Applying Vehicle Tracking and Palmtop Technology to Urban Freight Surveys

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Abstract

Following the success of the Victorian Activity & Travel Survey (VATS) of household travel, the Transport Research Centre (TRC) initiated a Freight Activity & Commercial Travel Survey (FACTS) to provide a much needed database of freight-related information for the Melbourne metropolitan area. The objective is to provide detailed, accurate and current data on freight travel and commercial activities in metropolitan Melbourne. FACTS aims to be an ongoing survey collecting information on travel, loading and unloading activities, the vehicle and some basic information on the driver.

The survey design requires that information on vehicle location be collected using a Geographic Positioning System (GPS) receiver, with GPS differential correction to increase accuracy to within 5m. This (GPS) tracking data will be linked to a Geographic Information System (GIS) package to allow vehicles to be geographically viewed as they move around the road network, and to enable mapping of the vehicle location trajectories to the underlying road network database. The GPS receiver will be linked to a palmtop computer housed in a portable Data Capture Unit (DCU) located within the vehicle cabin. A touch-screen on this palmtop will be used to obtain information from the driver about the loading and unloading stops.

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Introduction

The collection of urban freight movement data has always provided many challenges. Obtaining accurate, detailed data on freight for a reasonable cost has typically been fraught with low response rates, and survey methods such as intercept surveys have provided only a snapshot of information. Consequently existing data on freight is either, a group of fragmented snapshots, which are not often transportable, or is out of date since comprehensive studies are funded by government at the sparse interval of 10 or 20 years.

The Freight Activity and Commercial Travel Survey (FACTS), prototyped at the Transport Research Centre, Royal Melbourne Institute of Technology (RMIT) aims to develop a tool for freight movement data collection. The prototype uses the convenience and novelty of GPS and Palmtop technology to replace the traditional pen and paper questionnaire.

This paper is broadly discussed in two parts, firstly, the selection of an appropriate survey methodology and secondly, the development of an appropriate tool.

Survey objectives

The objective of FACTS is to provide current (continuous), accurate, detailed data of freight and commercial travel and activities in metropolitan Melbourne.

As part of the objective setting process, a freight reference group was established and a meeting held to discuss the concept of a Freight Activity and Commercial Travel Survey (FACTS) project, and provide feedback on the perceived uses and value of such a project. The reference group comprised experts and potential users from different areas of the frieght industry such as the Transport Workers Union, Victorian Road Transport Association, VicRoads, Department of Infrastructure, academia, and RACV. In addition to the expected value of the comprehensive freight project, other issues discussed included likely obstacles such as driver, owner or company cooperation.

The Reference Group concluded that the Australian Bureau of Statistics provided sufficient aggregate data to be useful for macro economic studies, but that at the traffic engineering and planning level there was a need for detailed, accurate data. The committee also agreed that in the past, when comprehensive freight studies have been undertaken, the data have quickly become out of date, so continuous data collection was preferable. (Continuous data collection is the process of collecting data on a regular basis: daily, weekly, monthly)

Methods of data collection

There are several methods which are used to collect freight movement data. The most common are personal interview, self-completion questionnaire and observation.

Personal interviews. Personal interviews are often by way of a roadside survey where vehicles on route are intercepted and the driver is asked questions about their origin and destination. This procedure usually involves the police since drivers need to pull over to the side of the road for the survey to take place. Respondents can only reasonably be expected provide information on a snapshot of the day's activities and the survey is inherently area specific.

Another type of personal interview is that undertaken at the depot or business headquarters. This usually requires an hour or so of the respondent's time (the respondent is usually the distribution manager or equivalent) allowing a greater depth of discussion and data collection. However this method is resource intensive and very expensive to implement on a large scale, making it suited to supplying anecdotal and contextual data (eg Chow and Hensher 1996).

In the USA, the telephone has been used to conduct personal interviews whereby the respondent relies on memory to provide data on the day's activities, etc. Intuitively this method is relatively simple and quick, however at the expensive of data accuracy. A study in the US found that recall of trips leads to an underestimate of the number of trips made and an overestimate of the distance and travel time (Battelle 1997).

Self-completion questionnaires. Self completion questionnaires are usually in the form of trip diaries which typically produce response rates of around 30% (Lau 1995). The advantages of driver self completion questionnaires are that they obtain precise data from the driver and can be filled out as events take place during the day. In practice, however the driver may forget to complete the questionnaire and retrospectively fill it out, or the driver may not have the knowledge to answer some questions. Generally the driver has knowledge of the destinations, the quantity of goods to deliver, which may be in pallets or boxes rather than tonnes, and the time of day deliveries will be received at a particular stop (Taylor 1998). Other than that, the driver may or may not know information on the vehicle specifications and tonnage of goods.

Observational. Data can be collected observationally by electronic means or by people stationed in the field. For the purposes of this paper we will focus on data collected electronically.

Automatic data collection can be categorised into four main groups (Williams 1997):

- Point data (eg loops, infrared sensors, counts). Point data is the most widespread data available.
- Section data (eg number plate matching techniques, beacon systems, enhanced loop techniques) - little data available. These data sources provide information along a

given section of roadway, usually data is restricted to through traffic. Typical data items include flow along the length, and vehicle journey time and journey speed.

- Origin-destination and route data (eg vehicle tracking, GPS, automated surveys, automated toll collection). This kind of data is largely concerned with network data such as the origin and destination of vehicles and travellers, route choice, journey purpose and journey time. Vehicle logging systems such as tagging, or number plate reading systems are examples of this type of system. The devices centrally log the passage of each vehicle at each beacon/number plate reader. Similarly a vehicle tracking system using GPS provides the vehicle route, speed and time of passage. However the advantages of this system are that the tracking of each vehicle depends on time rather than location relative to predetermined readers. GPS will be discussed in more detail later in this paper.
- Pedestrian and passenger data (eg in-flow, out-flow of passengers at stations) - data likely to improve with the privatisation of public transport. This type is not directly relevant to this paper.

Although there have, perhaps surprisingly, been many studies which have collected freight related information, the data has either been used for a specific purpose or is out of date because of the large amount of resources required to undertake a comprehensive survey. In the former case, any attempt to meet alternative objectives can lead to either heroic assumptions or erroneous conclusions.

Issues to consider in freight survey design

Over the last few decades there have been many urban goods movement studies undertaken around the world (Hasell et al 1978, Taylor et al 1994, Gorys 1991, Denis Johnston & Associates1991, Cristie et al 1977, Lau 1995, Ministry of Transportation Ontario 1991, Greater London Council 1975, Grenzeback et al 1990, Habib 1981, Ogden 1977, Rawling and Reilly 1987). These studies and others highlight issues which should be considered in freight data collection. A summary of these issues is provided below (Taylor 1997, and Ogden 1992):

- What is the desired level of accuracy? (for example, if the methodology employed is self-completion then driver fatigue may result since drivers are not familiar with the questionnaire requirements)
- It is important to enlist cooperation of drivers and companies; incorporate as much personal contact with the industry as possible in the preliminary design.
- Provide a thorough explanation of survey purpose and uses.
- Ensure adequate and advance publicity in the media, especially through truck industry publications and newsletters.
- Ensure that any mailed information is addressed to the correct individual using their name, rather than their job title, e.g. transport manager.
- Use an accurate sample frame to reduce wastage.
- Use good design and questionnaire technique.

- Use simple and clear survey forms (post interview checks on non-response have revealed that over 70% of non-response were due to the time required to respond to individual trip information, Battelle 1997)
- Ensure adequate testing, including focus groups, a skirmish and piloting.
- The sample size must be large enough to be representative, otherwise the objectives may need to be redefined in the context of available resources.

In addition there are some business concerns with participating in freight surveys. They include:

- The time involved in answering questions. A pilot undertaken for the US Department of Transport found that approximately 74% of the respondents reported that entering trip information onto a palmtop computer took 1 minute or less per trip and over 95% reported 2 minutes or less (Battelle 1997). Prima facie this sounds good, but if a commercial driver makes 10 trips a day this could take up to 20 minutes.
- Driver fatigue is high and perseverance low for paperwork which is ‘additional’ to the mandatory log book and invoice paperwork therefore the less information required the better from the drivers perspective.
- Important for drivers to have management approval, and often direction, to participate in the survey. This is especially in light of workplace agreements where some drivers are on bonus payments for higher productivity. Additionally, discussions at one large transport company revealed that the manager wanted to hand pick the most responsible drivers to participate in the pilot (Taylor 1998). This could mean a driver is less likely to provide accurate data if they are considered a ‘bad’ driver, in turn affecting the representativeness of a sample, especially if say 30% of commercial drivers are in this category.
- Respondents need to understand the possible future benefits of participating in the survey.
- There may be a feeling of being watched and therefore there exists a risk of altering normal driving and working habits or not reporting them.

To obtain the level of detail and coverage specified in the objectives mentioned earlier, the study team decided to pursue the concept of the ‘self-completion’ survey methodology.

FACTS survey methodology

One of the potentially most damaging issues is the accuracy of self-completion questionnaires and the reliability of data provided by the driver. On the other hand, of all the methodologies, the self completion questionnaire potentially provides the greatest quantity and quality of data. The need to deviate from a pen and paper questionnaire was considered necessary to reduce respondent burden, create an incentive to respond, and provide self-checking multiple choice questions. While the opportunity to incorporate vehicle tracking technology provided a method of accurate, non-intrusive data collection on route choice, origin and destination, speed, distance and time.

The challenge with the self-completion component was, 'What was a realistic alternative to the self-completion questionnaire?' Several ideas were considered:

- a voice actuated tape recorder,
- a central call centre whereby a telephonist records (on PC) the verbal information translated by the driver, or
- a palmtop computer and touchscreen, simple enough for the driver to use.

The first option was discarded quickly as the second two options were more accessible. After investigating the costs of the second and third options, the third was agreed to because it was cheaper!

NB The cost for personal attention by a telephonist proved to be more expensive than the project's resources. It should be noted that this option could be pursued in future providing there was a suitable way to reduce a telephonist's time.

The next sections describe the development and attributes of the GPS, GIS and palmtop for collecting data.

Vehicle tracking using GPS

Global positioning system (GPS) provides data on the position, timing, and therefore speed of a point, object or person fitted with a GPS receiver. The GPS receiver receives data from a subset of the 24 GPS satellites orbiting the earth. Providing there is an unimpeded view from the receiver to the sky the system operates in all weather conditions. The frequency of recording data at the receiver is referred to as the update rate and if required can be set at less than one second.

GPS was developed by the US Department of Defence (DoD) and the satellites are still maintained by this organisation. The accuracy of GPS (without GPS differential) is often quoted as being ±50m and this depends on the number of satellites in view and the type of GPS receiver (Zito 1997, Leick 1995). The more satellites in view, the greater the accuracy although from experiments four satellites seems to give adequate accuracy. The largest error source is due to Selective Availability which is a deliberate error introduced by the DoD for civilian users. This error is introduced by a pseudo random code which degrades the signal accuracy, to prevent unauthorised people using the system for military purposes. However, it is intended that this error be phased out by 2007 (Gibbons 1996). It should be noted that even without selective availability, the accuracies will be ±10 to ±20m (Zito 1997).

The accuracy of positioning can be improved to ±5m using a GPS differential device which connects to the GPS receiver. The principle of the differential is that errors at a known point are applied to a roving or stationary GPS receiver. There are two forms of differential correction. They are block shift and pseudo range differential corrections (Zito et al 1997). In summary:

Block shift correction:

- Easiest and simplest.
- Compares the coordinates of a known point with the GPS receiver's point, and calculates the error coordinates Δx, Δy and Δz.
- For the correction to be valid the receiver must have the same constellation of satellites in view as when the error was calculated.
- Limited application.

Pseudo range differential correction:

- Same as the block shift in that it compares the coordinates of a known point with the GPS receiver's point. However, the method involves measuring the range error, where the range is the distance from the GPS satellite to GPS receiver. The difference between the measured range and known range (using the coordinates of the known point) is calculated as the pseudo range error, and is calculated for every satellite in view.
- Larger amounts of data are required to be broadcast from base station to GPS receiver placing a greater strain on the communications system.

AUSNAV uses the radio channel Triple J to broadcast the *pseudo range differential* correction. Since this broadcast has good area coverage (ie most of the State of Victoria) it is an appropriate method of differential correction and is used for the FACTS prototype.

Displaying results using a Geographical Information Systems (GIS)

The tremendous growth in desktop computing power has meant GIS packages now run effectively on personal computers. PCs, installed with GIS have the ability to display and manipulate images including aerial photography, satellite imagery and street directories. When GIS is combined with the windows operating system, a user friendly environment exists, catering for all types of GIS users:

- those who know very little about GIS and need a familiar tool (eg web browser) to view the output,
- those who use GIS to analyse data, manipulating the data into a more usable form, and
- those who set up the technical database which the GIS accesses.

Traditional information system providers have developed universal relational databases which have a spatial indexing system allowing fast access to spatial data. This means that spatial data is no longer treated differently to other data in information systems.

Applying GPS data to a street network

Location data from the GPS system was recorded every 2 seconds on a Newton MessagePad 2000 palmtop computer, using custom-written software. At a travel speed of 100 km/h this provides location data (ie longitude and latitude) at approximately 55 metre intervals. Raw GPS data is, however, of very limited use in automatic analysis, and the first process in recording GPS data is to transform longitudes and latitudes to a sequential list of roads to make a travelled route. For example, see Figure 1.

However, there are a number of possible inaccuracies in this conversion process. These are discussed below.

GPS inaccuracy

The system used (with pseudo range differential correction) claims an accuracy of ±5m, under ideal conditions. Ideal conditions assume sufficient satellites are in view, and the differential radio signal is also directly in view. In practice this is not always the case, for example when travelling along urban roads a direct line of sight to satellites may be impeded by adjacent high-rise buildings which restrict the GPS receiver's view to the sky. Further, some buildings can produce reflections of the satellite signals resulting in an erroneous distance calculation between satellite and receiver producing a less accurate position. This has been found to occur in the central business district of Melbourne, where GPS records on some streets exhibit consistent inaccuracies. Once sufficient data has been collected, it may be possible to map these inaccuracies. Other locations may exhibit similar inaccuracies though they are probably in lightly trafficked areas and will therefore take some time to detect. Examples of this are not discussed further in this paper.

Temporary loss of accuracy may be caused by large vehicles travelling alongside the receiver, or for other reasons as yet unknown. One common manifestation of this is known here as 'straight line drift', where the GPS system, having lost accuracy, continues to record locations based on the last known speed and direction. Figure 2 shows how the 'straight line drift' is tangential to the last known point. When accurate signals are restored, the recorded path jumps back to an accurate location.

The GPS system used here provides an estimate of Horizontal Position Error (HPE) for every recorded point. A HPE greater than 60m generally indicates an inaccuracy high enough to warrant ignoring that point in further analyses. All points along 'straight line drifts' have had HPE values greater than 60, so this measure in itself excludes points in the drift line. Smaller numbers of contiguous points also have HPE values over 60m, but whether they are drifting along a straight line that happens to coincide with a straight-line travel path, or have high HPE values for other reasons, is currently unknown.

Mapping GPS data points to road links.

Having eliminated those GPS points considered inaccurate, the mapping of each recorded data point to the road network can begin. The electronically mapped Melbourne road network used to map the GPS data consists of road centre lines, so even when the GPS is completely accurate the GPS points will not fall exactly on the roads because vehicles drive in the left hand lane. To automate the mapping process an algorithm was developed to determine which roads are included on the travelled route.

The algorithm results in a series of road link identification numbers, which can be displayed in a GIS system. Figure 3 shows the results of this manipulation for a relatively straightforward section of travel. The bold solid lines indicate road links accepted according to the algorithm, with appropriate parameters. While the broken lines indicate road links that may have been accepted on a simple nearest-link method, but were rejected as not meeting the threshold parameter defined by the algorithm.

Brief description of palmtop computer

The Apple Newton MessagePad 2000 is a large-palmtop sized computer with a 12.5 x 8.5cm LCD screen. The Newton caters for all user interaction through touching the screen rather than providing a keyboard, though a keyboard can be attached. Programs created on a desktop PC may be downloaded via a standard serial cable. GPS data strings generated by standard GPS equipment can be received by the same method, and data downloaded to the desktop using standard communications software.

A simple (electronic) questionnaire using a step-by-step user interface was designed to enable inexperienced users to answer a series of questions about freight-vehicle stops and associated goods transfers. This interface is still subject to field trials and initial testing has produced positive feedback from drivers.

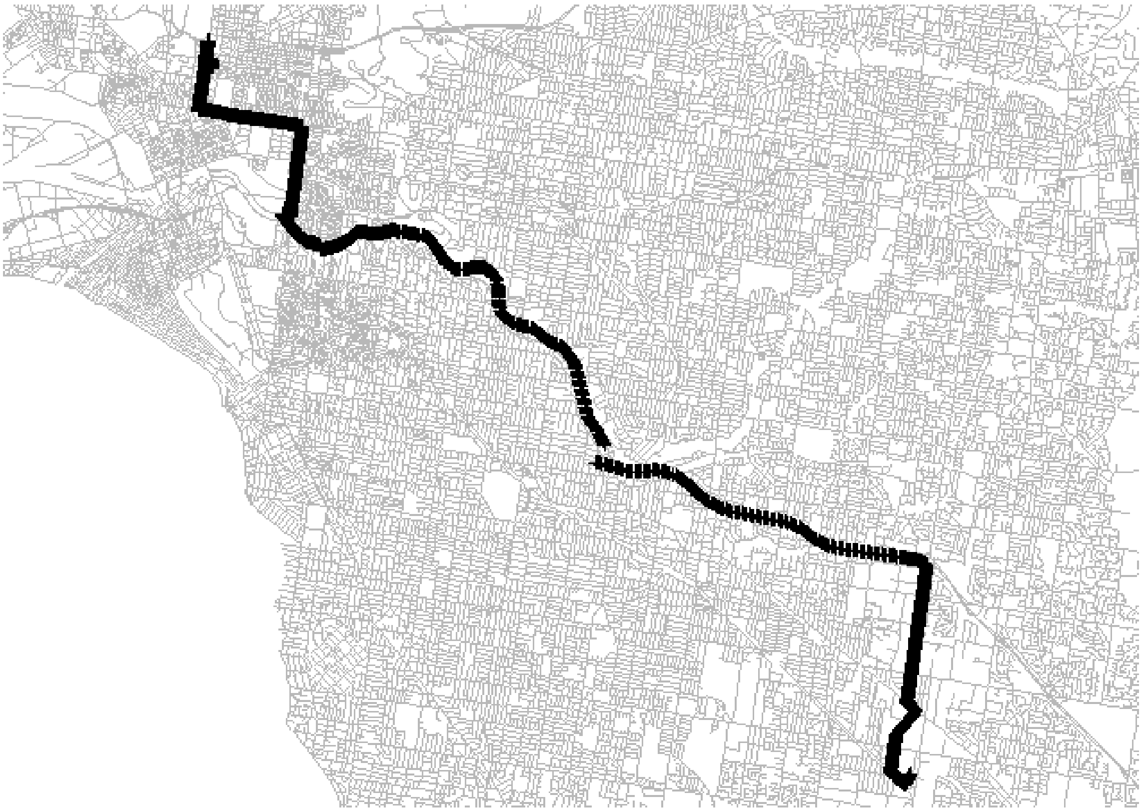

Figure 1 Mapping GPS records to a GIS

Figure 2 Example of straight-line drift, where a GPS receiver has lost its accuracy. The GPS continues to record locations based on its last known speed and direction.

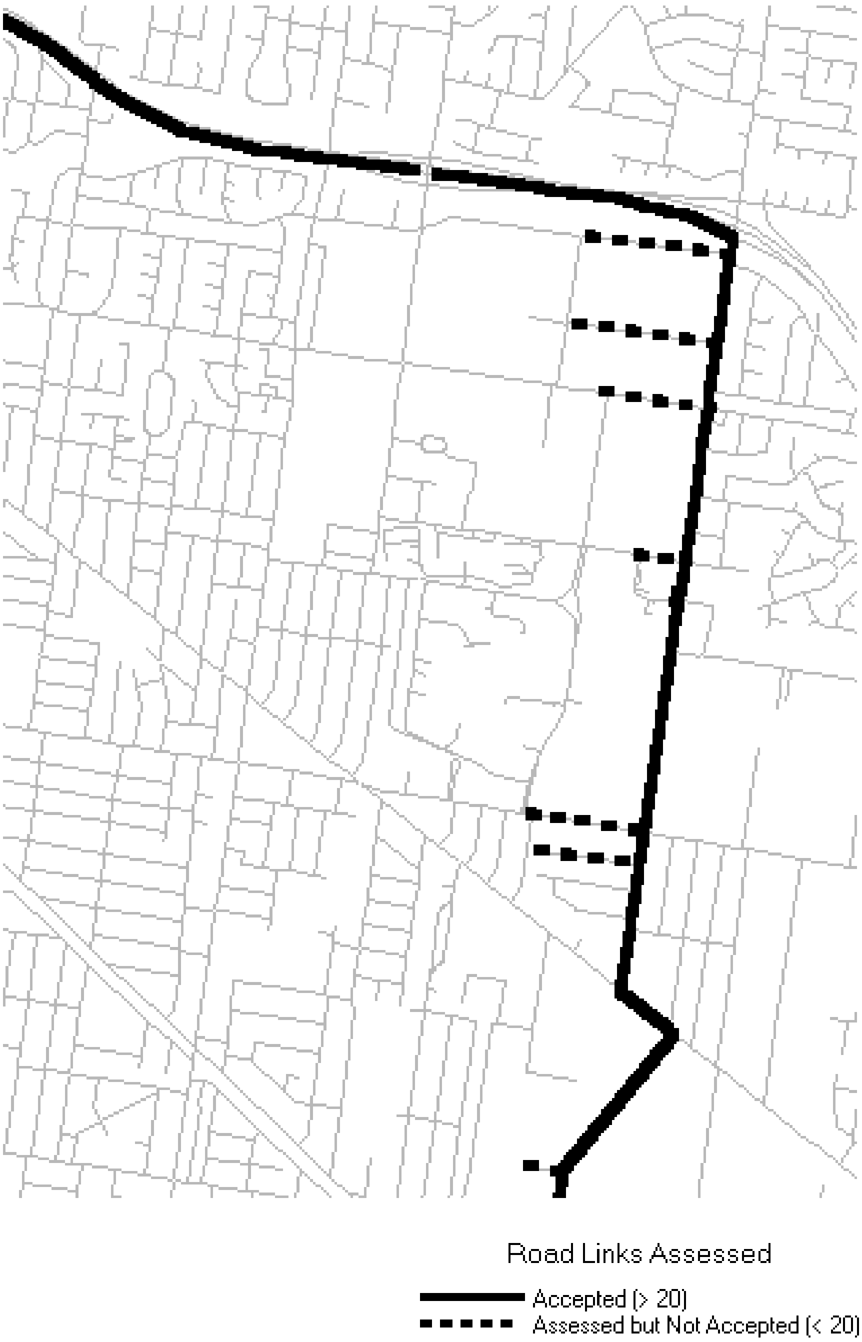

Figure 3 Mapping GPS data to road links: accepted and not accepted points

Discussion

It is interesting to note from the outset that the main shortcomings of traditional methods of data collection are that they can be expensive to conduct, obtain limited amounts of data, and can be inaccurate and open to subjective analysis (Williams 1997).

So, it is within this context that the development of an electronic data collection tool takes place.

The FACTS tool using GPS, GIS and palmtop potentially provides a neat and effective method of collecting freight data from commercial vehicle drivers. As well as the numerous advantages it promises such as accurate route choice, speed, location, time and distance, it provides a novel tool to encourage drivers to provide information on the vehicle, themselves and the goods delivered. Initial testing of both the GPS and questionnaire indicates that there is plenty of encouragement, cooperation and interest from industry; a critical factor in the success of these surveys. Driver feedback from the questionnaire was positive and of the drivers tested so far, all have successfully completed the questionnaire.

In addition to the positive feedback there are several practical issues which need to be resolved before the device can be used for mass data collection and these include:

- the power source. Initially the cigarette lighter was thought to be the best power source however given that the vehicle is turned on and off throughout the day, power surges may damage the electronics. Battery power is theoretically more reliable but trialing showed the battery life to vary from that expected. If the length of the survey for each driver is greater than 2 days, an alternative power source will need to be used.
- the GPS aerial which is currently attached via a cord through the passenger side window. If drivers are two-up driving, this is more likely to be damaged by being caught in the door.
- prompting the driver to respond to the questionnaire on the survey day. Commercial vehicle drivers by nature have no office - the cabin is their office and this changes from day to day. There needs to be a method by which drivers are reminded to install the device and or switch it on.
- security of the device while the driver is away from the vehicle such as during a delivery, and overnight if the survey is over two days.
- transporting the device (GPS and palmtop) between selected survey respondents.
- representative data. There will need to be further research into the best methods to achieve a suitable sample for the survey. A random sample at this stage is expected to produce a very low response rate and be not a very economical way of proceeding. Whereas, a selected sample with known bias is expected to produce a more economical and reliable result. At the very least the bias would be known which in itself is a good thing (Taylor 1997). However, detailed discussion on this issue is beyond the scope of this paper suffice to say that more research is needed!

Conclusion

In conclusion this paper has presented a prototype data collection tool for freight travel and activities using GPS, GIS and the Apple Newton palmtop. Although still in the early stages of development the prototype has provided an excellent opportunity to explore the many issues associated with freight data collection. These issues range from the technical aspects of the GPS, palmtop and GIS mapping to the practical issue of being simple and easy for the driver to use. The issues are discussed in detail in the body of the paper.

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