ABSTRACT
The efficient movement of freight is especially important in Singapore which aspires to become a premier logistics hub for the region. Research on freight transport has received less attention compared to passenger transport. The objective of this paper is to discuss findings from the study of 80 local freight companies and developing a research agenda in road freight transport. The survey investigated a wide range of issues – the characteristics of freight vehicle fleets and their movements, the impact of traffic management measures and information technologies (IT) as well as the critical issues of concern to the local companies. The survey suggests that measures such as Electronic Road Pricing (ERP) and Vehicle Parking Certificate (VPC) do have some impact upon freight operations and congestion remains to be an issue of concern. The results suggest an average distance per trip of 6.8 km for light goods vehicles (LGV), 18.6 km for prime movers and 15.5 km for heavy goods vehicles. The average distances travelled per day ranged from 190 km for LGVs to 230 km for prime movers. These values are higher than national averages for trucks, indicating that freight companies utilize their vehicles more extensively. It is also clear that future freight studies must pay more attention to LGVs if a freight model is to be accurate for demand forecasts. A future research agenda has been prepared as part of the study. It consists of topics such as: advanced methods for freight data collection using GPS to capture truck movements, performance assessment of computerised fleet management technologies, designing of truck routes and incorporation of congestion effect in vehicle routing and scheduling.

INTRODUCTION
The efficient movement of goods is vital to the economic development of any country. Freight transport costs constitute a significant proportion of the Gross Domestic Product (GDP). In a country such as Australia, this proportion is about 5% for urban freight and another 5% for inter-urban freight (Ogden 1992). The total proportion of GDP will be higher if logistics costs (i.e. warehousing and inventory costs) are also considered. Despite these facts, research on the movement of goods has not attracted as much attention as the movement of people or the supply chain management.

Some possible reasons for this apparent lack of interest (Luk and Chen 1997; Wigan and Rockliffe 1998) are as follows:

- The movement of goods is a complex transport chain, often with multiple (and undefined) destinations from a single origin.
- Freight data are not usually collected by government agencies and those from individual companies are not available to outsiders because of the fear of competition from other companies in the same industry.
- While an efficient and safe movement of freight is of concern to many parties and several government agencies are involved, there is no single champion of freight issues.

Research on freight is especially important in Singapore which now aspires to become a premier logistics hub for the South-East Asian region. Efficient movement of freight between factories,
port and airport terminals, distribution centres as well as other customers is critical in order to compete with the neighbouring countries. In recent years Singapore has witnessed rapid growth of the logistics and warehousing industry. However, up to now, there has been very limited research on freight movements in Singapore.

To address these needs, an exploratory study entitled: “Freight transport research strategy” has been conducted at the Nanyang Technological University (NTU) between 2000 and 2002. A step-by-step approach was adopted in view of the complexity of issues involved in the transport of goods. The aim of the study was to investigate the state of the industry and eventually to develop a freight research strategy for the country.

The objective of this paper is to discuss findings from the study, especially the results of the survey of 80 local freight companies related to goods vehicle fleets and their movements as well as the effects of traffic management measures on freight operations. Other aspects covered by the study, such as the use of information technology, have been reported elsewhere (Olszewski et al. 2001).

SURVEY OF FREIGHT COMPANIES

The survey of freight companies was a key task of this research study. The aim was to get a better understanding of the operations and needs of the local freight transport industry. The survey investigated a wide range of issues – the characteristics of freight vehicle fleets and their movements, the impact of traffic management measures and information technologies (IT) as well as the critical issues of concern to the local companies. The survey was also meant to explore the methodological issues of surveying the freight industry: the problems of survey instrument design, sampling and interview methods, with a view of conducting a more comprehensive survey in future.

Organisation and Survey Execution

The survey has been conducted by NTU with co-operation from Land Transport Authority, Trade Development Board and Infocomm Development Authority. The focus of the survey was on freight movements, goods vehicle fleets, transport operations and current important freight issues. The intent was also to investigate how traffic management measures and information technologies could facilitate freight transportation within Singapore.

The survey was addressed to companies which manage their own fleet of goods vehicles. A pilot survey of two companies was carried out in order to test and streamline the questionnaire. The final survey instrument included 30 questions, divided into the following five parts:

1. General Company Information
2. Goods Vehicle Fleets and Transport Operations
3. Use of Information Technology (IT)
4. Impact of Traffic Management Schemes
5. Rating of Freight Issues

The target population was about 500 companies in the logistics and transport sector. From a local company database, a selection was made of companies involved in activities such as road transport, freight services and warehousing. This list was later cross-checked and supplemented with names of largest goods vehicle fleet operators. The final list comprised 474 company names and the questionnaires were mailed out in batches in November 2000.

After the first round of the survey in November-December 2000, only 50 completed questionnaires were obtained, giving the response rate of around 10%. An additional effort was made in the middle of 2001 to increase the sample size, resulting in 30 more completed survey forms. Thus the final response rate stands at 16.8% or about one in six companies approached.
The reasons for the poor response and problems encountered during the survey are discussed below.

- **General reluctance** – In general, companies were reluctant to participate in the survey. This can be attributed to survey fatigue, lack of time, concerns about data confidentiality or failing to see any usefulness of the study.
- **Mode of communication** - Face-to-face interviews proved to be impractical as respondents preferred to mail back the form. In the end 78% of all respondents returned the questionnaire by mail or fax and only nine face-to-face interviews were conducted.
- **Wrong timing** – Apparently, end of the calendar year is the busiest time for the freight industry and therefore many companies could not afford to give any attention to the survey.
- **Wrong respondent** – The questionnaire was supposed to be filled by a manager responsible for freight or logistics operations. However, questions were often answered by junior personnel who might not have had the knowledge to provide meaningful responses.
- **Bad past experience** – Some companies refused to participate because past surveys resulted in policies which increased their operating costs instead of bringing promised benefits.
- **Changes in the industry** – Some freight companies were in a state of flux. Companies were changing address, merging or being taken over by others.

**Characteristics of Participating Companies**

The eighty companies which responded to the survey varied greatly in size – the smallest had two employees while the largest over 1000. The mean size was 130 employees. Some 80% of the companies had less than 200 employees and can thus be classified as small and medium enterprises (SMEs).

In Part 1 of the survey questionnaire, respondents were asked to indicate the main business activities of their companies. The choices given included: warehousing, different modes of transport (air, sea, land), as well as manufacturing and trade. Companies were classified into different groups based on reported combinations of transport and warehousing activities. Table 1 shows that a total of 63 (79%) companies provided at least one mode of transport service; over one third (37%) of the companies provided a comprehensive suite of services including airfreight, sea freight and local land transport. A tenth of the companies indicated that their main business involved only warehousing.

**Table 1: Classification of companies by business activities**

<table>
<thead>
<tr>
<th>Business Activities</th>
<th>Number</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airfreight, Sea Freight &amp; Land Transport</td>
<td>29</td>
<td>37</td>
</tr>
<tr>
<td>Airfreight &amp; Land Transport</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Sea Freight and Land Transport</td>
<td>13</td>
<td>16</td>
</tr>
<tr>
<td>Local Land Transport Only</td>
<td>18</td>
<td>23</td>
</tr>
<tr>
<td>Warehousing Only</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Others</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>80</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

**Characteristics of Vehicle Fleets**

Part two of the questionnaire was concerned with the details of goods vehicle fleet used by the company and their movements. It seems that the majority of companies (81%) operated only a small fleet of vehicles: less than 20. On average, each company operated 17 vehicles, 66% of them owned and the rest leased or hired.

Table 2 shows a comparison of the numbers of vehicles in the sample and in Singapore. Overall, the sample companies used 1,657 goods vehicles which constitute only 1.5% of all goods vehicles registered in Singapore (LTA 2002). Thus, the sample in terms of vehicle fleet covered is small. It is also not representative with respect to vehicle types: it covers 22.2% of prime movers but only 0.4% of Light Goods Vehicles (LGV). These differences are not
unexpected – the freight industry uses mostly large vehicles to transport high volume of goods. LGVs, like vans and pick-up trucks, are mostly used by the service and other industries in supporting roles. Thus, the conclusion is that a survey of the transport sector alone cannot provide representative data on movements of goods vehicles.

Table 2: Types of goods vehicles in the sample and in Singapore

<table>
<thead>
<tr>
<th>Vehicle Type*</th>
<th>Sample (n=76 companies)</th>
<th>Population</th>
<th>Sampling</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Size</td>
<td>%</td>
<td>Size</td>
</tr>
<tr>
<td>LGV</td>
<td>340</td>
<td>21</td>
<td>80,270</td>
</tr>
<tr>
<td>Prime Movers</td>
<td>748</td>
<td>45</td>
<td>3,366</td>
</tr>
<tr>
<td>HGV</td>
<td>569</td>
<td>34</td>
<td>28,467</td>
</tr>
<tr>
<td>Total</td>
<td>1,657</td>
<td>100</td>
<td>112,103</td>
</tr>
</tbody>
</table>

*excluding specialised vehicles like cement mixers, cranes, etc.

Another interesting aspect of the vehicle fleet was the ratio of container trailers to prime movers. Generally, one prime mover can use several trailers which are stationary while the containers are being loaded or unloaded. Trailers come in 3 sizes, designed for 20’, 40’ and 45’ containers. Table 3 shows the distribution of trailers by size and the ratio of trailers to prime movers, determined by linear regression. About half of the trailer fleet comprised short vehicles, suitable for 20-foot containers. On average, there were 6.7 trailers of all sizes per prime mover.

Table 3: Distribution of trailers and trailer to prime mover ratio

<table>
<thead>
<tr>
<th>Trailer type</th>
<th>Number</th>
<th>Percentage (%)</th>
<th>Trailer to prime mover ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>20-footer</td>
<td>2,865</td>
<td>50.9</td>
<td>3.7</td>
</tr>
<tr>
<td>40-footer</td>
<td>2,115</td>
<td>37.5</td>
<td>2.1</td>
</tr>
<tr>
<td>45-footer</td>
<td>652</td>
<td>11.6</td>
<td>0.9</td>
</tr>
<tr>
<td>Total</td>
<td>5,632</td>
<td>100.0</td>
<td>6.7</td>
</tr>
</tbody>
</table>

TRUCK TRAVEL CHARACTERISTICS

Number of Vehicle Stops

Each company reported the average number of stops for loading and unloading (per vehicle per working day) for each vehicle type. This number corresponds to the number of vehicle trips per day. Figure 1 shows cumulative distributions of vehicles by the number of stops. The mean and median statistics for the three vehicle types are shown in Table 4.

As expected, LGVs had the larger spread in the distribution which basically reflected the greater diversity in their usage. Nearly two-fifths of the LGVs had 15 or less stops. There were several international courier companies with large fleets of LGVs reporting high numbers of stops, hence the discrepancy between the mean and median statistics.

The median values of stops for HGVs and prime movers were the same at 8 stops. Some 37% of HGVs and 5% of prime movers made 15 or more stops, indicating that these vehicles were better utilised, probably being operated for longer hours.

Vehicle Travel Distance

Companies were also asked to report the average travel distance (per vehicle per working day) for each vehicle type in the following intervals: less than 100 km, 100-200 km, 200-300 km and more than 300 km. Figure 2 shows the resulting mileage distributions.
LGVs generally covered shorter distances, with no reported mileage exceeding 300 km per day. Overall, there were small proportions of vehicles covering distances less than 100 km per day. The goods vehicles were thus generally well-utilised, especially the larger vehicles like prime movers (nearly three-quarters prime movers had travel distances over 200 km). This finding is similar to the findings from the survey done in Chicago in 1987 which indicated that larger trucks were more heavily utilised (Reilly et al. 1987).

Using the mid-point of each distance class, the average daily mileage and average distance per stop were calculated (Table 4) for each vehicle type. The average distance per stop for LGVs was quite short at 6.8 km, less than half of those for prime movers and HGVs.

Table 4: Vehicle travel statistics

<table>
<thead>
<tr>
<th></th>
<th>LGV</th>
<th>Prime Mover</th>
<th>HGV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean number of stops per day</td>
<td>28.4</td>
<td>9.0</td>
<td>12.3</td>
</tr>
<tr>
<td>Median number of stops per day</td>
<td>31.0</td>
<td>8.0</td>
<td>8.0</td>
</tr>
<tr>
<td>Average daily mileage, km/veh</td>
<td>190.0</td>
<td>229.0</td>
<td>209.0</td>
</tr>
<tr>
<td>Average distance per trip, km</td>
<td>6.8</td>
<td>18.6</td>
<td>15.5</td>
</tr>
</tbody>
</table>

The survey results were also compared with those estimated from truck generation and distribution model (Sreekumar et al. 2002). This model represents an initial effort in developing a national methodology for estimating an origin-destination freight trip matrix. The average distances travelled per day obtained from the survey are higher than national averages for trucks, indicating that freight companies utilize their vehicles more extensively. It is also clear that future freight studies must pay more attention to the role that LGV plays if a freight model is to be accurate for demand forecasts.

**IMPACT OF TRAFFIC MANAGEMENT ON FREIGHT OPERATIONS**

The impact on freight operations of two traffic management measures was investigated in Part 4 of the questionnaire: the Electronic Road Pricing (ERP) and the Vehicle Parking Certificate scheme. The questions asked concerned additional costs caused by the schemes as well as the perceived benefits and/or problems arising from the two traffic management measures.

**Electronic Road Pricing (ERP)**

Like all vehicles in Singapore, goods vehicles are subject to road pricing when entering the central area (known as Restricted Zone) during most of the day as well as when passing some sections of expressways and arterials in the morning (for more details see: Luk 1999; Menon 2000). In the year 2000, the charges varied according to location, time of day and vehicle category as follows:

- Light Goods Vehicles: S$0.25 – S$1.90
- Heavy Goods Vehicles: S$0.40 – S$2.90

Companies were asked if they experienced an increase in the operating cost of their transport services due to ERP. Some 63% said “Yes” and 37% “No”. The responses about the magnitude of the increase were very diverse and ranged from “negligible” to as much as S$500 per truck per month. The average obtained was S$95.20 which cannot be considered a reliable value. An analysis of ERP revenue data (Yap 2002) showed that the average ERP fees paid by LGVs and HGVs per week were only S$3.15 and S$4.30 per vehicle, respectively.

It is generally recognised that ERP is an effective tool in controlling traffic congestion, and as such should in theory bring benefits to freight operators in terms of reduced travel time and greater reliability and timeliness of deliveries. Respondents were asked to assess these potential benefits of ERP on a three point scale ranging from “No/little effect” to “Significant effect”. Figure 3 shows that a significant proportion of respondents perceived such benefits: 41% felt
that there was some or significant effect on reduction of travel time, while 31% felt the same about getting more on-time deliveries.

As going through ERP road sections results in extra cost, some operators may be planning their vehicle trips in such a way as to minimise these charges. This could be achieved in a number of ways:

- by timing trips outside the ERP operating hours;
- by routing trips to go around the Restricted Zone or avoiding expressway ERP gantries;
- by consolidating shipments in order to minimise the number of trips subjected to ERP.

Respondents were asked how frequently they took any one of the above actions. The distributions of responses are shown in Figure 4. It seems that goods consolidation is the most commonly used way of minimising ERP costs. If “sometimes” and “most of the time” are considered together as positive responses, then goods consolidation was practised by 44% of companies, re-routing by 33% and re-timing by 28%. Considering the fact that ERP only covers the central area and selected expressways in the morning, this shows that ERP does have an impact on daily operations of the freight industry.

**Vehicle Parking Certificate (VPC) Scheme**

The VPC Scheme, implemented in Singapore in 1995, requires all heavy goods vehicles with a maximum laden weight exceeding 5,000 kg to have an allocated licensed place for overnight parking (Menon et al. 1997). The objective of the scheme is to minimise the negative impact of the overnight parking of goods vehicles, which used to park indiscriminately in housing estates, causing noise nuisance, air pollution and safety hazards.

While the aims of the VPC scheme are fair, it does complicate life for freight operators, as vehicles may be required to park overnight in an inconvenient location. This situation may result in more empty runs. If, however, the vehicle is parked illegally in a more convenient place, fines may be imposed. The scheme may also cause the drivers to complain, as they would prefer to be able to park overnight near their homes.

To analyse the impact of VPC, only 62 companies which had fleets of heavy vehicles were considered. Some 46% reported that there was an increase in operating costs due to VPC. The average amount of increase was S$118 per vehicle per month. Respondents were then asked to rate how frequently they were affected by the various possible impacts of the scheme. The results are summarised in Figure 5.

The effect on increasing the number of empty runs was reported by 22% of companies (sometimes + most of the time). Slightly more respondents (34%) reported receiving more parking fines. The general complaint (51% of companies) was the difficulty in getting conveniently located parking lots which means, most likely, near drivers’ residences. However, such lorry parks near housing estates are in short supply. The result of this situation is the high frequency of complaints by drivers (occurring in 46% of companies sometimes or most of the time). Drivers are frustrated if they have to travel far by public transport in the morning to reach their vehicles.

**FUTURE RESEARCH AGENDA**

Freight transport operations involve many parties or stakeholders and, as already mentioned, freight research is a complex topic. The difficulty in obtaining information due to the risk of losing commercial competitive advantage is real. At the same time, technologies beneficial to freight operations, such as IT, track-and-trace and fleet management, are being developed. However, the survey suggested that these technologies have not been actively taken up by the small and medium enterprises, mainly due to the high start-up cost. High operating costs are of concern to logistic service providers. There is a real risk of moving manufacturing plus logistics
operations off-shore to places where these costs are relatively lower. Two groups of activities can address these concerns.

**Information Collection and Sharing**

The poor response rate in the freight survey is generally expected for reasons already mentioned. There is an urgent need to develop trust amongst various stakeholders in the freight logistics sector (Hensher and Brewer 2001). The stakeholders include: freight transport operators and logistics service providers, their trade associations as well as related government authorities.

The academic/research community can play a facilitating role in gathering these stakeholders together. A seminar held at NTU in October 2002 to disseminate the research findings of this study was attended by some 150 participants from the industry and the government. Most of the stakeholders who have been involved in the study process took part. A desired future development, discussed at the seminar, is the technology transfer or demonstration projects. The use of IT and related location technologies (e.g. GPS) have not been widely adopted by the local freight industry. One way to overcome the cost barrier would be to pool resources.

**Proposed Research Topics**

The following is a list of research topics prepared based on survey findings, the seminar held at NTU in October 2002 and subsequent discussions with some stakeholders in the industry.

- **Advanced Methods of Freight Data Collection**
  The difficulty of conducting a freight survey using the traditional questionnaire method, whether by personal interviews or mail-back, is well recognised. An alternative is to utilise GPS vehicle location technologies. A truck driver will not need to record where and when he has been during a working day. A simple form of data entering at each stop can complement the location technology. Key parameters such as trip generation rates and trip length distributions can then be measured accurately.

- **Performance Assessment of Computerised Fleet Management**
  The benefit of vehicle location and computerised fleet management for road freight transport is generally accepted. A systematic assessment of the improvements of vehicle utilisation and benefit/cost ratio of the technology can further promote its use and identify its advantages to all, including the truck drivers.

- **Truck Routes**
  Truck routes are common in many large cities but are not adopted in Singapore. Truck routes concentrate heavy vehicles onto declared roads and prevent excessive entry of these vehicles into the local roads, where noise and air pollution are of concern to local residents. These routes also facilitate the movement of hazardous materials. This issue can become significant when environmental protection receives priority.

- **Incorporation of Congestion Effect in Vehicle Routing and Scheduling**
  Current algorithms for vehicle routing and scheduling seldom include the traffic congestion effects. Usually a speed value is assumed constant for a particular route and optimisation is applied to minimise, say, the number of trucks used. However, the number of trucks used can in turn affect the speed value. This issue has received attention from some transport researchers (Thompson and Taniguchi 2001).

**CONCLUSIONS**

The survey of freight and logistics industry companies in Singapore, conducted in 2000-2001, has resulted in 80 completed questionnaires. This represents only 16.8% of the companies to which the survey forms were mailed. It seems that the amount and accuracy of data that can be practically obtained is moderated by the generally low willingness of the freight industry to participate in the survey. The reasons cited most often were: lack of time, busy end-of-the-year period, perceived lack of usefulness and previous bad experience with similar surveys. Very often, the only people who had the relevant information were too busy to fill the forms.
Problems faced in this survey confirm the general difficulties of collecting data on freight movements known from the literature and overseas studies. However, it is hoped that the experience gained on the proper survey instrument design, sampling and interview methods will be useful for planning more comprehensive freight surveys in future. For example, it became evident that transport companies use mostly heavy goods vehicles and prime movers and only relatively few light goods vehicles. Thus, if the survey objective is to obtain a representative sample of trips of all goods vehicles, a different sampling approach will be needed.

Despite the small sample size, the results provide a better understanding of the operations and needs of the local transport industry and the current freight issues. Majority of the companies now offer comprehensive logistics services, including warehousing as well as transport by land, air and sea. The survey results suggest that road congestion is of concern to the freight transport operators. There is some impact on their operations due to traffic management schemes such as Electronic Road Pricing and Vehicle Parking Certificate. The impact is not excessive.

The survey results were also compared with those estimated from a freight vehicle generation and distribution model. This NTU model represents an initial effort in developing a national model for estimating an origin-destination freight trip matrix. The survey suggests an average distance per stop of 6.8 km for light goods vehicle, 18.6 km for prime movers and 15.5 km for heavy goods vehicle. The model forecasts an average distance of 8.5 km per stop for all vehicle types. It is concluded that future freight studies must pay more attention to the role that LGVs play if a freight model is to be accurate for demand forecasts.

A research agenda has been prepared in this report. It consists of topics such as: advanced methods for freight data collection, performance assessment of computerised fleet management technologies, design of truck routes and incorporation of congestion effect in vehicle routing and scheduling.

**REFERENCES**


**AUTHOR BIOGRAPHIES**

Piotr Olszewski was born and educated in Poland. He has obtained his Masters and Ph.D. degrees from the Warsaw University of Technology. He is now Associate Professor in the School of Civil and Environmental Engineering, Nanyang Technological University. His research interests include modelling of transportation systems and transport logistics.

Yiik-Diew Wong is an Associate Professor in the School of Civil and Environmental Engineering, Nanyang Technological University. He graduated with PhD in Civil Engineering from the University of Canterbury, New Zealand. His research interests are in road safety and travel behaviour.

James Luk has academic degrees in electronics and traffic engineering. He joined ARRB in 1975 to undertake research in traffic control and was a Chief Scientist before taking up an academic position in 1998 with the Nanyang Technological University in Singapore. He has rejoined ARRB since July 2002.
Figure 1. Cumulative distributions of vehicles by the number of stops per day

Figure 2. Distribution of vehicles by distance travelled per day
Figure 3. Benefits of Electronic Road Pricing for freight transport

Figure 4. Impacts of Electronic Road Pricing on freight operations
Figure 5. Impacts of the Vehicle Parking Certificate scheme on freight operations