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Urban Freight Data Collection and Forecasting

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Abstract:

Australian and overseas studies are reviewed in a wide ranging examination of freight data collection and forecasting options for metropolitan areas. Particular attention is given to issues related to sampling frames, collection methods, sample expansion and trip table production. The latest trends are examined, and possible strategies for improving current data collection and forecasting are discussed

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Introduction

There is renewed policy interest in metropolitan freight movements, and there is a need to revisit methods of collecting and presenting appropriate freight information inputs to policy and planning.

Providing policy-useful freight information is often complicated by poor communication between the information supplier and the end user, and by the great complexity of freight movements in metropolitan areas. Despite this complexity, studies of freight movement are rarely afforded the same resources as studies of passenger movements even though the total resource costs of urban freight movements is approximately equivalent to those of passenger movement (Ogden 1996).

This paper primarily investigates methods of data collection and forecasting to provide information for policy input. Australian and overseas studies are reviewed in a wide-ranging examination of freight data collection and modelling options for metropolitan areas. This is a discussion paper which offers no definitive answers, but seeks to promote debate on appropriate methods to obtain policy-useful freight information.

Freight policy and information needs

The main aim of freight movement policies in the metropolitan environment is to promote the efficient and effective movement of goods by constructing and operating the transport network optimally for freight movement while minimising the externalities to the community. Constraints on urban rail freight operations (in terms of hours of access to the metropolitan network, and the inflexibility of the network) make *road* the primary freight carrier in urban areas, and thus the main policy focus.

Data on metropolitan freight movements in Australia are rarely collected. The Australian Bureau of Statistics' (ABS) only freight-specific data collection, the Freight Movement Survey (FMS), did not collect data on intra-urban movements before it was suspended. Lack of alternative data sources has encouraged State Governments to undertake their own surveys of freight movements in their capital cities, but resource constraints mean these occur infrequently and they are rarely comprehensive in their coverage or reliable in their results. A detailed discussion of freight data sets available in NSW is contained in Transport Data Centre (TDC) (1996a).

Despite the rarity of quality urban freight information, there are some important information needs for policy makers. The Transport Data Centre of the NSW Department of Transport has monitored the use of its own freight data set, the 1991/92 Commercial Vehicle Survey of Sydney (Sydney CVS). Through this monitoring and ongoing consultation with users about their data needs, TDC has identified the following policy uses of the data in Sydney:

- road asset management
- traffic control and network development
- terminal and interchange planning

- project evaluation
- air quality modelling
- managing the movement of dangerous goods
- producing forecasts for network planning

The core data items required to respond to these needs relate to characteristics of freight trips and their origins and destinations. Useful data items include the location of trip *origins* and *destinations* by *travel zone*, the *economic sector* of the origin and destination, *trip timing*, *commodity type*, *weight*, *value*, *mode used*, *vehicle type*, and forecasts of these.

The main clients for urban freight information are the State authorities with responsibility for roads, ports and the environment, thus this paper focuses upon how to collect information useful for locating and building the road network, and once built, how to manage and maintain it with minimal community impact. Without information on road use at different locations on the network and at different times of the day and week, both current and projected, it is very difficult to make an informed decision about any of the key issues listed previously.

The key processed output from transport data collection and modelling is the *trip table*. At present, freight is normally accounted for in trip tables by adding a percentage of *passenger car equivalents* to passenger trip tables. At present, most freight data sets have an insufficient sample size to produce meaningful freight trip tables at a small geographic level like a travel zone (there are over 1,000 travel zones in the Greater Sydney Metropolitan Region (GSMR)). There is a need to move towards the development of stand alone freight trip tables which can be presented separately or used in conjunction with passenger trip tables for travel demand forecasts

Problems in providing appropriate freight data

> ... "there is no evidence of a clear solution to the issue of estimating truck trips as part of total travel for a metropolitan area, much less a cost effective data collection methodology or truck trip modelling process.." (INCOG, 1990:10).

The gathering and presentation of useful information on freight movements has been hampered by a range of factors, though the two key factors are complexity versus funding:

- freight movements make up only about 10% of all transport movements in the metropolitan area, thus research into freight movements receive only a small proportion of the funding available to study passenger movements
- freight movements are far more complex than passenger movements, as they involve different commodities, and complex trip patterns. To gain an accurate picture of freight movements, much larger samples, more complex sampling procedures and data collection methodologies are required.

With this complex problem, and limited budgets, what has been the experience with freight data collection? Key problems lie with:

- limited sample sizes due to lack of funding

- biased sampling frames
- inadequate control totals for sample expansion
- limited modelling capabilities
- few methods suitable for determining trip table accuracy
- little understanding of the causative factors driving the demand for freight movements, and thus limited forecasting ability.

We have established that the key output which will be of use is a trip table, preferably by time of day and vehicle type, for a base year and forecast year(s). With limited resources, what can be achieve and what is the experience elsewhere?

Producing a freight trip table and projecting it

In order to produce a trip table, and forecasts of that trip table, data must be collected and transformed, and this involves four broad steps:
1. designing a sample
2. collecting origin/destination (OD) and trip information from the sample
3. expanding the sample to a trip table
4. projecting the trip table.

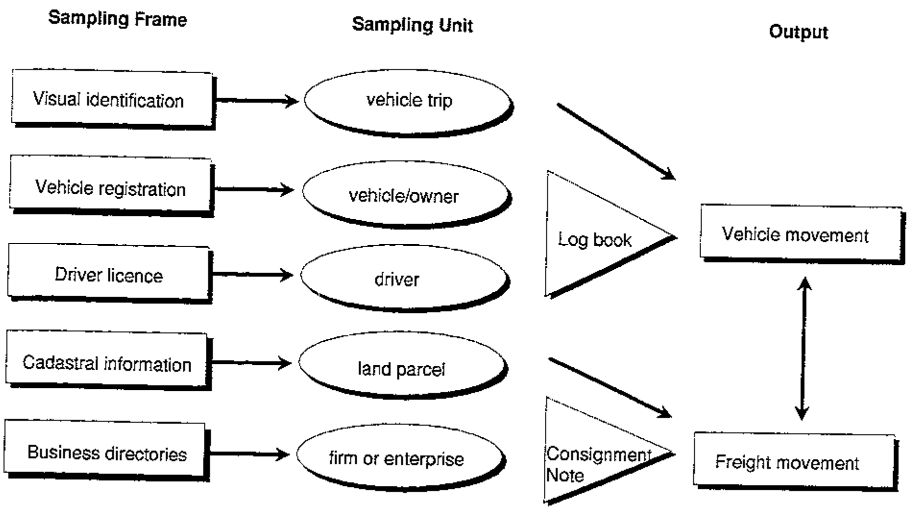
Each of these steps is discussed in turn, using examples from Australia and overseas to illustrate particular issues to consider at each stage. In particular, the US experience is examined since it is currently the focus of developments in freight data collection and forecasting. These developments are largely driven by the Intermodal Surface Transportation Efficiency Act (ISTEA) which ties the funding of Metropolitan Planning Organisations to the conduct of research into both passenger and freight movements.

Designing a sample

The primary aim is to gather data on freight trips to fill the trip table. There is thus a need to identify a population, or frame, from which there is a means of identifying freight trips A sample can then be drawn from this frame. Figure 1 indicates some possible frames, their sampling unit, and likely output.

Visual identification

Visual identification of freight vehicles as they pass a point during a trip can be used to provide a population frame for freight vehicles. Visual identification usually involves a person recording and classifying all commercial vehicles that pass an intercept point. In the US and UK, this is an extremely popular method which often accompanies roadside surveys in order to provide a population with which to scale up the sample.



Source: Adapted from FDF Management and ITS Monash (1996:16)

Figure 1 Sampling frames for freight data

The key problems with this frame are that:

- while most larger vehicles can be easily identified by sight (or equivalent electronic means), it is more difficult to distinguish light vehicles which carry freight from those that carry passengers;
- visual identification intercept sites do not cover all roads on the network, thus arterial vehicles operating primarily on local roads will have less chance of being identified. This will result is some systematic bias, primarily against lighter vehicles that are more likely to operate on local roads.

The visual identification frame is particularly useful for external cordon surveys as it is primarily large, identifiable, freight vehicles which operate between urban areas.

A variation of the visual identification method is the recording of number plate details of all commercial vehicles passing a site. This information can be matched to registration records, enabling the identification of vehicles registered as commercial. The owners/drivers can then be sampled. This method improves on a straight vehicle registration frame as it can capture all vehicles operating in the area, no matter where they are registered

Vehicle registrations

Vehicle registration records can be used to identify commercial vehicles and the contact details of their owner/driver. A sample of owner/drivers can then be contacted to provide details of the trips undertaken by that vehicle.

Vehicle registrations are the most commonly used sampling frame for freight studies. They were used in the Sydney CVS, and in most overseas studies, including in recent studies in Phoenix, Vancouver, Washington and Houston-Galveston (Barton-Aschman Associates 1994, Vancouver City Engineering Department 1990, Metropolitan Washington Council of Governments 1996, Wilbur Smith Associates *et al.* 1994).

The vehicle registration frame is not ideal because it underestimates the number of vehicles operating in the metropolitan area in a number of ways. Firstly, not all freight-carrying vehicles are registered as commercial vehicles. Some smaller vehicles may be registered for private use even though their primary purpose is to move freight. Secondly, identifying those vehicles registered in the metropolitan area is unlikely to include all vehicles operating in the area. Vehicles registered to an address outside the region may operate within, to or from the region, while vehicles registered in the region may operate elsewhere. For example, some national organisations register their entire fleet to their head office in one city, no matter where their area of operation. In addition, some vehicles are leased to other organisations operating in other areas. Thus, the vehicle registration frame has significant biases that are difficult to quantify.

The problem of identifying vehicles registered outside the study area that operate within it is usually partially overcome by undertaking an external cordon survey. This method was used in Sydney, Phoenix, San Francisco, Vancouver and Washington (TDC 1996b, Barton-Aschman 1994, 1992, Vancouver City Engineering Department 1990, Metropolitan Washington Council of Governments 1996), however, it does not capture movements of vehicles registered outside the study area which operate wholly within the study area.

A common variation on the use of the vehicle registration frame is the identification of trucks and their owners through the registration database, and then sampling all vehicles in the business fleets identified. The businesses then become the sampling unit, not the vehicle or driver, and sampling can be stratified by fleet size. This method has potential advantages over straight vehicle sampling as it can over-sample the more heterogenous sections of the market.

A problem with this variation, and with using vehicle registration databases in general, is that the accuracy of database details are not often of high quality. For example, in Atlanta (NuStats International 1997), virtually all fleets contacted had slightly different fleet details to those obtained from the registration database. Similar problems have been experienced by the ABS with their FMS

Driver licence

Truck drivers require a special licence to operate a heavy vehicle, thus all drivers with a licence to drive a truck can be identified from the licence database. The main problem with using this database as a frame for all commercial transport drivers is that drivers of light commercial vehicles can operate using a standard passenger car licence and thus cannot be distinguished.

In addition, a licence frame has a similar problem to the vehicle registration frame because drivers not living within the region of interest may operate commercial vehicles in that area.

Land use (Cadastral information)

A frame of land uses within the metropolitan region can offer the opportunity to sample from those land uses, perhaps by land use type. This is a very different approach to focusing on vehicles and drivers It works because freight is generated from and attracted to land uses—all freight has an origin and destination.

Cadastral information on the zoning of particular land parcels can be used to identify likely freight attractors and generators, and they can be surveyed directly, either by cordon counts or surveying the business/enterprise at that location. A problem with this approach is that cadastral information doesn't necessarily correlate to land use—the land may be vacant or put to a different, special use. Other land use information may be necessary to supplement cadastral information.

Business directories

Directories of businesses can be used as a population frame in much the same way as cadastral information, except with more certainty about the land use in a given location. However, while businesses are the primary attractors and generators of freight, there are other sectors such as the household, government and waste sectors which may not be listed but are legitimate land uses which must be sampled from.

The major problem with business directories is that businesses change rapidly, and directories often lag in the information provided. The major advantage over traditional vehicle-based frames is that the researcher can be assured that the business operates within the study area.

A study in Amarillo, Texas, (Parsons Brinckerhoff Quade & Douglas *et al* 1991), attempted to identify businesses in the yellow pages that might operate commercial vehicles, and sampled from these. There is a danger in subjectively determining the likelihood of commercial vehicle operations, but the approach is much more cost effective as it avoids contacting those organisations which are unlikely to operate commercial vehicles (which can be around 50% of businesses).

To conclude this section on sampling frames, it seems that spatial rather than vehicle-based frames have a theoretical advantage in identifying the population of interest, though vehicle-based frames are still by far the most popular frame used in contemporary freight studies. The problem most difficult to address for vehicle-based frames is the identification of light commercial vehicles. Issues related to sample size are discussed in the later section on sample expansion.

Collecting OD and trip information from the sample

Once the frame is decided and the sample drawn, there are several options for the collection of trip data from the sampling unit. Table 1 presents a typology of data collection methods.

Table 1 Methods for collecting freight data

	Location of data collection		
Sampling Unit	*Workplace*	*Roadside*	*Electronic*
Driver/carrier	•	•	•
Producer/recipient	•		•
Vehicle/trip		•	•
Consignment	•	•	•

Source: Adapted from FDF Management and ITS Monash (1996:19)

This typology can be further simplified into 5 key approaches, shown in Table 2, which are discussed in turn. Each of these methods can produce information which can be used in the construction of a trip table.

Table 2 Key freight data collection methods

Method	Sampling unit
• trip diary	driver
• administrative by-product	carrier/consignment
• automated counts/identification	vehicle/trip
• roadside intercepts	driver/vehicle/trip
• enterprise surveys	producer/recipient

Trip diary

Description: In freight studies, a trip diary is a survey usually filled in by a truck driver, which asks the driver to record his movements in his vehicle for one or several days. This method has remained the most popular method for collecting information of freight movements, particularly when origins and destinations are required. One day trip diaries were used in the Sydney CVS, and for studies in Phoenix, Vancouver, Washington, Atlanta, Houston-Galveston, North Carolina and Amarillo (TDC 1996b, Barton-Aschman 1994, Vancouver City Engineering Department 1990, Metropolitan Washington Council of Governments 1996, NuStats International 1997, Wilbur Smith Associates *et al* 1994, Barton-Aschman Associates 1996, Parsons Brinckerhoff Quade & Douglas *et al.* 1991). Most of these surveys were accompanied by cordon surveys, to capture external trips, and classified counts for calibration.

The popularity of this method is often ascribed to the fact that trip diaries are the standard approach used for passenger movement data collection, and thus are intuitively easier to understand for the analyst. For freight, the method is well suited to the collection of information on the structure of freight vehicle trips.

Data: Trip and vehicle information is best collected from the driver/carrier, though some important characteristics of the trip origin and destination, such as economic sector and number of employees, will not be known by the driver. In addition, the commodity being carried is often only known in a general sense, or in the case of containerised goods, sometimes not known at all.

Advantages/Disadvantages: The major disadvantage with this methodology is the limited number of variables the truck driver is likely to know about their trip and cargo. The contents of a truck's consignment, particularly when containerised, is often not known by the driver. In addition, detailed characteristics of the operations at the trip origin and destination are also not likely to be known by the driver. These are both important data items for freight forecasting purposes.

Another problem is a reluctance to complete surveys on the part of drivers. In the Sydney CVS, it was reported that 36% of vehicles were not used on an average weekday. Industry representatives believe this figure is much too high, and may indicate drivers taking the "easy option" and not recording any of the trips on travel day.

Variations: The trip diary is most popularly a mail out survey which is preceded by a telephone call to introduce the study. However, surveys can also take the form of personal or telephone interview, or the data can be extracted electronically and transformed into appropriate information. The latter facility is currently available for only a small proportion of firms.

Administrative by-product

Description: Consignment notes, vehicle log books or electronic information on freight and vehicle movements is another source of data used in many studies. This type of information may be obtained directly from the transport operator or the freight producer/recipient as a by-product of their operations. Virtually all firms have a record of deliveries of goods in and out, and, according to FDF Management and ITS Monash (1996), they are usually willing to divulge this information on a suitably aggregate basis because it is not market share information and thus not perceived as confidential. Some firms keep this information electronically, while manual records need to be transcribed.

Data: Most data items related to the movement of freight and details about the consignment can theoretically be captured from this source, though economic and employment details about the trip origins and destinations are unlikely to be available. Detailed information on the route of movement is also unlikely from this source.

Advantages/Disadvantages: Often administrative by-product data does not include all the data items required, and varies greatly from firm to firm. Often it needs be supplemented with surveys or additional data from other sources.

Variations: Administrative by-product data is usually held in a form incompatible for use in policy or planning. The ABS has found that setting up the company's administrative reporting system to provide output data in a useful format is an important first step in collecting data in this way.

Automated counts/identification

Description: There are a wide range of automatic methods available to collect information on freight movements. The simplest are traffic counts, but there are more complex methods such as electronic vehicle tracking systems.

Data: Standard outputs from automatic traffic counters are the number of vehicles passing the intercept point. These vehicles may be classified by vehicle type, and in more advanced cases, may give vehicle and axle weight and speed. Vehicle tracking systems will also provide full information on origin, destination and route.

Advantages/Disadvantages: Classification counts are a cheap way of accessing a high volume of data. They can be automated, or conducted visually. Visual classification remains superior to automated classification because determining commercial or private use is possible. This can largely be overcome if the automated system captured registration numbers that can be linked to the registration database however.

A disadvantage of automatic counts, whether visual or otherwise, is that they are restricted to covering particular routes, and usually this will mean trips on minor roads will be under-represented in any sampling.

Despite not providing origin/destination data directly, traffic counts indicate flows at particular points on the network, and when combined with land use information, a transport network and a gravity model, can produce reasonable trip table estimates.

Variations: Enhancements on basic classification counts include the automatic measurement of vehicle weight, axle weight and vehicle speed which are available from modern, but expensive weight in motion devices. In NSW, some of these sites are combined with SafetyCam, an automated number-plate reading camera which can link all these details to the vehicle registration database, allowing the separation of private from commercially registered vehicles.

Apart from cost drawbacks, most of these advanced counters still have problems identifying vehicles in congested conditions, and light commercial vehicles are often indistinguishable from passenger vehicles.

Another variation on automatic counts is monitoring of vehicle movements via a vehicle tracking system. These can identify vehicle origins, destinations and route using global positioning or similar technology, but the cost of installing receivers/transceivers in enough vehicles for a reasonable sample is still prohibitive.

Roadside intercepts

Description: This method involves intercepting trucks during a trip and administering a short interview or questionnaire about the nature of that trip and what they are carrying. Traffic counts are usually conducted at intercept sites in order that the sample can be expanded to the population for that corridor.

Data: Full trip details reported by the truck driver will be available, though detailed commodity and origin/destination data may not be known by the driver. A by-product of roadside intercepts is some information on the route taken since vehicles are intercepted en route

Advantages/Disadvantages: Roadside intercepts are useful for corridor or cordon studies, but will cause bias when used for creating a trip table for a whole urban area since only users of some parts of the network have been sampled, with a likely bias against users on minor roads.

This approach can introduce biases because of the difficulty of sampling at night or in poor weather conditions. The actual logistics of stopping trucks, and the legalities in allowing this to happen also make it difficult to implement. In addition, for an ongoing study, a permanent intercept location will almost certainly lead to avoidance

Data quality for some items such as commodity and the economic sector of the origin and destination can be poor because of reliance on the driver for reporting, but the quality of the weight variable can be overcome by having a mobile weigh station at the intercept site.

Enterprise surveys

Description: Enterprise surveys can consist of brief interviews of businesses, often by telephone, accompanied by aggregate data collection from annual reports and the like, and combined with mathematical inference, to obtain commodity flow information. Commodity flows can be converted to trips using a vehicle loading model. A more detailed enterprise survey might include a personal interview and site visit covering a wide range of variables related to commodity movements and vehicle movements into and out of the premises.

Such surveys, usually sampled from business directories, have been undertaken at a regional or aggregate level in Australia by FreightInfo (FDF Management 1997), CENTROC (SMEC Australia 1996) and NAROC (Horwood and Powell 1991). Some overseas cities have implemented this type of methodology, notably Portland (Metro and the Port of Portland 1996) and San Francisco (Barton-Aschman Associates 1992), though the scope varies greatly.

Data: Every trip and freight flow has a source, or producer, and a recipient, thus it is theoretically possible to extract origin, destination and commodity information from the producers and recipients of freight flows. Surveying at the enterprise level also provides accurate information on the type of land use at that location.

Advantages/Disadvantages: Enterprise surveys have an advantage over vehicle-based surveys in collecting commodity information and details of the economic sector of the origin and destination. This information is very useful for forecasting purposes Enterprise surveys are less likely to have complete information on the trip between the origin and destination unless vehicles owned by the enterprise are used.

Variations: A useful by-product of enterprise surveys can be micro-land use data, or trip generation and attraction rates for different types of land use. These rates can be applied when investigating the likely impact of new developments of particular types.

Expanding the sample to a trip table

Previous sections have outlined possible population frames and sampling techniques, and their limitations have been discussed. One problem which has yet to be explored is *sampling error*.

FDF Management and ITS Monash (1996:35) argue that "sampling alone is inadequate to achieve acceptable accuracy" in the Sydney situation where we wish to estimate a trip table of movements between approximately 1,000 traffic zones. This means that the trip table has approximately one million cells. Of these one million cells, only 94 had a relative standard error of 30% or less for the Sydney CVS, which obtained approximately 25,000 useable trip records.

If trips between these 94 zone pairs accounted for the majority of trips, the Sydney CVS sampling rate of 6.8% of vehicles might be deemed acceptable, but the 94 zone pairs account for only about 10% of trips. Indeed, half the sampled trips were in cells which recorded only one trip. According to FDF Management and ITS Monash (1996), these statistics rule out constructing a reliable trip table by sampling alone. An additional method to partially synthesise the trip tables is necessary.

Most international studies have a lower sampling rate than the Sydney CVS, and faced with the same problem of sampling error, calibrate sample-based results using classified traffic counts. Recently methods have become available to formalise this calibration process by combining a range of data sources, along with user defined confidence rates, to produce an optimal trip table based on all inputs (e g List and Turnquist 1995).

A more conventional approach to building a trip table has been to build a series of different estimates from different sources, and combine the resulting flows into a single matrix. This is often achieved using a gravity approach (e.g in Phoenix (Ruiter 1992)), with trip generation equations built on the basis of zonal population and employment.

FDF Management and ITS Monash (1996) suggest that the accuracy of expansion can be enhanced by using commodity flow information (collected from enterprises and secondary data sources) converted to trips (using a vehicle loading model) as a control total for the totals in the matrix

The trip table which results can be assigned to the road network, taking into account restrictions on the movement of particular types of freight vehicles, and then mapped.

Projecting the trip table

There are several approaches to projecting a trip table, and each involves projecting some key variables which help determine the trip table.

By far the most common method is the four step forecasting procedure also used for passenger forecasting. It has been applied in Chicago, Phoenix, North Carolina and Vancouver (Rawling and Duboe 1991, Barton-Aschman Associates 1994, 1996, Vancouver City Engineering Department 1990). The first step, *trip generation*, involves the projection of the amount of economic activity in each zone by economic sector. Trip generation and attraction rates for each type of economic sector are determined from the survey data.

Economic activity is used as a proxy for trip generation and attraction—the more economic activity, the more trips. Which economic variables are most closely related to trip generation and attraction is different for different industries. The amount of employment in an industry may be a useful indicator for some industries, while land area or floor space may be more useful for other sectors Brogan (1979) studied the use of trip generation rates based on land area and found that there was great variability in trip generation within land use categories, and that the intensity of land use at a site was not reflected by land area. Employment by industry type is thus the most popular proxy, but more work is required to determine the most appropriate proxy for each economic sector, and whether its relationships to trips generated or attracted is likely to change over time

The next step, *trip distribution*, determines the destination of the trips generated. This is sometimes achieved using the Fratar expansion method, where a base year trip table is reconciled with projected row and column totals. A gravity-type approach is also often used to distribute trips from known generation points to known sites of demand

The final two steps in the four step model are *mode split*, where survey data determines which mode is used to carry different types of freight, and *trip assignment*, which assigns the resultant modal trip table to the transport network.

A popular and related method in the US is the *quick response* approach. Based on the standard four step modelling approach, this approach borrows model parameters from another environment (or city), and adjusts the model to fit local conditions. In this way, costly new surveys are avoided, but the level of confidence in results might be lower.

A different forecasting approach used in the US (Rawling and Duboe 1991) has been to forecast truck registrations by vehicle type. The historical trend in the number of trucks by type is extrapolated, and truck trip rates from the base year are applied to the projected fleet. These are then applied by weight and land use to zones. For residential land, density was measured by number of households, while employment was used as the proxy for all other land uses.

A final approach, recommended by the US National Cooperative Highway Research Program (NCHRP) Report 260 (Horowitz 1996), but yet to be used in the urban environment, is the forecasting of commodity flows using input-output analysis. The generation and attraction rates of commodities by sector are determined, and distributed in a similar way to passenger forecasts. Tonnage flows are then converted by a vehicle loading model to vehicle trips by vehicle type, and assigned to a network. A vehicle loading model applies a profile of vehicle types and logistics practices of a particular economic sector to convert the total tonnage into a series of trips by vehicle type. There is a need to update it regularly to keep abreast of changes in vehicle technology and logistics practices in different sectors.

Summary of Key Findings

Freight data collection and forecasting can aid transport policy and planning by providing an indication of current behaviour, and likely future behaviour under a number of scenarios. Reliable base year and projected trip tables appear to be the key policy requirement.

The key findings of this review are:

(i) A spatial sampling frame has theoretical advantages over more traditional vehicle-based frames, though in practical terms this may not be the case

(ii) It is apparent that both vehicle and enterprise-based surveys are necessary to reliably collect all variables necessary for producing and projecting a trip table.

(iii) The production of reliable trip tables at a detailed geographic level requires more than sampling. A matrix estimation procedure capable of using a wide range of input data, including top-down commodity-driven control totals, can greatly improve trip table estimates.

(iv) In order to produce trip table projections, it is necessary to collect explanatory variables which can help explain the production and attraction of freight. These include commodity and sector of origin and destination, neither of which have been reliably collected in Sydney.

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