FREIGHT SURVEY REQUIREMENTS FOR URBAN AREAS

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ABSTRACT

Commodity, goods and commercial vehicle flows are critical in different ways at urban and regional scales. The flows of commodities are most important at the intercity level, while vehicle movements dominate concerns at the urban scale. Appropriate sampling frames are of different effectiveness and relevance at each scale, and the major alternatives are considered. Surveys of commercial, freight and goods vehicle movements in urban areas are assessed, and the limitations of survey methods for urban applications demonstrated using the example of Greater Sydney, Australia. While direct matrix estimation processes can produce vehicle flows from link counts, the practical need for greater details of the vehicle loads, types and commodity movements requires a combination of different types of information and data to be collected and used. The strategies required to collect and exploit such diverse data sources in an integrated manner are illustrated, and the requirements to extend the methods currently used to build origin-destination movement matrices for commercial, freight and commodity movements to meet these needs are considered.

INTRODUCTION

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While direct matrix estimation processes can produce vehicle flows from link counts, the practical need for greater details of the vehicle loads, types and commodity movements requires a combination of different types of information and data to be collected and used. The strategies required to collect and exploit such diverse data sources in an integrated manner are illustrated, and the requirements to extend the methods currently used to build origin-destination movement matrices for commercial, freight and commodity movements to meet these needs are considered.

The assembly of effective commodity flow and trip matrix representations of freight movements requires considerably more attention to be paid to issues of definition as well as some further work on colecting appropriate data. Matrix estimation processes offer the opportunity to make considerably better use of what we currently collect - but do not replace the necessity to obtain freight and truck specific data on the ground, and to improve what is currently a fragile basis for forecasting truck and commodity flows.

COMMERCIAL TRIPS, GOODS VEHICLES, FREIGHT OR COMMODITIES?

Freight and goods vehicle movement in cities are critical to the functioning of urban areas. Unlike inter-regional freight movements between major production or consumption points, the complex nature of cities breaks the direct links between commodity flows and numbers of vehicles (Hassall and Chrstie, 1978). Freight flows in large units to break bulk areas, and are distributed from there in smaller units. Consequently the major importance of freight vehicle movements within cities as against the flows of freight tonnages between regions or cities. In cities most of the tonnage is moved by a few large vehicles, but the smaller - largely distribution - goods vehicle movements are many times more important in terms of movements.

Typically 5-50 times as many goods vehicle trips emerge from a warehouse as enter them (Wigan, 1979), and less than 5% of urban goods vehicles are the large or articulated trucks that carry most of the tonnage (Fryer, Hassell and Wigan, 1977; Wigan, 1979). It is also important to realise that a larger tonnage *leaves* manufacturing premises than is *delivered* to it, as water and other goods delivered by pipeline are normally not counted in commodity flows until close attention is paid to such issues (Wigan, 1979).

It is therefore essential to distinguish between goods vehicle movements and commodity flows - and to attempt to distinguish at least between the tonnage that enters and moves about an urban area and the number of times that it is counted.

A further necessary distinction must be drawn between vehicle movement for the purpose of carrying freight and commercial vehicle movements which carry freight only incidentally - but where such carriage is an essential component of the movements.

The assumptions underlying gravity models work at least as a first order approximation for intercity flows. As the road segment of the flows are usually carried by large vehicles, these flows correspond reasonably well to goods vehicle flows. However, this association fails within urban areas, when a very different distribution logic drives the movements and routings of commodity tonnages and goods vehicle movements.

It is increasingly important to identify and work with the different segments of the travel market with a greater level of understanding. The present paper addresses a progressive approach towards the refinement of commercial, goods, and commodity flow segments, and highlights the survey and data needs required if we are to address these segments with an appropriate level of understanding.

Commercial transport may be defined in terms of the trip purpose, the carriage of freight, and the type of vehicle used. Although the three definitions overlap, each offers advantages and disadvantages. Trip purpose defines the commercial trip, but is not directly observable. The carriage of freight as a basis requires the carrier to regard the goods carried as 'freight'. This will not always be the case, eg. for many professional trips where equipment is taken along. Categorisation by vehicle type will omit the many trips where goods are carried in private vehicles.

Ideally we wish to define commercial transport in terms of trip purpose. In practice it is advantageous to define commercial transport as commercial-purpose trips which either (1) carry freight, or (2) use an identifiably commercial vehicle, or (3) both (the shaded area on Fig. 1). This definition is easier to work with than one based solely on trip purpose as it uses mainly observable criteria. Although it omits business travel and includes certain non-commercial trips, these discrepancies can be managed. Business travel can for instance be captured by conventional household-based surveys; and trips for non-commercial purposes, which are in any case proportionately small, can be adjusted for.

However the generic requirements for commercial trips, and freight vehicle movements may relate either to vehicle trips or to freight flow as the sampling unit; and this influences which data items are collected (Table 1) how they are collected, and how they are used.

Data on vehicle trips and freight movements must be organised in a way which recognises the sometimes complex links between different data items. There is for instance a one-to-many correspondence between trips and links, and a many-to-many correspondence between trips and consignments (Figs. 2, 3 illustrates this structure). The definitions of trips and intermediate stages differ for the vehicle and for the commodities carried.

The database must also permit easy linking to other data sources. For instance, by recording the vehicle registration number one can capture all the data items relating to that registration number (such as vehicle age, type, gross mass, ownership etc) which are to found on the database of vehicle registrations. Similarly commodity characteristics (such as value-density, hazard, reefer etc) may often be inferred from a description of the commodity itself.

DATA COLLECTION METHODS

Although trips are usually the primary concern, sampling frames relating to vehicles and drivers are also of interest because they relate indirectly to trips. So too do sampling frames relating to land parcels and firms because they relate indirectly to freight movements, and thence to trips. Trips and freight movements are linked via a loading model. If trips are known, then freight movements can be inferred and vice versa.

Driver/carrier surveys

Drivers and carrier movements may be traced both at their places of work and through roadside interview. Interviews may be conducted in person, by telephone, or by several variants of self-completed questionnaire/diary. The driver/carrier survey is the freight analog of the traditional household interview survey, and shares many of its strengths and weaknesses, in particular high cost and logistic complexity. Driver-based sample frames offer the opportunity for continuous sampling by drawing from a consistent frame with known biases.

Consignor/consignee surveys

Large scale surveys of this type were undertaken for urban freight policy development in the 1970s in the UK (Hassall and Christie, 1978) but in Australia such data has never been systematically collected on a large scale prior to Quinlan's pioneering of what has become FreightInfo, a periodically updated proprietary freight database of freight movements by all modes throughout Australia at a coarse spatial level of disaggregation (Rockliffe, Wigand and Quinlan, 1998) It is based on a combination of empirical observation and mathematical inference, using data from industry interviews and published sources. FreightInfo records (1) origin and destination zone (133 zones throughout Australia), mode (road, rail, sea, air, pipeline and conveyor), commodity (73 categories), and mass uplifted. Other data items such as value and the economic sectors of producer and recipient are also covered, and the limited available (if partial) official sources are also contribute where possible.

Consignor/consignee surveys vary greatly in scope and depth. Locational surveys are normally conducted on the premises of the firm or organisation, and range from the detailed to the abbreviated. Sectoral surveys make up in coverage what they lack in detail; they integrate company interviews with desk research using aggregate data and inference and form a valuable complement to more conventional locational and cordon surveys (Fryer et al, 1977; Taylor et al, 1994).

A sampling frame of freight producers can be drawn from commercial business directories. Experience suggests that clusters of interviews at specific sampled locations provide is effective. Warehousing plays a major role and needs to be specifically targeted. An alternative approach is to sample locations from specified land uses, where such data are available, from the formal designations in local planning schemes, land use inventories, or a cadastral database of land parcels held in a Geographic Informaton System (GIS) framework. The latter provides a new and potentially invaluable resource, enabling multiple sample frames, data integration and subseqent analysis.

Sectoral surveys

Sectoral surveys are not based on sampling. Instead most large freight producers and recipients are interviewed, and flows between smaller firms inferred from published and unpublished statistics.

Sectoral surveys are useful for assembling aggregate data rapidly and cost-effectively, as few details are sought. For instance, they do not normally record origin and destination addresses, or details of vehicle type etc. By omitting these details, respondents can provide data as annual aggregates. Validation is only possible at the regional level by comparison with other aggregates.

If further details are sought, in particular origin and destination addresses, a more demanding and costly locational survey is needed. Nevertheless, previous studies show that a good response can be obtained (GLC Freight Unit, 1978). Unlike with sectoral surveys, some limited validation is possible at the local level by comparison with local traffic counts.

Producer/recipient surveys suit continuous collection as expertise is cumulative and different regions and types of firms can be surveyed in rotation.

Automatic monitoring

The following automatic systems are some of the rapidly growing number that generate data on commercial goods and freight vehicle transport data, each with a different sampling frame to match.

- records of vehicle and driver status
- freight-finding bulletins
- freight-tracking systems
- vehicle scheduling and routing systems
- fleet condition monitoring systems
- safety monitoring systems
- tollway fee collection systems
- vehicle monitoring and tracking systems using Georgraphic Positioning Systems (GPS)

Area traffic control systems provide a further static sampling frame of on-road traffic control locations which ideal for monitoring flow patterns. Many of these are not yet linked to identification tags for commercial and freight vehicles. These systems will pick up non-locally based vehicles - but only if they are fitted with transponders. In areas where private tollroads are operating, commercial and privacy problems may be encountered if access is sought to these transponders.

Automatic Vehicle Location (AVM) potentially offers not only detailed routings but also times spent in deliveries, loading areas, and precise locations of vehicles even within ports and large warehousing areas. AVM tagging is expected to become widespread in the longer term, especially through tollway agreements, but biases in the vehicles and drivers taking up these tags would then need to be determined and monitored as the rates of usage climbed and this will delay the widespread use of AVM for freight and goods vehicle movements. However, even a small number of freight vehicles fitted with AVM can provide good quality transport network performance information.

Administrative by-data

There exists a wealth of data relating to commercial transport. Some, like the data published by public bodies, is gathered for sale or provision to the public. Other data, like firms' consignment documentation, is intended for private use but a number of companies approached have stated that it could be made available subject to customer confidentiality constraints. In these interviews, the effort required rather than confidentiality was stated to be the key problem.

- *Official Government data source on commercial vehicles and freight.* Many government statistical agencies produce data on commercial vehicles and freight. But for reasons of confidentiality, individual records are rarely, if ever, available.

- *Industry production data.* Government statistical agencies public bodies generally gather production statistics for most sectors of the economy.

- There is an important special case of this type, where economic Input-Output tables are produced. The University of New England at Armidale produces subregional input output matrices, and DJA-Maunsell (under contract to th NSWDepartment of Transport) has used these to estimate freight commodity and truck movements, using a range of intermediate items such as vehicle loadings, commodity values etc. This is perhaps the most extensive of the "Adminstrative by-data" approaches, and can justifiably be considered a methodology in its own right.

- *Logbooks and consignment documentation.* Most firms record deliveries of goods in and out, and many are willing to divulge it on a suitably aggregated basis. Carriers may also be willing to reveal driver logbooks under similar conditions (although it can prove costly to transcribe data from this source into a useable electronic format). At present we know of no carriers which routinely provide internal company documentation of this kind to road authorities. But this may change with the increasing use of automatic vehicle monitoring. Some systems require road authorities to gather real-time vehicle movement data for their own use and that of the carrier. It is a short step from that to a more fulsome data interchange. If carriers were also to supply consignment and other details, the resulting 'enhanced' data could be used to improve freight vehicle and commodity flow monitoring and data collection.

· *Driver license, vehicle registration, cadastral land parcel-based data (usually held in Geographical Information Systems), and business directories.* Public agencies maintain databases of driver license holders, registered vehicles and land parcels, and certain private organisations publish business directories. These databases can be used as sampling frames. They may also be used to provide data on vehicles, drivers, land parcels and firms. These data may be used for sample stratification and modelling.

The most valuable sample frames for administrative by products will be from legally or financially mandated administrative systems such as driver logbooks, official data requirements and Electronic Data Interchange (EDI) records. These sample frames fall into three distinct categories:

· census-style mandated coverage (returns required of all businesses);
· sample coverage of returns required under law (includes many Government surveys); and
· records held by all parties but accessed by drawing an external sample.
·

The confidentiality limitations on the first two data items are significant. Although there are mechanisms by which special studies can be done under the aegis of the national Census body (in Australia this is the Australian Bureau of Statistics), they are exceptional and difficult. The third is workable, and, in the case of driver logbooks, follows from a sample drawn on drivers or locations or businesses. Consequently a separate sample frame is not required. For broader coverages, sampling would best be by economic sector, concentrating efforts on correlation of data on the freight movement structures in that sector on a rotating annual basis, as one-off major freight surveys are expensive and this can be tailored to meet a continuing budget. The distinction between commodity and vehicle movements always requires care.

Response rates from official surveys are generally good due to their legal backing, but the area of greatest interest—drivers logs and similar daily records—depend on sound working relationships being set up with respondents. Care in prior warning of logbook sampling or retention and other details will greatly improve response rate and compliance. Provision of information on the purposes, usage and feedback of findings will all be needed to ensure minimal bias and non-response bias.

The broader approaches must be maintained on a continuous basis or the data cannot be reliably assembled. The official surveys are done on an official cycle which is not open to many organisations to influence, but the use of administrative by-data as a data multiplier from samples drawn from driver, business or location samples is ideal for continuing collection processes. In addition, the confidentiality requirements of national Government bodies are very constraining as details of origin and destination and destination cannot be provided due to the possibility of respondents being identified.

SYDNEY 1991 COMMERCIAL VEHICLE SURVEY

The consideration of data collection bases and sample frames was prompted by the need to improve on the most recent major urban Australian Commercial Vehicle Survey (CVS), which was carried out in the Greater Sydney region in 1991 (Taylor, Maldonado andn Ogden, 1994). The CVS was a driver/carrier survey which produced about 25 000 useable trip records. It had inherent biases as a result of low response rates and the operator-based sample frame chosen for the survey. The CVS produced many useful results, but despite its size it did not, and could not unaided, as had been hoped, produce accurate estimates of most zone-to-zone flows. Out of about a million possible zone-to-zone flows, only about 16 000 (1.4%) recorded any trips at all; and only 94 (less than 0.01%) recorded enough trips to achieve relative standard errors of 30% or less (Fig. 4).

These findings are unsurprising. If all origins and destinations were identical we could characterise the allocation of all 25 000 sample trips to zone-pairs as a Poisson process with a mean probability given by the sample size divided by the number of possible zone-pairs.

We would then expect to find about 24 735 cells with one or more trips. In fact we observe rather fewer because zones are not identical, hence some few zone-pairs receive more trips than they would otherwise, and most receive fewer. This shows that we would need a very large sample indeed to achieve anything other than an extremely sparse sample trip table.

This would be acceptable if most trips were concentrated in and between those zones for which we have low standard errors. But they are not. The 94 cells with relative standard errors of less than 30% accounted for only about 3000 trips—slightly over 10% of the sample; and 12 000 trips—about half the sample—were in cells that recorded only a single trip. In other words freight trips are very diffuse, and accurate origin–destination estimates are available for only about 10% of them.

The practical implication of this is that little if any reliance can be placed on most of the specific origin-destination flows represented by the cells in the sample trip table. To put it another way, were the CVS to be conducted again it could produce a quite different trip table: many zone-pairs which previously recorded no trips would now record small numbers of trips and vice versa. In general only low zone-pair flows would be affected in this way, but these would represent much larger flows if the sample trip table were to be scaled up to represent the total trip table, however misleading it might be to do so.

This effectively rules out the option of creating a trip table by sampling alone. But although sampling is unlikely to provide us with accurate estimates of flows between zone-pairs, it does provide useable estimates of all flows to and from individual zones—that is, row and column totals in the sample trip table. The reason is that these measures contain many more observations than do individual zone-pairs. As a result the CVS provides estimates having a relative standard error of 30% or less for over half of all origins and destinations. This suggests that an estimation procedure to synthesise a trip table from row and column totals and other data is essential - even before disaggregation into different types of vehicle etc.

CONSOLIDATING DIVERSE DATA SOURCES

An ideal estimation procedure for synthesising trip tables for road freight would permit different forms of commercial vehicle data to be consolidated into a single framework. This in turn would allow the extraction of the best from each and ensure consistency.

Corridor traffic studies frequently require trip tables, but rarely justify the full origin–destination transportation surveys usually required to construct them. A common response is to conduct number-plate surveys at one or more cordons, and to estimate the trip table from them using maximum likelihood: usually with a prior estimate of the trip matrix to start from. Several researchers have explored ways of combining equilibrium assignment (with its multiple flows) with direct matrix estimation, usually as an iterative procedure (Hall, van Vliet and Willumsen, 1980; Zuylen and Willumsen, 1980). There are many subsequent variants of this approach, but when applied to freight movements these have been mainly at an interregional rather than an urban scale.

These approaches all depend on determining the most likely matrix from a starting matrix (directly specified or defined in a prior model), using measured link flows with a greater or lesser reliance on the accuracy and reliability of these newly measured flows.

In interurban or regional studies of freight these methods may well suffice, but in urban areas the levels of detail and disaggregation demand additional information. Such information can be obtained from a variety of sources, most importantly trip generation rates for the defined freight categories on specific forms of land use, and control totals for specific commodities from broader strategic data sources such as FreightInfo. An integrated estimation procedurre would need to be able to take advantage of all of these different types and scales of data resources.

Trip generation and attraction rates

A source of commercial vehicle data is the generation and attraction rate from and to specified locations and land-uses. Commercial vehicle traffic visits all types of land-uses, but is heavily concentrated on commercial and industrial land-uses. Each type of company has a different character in terms of the numbers and types of vehicles visiting it, and use is made of such information at a detailed level when considering the traffic impacts of possible developments of different types.

It is possible to build up a matrix of freight flows between aggregated areas (far larger than traffic zones) by collating data on the production and consumption of commodities of various kinds. This process includes direct interviews on overall patterns of flow, manufacturing and demand, reassessments of public data sources and annual reports, and other sources. While this form of freight data assembly requires a great deal of cross-checking and a patchwork style of assembly, the overall figures obtained in this way are probably the best we have for commodity flows in Australia. In some cases individual zone-to-zone flows are identified (for example a cement plant feeding a manufacturing plant), and sometimes are also known to be carried by a specific type and category of vehicle. These flows provide valuable, but isolated, entries in the flow matrix.

The overall total aggregate area-area commodity flows can also be converted into vehicle flows. This requires that vehicle loading practices be established for each commodity. This type of loading conversion formula can be constructed from a combination of producer/recipient and driver/carrier interviews combined with delivery and shipment survey data at the points where the vehicles collect or drop goods.

Unless all these diverse types of data are assembled in a manner that allows the contributions of each to be fully realised, then the estimation of a trip table will be less accurate than if it were to be constructed from a single type of data.

The CVS style of survey uses driver logs drawn from registration sample frames. This cannot cover all freight movements, and is seriously deficient as many vehicles (particularly those in fleets) are not registered in the area in which they tend to operate. The response rate from this style of survey is low—around a third—and must raise concerns of bias. Larger fleets are in general well covered, but the numerous small vehicles and small operators are likely to be under-represented, bringing unknown biases.

Clearly CVS (ie. vehicle log) data are useful: but can they be combined with other data so that the full benefit can be realised in an overall matrix estimation? If so, the accuracy of the resulting trip tables will be both higher and less biased than those decided from the CVS alone.

The CVS can improve the sampling efficiency of samples from screen-lines, freight producers, and vehicle registrations by using the CVS data to stratify the samples, but a more important issue is the reduction of biases. The CVS has a number of evident and not so evident sources of bias, due to the low useable response rates obtained by this form of survey (see also (Lau, 1995))

A common approach to building a freight trip table has been to build a series of different estimates from different sources, and combine the resulting flows into a single matrix (Logie and Hynd, 1989). In cases such as Phoenix (Ruiter, 1992). a gravity model was used to assist in this process, with trip generation equations built on the basis of zonal population and employment.

It is clear that better methods of employing different forms of data in a single framework are needed for urban freight vehicle movement analysis.

ASSESSMENT OF DATA COLLECTION METHODS

The choice of a data collection procedure must be founded on three key propositions:

- diverse data must be consolidated to achieve acceptable accuracy;
- sampling alone cannot achieve acceptable accuracy; and hence
- some form of modelling is required.

The most effective way to ensure that all the different types of commercial vehicle freight data can be brought together to provide the best available trip tables is to define a method of estimation that includes all the different data types.Willumsen (Tarmin and Willumsen, 1992) illustrates the use of a simplified gravity model fitted directly to the small number of observations of inter-regional freight movements in Bali using a variety of least-squares and other fitting procedures, while Fig. 5 illustrates the extended framework advocated here.

It is necessary to extend and revise the trip matrix estimation process to include the row totals (trip generation figures from trip generation studies in the Study Area), trip attractions (trip attraction figures derived from special delivery point surveys at various land-uses in the Study Area), and the few specific traffic zone to traffic zone movements identified in the broad economic sector data assemblies. This approach can also incorporate the freight flow tonnage(s) if vehicle loading submodels are developed to permit this.

The specification errors introduced by a CVS-type sampling frame cannot be corrected without using other sources of information. This already biases maximum entropy direct matrix estimation approaches based on CVS forms of data, and specific corrections and broader control totals are needed if CVS-style data are to be used effectively for trip matrix estimation.
Thus this integrated approach addresses the need for:

- better accuracy of the trip table elements;
- correction of some of the systematic biases inherent in currently available data; and
- integrating more diverse data

Some users of CVS data require matrices of heavy vehicles alone (usually the sole target of freight modelling in the past), and also of light vehicles. Other segments are of interest to different parties. Although trip generation and attraction values are input for both categories of commercial vehicle, the screen line/cordon surveys may not include the same levels of disaggregation. If they did, then two independent matrices could be estimated, but in most cases the levels of disaggregation available in the data of different types will not fully correspond from one survey type to another. In such cases an improved matrix estimation procedure could test the combined values of heavy and light vehicles (in this case) against the observed total flows at specific points on the network.

Data exploited for trip table estimation

Zonal attributes are needed as variables in our trip attraction and generation functions. In the estimation procedure as it stands, attributes are of two kinds: those relating solely to the zone (X_i, Y_j); and those relating both to the zone and the economic sector of the trip ($M^a{}_i$, $M^b{}_j$). The former kind of attribute may not be needed at all, but the latter certainly will, and can be regarded as a measure of the importance of each economic sector in each zone. Fig. 6 specifies the framework advocated to address the needs of freight movement matrices using an extended range of data sources.

Typical attributes include:

- sectoral employment
- floor space of firms in the sector
- turnover of firms in the sector
- land area occupied by firms in the sector
- dummy variables for certain classes of activity that generate large freight movements to and from a zone, for instance modal interchanges.

Since we define 'economic sector' to include, for instance, the primary, household and retail sectors, we may also include for certain purposes:

- output of quarrying activity
- retail area
- size of landfill activity
- number of households

These attributes can generally be obtained as administrative by-data from public sources, if necessary augmented by specialist. For example planning schemes are required to indicate permitted and designated land-uses, which relate, if imperfectly, to actual land-use.

The sector-to-sector matrix of freight movements (Q^{ab}) can be regarded as the analog of the economist's input–output table with physical flows in place of financial. This matrix is in effect a way of marshalling some of the data that will be later needed to estimate the trip table (see later). The data for it are gathered by means of a producer/recipient survey. In general, each cell in the matrix will represent a unique commodity, being the commodity which is produced by sector *a* and consumed by sector *b*.

A vehicle loading submodel is needed in order to convert freight movements into vehicle trips. Loading models can be complex. It is not simply a matter of estimating the average payload. Trucks, especially light commercial vehicles, rarely deliver single loads and therefore rarely take the shortest route for each consignment and can best be treated as undertaking tours rather than trips.

The data will come from:

- a producer/recipient survey, for estimates of trip generation and attraction rates
- a driver/carrier survey, for estimation on how trips are chained to create tours
- administrative by-data for area-wide average payloads and similar measures.

The vehicle loading submodel embodies the link between the mass of the freight moved and the number of commercial vehicle trips. Ultimately all measures of freight movements - wheater mass input into the supply chain, uplifted, freight task (tonne-km) or road traffic (number of trips) - derive from the level of economic activity. However, the link is indirect and mediated by several parameters - value density, handling factor, haul length and parcel size.

Since the parameters are gradually changing there is no straightforward relationship between economic activity and freight movement. It is true that researchers have found a sometimes close link between gross product (being one measure of economic activity) and the freight task (measured, say, in tonne-km). However, as Mckinnon (Mckinnon, 1996) points out: '*Even at a sectoral level…past trends in freight traffic growth need not provide a reliable guide to the future demand for freight transport*.' This is because the parameters which mediate economic activity and road traffic are unstable.

This suggests that one would need to re-estimate a vehicle loading model frequently, say every five years or so, to ensure that it incorporated the current values of these unstable and evolving parameters. It also suggests that forecasts beyond, say, ten years would have to be treated with caution. Currently freight data surveys in Australia are rarely undertaken at intervals of less than ten or even twenty years.

The trip table should incorporate data from all data collection *indirectly* via the broader estimation process. It will also incorporate data *directly* from the producer/recipient survey wherever significant individual flows can be established and are large enough to warrant inclusion as constraints.

Any matrix estimation procedure that relies on several different types of data sources, each of which relates to trip table estimation differently makes accuracy estimation mathematically intractable. In addition, specification error and measurement error are also likely to be important. Specification error arises where relationships lack the necessary independent variables; our submodels for trip generation and attraction—based as they may be on designated land-use—are certain to suffer from some degree of specification error.

Measurement error arises where what we in fact measure is not what we want to measure. Producer/recipient surveys, even if they are notionally complete censuses, are prone to measurement error, because respondents may systematically understate certain freight movements and overstate others. The accuracy of trip table elements could, if necessary, be estimated by Monte Carlo simulation and re-estimation.

CONCLUSION

Freight data collection cannot easily be differentiated from the scale and nature of definition of 'freight' employed. Commercial vehicle, freight vehicle, commodity flow are all different categories. Although the differences are not usually significant for inter-urban or inter regional work, they become highly significant within urban areas.

Once intra urban movements are of prime importance, then the biases inherent in omitting non-resident vehicles become important for heavy vehicles (though often not for smaller vehicles), introducing important sources of bias.

The estimation of O-D trip matrices for freight movements in urban areas demands the inclusion and reconciliation of a wider range of data sources than direct driver surveys and a few link and cordon vehicle counts. Such data is available from commodity flow producer/consumer sources, and from the implied connection between trip generation and attractions of the appropriate types at specified land uses. The framework required for such an enhanced approach is summarised and illustrated in this paper.

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Table 1 Data items required for commodity and vehicle movement coverage

Data item	Description	Sampling unit	
		Vehicle trip	Freight flow
Origin			
Address	Actual point where trip originated	•	•
Sector	Economic/industry sector of producer	•	•
Timing	Time/date of pick-up	•	
Destination			
Address	Actual point where trip originated	•	•
Sector	Economic/industry sector of recipient	•	•
Timing	Time/date of delivery	•	
Route			
Link	Link identification code	•	
Mode/vehicle			
Vehicle type	Vehicle type	•	•
Registration	Registration number of road vehicles	•	
Consignments			
Quantity	Mass of consignment	•	•
Commodity	Commodity type	•	•

Table 2 Characteristics of sampling frames

Sampling frame	Sampling unit	Overcount	Undercount	Assessment
Visual inspection	Trip	Commercial vehicles used privately	Trips by vehicles not registered as ‘commercial’	Not all commercial trips can be identified visually. This is a major shortcoming and means we cannot flag down identifiably commercial vehicles at checkpoints and expect to capture all commercial trips.
Vehicle registra-tion	Vehicle	Business vehicles used privately	Vehicles not registered as ‘commercial’	There are several categories of vehicle registration which could be termed ‘commercial’ but none is an adequate sampling frame for commercial trips as many smaller vehicles—which account for many trips—are not registered in any readily recognisable way.
Driver license	Driver	Inactive commercial drivers	Drivers of vehicles not registered as ‘commercial’	Drivers of heavy vehicles, nearly all of which are mostly used for commercial trips, are required to possess special licenses. However, this sampling frame fails to capture drivers of smaller vehicles which are also used for commercial trips.
Cadastre	Land parcel	Vacant land	Freight not linked to land parcels or their occupants	The cadastre (land property boundary GIS data base) can be used in conjunction with other geospatial data (such as designated land-use) to select land parcels that are likely to generate and attract freight. Land parcels can then be surveyed directly, say by cordon counts, or used to identify firms which can themselves be surveyed.
Business directories	Firm or enterprise	Multiple listings	Freight not generated by firms	Most cities possess business directories which can be used to find firms, though some directories are notoriously inaccurate.

Table 3 Contribution of data collection methods to data required for trip table estimation

Data collection method	Data for trip table estimation: Zonal attributes	Sector-to-sector freight movements	Parameters for trip attr'n and gen'n	Parameters for vehicle loading	Trip table
Driver/carrier survey					
Roadside					•
Locational				•	•
Producer/recipient survey					
Sectoral		•			
Locational		•	•	•	•
Automatic monitoring					
Number-plate					•
Weigh-in-motion					•
AVM*					•
Administrative by-data					
ABS** data	•	•			
Industry production data	•	•			
Consignment document'n		•			
Driver logbooks		•			•
Driver license					:
Vehicle registration					:
Cadastre	:	:	:	:	
Business directories	:	:	:	:	:

AVM = Automatic Vehicle Monitoring
ABS = Australian Bureau of Statistics. ie available from Government collected sources

Key: • **Used as data source**
: Possibly used as sampling frame

FIGURE 1 Comparison of selected criteria for commercial transport

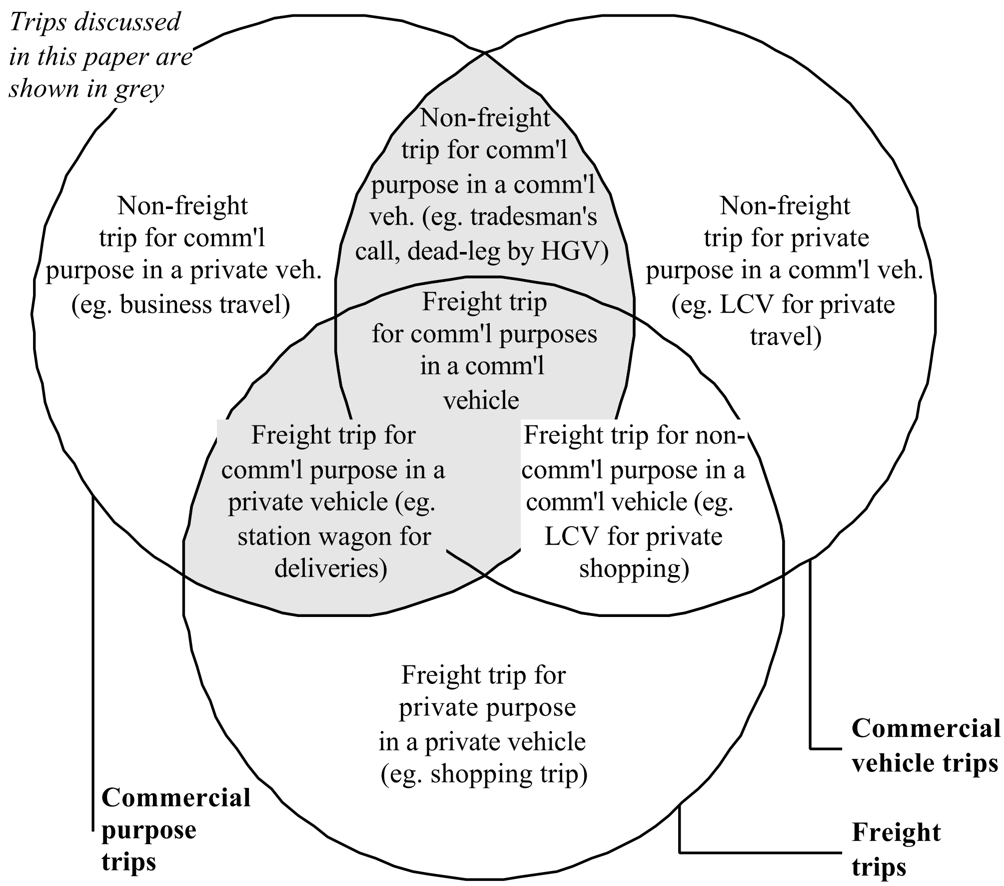
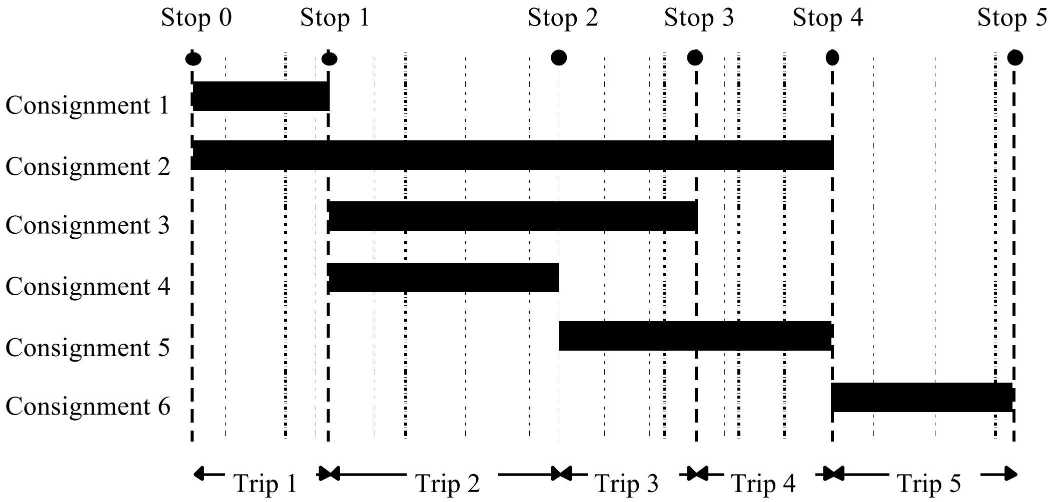


FIGURE 2 ***Relationship between trips, consignments and links for a hypothetical vehicle***

during the course of a day



Key: Thin dotted lines indicate link ends.

FIGURE 3 Relationship between trips, consignments and links for a hypothetical vehicle during the course of a day

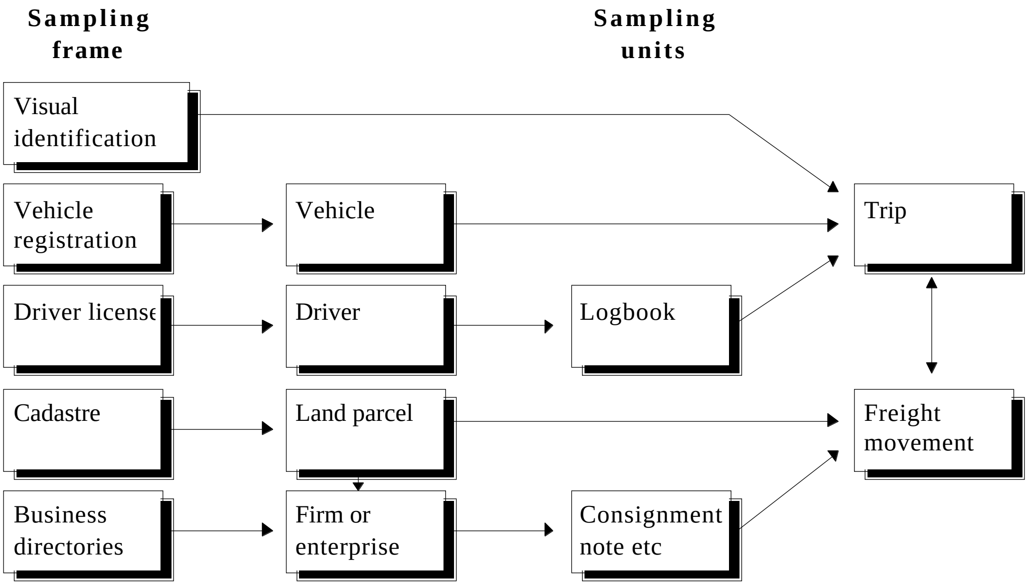


FIGURE 4 Number of zones as a function of number of trips: 1991 Sydney CVS

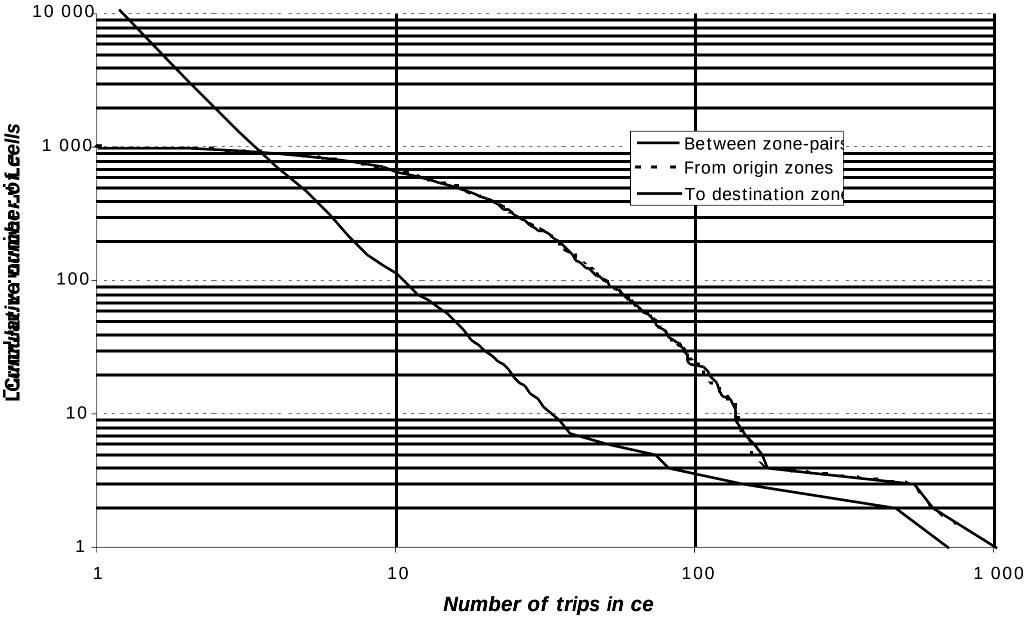


FIGURE 5 Procedure for estimating the freight trip table

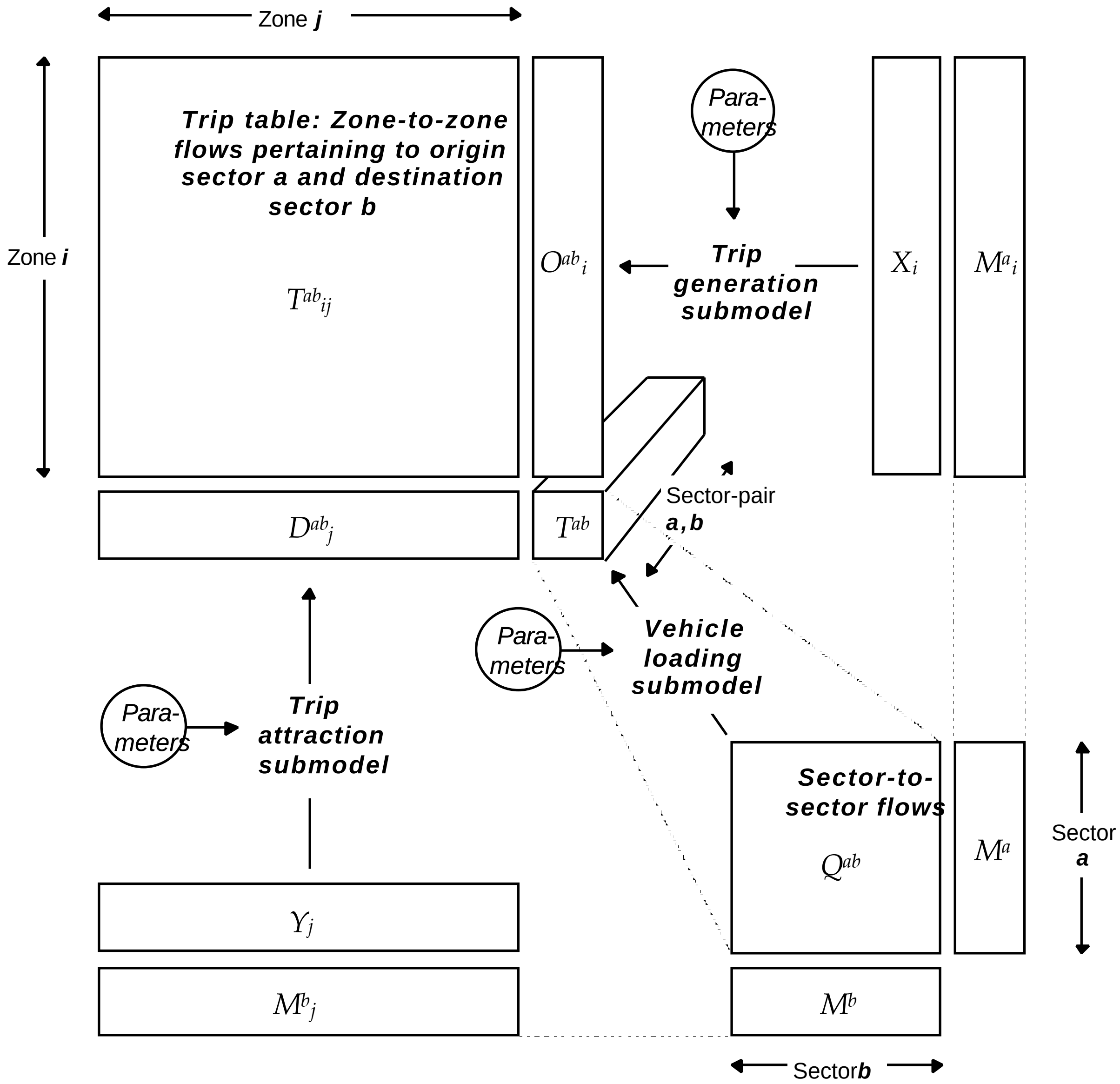
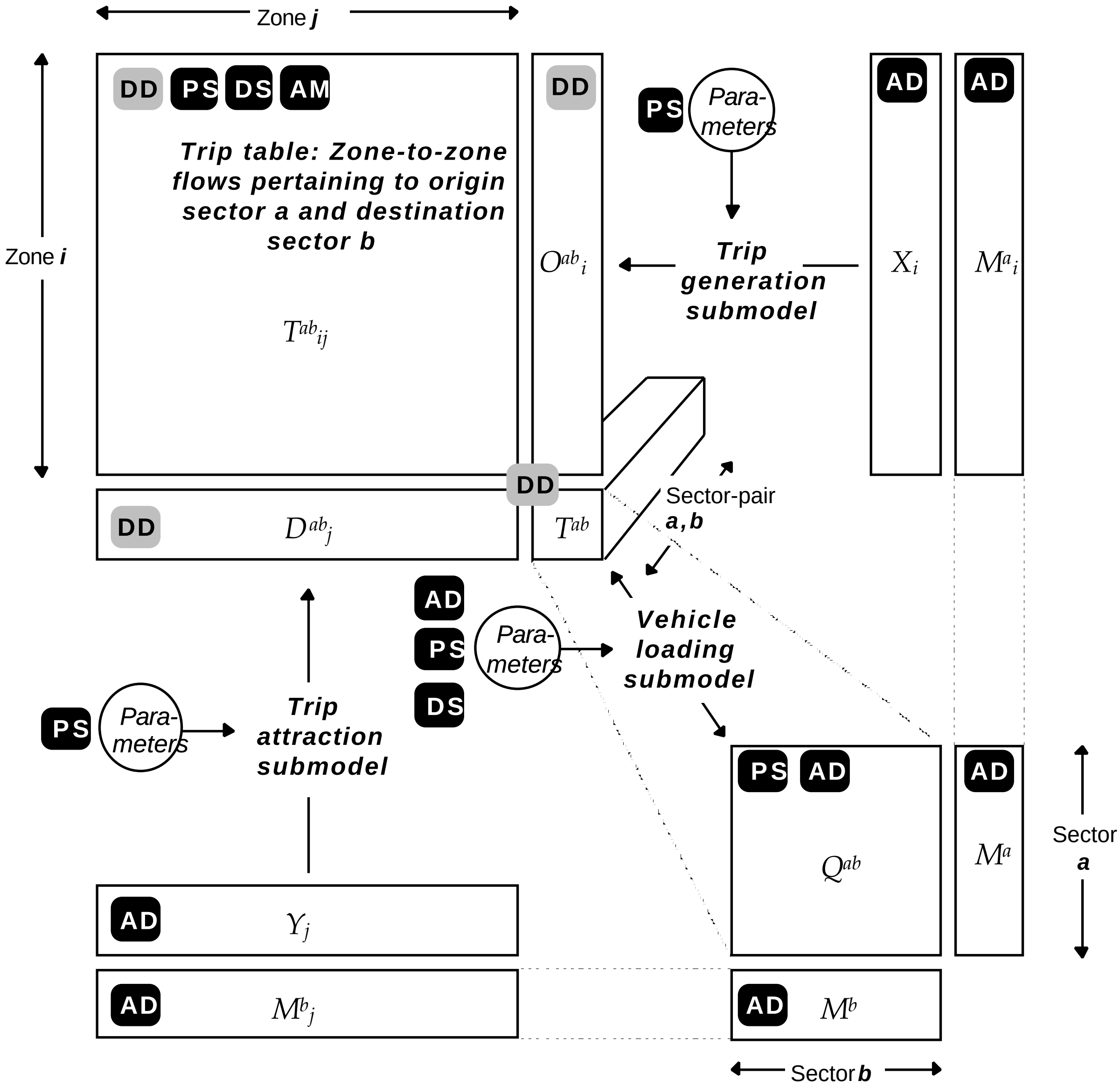


FIGURE 6 ***Data sources for estimating the freight trip table***



Key

- AD — Administrative by-data
- PS — Producer/recipient survey
- DS — Driver/carrier survey
- AM — Automatic monitoring
- DD — Derived data