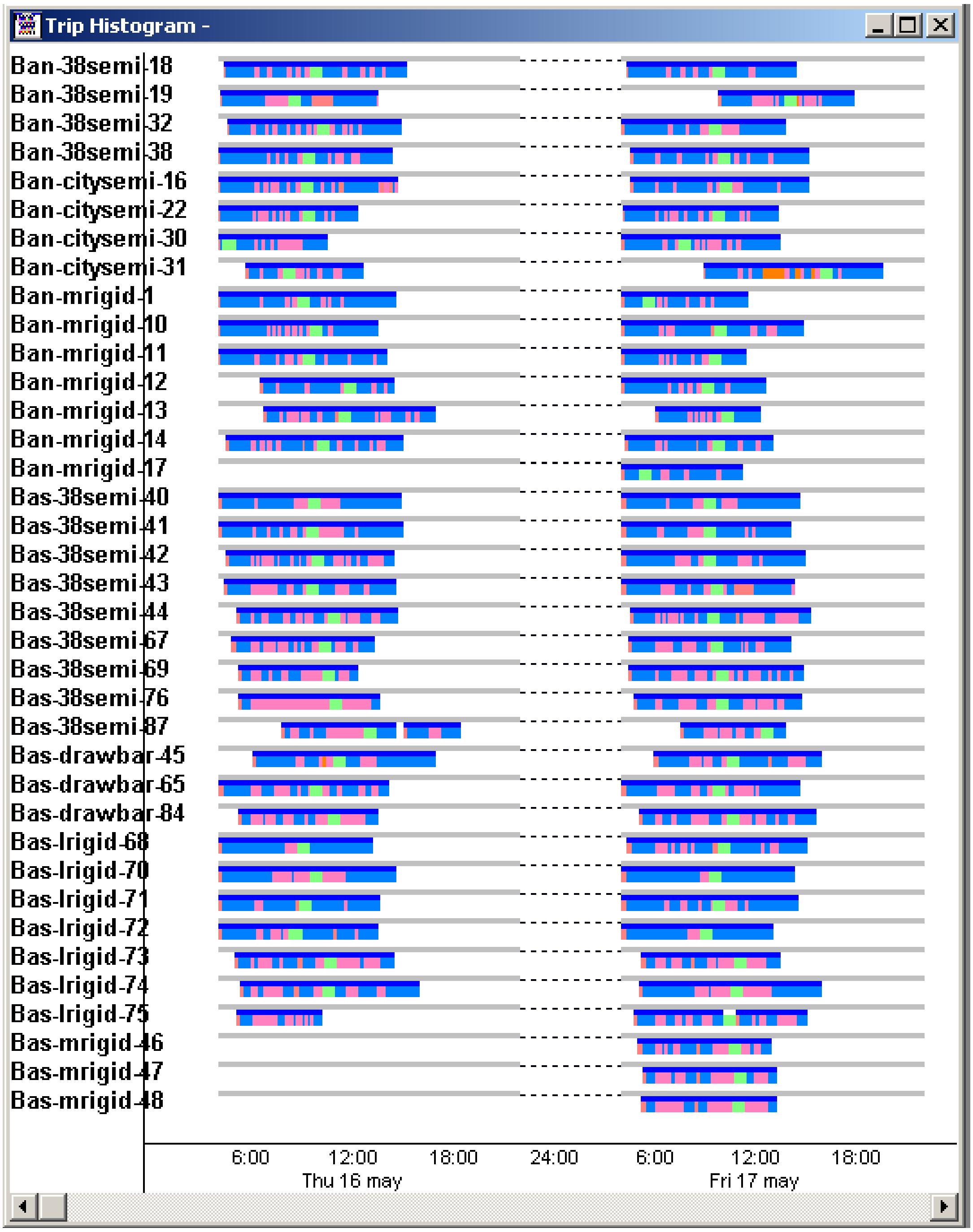


Figure C. 2 . *Trip histogram for company A's two depots (Base Scenario)*

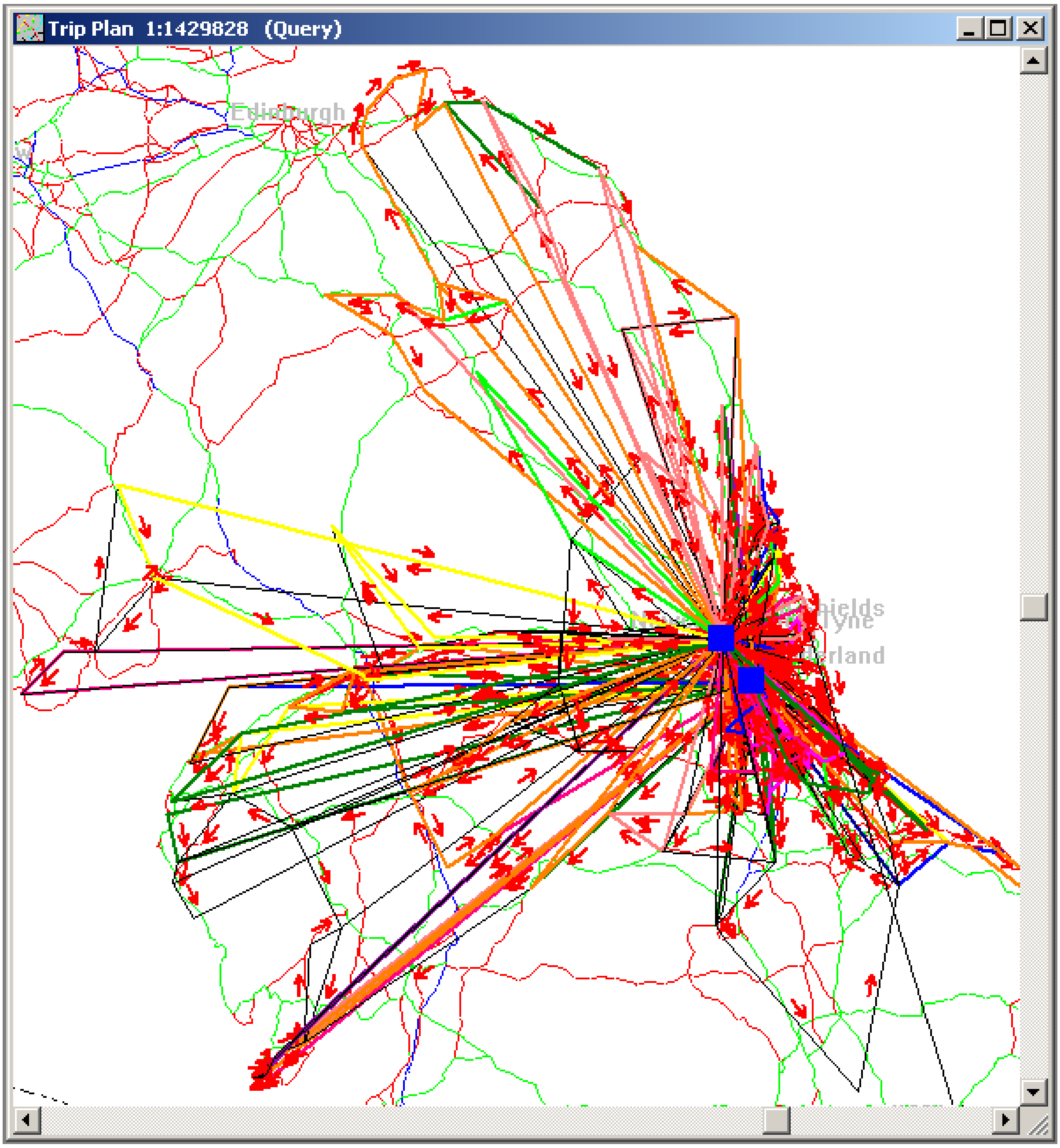


Figure C. 3 . *Distribution of trips for company B's two depots in NE England (Base Scenario)*

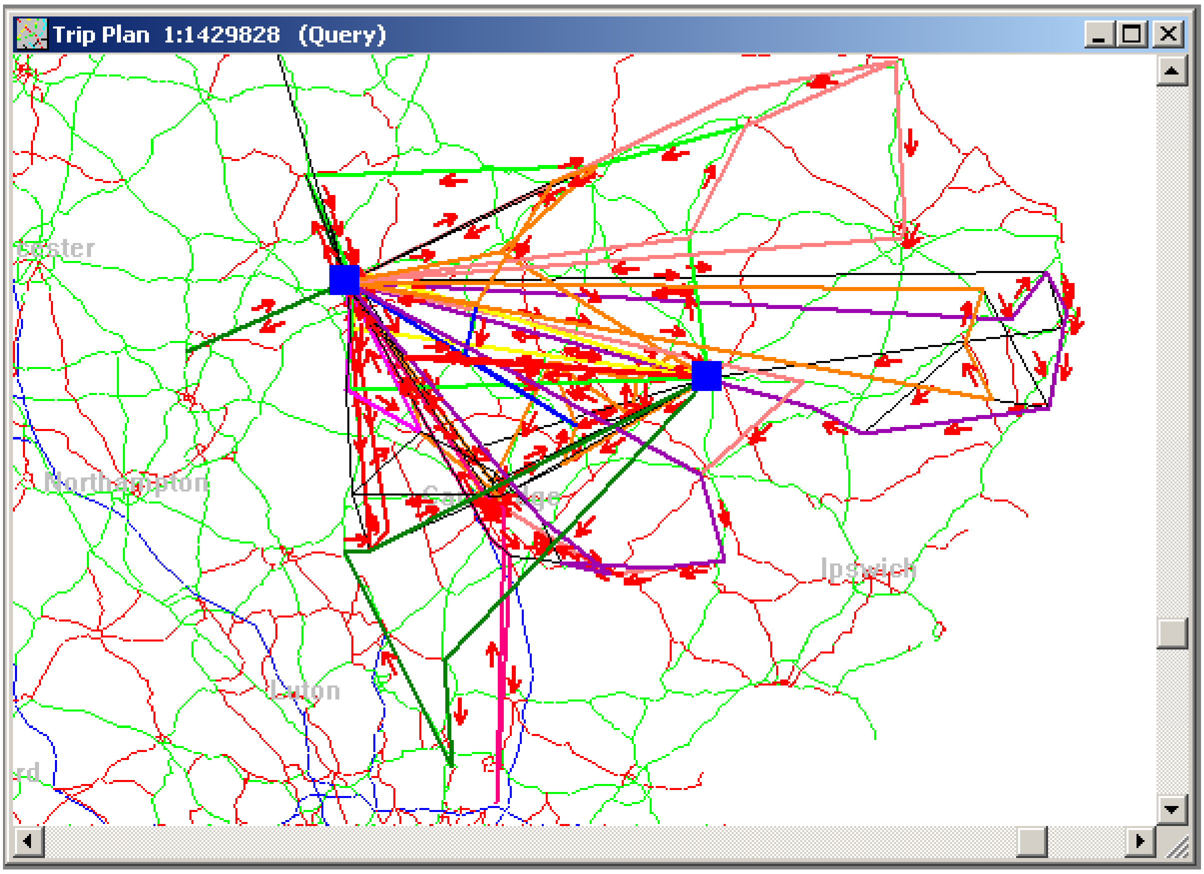


Figure C. 4 . *Actual trips for company B's two depots in E Midlands / E Anglia (Base Scenario)*

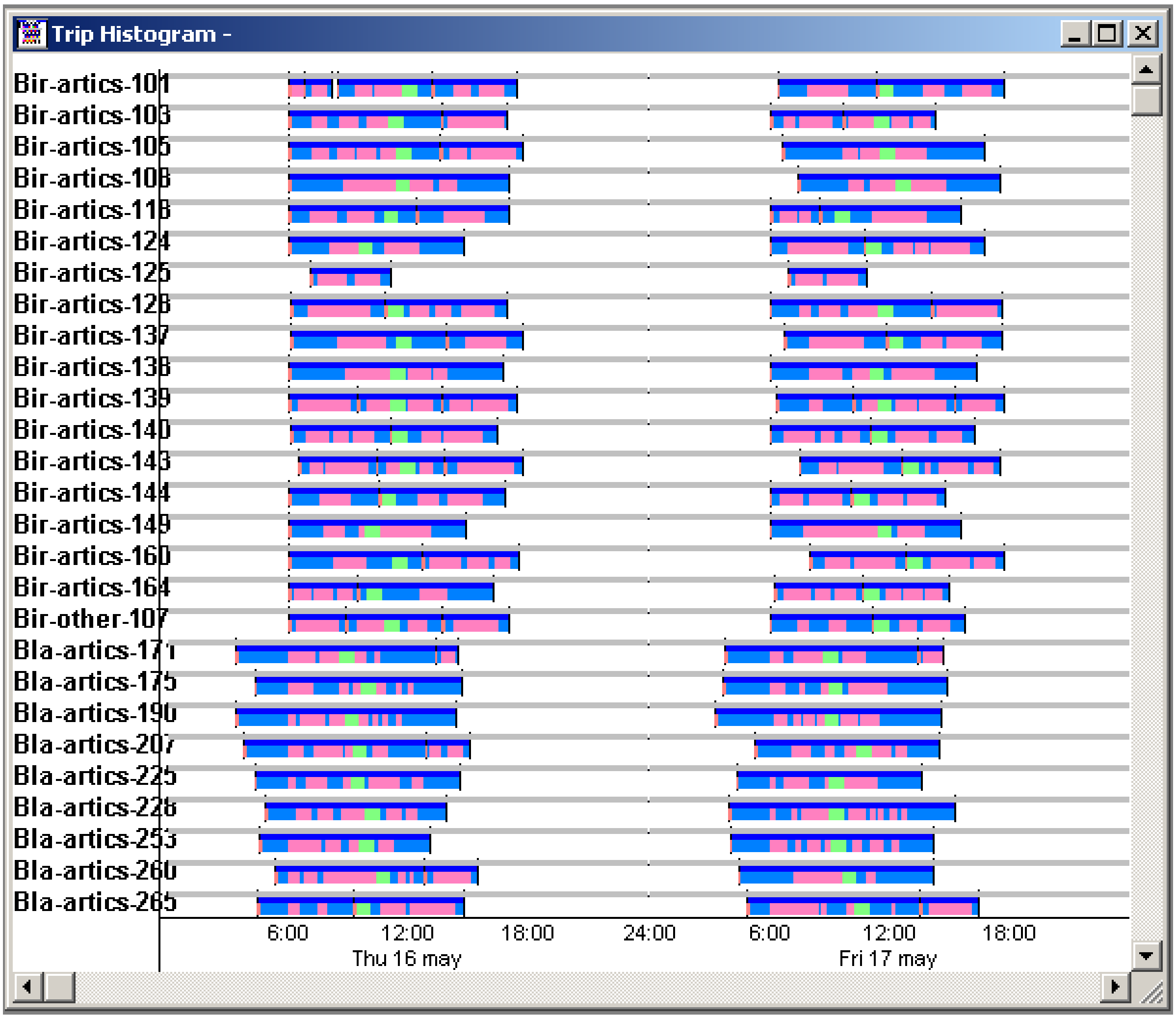


Figure C. 5 . *Trip histogram of company B's operation (Base Scenario)*

Appendix D. GIS INTERFACE FOR BACKLOADING ANALYSIS

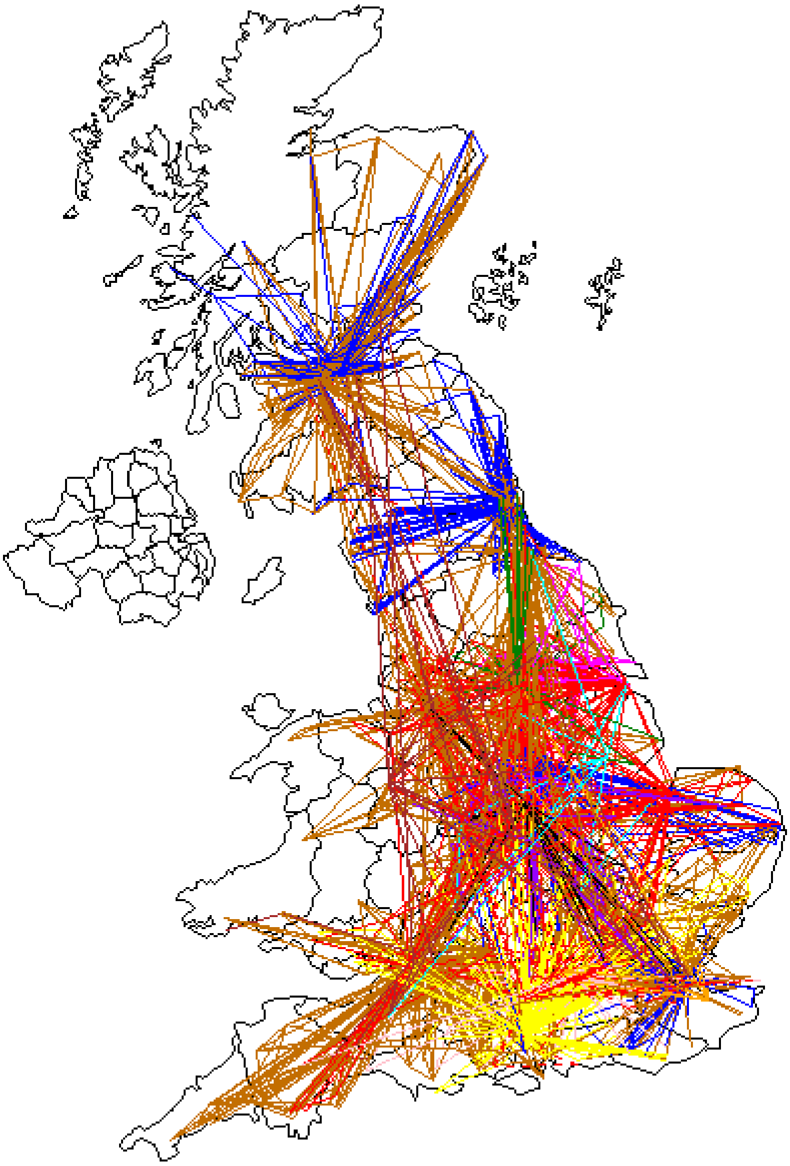


Figure C. 6 . *The distribution network of the fleets selected in the sample*

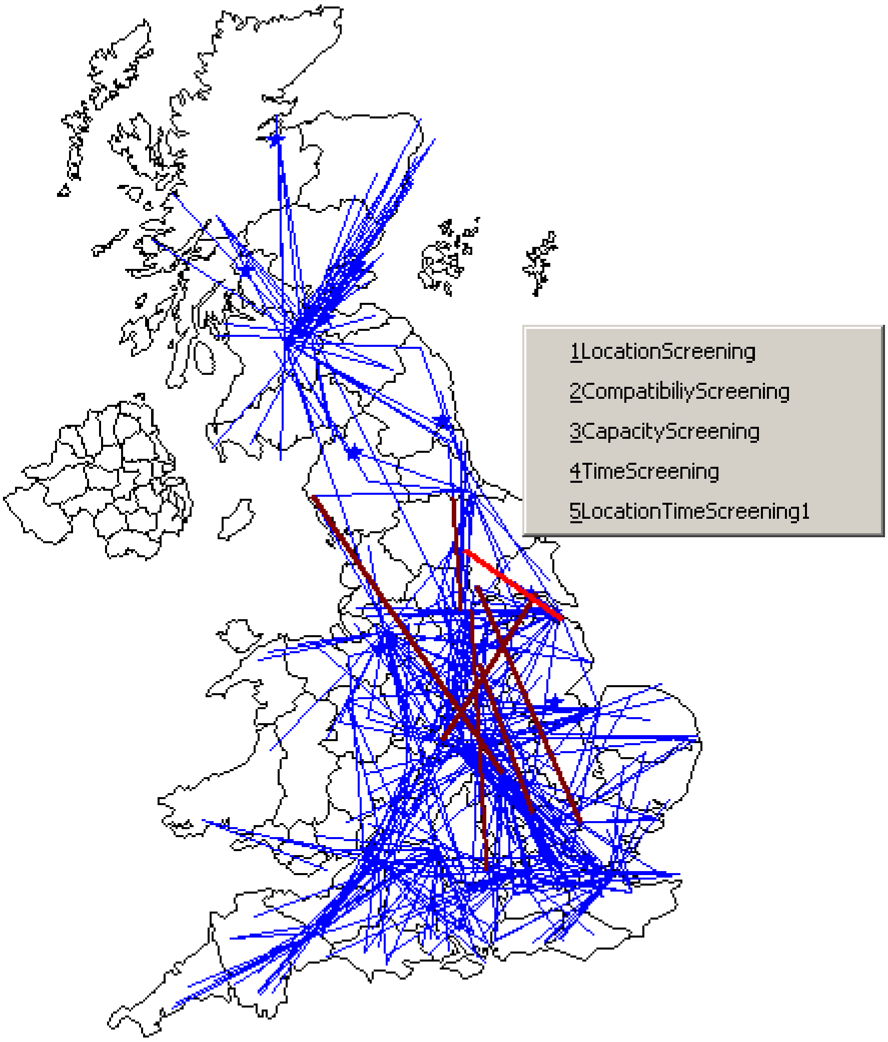


Figure C. 7. *Actions for interactive analysis (for selected objects)*

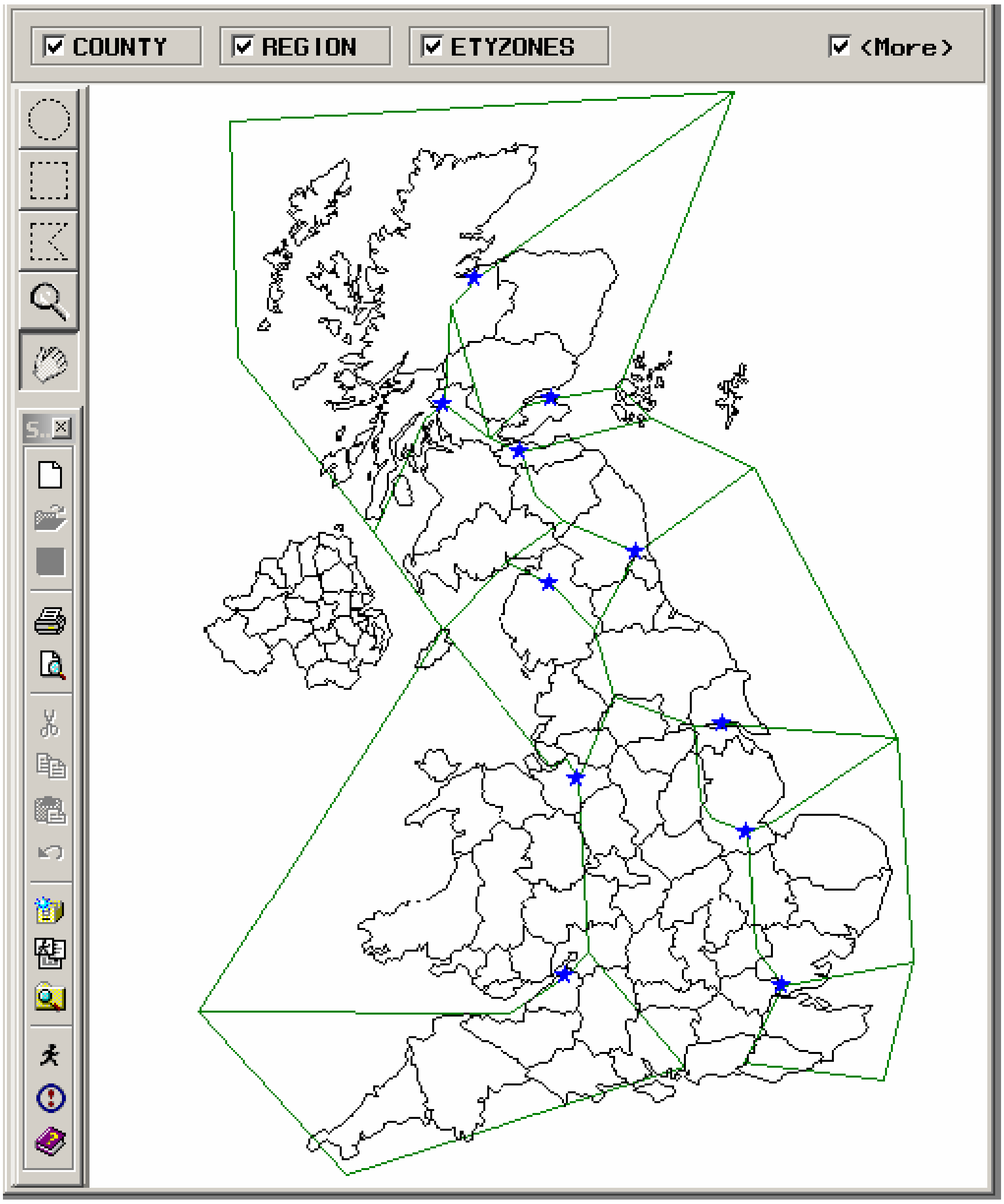
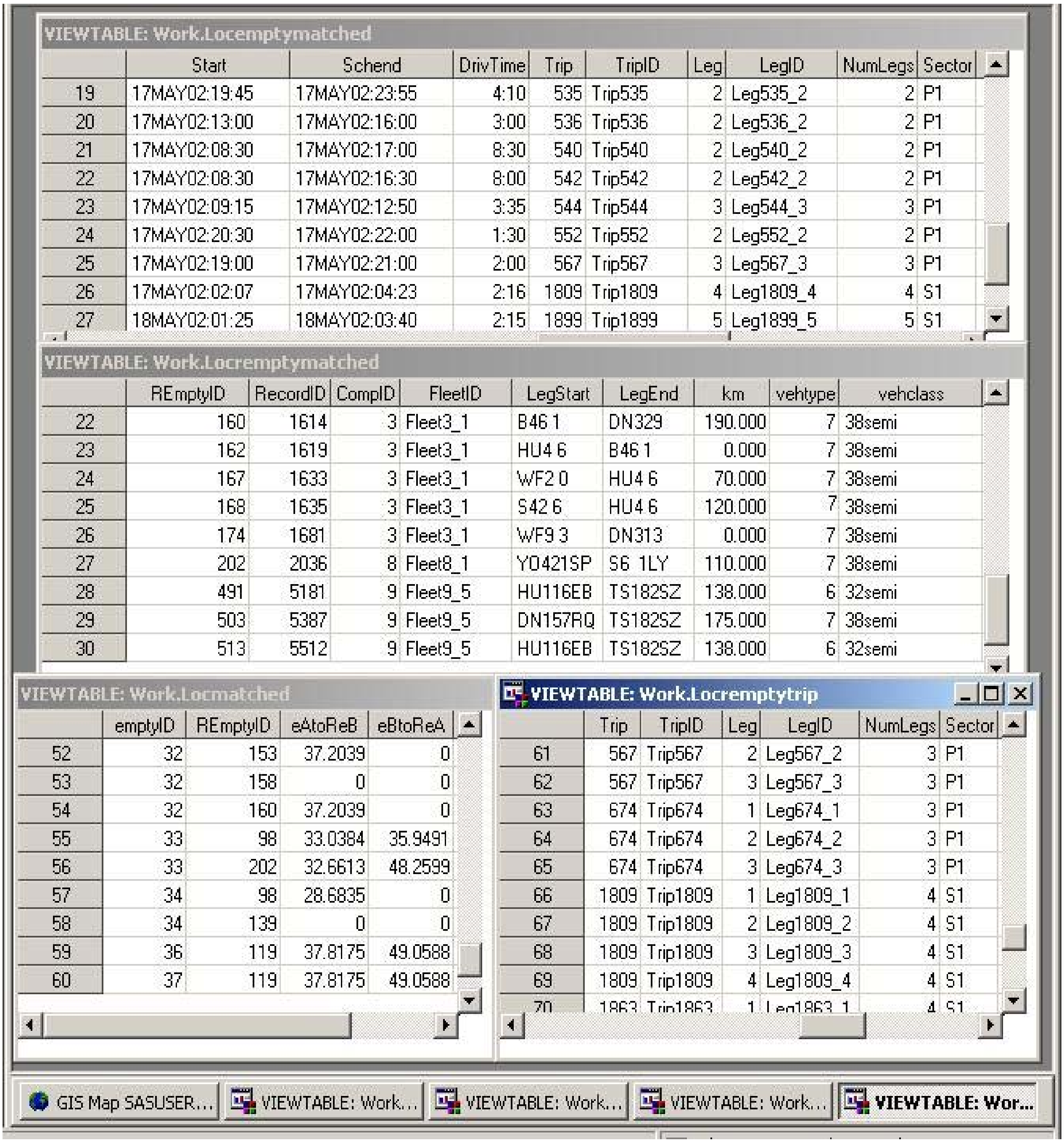


Figure C. 8 . *Estuary Zones and Way Points*

Appendix E. GIS INTERACTIVE ANALYSIS RESULTS

A. Location screening

Table E. 1 . Screening results in table format



VIEWTABLE: Work.Locemptymatched

	Start	Schend	DrivTime	Trip	TripID	Leg	LegID	NumLegs	Sector
19	17MAY02:19:45	17MAY02:23:55	4:10	535	Trip535	2	Leg535_2	2	P1
20	17MAY02:13:00	17MAY02:16:00	3:00	536	Trip536	2	Leg536_2	2	P1
21	17MAY02:08:30	17MAY02:17:00	8:30	540	Trip540	2	Leg540_2	2	P1
22	17MAY02:08:30	17MAY02:16:30	8:00	542	Trip542	2	Leg542_2	2	P1
23	17MAY02:09:15	17MAY02:12:50	3:35	544	Trip544	3	Leg544_3	3	P1
24	17MAY02:20:30	17MAY02:22:00	1:30	552	Trip552	2	Leg552_2	2	P1
25	17MAY02:19:00	17MAY02:21:00	2:00	567	Trip567	3	Leg567_3	3	P1
26	17MAY02:02:07	17MAY02:04:23	2:16	1809	Trip1809	4	Leg1809_4	4	S1
27	18MAY02:01:25	18MAY02:03:40	2:15	1899	Trip1899	5	Leg1899_5	5	S1

VIEWTABLE: Work.Locremptymatched

	REmptyID	RecordID	CompID	FleetID	LegStart	LegEnd	km	vehtype	vehclass
22	160	1614	3	Fleet3_1	B46 1	DN329	190.000	7	38semi
23	162	1619	3	Fleet3_1	HU4 6	B46 1	0.000	7	38semi
24	167	1633	3	Fleet3_1	WF2 0	HU4 6	70.000	7	38semi
25	168	1635	3	Fleet3_1	S42 6	HU4 6	120.000	7	38semi
26	174	1681	3	Fleet3_1	WF9 3	DN313	0.000	7	38semi
27	202	2036	8	Fleet8_1	YO421SP	S6 1LY	110.000	7	38semi
28	491	5181	9	Fleet9_5	HU116EB	TS182SZ	138.000	6	32semi
29	503	5387	9	Fleet9_5	DN157RQ	TS182SZ	175.000	7	38semi
30	513	5512	9	Fleet9_5	HU116EB	TS182SZ	138.000	6	32semi

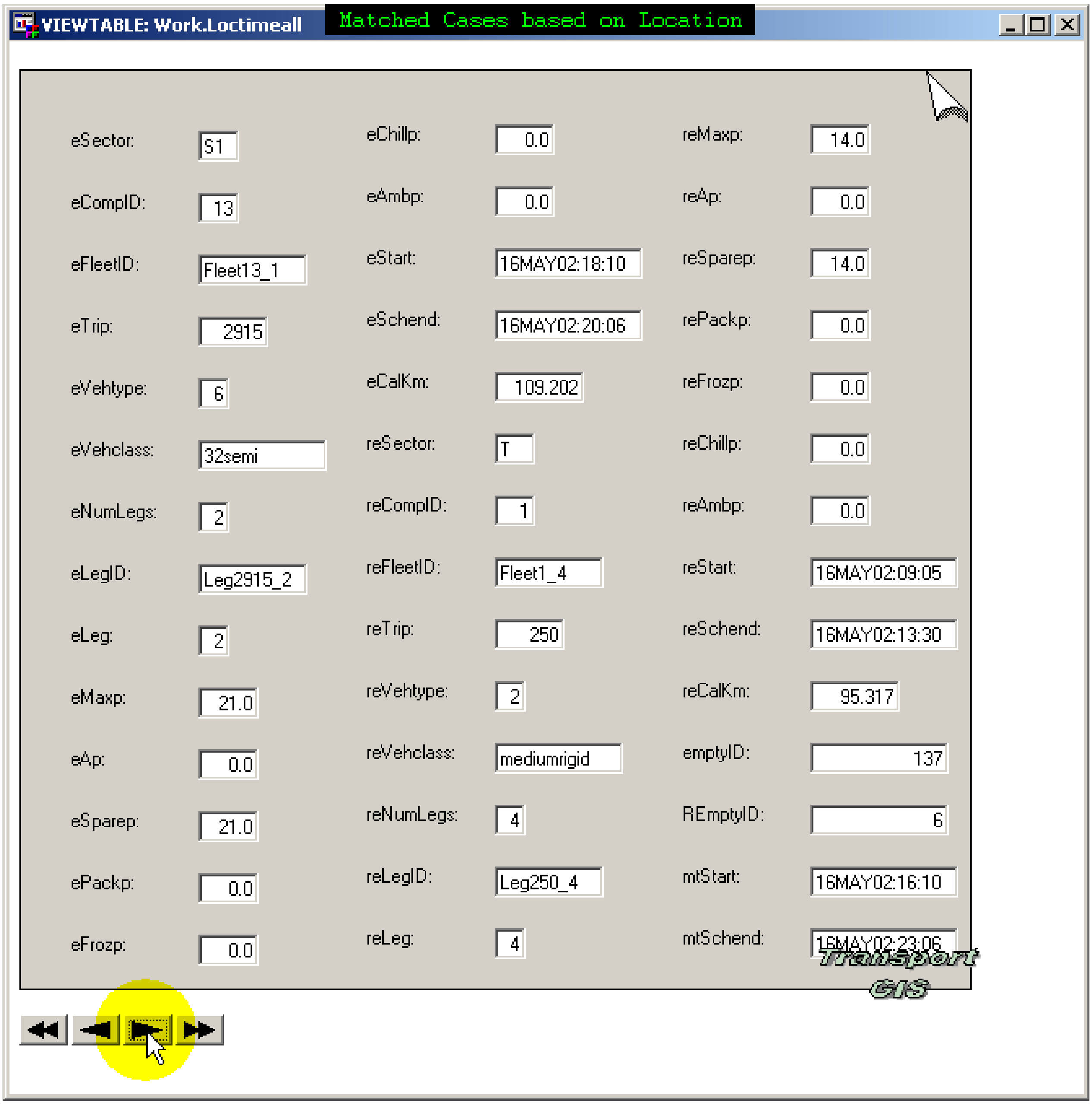
VIEWTABLE: Work.Locmatched

	emptyID	REmptyID	eAtoReB	eBtoReA
52	32	153	37.2039	0
53	32	158	0	0
54	32	160	37.2039	0
55	33	98	33.0384	35.9491
56	33	202	32.6613	48.2599
57	34	98	28.6835	0
58	34	139	0	0
59	36	119	37.8175	49.0588
60	37	119	37.8175	49.0588

VIEWTABLE: Work.Locremptytrip

	Trip	TripID	Leg	LegID	NumLegs	Sector
61	567	Trip567	2	Leg567_2	3	P1
62	567	Trip567	3	Leg567_3	3	P1
63	674	Trip674	1	Leg674_1	3	P1
64	674	Trip674	2	Leg674_2	3	P1
65	674	Trip674	3	Leg674_3	3	P1
66	1809	Trip1809	1	Leg1809_1	4	S1
67	1809	Trip1809	2	Leg1809_2	4	S1
68	1809	Trip1809	3	Leg1809_3	4	S1
69	1809	Trip1809	4	Leg1809_4	4	S1
70	1863	Trip1863	1	Leg1863_1	4	S1

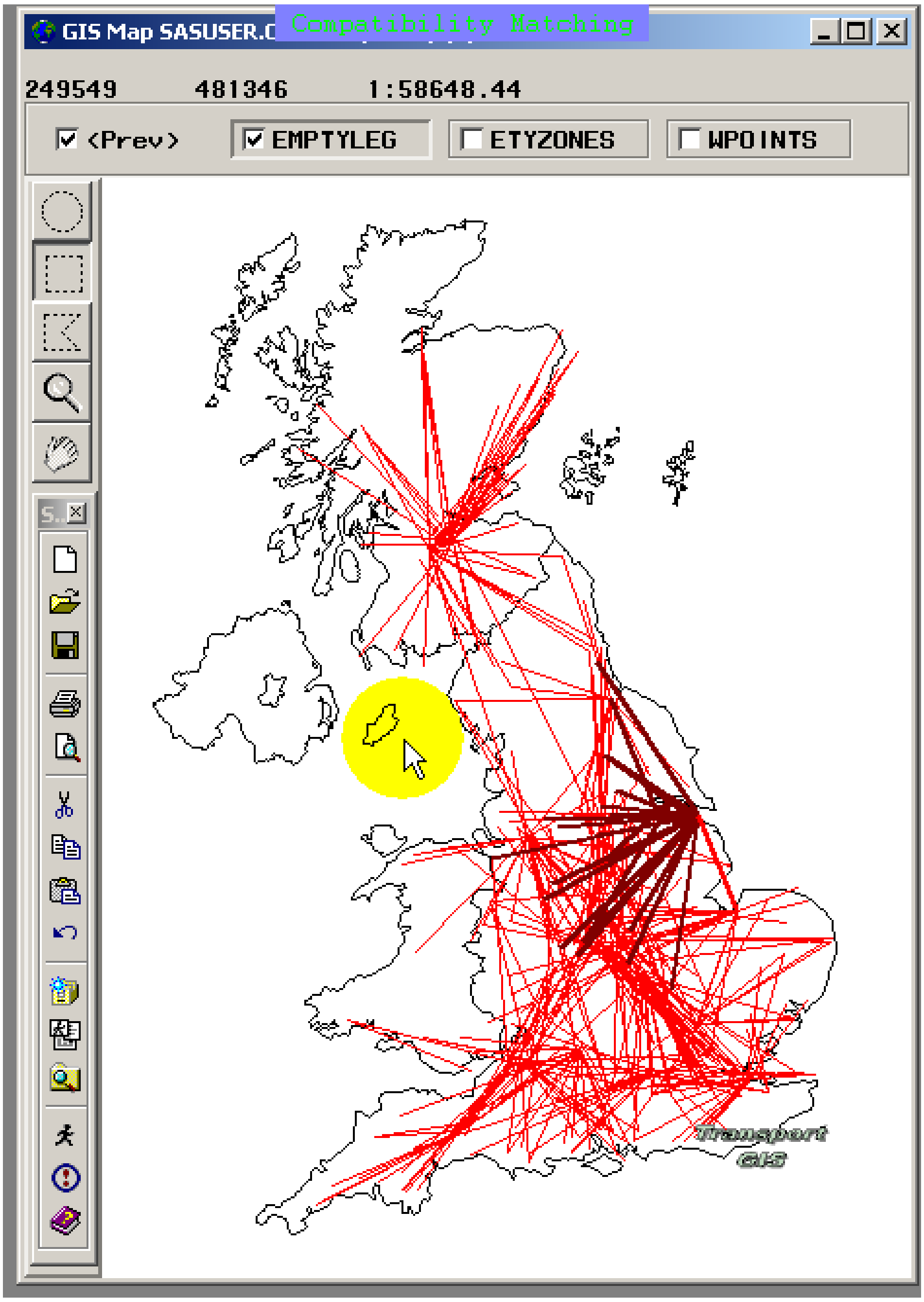
Table E. 2. *Screening results in form format*



VIEWTABLE: Work.Loctimeall Matched Cases based on Location

eSector:	S1	eChillp:	0.0	reMaxp:	14.0
eComplD:	13	eAmbp:	0.0	reAp:	0.0
eFleetID:	Fleet13_1	eStart:	16MAY02:18:10	reSparep:	14.0
eTrip:	2915	eSchend:	16MAY02:20:06	rePackp:	0.0
eVehtype:	6	eCalKm:	109.202	reFrozp:	0.0
eVehclass:	32semi	reSector:	T	reChillp:	0.0
eNumLegs:	2	reComplD:	1	reAmbp:	0.0
eLegID:	Leg2915_2	reFleetID:	Fleet1_4	reStart:	16MAY02:09:05
eLeg:	2	reTrip:	250	reSchend:	16MAY02:13:30
eMaxp:	21.0	reVehtype:	2	reCalKm:	95.317
eAp:	0.0	reVehclass:	mediumrigid	emptyID:	137
eSparep:	21.0	reNumLegs:	4	REmptyID:	6
ePackp:	0.0	reLegID:	Leg250_4	mtStart:	16MAY02:16:10
eFrozp:	0.0	reLeg:	4	mtSchend:	16MAY02:23:06

B. Interactive vehicle compatibility screening

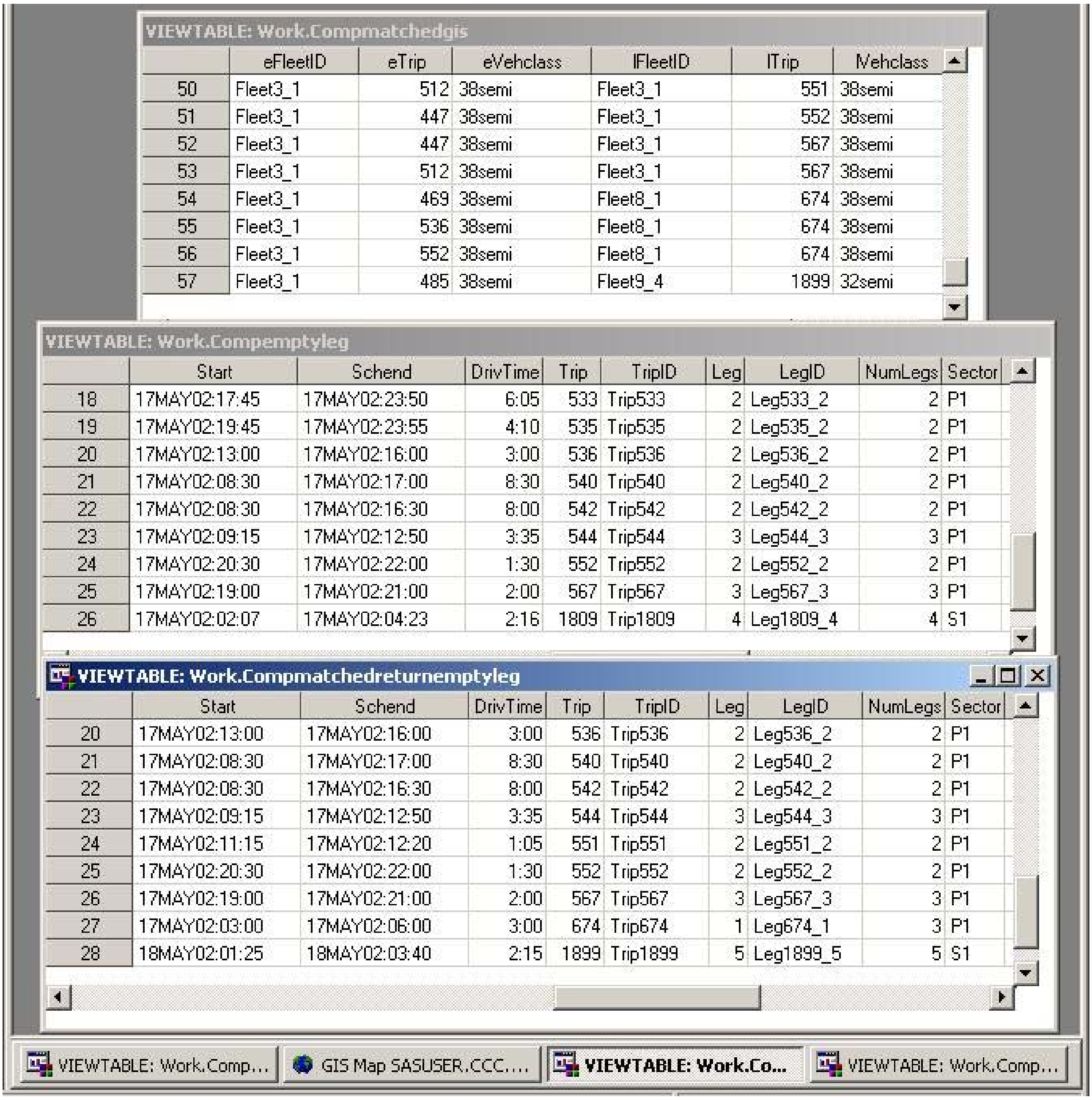


249549 481346 1:58648.44

☑ <Prev> ☑ EMPTYLEG ☐ ETYZONES ☐ WPOINTS

Figure E. 1 . *Empty legs selected for backloading analysis*

Table E. 3 . *Screening results in table format (based on location and vehicle compatibility)*



VIEWTABLE: Work.Compmatchedgis

	eFleetID	eTrip	eVehclass	lFleetID	lTrip	lVehclass
50	Fleet3_1	512	38semi	Fleet3_1	551	38semi
51	Fleet3_1	447	38semi	Fleet3_1	552	38semi
52	Fleet3_1	447	38semi	Fleet3_1	567	38semi
53	Fleet3_1	512	38semi	Fleet3_1	567	38semi
54	Fleet3_1	469	38semi	Fleet8_1	674	38semi
55	Fleet3_1	536	38semi	Fleet8_1	674	38semi
56	Fleet3_1	552	38semi	Fleet8_1	674	38semi
57	Fleet3_1	485	38semi	Fleet9_4	1899	32semi

VIEWTABLE: Work.Compemptyleg

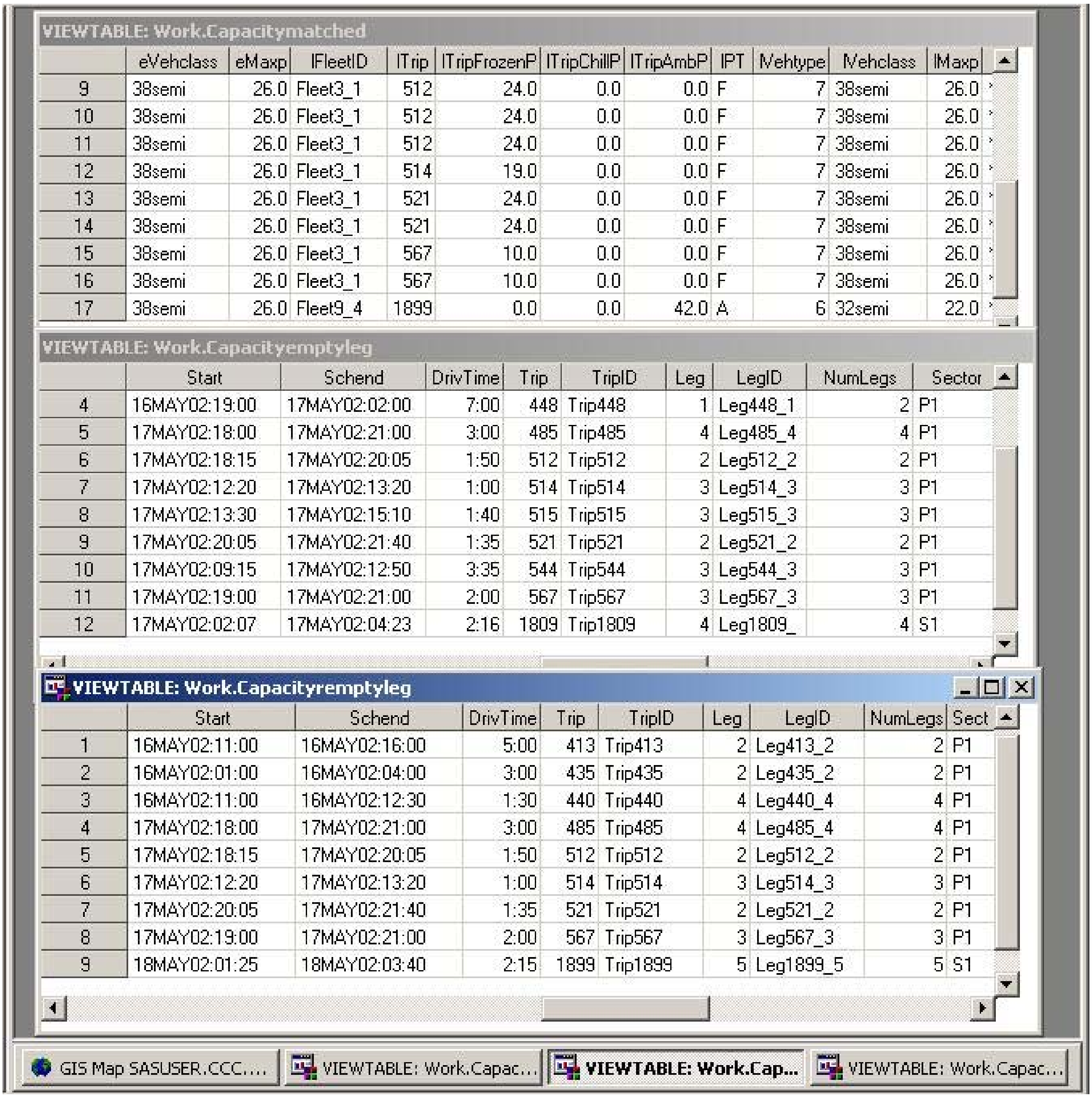
	Start	Schend	DrivTime	Trip	TripID	Leg	LegID	NumLegs	Sector
18	17MAY02:17:45	17MAY02:23:50	6:05	533	Trip533	2	Leg533_2	2	P1
19	17MAY02:19:45	17MAY02:23:55	4:10	535	Trip535	2	Leg535_2	2	P1
20	17MAY02:13:00	17MAY02:16:00	3:00	536	Trip536	2	Leg536_2	2	P1
21	17MAY02:08:30	17MAY02:17:00	8:30	540	Trip540	2	Leg540_2	2	P1
22	17MAY02:08:30	17MAY02:16:30	8:00	542	Trip542	2	Leg542_2	2	P1
23	17MAY02:09:15	17MAY02:12:50	3:35	544	Trip544	3	Leg544_3	3	P1
24	17MAY02:20:30	17MAY02:22:00	1:30	552	Trip552	2	Leg552_2	2	P1
25	17MAY02:19:00	17MAY02:21:00	2:00	567	Trip567	3	Leg567_3	3	P1
26	17MAY02:02:07	17MAY02:04:23	2:16	1809	Trip1809	4	Leg1809_4	4	S1

VIEWTABLE: Work.Compmatchedreturnemptyleg

	Start	Schend	DrivTime	Trip	TripID	Leg	LegID	NumLegs	Sector
20	17MAY02:13:00	17MAY02:16:00	3:00	536	Trip536	2	Leg536_2	2	P1
21	17MAY02:08:30	17MAY02:17:00	8:30	540	Trip540	2	Leg540_2	2	P1
22	17MAY02:08:30	17MAY02:16:30	8:00	542	Trip542	2	Leg542_2	2	P1
23	17MAY02:09:15	17MAY02:12:50	3:35	544	Trip544	3	Leg544_3	3	P1
24	17MAY02:11:15	17MAY02:12:20	1:05	551	Trip551	2	Leg551_2	2	P1
25	17MAY02:20:30	17MAY02:22:00	1:30	552	Trip552	2	Leg552_2	2	P1
26	17MAY02:19:00	17MAY02:21:00	2:00	567	Trip567	3	Leg567_3	3	P1
27	17MAY02:03:00	17MAY02:06:00	3:00	674	Trip674	1	Leg674_1	3	P1
28	18MAY02:01:25	18MAY02:03:40	2:15	1899	Trip1899	5	Leg1899_5	5	S1

C. Interactive vehicle capacity screening

Table E. 4 . *Screening results in table format (based on location, vehicle compatibility, and capacity)*



VIEWTABLE: Work.Capacitymatched

	eVehclass	eMaxp	lFleetID	lTrip	lTripFrozenP	lTripChillP	lTripAmbP	lPT	lVehtype	lVehclass	lMaxp
9	38semi	26.0	Fleet3_1	512	24.0	0.0	0.0	F	7	38semi	26.0
10	38semi	26.0	Fleet3_1	512	24.0	0.0	0.0	F	7	38semi	26.0
11	38semi	26.0	Fleet3_1	512	24.0	0.0	0.0	F	7	38semi	26.0
12	38semi	26.0	Fleet3_1	514	19.0	0.0	0.0	F	7	38semi	26.0
13	38semi	26.0	Fleet3_1	521	24.0	0.0	0.0	F	7	38semi	26.0
14	38semi	26.0	Fleet3_1	521	24.0	0.0	0.0	F	7	38semi	26.0
15	38semi	26.0	Fleet3_1	567	10.0	0.0	0.0	F	7	38semi	26.0
16	38semi	26.0	Fleet3_1	567	10.0	0.0	0.0	F	7	38semi	26.0
17	38semi	26.0	Fleet9_4	1899	0.0	0.0	42.0	A	6	32semi	22.0

VIEWTABLE: Work.Capacityemptyleg

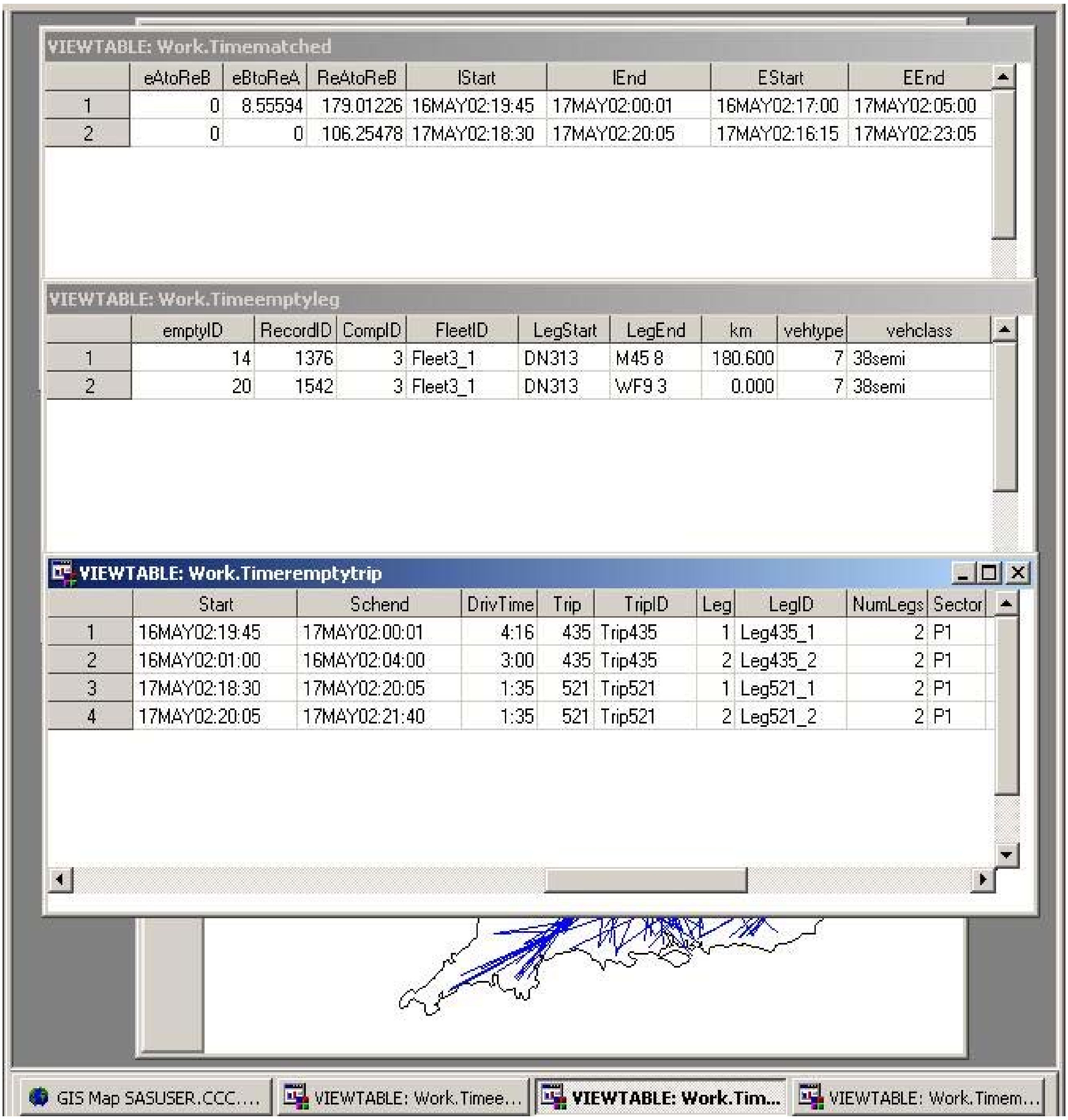
	Start	Schend	DrivTime	Trip	TripID	Leg	LegID	NumLegs	Sector
4	16MAY02:19:00	17MAY02:02:00	7:00	448	Trip448	1	Leg448_1	2	P1
5	17MAY02:18:00	17MAY02:21:00	3:00	485	Trip485	4	Leg485_4	4	P1
6	17MAY02:18:15	17MAY02:20:05	1:50	512	Trip512	2	Leg512_2	2	P1
7	17MAY02:12:20	17MAY02:13:20	1:00	514	Trip514	3	Leg514_3	3	P1
8	17MAY02:13:30	17MAY02:15:10	1:40	515	Trip515	3	Leg515_3	3	P1
9	17MAY02:20:05	17MAY02:21:40	1:35	521	Trip521	2	Leg521_2	2	P1
10	17MAY02:09:15	17MAY02:12:50	3:35	544	Trip544	3	Leg544_3	3	P1
11	17MAY02:19:00	17MAY02:21:00	2:00	567	Trip567	3	Leg567_3	3	P1
12	17MAY02:02:07	17MAY02:04:23	2:16	1809	Trip1809	4	Leg1809_	4	S1

VIEWTABLE: Work.Capacityremptyleg

	Start	Schend	DrivTime	Trip	TripID	Leg	LegID	NumLegs	Sect
1	16MAY02:11:00	16MAY02:16:00	5:00	413	Trip413	2	Leg413_2	2	P1
2	16MAY02:01:00	16MAY02:04:00	3:00	435	Trip435	2	Leg435_2	2	P1
3	16MAY02:11:00	16MAY02:12:30	1:30	440	Trip440	4	Leg440_4	4	P1
4	17MAY02:18:00	17MAY02:21:00	3:00	485	Trip485	4	Leg485_4	4	P1
5	17MAY02:18:15	17MAY02:20:05	1:50	512	Trip512	2	Leg512_2	2	P1
6	17MAY02:12:20	17MAY02:13:20	1:00	514	Trip514	3	Leg514_3	3	P1
7	17MAY02:20:05	17MAY02:21:40	1:35	521	Trip521	2	Leg521_2	2	P1
8	17MAY02:19:00	17MAY02:21:00	2:00	567	Trip567	3	Leg567_3	3	P1
9	18MAY02:01:25	18MAY02:03:40	2:15	1899	Trip1899	5	Leg1899_5	5	S1

D. Time screening

Table E. 5 . *Screening results in table format (based on location, vehicle compatibility, capacity, and deliver time window)*



VIEWTABLE: Work.Timematched

	eAtoReB	eBtoReA	ReAtoReB	IStart	IEnd	EStart	EEnd
1	0	8.55594	179.01226	16MAY02:19:45	17MAY02:00:01	16MAY02:17:00	17MAY02:05:00
2	0	0	106.25478	17MAY02:18:30	17MAY02:20:05	17MAY02:16:15	17MAY02:23:05

VIEWTABLE: Work.Timeemptyleg

	emptyID	RecordID	CompID	FleetID	LegStart	LegEnd	km	vehtype	vehclass
1	14	1376	3	Fleet3_1	DN313	M45 8	180.600	7	38semi
2	20	1542	3	Fleet3_1	DN313	WF9 3	0.000	7	38semi

VIEWTABLE: Work.Timeremptytrip

	Start	Schend	DrivTime	Trip	TripID	Leg	LegID	NumLegs	Sector
1	16MAY02:19:45	17MAY02:00:01	4:16	435	Trip435	1	Leg435_1	2	P1
2	16MAY02:01:00	16MAY02:04:00	3:00	435	Trip435	2	Leg435_2	2	P1
3	17MAY02:18:30	17MAY02:20:05	1:35	521	Trip521	1	Leg521_1	2	P1
4	17MAY02:20:05	17MAY02:21:40	1:35	521	Trip521	2	Leg521_2	2	P1

Appendix F. SAMPLE STATISTICS

Table E. 6 . *Sample statistics at company level*

Company	average distance per leg (km)	Number of legs	Number of trips	
1	57.3	949	328	11.1%
2	65.8	274	62	2.1%
3	116.1	461	178	6.0%
4	90.3	62	27	0.9%
5	105.9	35	12	0.4%
6	126.8	17	6	0.2%
7	36.7	192	48	1.6%
8	135.8	100	28	0.9%
9	84.0	6,256	2,028	68.6%
10	69.3	234	66	2.2%
11	107.9	46	16	0.5%
12	106.3	155	53	1.8%
13	71.1	213	105	3.6%

Table E. 7 . *Sample statistics of fleets from one company*

Fleet	average distance per leg (km)	Number of legs	Number of trips	
Fleet9_1	64.4	554	143	7.1%
Fleet9_10	91.6	778	210	10.4%
Fleet9_11	74.5	321	96	4.7%
Fleet9_12	104.6	273	69	3.4%
Fleet9_2	77.7	230	60	3.0%
Fleet9_3	74.4	1,385	615	30.3%
Fleet9_4	78.0	840	275	13.6%
Fleet9_5	111.0	726	198	9.8%
Fleet9_6	62.0	347	126	6.2%
Fleet9_7	86.6	170	66	3.3%
Fleet9_8	104.0	279	83	4.1%
Fleet9_9	96.1	353	87	4.3%

Appendix G. QUESTIONNAIRE FOR VTS SUPPLIERS

Survey of Vehicle Tracking Suppliers

1. **Date surveyed**

2. **Name of company**

3. **Contact name**

4. **Telephone number**

5. **E-mail address**

Section 1 Nature of Organisation

Is your company a

6. **Vehicle tracking/telematics supplier that supplies the road transport industry**

Section 2 Details of System/Service Offering

Does your service offering include

7. **GPS positioning**
8. **Live tracking**
9. **Historic tracking**
10. **Remote upload of data**
11. **Local upload of data**

Vehicle telemetry data

12. Fuel consumption
13. Driver hours
14. Engine hours
15. Engine idle time
16. Door open
17. Temperature monitoring
18. Weight/load sensing
19. Over-revving
20. Gear changes
21. Other

If so, what

Communications capability

1. GSM
2. Public Access Mobile Radio (e.g. Band 3)
   Is this
3. Analogue
   or
4. Digital
5. WAN/LAN (Wireless)
6. Satellite
7. Other

If so, what

Is data accessed through

8. Web-based bureau
9. Customer site direct to vehicles
10. Network to central bureau
11. Other

If so, what

Data storage system

Is data stored

12. Not stored at all

go to question 61

13. Remotely at customer site(s)
14. Centrally at VTS site
15. Other

If so, what

Does stored data contain

Start and finish points for each

16. journey leg
17. trip
18. other
19. Time, date and position for each event

What triggers the recording of this information

20. Driver input
21. Automatic from system
22. Other

If so, what

23. Load details
    Is this by
24. Weight
    or

Specify measure used

25. Volume

Specify measure used

26. Positional information
27. By x-y co-ordinates
28. Latitude and longitude
29. Postcode
30. Grid reference
31. Street name, Town
32. Vehicle type
33. Other

If so, what

What is the basic structure of the database

1. MS Excel
2. MS Access
3. MS SQL
4. Other

If so, what

Can data be exported

5. In CSV format
6. Other *If so, what*

KPI Data

Does your system provide any of the following KPI measures

7. Vehicle fill/ loading factors
8. Empty running
9. Vehicle time utilisation
   if so
10. Can you differentiate between Tractor and trailer utilisation
11. Deviation from schedule
12. Fuel consumption
   Is this measured by
13. MPG/litres per 100km
14. Measure of energy intensity – fuel consumed relative to load carried/distance
15. Other
   If so, what

To what extent do you customise KPI data for your customers

16. Not at all
17. Choice of standard KPI's from list
   Please list
18. Any, at customers request
19. By sector
   If so, what

Does your system interface with other commercially available

20. Routing and scheduling software
   which
21. Optimisation software
   which
22. Fleet maintenance software
   which
23. Bespoke systems
24. ERP systems
25. MRP systems
26. Dispatch software
27. Customer order
28. Warehouse Management System (WMS)
29. Dock Management Systems
30. Other
   If so, what

1. **Does your system allow for retrospective analysis of the data**
   If yes,
2. Do you perceive it as being desired by customers
   If no,
3. Is this a feature you would like to offer

4. **Do you assist customers proactively in identifying potential efficiency improvements**

5. **Do you offer a benchmarking service to customers**
6. Within their own fleet
7. By industry type/sector
8. Across all fleets

9. **Do you offer an advisory service to customers in respect of opportunities to consolidate traffic/loads**

10. **Which software tools do you use to perform the above analysis (2L-O)**

11. **Who owns the data**

12. **What is the number of vehicle fleets using your system**

13. **What is the total number of vehicles fitted with your system**

14. **List the five most common fleet types fitted with your system**

15. **Describe any new service offerings currently being considered/developed**