Future Directions for Freight and Commercial Vehicle Modelling

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1 Introduction

This paper is based on research carried out for an Austroads internal report prepared by SKM on the current state of practice in freight modelling and considers how it may be applied in an Australian context. It represents the private views of the authors and is not intended to represent either the Austroads report or the views of Austroads. The paper:

- Considers the state of practice in land freight and/or commercial vehicle models internationally,
- Identifies the data requirements to implement them;
- Compares data requirements to datasets currently available in Australia; and
- Makes recommendations for improvements to current practice.

1.1 Modelling objectives

In principle, models should be designed to meet the objectives of their users. These matters have not been reviewed in the Australian context, but we can identify typical objectives elsewhere, assuming that some of these apply here.

At the micro (city) level, information on commercial vehicle traffic on the roads, at junctions or local developments is needed for infrastructure planning, safety and environmental evaluations. While this is most heavily dependent on good information on current travel patterns, projections of future growth will be material.

Simple projection methods appear generally to suffice for demand forecasting in urban areas, but in particular circumstances or in broader contexts (e.g. state/national) may not. In such examples there may be specific interest in the effects on the growth in freight movements (not limited solely to vehicles) of, for example, developments in the economy relating to specific industries (the freight-economy linkage), changes in industrial location decisions and in changes in logistics practices.

Additionally, in metropolitan areas there may be concern about the impacts of infrastructure or other policies on commercial vehicle travel patterns, industrial location etc. At a national/state level, there will be considerations relating to mode share and intermodal issues: these are generally most relevant for interurban/interstate freight movement.

More generally, there are issues concerning how government strategies and policies, including weight limits, technology advances, environmental policies, charging/taxes (the effect of cost on freight patterns), technological developments (which would affect logistical practices and supply chains) affect the patterns of freight movement, the sizes of vehicles (changes in vehicle types/weights), their journey lengths etc.

To date Australia freight models have not been sensitive to these objectives and even internationally, the level of appreciation of the more ambitious objectives is limited and still being researched.

1.2 Corresponding model types

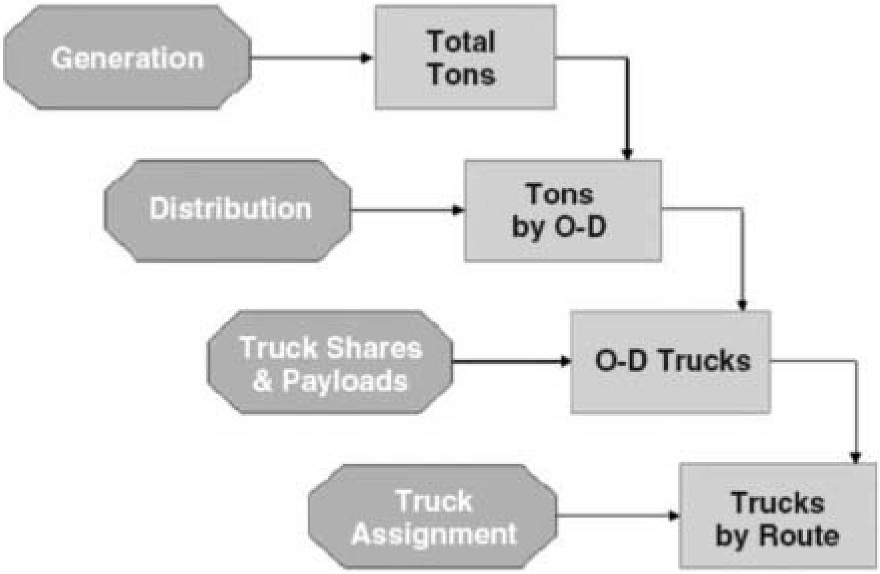
Freight transport models may be classified by their geographic scope and the degree of complexity with which they consider drivers of demand.

The degree of complexity with which demand drivers such as economic factors and logistics are incorporated into city or regional freight models may be categorised as follows (Giamo 2006):

- Undifferentiated (commercial vehicles included with other vehicle types in model with no special treatment)
- Commercial vehicle (matrix developed, for example, within a four step model process or matrix estimation)
- Commodity based (commodity flow matrix developed and converted on numbers of trucks and trains based on static factors from past experience)
- Integrated Land use – economic commodity models (as commodity model, but economic input-output model with feedback loops used to produce commodity flow matrix)

In addition to these types, there are many other approaches addressing specific aspects of the logistics system and specific local or national issues.

To illustrate the differences in complexity between these model types, flowcharts of three example freight models of increasing levels of complexity are shown in Figures 1, 2 and 3. The first (Figure 1) is a simple road freight model designed on the traditional four-step approach. The second (Figure 2) adds modules for integrated land use, economic change and activity modelling to trip generation and distribution steps. The third (Figure 3) adds modules for logistics to the trip generation (above the doted line) and distribution steps (above the blue line) and vehicle loads to the assignment step (below the blue line). In the more complex freight models the modules become interrelated, and so the analogy to the four-step model is only approximate. As will be seen, data requirements increase proportionally with complexity.



Source: NCHRP Synthesis 358, Statewide Travel Forecasting Models

Figure 1 Wisconsin Statewide Model Freight Component (Giamo 2006)

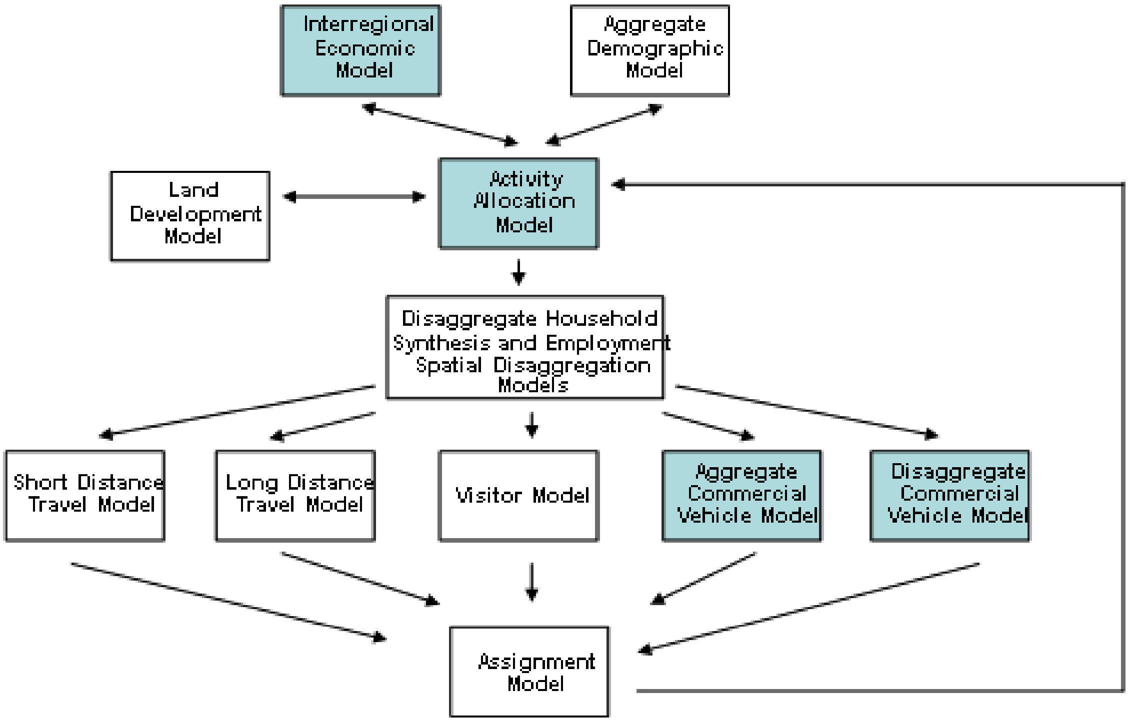


Figure 2 Ohio Integrated Land Use/Economic/Transport Model (Giamo 2006)

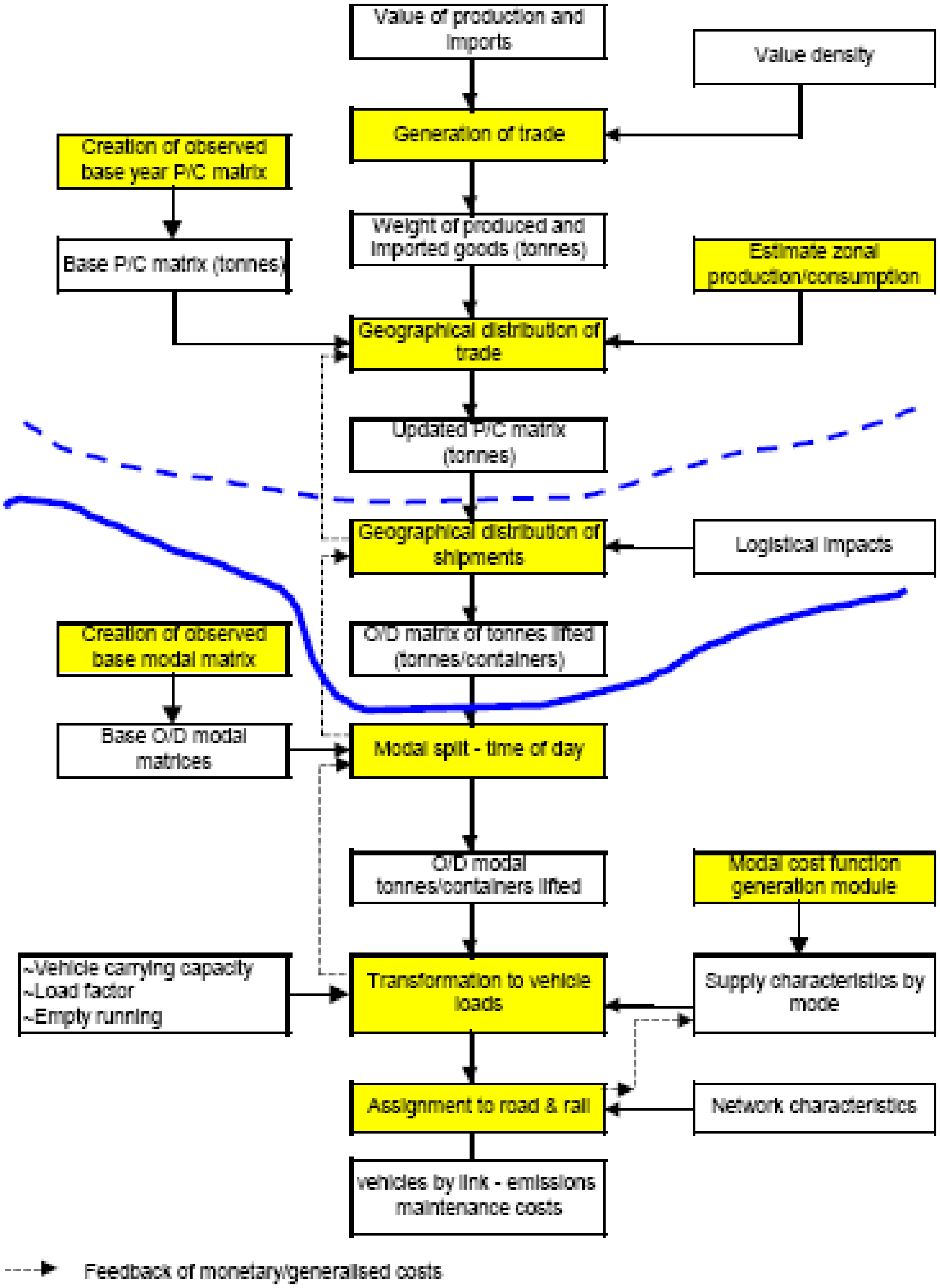


Figure 3 Recommended Structure of Great Britain Freight Model (WSP 2005)

2 Current Freight Modelling Practice

Internationally the developing practice appears to be to link fairly straightforward but well-founded metropolitan commercial vehicle models to more behaviourally-based national/state freight models. This requires a variety of types of datasets including freight movements, commercial vehicle trips, demographic (employment), economic (input/output) and detailed transport costs. These datasets need to be available at a regional or lower level.

2.1 National Freight Modelling Internationally

Sources

This note records the main activities in European freight modelling. It has been done essentially on the basis of our knowledge of current practice and has not involved any specific investigation. Thus there may be other areas or institutions in which active freight modelling is taking place, though it is believed that the main efforts have been described .

General

Freight has generally been neglected in transport modelling, where the concentration has been on the movement of persons. In most transport models, freight traffic is introduced as a fixed matrix, sometimes segmented by vehicle class, without any behavioural response to transport costs. The quality of such matrices has usually been poor, based on simplified “gravity model” concepts, possibly adjusted by means of matrix estimation from counts.

Within the last 10 years or so, however, there has at last been a developing interest in improving freight modelling, driven in part by the particular problems which freight vehicles cause in terms of environment and congestion, and also by the possible economic consequences of insufficient capacity for freight movements. There has also been, within the last 20 years, a major re-organisation of the freight industry, with greatly increased average “length of haul”, and near-annihilation of non-road modes (in particular, rail and water). This is generally understood as having been facilitated by the improved express road network (motorways), with a concomitant switch to centralised warehousing and distribution processes.

There are however substantial obstacles in the way of producing freight transport models which approach the capability of person transport models. Firstly, there is much more variety in freight, in terms of the commodities which need to be transported, many of which have specialised requirements. Secondly, the movement of freight is under more control (by industry, and the haulage industry), so that it is much less well modelled by the essential statistical processes that underlie most person transport models. Thirdly, the actual details of freight movement are only understood by a small group of experts, who do not necessarily communicate easily with the traditional modelling community. And finally, there are severe data problems, partly institutional, partly because of inherent complexity, and partly for reasons of commercial confidentiality (particularly, in this last case, in relation to the rates charged for moving freight).

All this means that freight modelling remains in its infancy, and there are substantial challenges to making progress. Much of the original impetus for improvement has come from EU-funded projects. By their nature, these tend to be somewhat cumbersome, but they have provided the nucleus for further development by a small group of committed modellers.

The main current locations for freight models are in the Netherlands and in Scandinavia, as well as some interesting work in the UK. These are the variants that we shall concentrate on. However, there is a general agreement between the modellers in these locations about desirable methodology and data requirements, so most of what is written here aims to reflect this agreement.

Broad methodology

While there are substantial differences between freight and person transport modelling, there are also similarities which are useful. Essentially goods are moved between producers and consumers – the latter includes both "traditional" consumers and "intermediate" consumers of commodities that are used for further production. This basic process is complicated by the existence of intermediaries, which may be conventional wholesalers as well as more sophisticated warehousing operations, some of which may have production functionality (eg components may be stored in warehouses, but also assembled on demand).

For the purpose of making forecasts of changes in total freight activity, the "Production-Consumption" definition is now seen as essential, since it is only in this way that it is sensible to predict growth at the two "ends" of the movement: this is a similar argument to that for "Production-Attraction" modelling in person transport. However, because of the high incidence of intermediate stops, particularly for longer distance movements, this is not an easy concept to operationalise.

Of course, some movements between production zone and consumption zone will choose "direct" means of transport, and in this case the modelling problems are essentially confined to route and mode choice, together with frequency/shipment size considerations (since unlike passenger models, freight models typically deal with **annual** movements). However, once we have to consider actively the intermediate points (ie consolidation and distribution centres, as well as more generalised freight terminals and ports etc.), the problems becomes much more complex. This area of the model is generally described as **logistics**, and typically includes the choice of shipment size.

Along these lines, the Scandinavian work to be briefly described below envisages a matrix of annual transport demands, in Production-Consumption format, which are then input to the logistics model. This then considers the various tradeoffs in terms of cost, time requirements, storage etc., and allocates the total demand among a set of shipments which are then distributed among vehicles (for all modes) of different sizes. For non-direct movements, the costs of transferring from one vehicle to another, or to and from storage, are also considered. A key difficulty is in deciding where the intermediate transfer points should be located (or rather, which of the possible points to use). It is also necessary to take account of restricted access to facilities, either because of private ownership, or because of other conditions (eg hazardous materials).

An essential distinction is, of course, by commodity type. Here, however, great compromises have to be made. The models described here deal with between 10 and 40 categories of commodity, but even this level of detail hardly deals with the huge variety of handling and other requirements (bulk/liquid, packaged, perishable, high/low density, hazardous, refrigerated, high/low value etc.). Inevitably, any practical commodity classification will involve substantial approximation.

Since there is a policy interest in non-road modes, it may be generally assumed that multi-modal networks are required to reflect all the possibilities, and these must have suitable connection points for modal transfer. It may also be appropriate (as for example in the Scandinavian work) to recognise multiple vehicle types, though some models merely allocate tonnage to modes, and leave the vehicle type (and, by implication, shipment size) implicit.

The choice of shipment size is, however, a key element in considering the tradeoff between high levels of inventory holding and high frequency of delivery. Generally the tendency, which appears, at least for the moment, to be prevailing, is for inventory (stocks) to be minimised, with "just-in-time" production, and high frequency deliveries to consumption outlets.

2.2 City commercial vehicle modelling internationally

Sources
Much of the international research into strategic commercial vehicle forecasting has been at a national level. It is beyond the scope of this exercise to review the proliferation of city models worldwide. We therefore draw on other reviews to provide a brief indication of the present state of practice: a UK review of UK, European and wider international practice (SACTRA 2002, WSP 1999 and 2005) and various US guidelines (Cambridge Systematics 1996 and 2004).

UK practice
Existing UK conurbation commercial vehicle models are similar to Australia and NZ practice using growth factors applied to observed travel patterns, themselves usually derived from partial data sources using matrix estimation techniques. In the UK, the data sources often include roadside interviews.

The UK study recommendations for urban modelling continue to rely on observed commercial vehicle matrices as a basis, with a focus on improving the existing simple growth factor techniques. The general proposal was to develop national freight models linked to commodities and input/output tables, following European practice. Local model growth factors could then draw on the forecasts of the more sophisticated commodity-based national modelling. The national data was also anticipated to be the main source of growth forecasts for through/long distance external commercial vehicle traffic. Model refinements would of course be needed to deal with specific commercial vehicle policies.

In regard to Light Commercial vehicles (LCVs), the UK study commented on the absence of useful data and its major recommendation was to start to develop a data base upon which, in the future, LCV models could be specified and developed. The report classifies LCV trips into those carrying goods, service trips and other commercial activities.

The Standing Advisory Committee for Trunk Road Assessment (SACTRA) criticised current commercial vehicle forecasting methods in the UK in their report: Transport and the Economy (1999). The committee was concerned about the lack of ability of commercial vehicle models to predict freight operator responses to changes in road supply, the use of national growth factors locally and the use of traffic growth factors (rather than the freight which is being moved). In the UK further research into this area has been commissioned following these criticisms in the 1999 and 2002 studies.

European Practice
The UK study reviewed European models, but most of the interesting work was at a national scale. While some local models were described, no consistent practice is apparent.

United States practice
US urban network modelling practice concentrates on modelling truck flows and their impacts on the road system. The common practice is to use a 3-step gravity model comprising trip ends, distribution and assignment. This differs from the practice elsewhere is primarily in basing the Origin - Destination (OD) matrices on a distribution model rather than developing them from matrix estimation techniques.

The Quick Response Freight Manual provides information that can be used in setting up these models (and growth factor approaches) as well as advice on how to do this and the data to collect. In particular, standard trip rates are provided (developed from a Phoenix study) and deterrence function parameter values for different vehicle types. As elsewhere the issue of estimating and forecasting external traffic is raised.

The focus appears to be on freight vehicles, as distinct from service vehicles which are generally not separately modelled.

There is also current research on more sophisticated techniques including tour-based models, supply chain models and integrated models.

In summary the state of practice between the United States and Europe is quite similar. In both cases, urban freight models are simpler commercial vehicle models without mode choice or disaggregated commodity based freight movements. These are supported by more complex National (Europe) or State (USA) level models that produce estimates of overall intra-regional and inter-regional flows.

3 Data requirements

3.1 Requirements for national freight models

Freight surveys of any size are expensive, and it is necessary to make maximum use of official statistics. Unfortunately, these are of course collected for other purposes, and are not necessarily well-suited for modelling.

Within the European context (this appears to be much less important in Australia), imports and exports occupy a significant proportion of total freight movements, and they are, of course, not only of interest in value terms, but also in general political terms. In some countries, there is particular issue in freight **transit** traffic, which has neither end within the country of interest, but may cause considerable intrusion nonetheless.

As far as domestic freight is concerned (ie where both production and consumption are within the host country), most European countries operate some kind of “lorry (truck) survey” which, on a sample basis, seeks to find out what loads are being transported by road. The information contains commodity information, size of load (weight), origin and destination (though typically this is coded to quite large areas – eg in UK it is only coded to the county level [about 60 counties in Great Britain]), and something about the vehicle used. In the UK, this survey is carried out on a rolling basis, and is known as the CSRGT (Continuing Survey of Road Goods Transport): it is the main source of data on “tonnes lifted” and “tonne-Km”, which may be divided to give the average length of haul. A similar survey is conducted in Sweden (Bates 2004). However, these surveys are confined to heavy (or medium) goods vehicles only: light vans (under 3.5 tons) are excluded, and this remains a major problem, since these are a fast-growing category of traffic, and are particularly appropriate for shorter distances and lighter/smaller consignments.

A major problem with the truck surveys is that it is not possible to tell whether the movements recorded involve production or consumption zones, as opposed to intermediate points (eg at warehouses). While the proposal has been made at least to record the land-use of all locations, this has generally been resisted by those responsible for the survey. The result is that the data collected is strictly in origin-destination format. For the reasons given earlier, while this may be quite adequate for building commercial vehicle matrices for assignment, it is not appropriate for demand forecasting. A further problem is that “tours” with more than five stops en route are not recorded in detail, but only the distance travelled and the first and last stop are obtained.

In addition, the survey will pick up movements by host country vehicles with an origin or destination outside the country, but one end will be recorded as the port of entry/exit (rather than the true foreign location). Thus there is some overlap with the customs data. In addition, each EU member country is obliged to carry out an International Road Haulage Survey, in terms of the work done by its own registered freight vehicles in other countries. While in principle this could be collated to provide a complete picture of the movement of foreign registered vehicles within the host country, in practice the data from different countries is of very variable quality.

Other sources of road goods traffic can be obtained from a) Roadside Interviews and b) Traffic counts. Both of these are essentially O-D based, and are thus potentially useful in creating matrices of vehicle movements. By contrast, they are of little value for demand modelling.

Other sources of data are again modally-based. Both Port and Airport statistics contain substantial information about freight movements, but the locational detail is oriented towards the “non-landside” end of the movement. The published port statistics provide estimates of the number of tonnes, of containers and other forms of unitised goods, which are loaded and unloaded through the seaside of the port. They do not however, provide **direct** estimates of the **total** number of goods vehicles or rail wagons loading or unloading at a port. There is no straightforward method of estimating the level of road or rail traffic associated with the goods through ports since:

- a significant portion of the tonnage may not leave the port area at all, but may be processed locally (e.g. crude petroleum, coal for power stations, ores, etc.);
- or, in the case of liquid bulk products and containers, these may be transhipped to another port without ever leaving the land side of the port. Statistics on transhipment volumes are not currently published for ports, and are deemed commercially sensitive by some ports and so are not easily accessed.

There is a significant amount of data held by railways on rail freight movements, but it is not well arranged for modelling purposes, and is also generally treated as confidential. Thus any data which may be made available is likely to be aggregated. In addition, the actual rail-freight procedures are very specialised (marshalling yards etc), and reasonable knowledge is needed to understand the form of the data and its implications for the network.

Overall, therefore, the picture is very partial, and there are major problems involved in reconciling the disparate items of data, particularly in making the distinction between production/consumption and origin-destination movements, and commodities as opposed to vehicles. There is generally poor data regarding the **facilities** for transhipment (other than modal interchange – eg at ports), and on the road side, many of these are privately owned.

In principle, what is required to develop useful models of freight is a database which tracks individual shipments through the transport system. Some of the large freight companies do, of course, operating precisely such systems, and in Scandinavia discussions have been held with major companies as to whether they might release information, subject to the usual restrictions of commercial confidence. There may be a way forward here, though it is likely that any such data would require substantial processing.

In the absence of such data, the most useful source is the unique (in Europe – there is a corresponding survey carried out in the US) Commodity Flow Survey carried out in Sweden. The first such survey was carried out in 2001, and a second has recently been completed (2004/5). This produces data on the movement of goods in Sweden with Swedish and foreign recipients/consignors. It provides information on type of commodities shipped, their value, weight, and mode of transportation, as well as the origin and destination of consignments. It differs fundamentally from the modally-based surveys described above in that it relates to consignments, and takes account of transhipment. It thus offers the opportunity to investigate logistic functions.

Even so, this has some deficiencies. The details of transport chains are not recorded (eg it is known that a consignment experienced a change of vehicle/mode, but it is not known where this took place), and the classification of the receiving destination is not known (though this is being rectified in the more recent survey), so that it is not known whether the final destination was a wholesaler or final consumption.

3.2 Requirements for commercial vehicle modelling

For commercial vehicle models of cities, data requirements for freight generation and mode choice processes will not be an issue. Conversely requirements for trip origin-destination (O-D) data remain substantial. Obtaining data on trip chaining for commercial vehicle trips in cities is a particular issue (Jessup 2004).

It is assumed that such a model would be developed in the context of a national integrated freight model being available to forecast the impact of economic trends on freight movements. In the absence of this, the commercial vehicle model's ability to forecast future changes in demand due to changes in economics or logistics practices will be limited. A historical record of classified vehicle counts is useful for monitoring trends in commercial vehicle trips.

New technologies may offer some scope for the more efficient collection of this data, such as via GPS tracking of cargoes and vehicles (Taylor, Green & Richardson, 1998) or matching vehicles captured using Optical Character Recognition (OCR) cameras. However a number of types of data, especially on cargo type, are generally only obtainable through interview of vehicle drivers and/or freight forwarders. We see data as a very substantial obstacle to the future development of commercial vehicle modelling practice in Australia and New Zealand.

4 Data Availability in Australia

As remarked in our review of national freight modelling, it is the data issues which heavily determine the practicalities of modelling. The data requirements for commercial vehicle modelling of any precision are substantial (see) and, in the case of the most advanced commercial vehicle models, usually rely in part on already available sources collected for other applications. Much of this data is unavailable in Australia and New Zealand. The situation is summarised in Table 1**Error! Reference source not found.**.

- **Table 1 Australian Data Sources**

Freight and Commercial Vehicle Data Sources	Australian availability	
	National/regional level	City level
Classified counts	Yes	Yes
Vehicle on-road intercept surveys	No	No
Operators or premises/establishment surveys	No	Partial
Historic classified counts	Partial	Yes
Vehicle registration statistics	Yes	Yes
Input/output tables	Yes	No
Commodity flow surveys	No	No
Import/export statistics	Yes	No
Land use data : detailed employment data by zone by SIC	No	Estimated
Vehicle use surveys (where vehicles includes road and rail units)	Road Partial Rail No	Road No Rail No
Consignment surveys	No	No
Operating and consignment costs/tariffs for road and rail by commodity	No	No
Historic logistical and operational data based on some of the above surveys	No	No
In-depth interviews and stated preference data	No	Partial
One-off surveys	Yes	Yes

Estimated = not surveyed but regularly calculated by other means
Partial = data collected in some jurisdictions or for selected categories only

Note that since the Austroads study that this paper is based on was completed, DOI has released the Melbourne Freight Movement Model in April 2007. Details of this model have not yet been published, and we are not therefore able to comment further.

5 Recommendations to Improve Australian Practice

The objective of the Austroads study was to make recommendations regarding Austroads' future involvement in the area of freight modelling. This paper has been limited to consideration of data issues and modelling practice, and has not reviewed any specific Australian freight model. Hence in this section we seek to draw together options on data and modelling practices, drawing on the practice here and elsewhere. As this is a technical review, the question of who would be the responsible agency to fund and carry out the actions has not been examined.

The general concept that appears to be being developed internationally is one where there is an urban/metropolitan commercial vehicle model of a fairly straightforward type, designed to provide an accurate representation of current travel patterns assigned to a road network.

Ideally the forecasts of this detailed model are then related to more complex, behavioural state/national models which provide soundly based growth forecasts. It is at this level that research is mainly focussed on the more complex aspects of freight, logistics the economy and commodities.

Presently Australian and New Zealand models do not stand up well against these simple principles, for two main reasons:

- The travel patterns used in the urban models tend mainly to be based on updating past (somewhat old) survey information through matrix estimation techniques in conjunction with up-to-date classified traffic counts. This reliance on past data sources is principally because of the difficulty and cost of collecting CV OD data.
- The second is that the national level freight database, which is used as the basis for a higher level strategic model, is not sensitive to freight industry practices that affect transport demand, and does not encompass intra-metropolitan freight demand. Therefore it is not appropriate for providing growth forecasts for use in these models. While it is no doubt a useful model for inter-urban economic forecasting its scope and specification is very limited compared with the ideas now being researched internationally and reported earlier.

Here and elsewhere there is no question that commercial vehicle modelling is one of the least developed aspects of transport modelling practice posing significant issues for data collection and model specification. Consequently, many of the local and international models are based on old, unreliable and/or borrowed data and involve simple forecasting techniques.

Improvement rests in the short term on better data and more rigour in the simple models and in the longer term on the more behaviourally-orientated model structures that are presently being researched. We detail some of these areas below:

City Commercial Vehicle Models
(1) Light Commercial vehicle (LCV) proportions in traffic may be determined from other data, for example a sample of manual classified counts on different road types, from which general rules on LCV proportions can be deduced. A compendium of this data and the rules derived, may be of assistance to modellers generally.

(2) Collate surveys of trip generation rates for city trip-end models.

(3) Surveys trip generation rates for city trip-end models. Such analysis would rely primarily on company/driver interviews which, in this sphere, are risky.

(4) In some models deterrence functions are used in a distribution model. In principle, if well-established functions were available, these might be catalogued for others to use.

(5) Research is required into CV growth rates, based on analysis of historic trends in cities, where the relevant classified count data is available.

State/National Models
We presume that sufficient data and resources for developing a national model according with the latest developments in international practice are not likely to be available and justifiable relative to other modelling needs in the short term at least. Therefore:

(6) Consider promoting refinements to existing national freight databases:
- to extend the scope of the model to encompass intra-regional freight movement;
- to include LCV data in any national database

Data and Survey Techniques:
It is important to establish the characteristics of effective CV surveys via operators and the data which can reliably be obtained (by this we imply that the old travel diary approach may be best supplanted by much shorter questionnaires targeted at particular issues).

(7) Classified Traffic Surveys - In urban highway networks, classified traffic surveys (i.e. simple traffic counts) will remain the most economical means of obtaining data on truck volumes. This data should be collected regularly (at least every five years) for all major highways, as part of existing traffic survey programs.

(8) Roadside Interview Surveys - The most accurate form of observed CV trip data is derived from roadside interview/intercept surveys, generally not permitted in Australian states. Consider whether effort should be put into overcoming this constraint.

(9) LCV Data - Research is required into LCVs. These form a larger proportion of traffic flows than other CVs, yet are not well addressed either locally or internationally. If they are considered important, then new data collection and further work might be designed to assisted city modellers.

(10) GPS and OCR Technologies - Sponsor research, or monitor Australian and overseas research and experience[1] into the use of Global Positioning System (GPS) and Optical character recognition (OCR) or number plate reading technology to track freight movements. This may offer the opportunity to more economically and/or reliably obtain data.

(11) ABS Mailback Truck Survey - Consideration should be given to expanding the Freight Movement Survey undertaken by ABS, to include short trips (i.e. under 25km), MCV trips (i.e. trucks smaller than semi-trailers but greater than 4 tonnes) and, possibly, LCV trips. These comprise the majority of urban freight distribution, which in turn comprise the majority of urban freight trips. At present there is no reliable measure of the amount of intra-urban freight distribution trips available in Australia, either directly from surveys, or synthetically from a national model. Hence there are no control totals or estimates of trends in urban freight trips against which to validate urban commercial vehicle models.

Improving Modelling Practice

(12) Library - Document development of commercial vehicle models in Australian/New Zealand cities in a coordinated fashion. Similarly freight/commercial vehicle data could be shared in a common library, providing the opportunity for agencies to benefit from wider data sources.

(13) Coordination and Consistency - Our recommendations above typically concern sharing knowledge and data. This would have the greatest benefits if commercial modelling in Australia and New Zealand adopted a broadly compatible and consistent development path. Without this the value of polled knowledge and data will be less. There is a need for a forum and/or model development guidelines to encourage a move towards consistency.

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