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ANALYSIS OF FREIGHT TOURS IN A CONGESTED URBAN AREA USING DISAGGREGATED DATA: CHARACTERISTICS AND DATA COLLECTION CHALLENGES

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ABSTRACT

Confidentiality issues are usually an insurmountable barrier that precludes the collection of detailed and complete freight data. However, when detailed disaggregated truck activity data is available, the analysis of commercial vehicle routes and trip chain structures can provide insightful information about urban commercial vehicle tours, travel patterns, and congestion levels. Where truck data is usually aggregated and cross-sectional, this research analyzes several months of detailed truck activity records in a congested urban area and thus contributes a level of investigation unavailable with aggregated data. To the best of the authors' knowledge, there is no published research regarding the analysis of disaggregated truck data in congested areas. Data corresponds to the daily activity of less than truckload (LTL) delivery tours in the city of Sydney. The analysis of the data provides insightful information about urban truck tours and congestion levels. This paper identifies route patterns and analyzes their relationship to trip and tour length distribution. Travel between different industrial suburbs explains the shape of multimodal trip length distributions. Variations in daily demand explain the normal-like shape of the tour trip distribution. Tour data indicates that there is no clear relationship between tour distance, percentage of empty trips, and percentage of empty distance. Congestion data indicates that the standard deviation of travel speed is significant. In addition, correlations between travel times are positive and they should be used as an additional congestion measure for trip-chains or urban freight tours. Despite the availability of complete tour data, tour congestion analysis proved challenging due to the large number of customers visited and links traveled during the period of study.

KEYWORDS: Urban Freight, Congestion, Truck Trip Distribution, Empty Trips, Data Collection

1. Introduction

A primary reason for the limited understanding of freight movements in urban areas is the lack of detailed disaggregated data on commercial vehicle movements (Regan and Garrido, 2001). Confidentiality issues are usually an insurmountable barrier that precludes the collection of detailed and complete freight data. Understandably, companies are unwilling to disclose any type of information that may be used by competitors or that may infringe customers' rights regarding privacy, proprietary data, or security. Consequently, urban freight data needed for disaggregate models that predict trip generation, distribution, or network assignment is scant or nonexistent. Unlike the case of urban passenger surveys and models, urban freight data sources and models of behavior are mostly of an aggregated nature.

The lack of detailed or complete data sources is strikingly evident regarding urban truck tours or trip chains. A recent and comprehensive survey of urban freight modeling efforts across nine industrialized countries of America, Europe, Oceania, and Asia[1] confirms the absence of urban truck tour analytical models (Ambrosini and Routhier, 2004). Due to data limitations and availability, truck tours are largely ignored in traditional four-stage transportation modeling approaches borrowed from the passenger modeling literature or in most urban freight models. However, freight tours are critical as shown by a recent study of 13 American cities. This study indicates that a significant share of freight trips that contribute to commercial vehicle kilometers traveled (VKT) originate at distribution centers (DC) or warehouses (Outwater et al., 2005). Trips that originate at DCs or warehouses are tours or trip chains that usually involve more than 2 stops.

When detailed disaggregated truck activity data are available its analysis can provide a wealth of useful information for transportation planners as shown in this research article. The authors had access to detailed truck run sheets where the daily activities of trucks were recorded. The contributions of this research are novel insights and data analysis related to: a) characteristics of urban truck tours, b) empty trips, and empty distances, and trip-tour length distributions, and c) urban congestion analysis and data challenges.

The research is organized as follows: section two provides a literature review of truck tours in urban areas. Section three describes the data sources used in this research. Section four analyzes tour characteristics such as trip and tour length distributions, empty trips, and empty distances. Section five

[1] USA, Canada, Japan, Australia, Germany, UK, Netherlands, France, and Switzerland

discusses congestion data. Section six analysis the data challenges posed by congestion. Section seven ends with conclusions.

2. Literature Review

Most trucking companies keep run sheets of the daily truck activities for their own business and benchmarking purposes, these detailed records are generally not accessible to researchers or transportation planners since they contain sensitive customer information. To the best of the authors' knowledge, there is no published research regarding the analysis of disaggregated truck data in a congested area.

Data collection needs for urban freight modeling can be classified into five distinct themes: vehicle fleet, vehicle flows, commodity flows, major freight generators, and major freight corridors Ogden (1992). The data collection needs described by Ogden mostly apply to aggregated fleet and freight flows data. Issues related to distribution or service tours in urban areas were mostly ignored until recently.

Incipient work regarding truck tour data collection and modeling has recently begun. Data collection efforts that aim to capture the complex logistical relationships of commercial tours have been undertaken in Canada (Stefan et al., 2005), USA (Holguin-Veras and Patil, 2005), and the Netherlands (Vleugel and Janic, 2004). To the best of the authors' knowledge, there is no additional research or publication that describes or analyzes urban truck tour data.

Available tour data indicate that the average number of stops per tour is significantly higher than one or two stops. The city of Calgary reports approximately 6 stops per tour (Hunt and Stefan, 2007), Denver reports 5.6 (Holguin-Veras and Patil, 2005) and data from Amsterdam indicate 6.2 stops per tour (Vleugel and Janic, 2004). In the case of Denver, approximately 50% of single and combination truck tours include 5 to 23 stops per tour. Data from Amsterdam indicate that the amount of time that is taken during unloading/loading stops is 21 minutes on average (mode 10 min.) and that the average time to reach the service/delivery area is 25 minutes (mode 10 min.). The data suggest a skewed distribution which may be due to the impact of congestion and delays at stops.

3. Data Sources: Context and Collection Procedure

The analysis presented in this research is based on truck routing data provided by a freight forwarding company based in Botany Bay, Sydney, Australia. Botany Bay is an ideal location for a freight forwarding or distribution company due to its proximity to both the Port of Sydney as well as the Sydney International Airport (Figure 1). In addition, Sydney CBD is at a relative close distance, approximately 12 kilometers. Due to its strategic location, Botany Bay is not only the preferred location of many transport related industries and activities but also one of the most congested areas within Sydney. Congestion levels are significant within the Sydney area; the estimated costs of congestion in Sydney area was $3.5 billion Australian dollars in 2005 (BTRE, 2007).

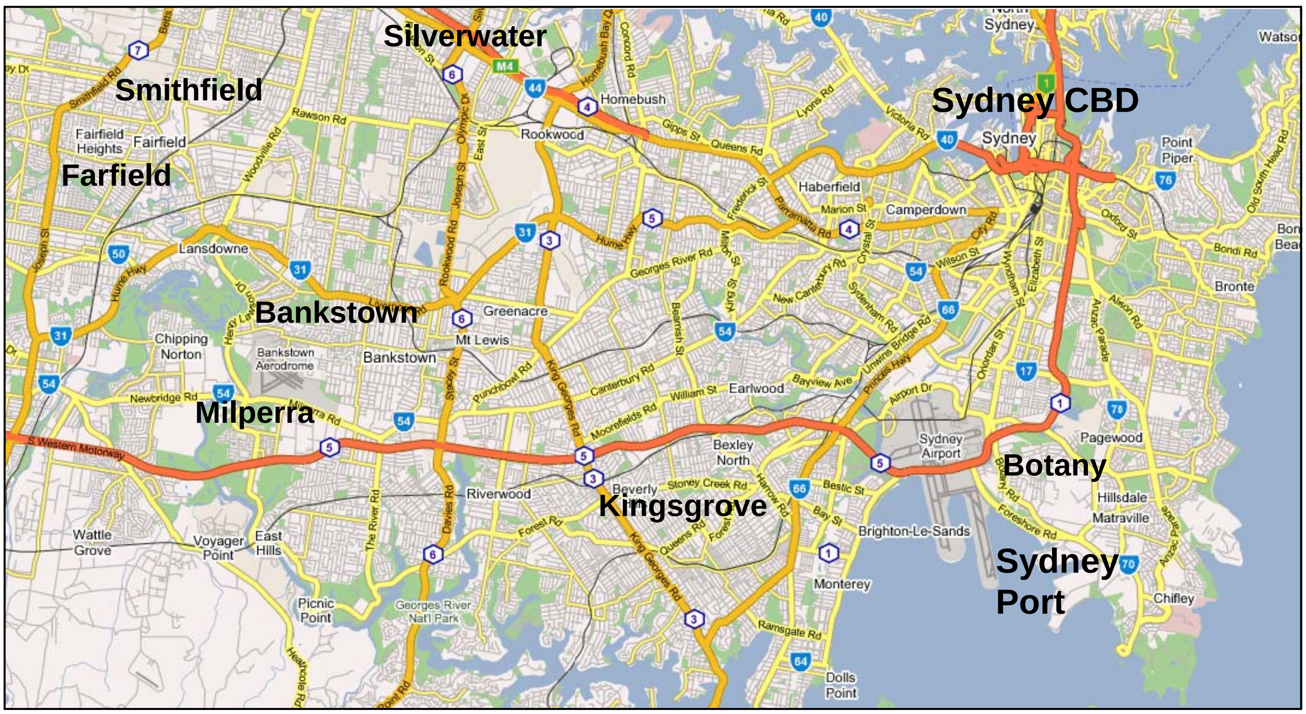

Figure 1. Relative Location of the Port of Sydney and Delivery Industrial Areas[2]

Access to detailed routing data is always difficult due to privacy concerns. Exceptionally, this was not an issue in this research because one of the research team members was at the time a student in the Masters of Logistics program at the University of Sydney and in a working relationship with a freight forwarding company. Ready access was allowed to daily truck activity sheets for an eight-month period, between September 2005 and April 2006. The data corresponds to the routes of a twelve-ton truck, driven by a

[2] Map adapted from Google maps (http://maps.google.com/)

driver with 35 years of working experience in the Sydney metropolitan region. The truck driver was also interviewed to check for data consistency and also to elicit his perceptions about congestion in the Sydney region.

The tour data shows that most pick-up trips are from the port terminals to the depot. Deliveries are concentrated in the Botany area itself and to industrial suburbs of Sydney, such as Bankstown, Kingsgrove, Milperra, Silverwater, and Smithfield. One-way trips in the Botany area range from 1 to 5 kilometers in length. One-way connecting trip between the depot and other industrial suburbs are substantially longer, usually ranging between 14 to 40 kilometers to/from the depot. Local trips within the industrial suburbs, for example connecting two customers in Silverwater, are roughly comparable in length to the local trips within Botany. Figure 1 shows the location of the Port of Sydney and the mentioned industrial suburbs.

Truck deliveries are less than truckload (LTL) to companies in the retailing, service, and manufacturing sectors. For this particular distribution operation time windows are not an overriding concern, customers are told that deliveries will take place in the morning or afternoon. However, deliveries must take place within the promised day. In addition, deliveries are to be carried out within normal business hours – most customers prefer morning deliveries. Hence, the starting time of the tour and its length are constrained to ensure that deliveries take place within normal working hours. This is clearly revealed in the aggregated data: 13% of the deliveries took place before 8 am, 45% of the deliveries took place before 11 am, 76% of the deliveries took place before 2 pm, and 99% of the deliveries took place before 5 pm.

In the eight-month period the truck served 190 different customers, however, the top 20% of delivery locations/addresses account for 71.2% of the total number of deliveries/stops during the eight-month period. Each daily route and sequence of customers differed depending on what freight was available on a particular day for collection and/or delivery. However, most routes followed one of these patterns: a) distribution in the Botany area, b) distribution in an industrial suburb after traveling a connecting distance from the depot/Botany area, or c) a combination of a) and b) patterns.

The distribution operations are partially outsourced, i.e., for hire truck-driver pairs are used to carry out the deliveries. Outsourced tours are paid based on tour duration. In general, the hourly cost per driver-truck unit depends on the vehicle size and type as well as the type of relationship (e.g. regular vs. sporadic contracts); a typical hourly cost may range between A$30 to A$40. Tolls are paid by the forwarding company. The number of tolls paid in a typical tour is six with a cost between A$50 to A$60.

4. Tour Characteristics

In this research, an urban tour is defined as the closed path that a truck follows from its depot to one or more customer destinations and final return to the depot during a single driver shift. Therefore, a tour is comprised of several trips; a trip being defined by the distance or time traveled between two consecutive stops.

Due to restrictions on average travel speed, loading/unloading times, number of stops, and number of working hours in a shift a complete tour usually amounts to less than 300 kilometers. Data estimates from the USA indicates that warehouse delivery vehicles average 105 kilometers (approximately 65 miles) per day per vehicle (CAMBRIDGE SYSTEMATICS, 2004). The value obtained as an average for the USA is very close to the values obtained for the study in Sydney. Using the collected data from Sydney, a "typical" or median tour can be defined as a tour of approximately 100 kilometers – see Table 1. The vehicle spends 4 hours on the streets at an average speed of 25 km/h and spends 3.5 hours stopped (loading/unloading, paperwork, parking, etc.).

	Trip Distance (km)	**Trip Travel Time (min)**	**Stop Time (min)**	**Average Speed (km/hr)**	**Stops per Tour**	**Tour Length (h:m)**	**Tour Distance (km)**
Average	14.1	28.2	38.7	26.6	6.8	7:57	108.6
Median	7.5	20.0	30.0	25.0	7.0	8:30	99.1
St. Dev.	15.4	21.4	31.3	17.0	2.4	2:07	53.6
Min.	0.1	5.0	5.0	0.2	1.0	1:45	7.9
Max.	100.7	195.0	285.0	109.9	12.0	10:00	290.9

Table 1 - Tour Summary Data

Table 1 indicates that although the average and median tour length are fairly close to a working shift of 8 hours, variations in daily demands may render tours as short as 1 hour and 45 minutes or as long as 10.5 hours. Stop duration time at customer stops is shown to vary widely between 5 minutes and a maximum of 285 minutes. Although the variation of stop time is significant, most of the variation can be satisfactorily explained when accounting for customer, type of product, delivery quantity, and type of loading/unloading facilities. Shortening the duration of customer stops can greatly improve the efficiency of truck tours as discussed in Figliozzi (2006). The data from Sydney reports an average number of 6.8

stops and a median value of 7 stops per tour which is comparable to previous studies in Amsterdam, Calgary, and Denver.

Empty Trips and Trip-Tour Distributions

As indicated in Figure 2, the trip length distribution shows a clear peak between 2 and 9 kilometers. This is explained by the short trips in the Botany area and the local deliveries in other industrial areas. A second peak is found between 21 and 33 kilometers. The second peak is caused by trips to/from industrial suburbs (connecting trips between the depot and distribution areas). For example, it may take a trip of 27 kilometers to arrive at Silverwater distribution area. This 27 kilometer trip may then be followed by shorter local trips, from 2 to 9 kilometers, within the Silverwater area.

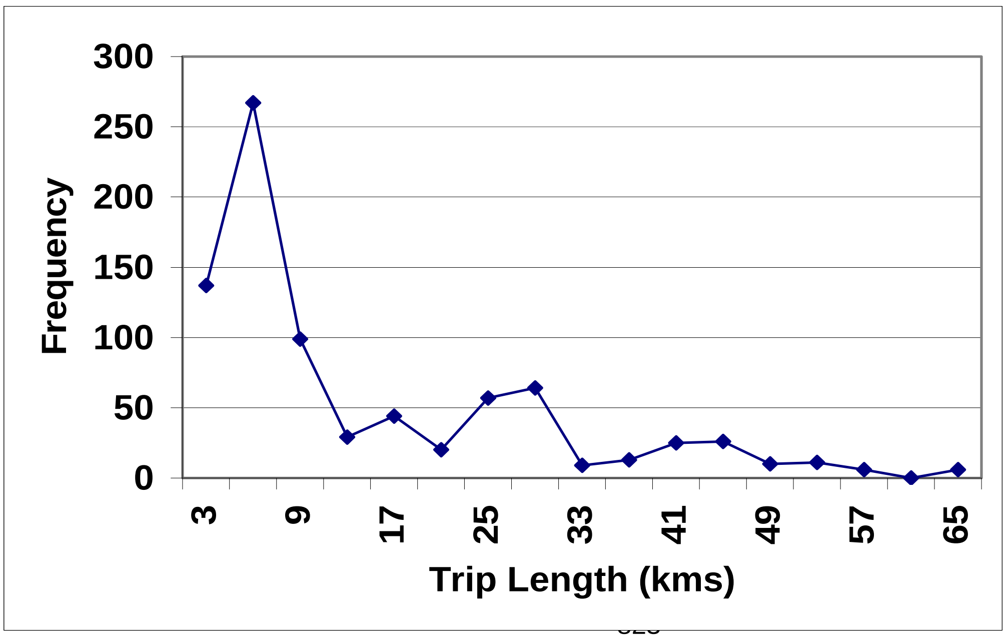

Figure 2. Trip Length Distribution

It is clear that the relative location of major freight generators (i.e. large factories, distribution areas, intermodal facilities, etc.) in relation to their service areas affect the shape of the trip length distributions. Empirical observations confirm that multimodal trip length distributions are found in practice as indicated by Holguin-Veras and Thorson (Holguin-Veras and Thorson, 2000) using aggregated data for Guatemala City. Their observations are confirmed by our results using disaggregated data. If the magnitudes of the connection distance and the average distance between stops are significantly different, a unimodal impedance function may not be able to adequately represent the distribution of trip lengths. A multimodal distribution will hinder the fit and calibration of a gravity model to model trip distribution. A gravity model is usually calibrated by comparing the trip length distribution (TLD) and trip length averages in the model against the observed trip length distribution and its average. In order to calibrate gravity models it is typically assumed that there is a decrease in the number of trips as distance or time between origins and destinations increases, i.e. a unimodal impedance function (Holguin-Veras and Thorson, 2000). As shown in Figure 2, the location of industrial suburbs can significantly alter the shape of the TLD and generate several peaks or modes.

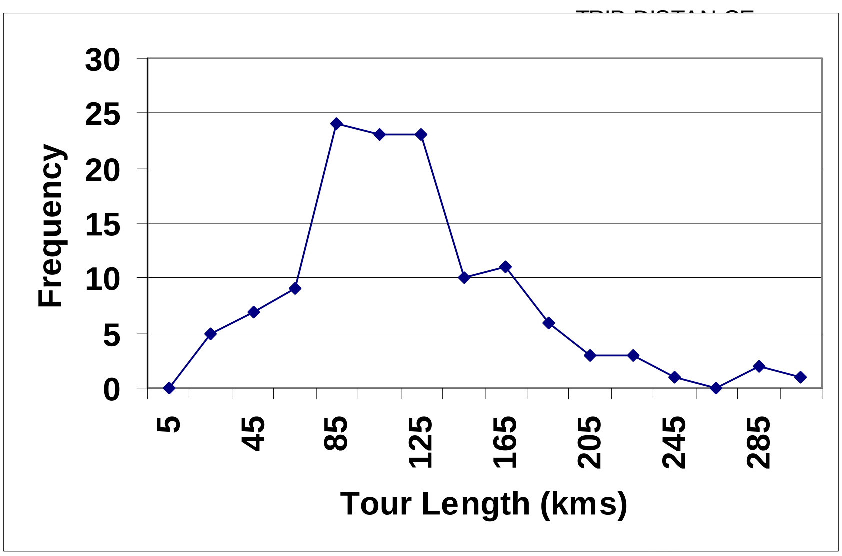

Figure 3. Tour Length Distribution

Figure 4. Number of Stops Distribution

Tour length distribution is significantly different from the distributions of trip-length and number of stops per tour. As shown in Figure 3, the tour length distribution resembles a normal or log-normal shape. This is not surprising since the tour length distribution reflects variations in the daily number of customer demand and locations. The distribution of tour lengths and the number of stops per tour do not follow the same pattern as shown in Figure 4. This is explained by the existence of long tours with few stops in a distant suburb and a short tour with many stops in a near suburb.

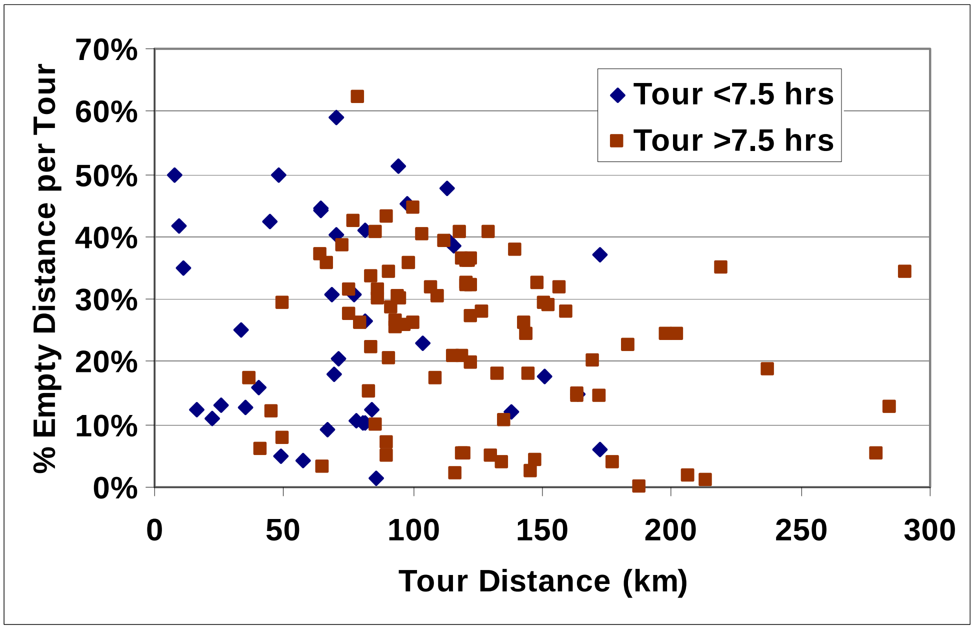

Figure 5. Percantage Empty Distance and Tour Distance

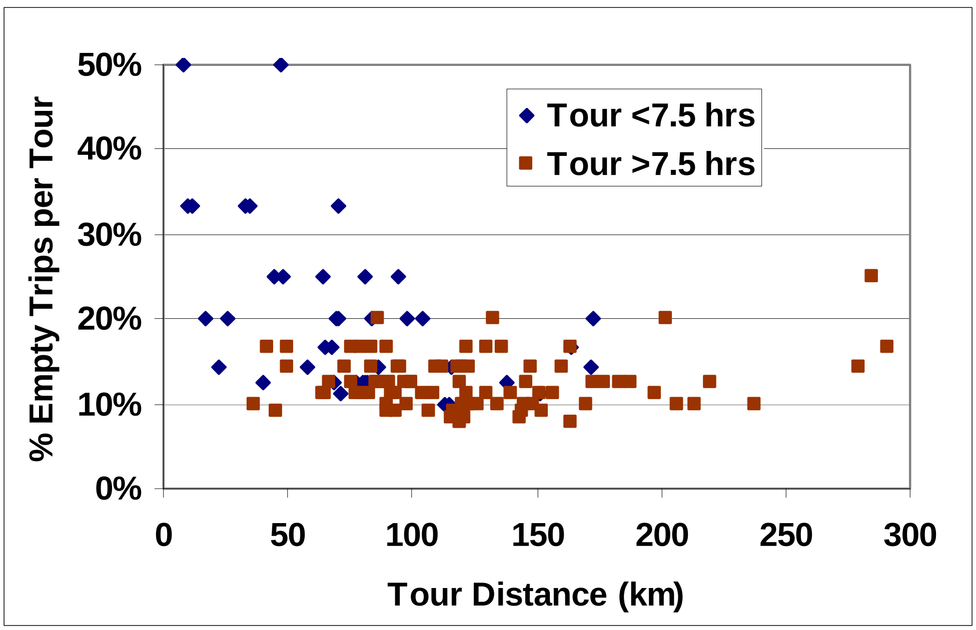

Figure 6. Percantage Empty Trips and Tour Distance

Tour Length and Percentage of Empty Distance/Trips

Figure 5 and 6 demonstrate the lack of a clear relationship between tour length and percentage of empty trips or empty distance per tour. Furthermore, there is no clear relationship between tour distance and percentage of empty trips per tour and percentage of empty distance per tour even after accounting per tour duration. The last leg or trip of the tour is the empty return to the depot. Hence, the percentage of empty trips per tour cannot exceed 50% (one customer per tour) and quickly decreases as the number of customers visited per tour increases: for 4 customers the percentage of empty trips is 20% and for 9 customers the percentage of empty trips is 10%. However, it is possible to have a percentage of empty distance per tour that exceeds the percentage of empty trips. For example, this is possible in a delivery tour where the last stop is the farthest point in the tour from the depot; in addition, after the deliveries are completed the driver may take a longer route to return to the depot to avoid tolled routes. Therefore, the percentage of empty trips per tour in an urban area can be a very poor indicator of the percentage of empty or total VKT. This result is also confirmed by analytical models (Figliozzi, 2007a).

5. Congestion, Tour Speed, and Efficiency

From the daily truck activity records, travel times were estimated as the difference between departure and arrival times. Distances between origin and destination addresses were calculated using a Sydney street network. The average speed between origin and destinations was estimated using the travel time and distance between addresses. By filtering the data obtained from the driver run sheets, delivery points and network links occurring frequently were identified.

To analyze the effects of congestion on travel speed, the data was aggregated by trip length and time of day. The trip lengths of 5 and 20 kilometers correspond to those points on the trip distribution chart that separate local trips from long connecting trips between suburbs (see Figure 2). Table 2 shows the speed average arranged by trip distance and time of the day. It is observed that short trips have the lowest travel speed; long trips have the highest travel speed. This can be explained by the type of streets and highways used by short and long trips. Short trips take place mostly on local streets; long trips are more likely to use freeways or primary highways. In all cases, the average speed decreases from the early morning period (trip departure before 7:30am) to the morning peak hour period (trip departure between 7:30-9:00am). The average speed recovers after 9:00 am for medium and long trips. The average speed does not recover for short trips. According to driver commentary, a constant level of congestion is found in the Port Botany-Botany areas where the traffic levels are higher; this area holds most of the infrastructure used for the international forwarding industry. It is worth mentioning that the driver's perception of traveling times between the depot and industrial suburbs was in fact within five minutes of the actual recorded times. This driver has 35 years working experience driving within the Sydney metropolitan area.

Speed Average				
Trip Distance	**5:30 to 7:30**	**7:30 to 9:00**	**9:00 to 11:00**	**11:00 to 16:00**
0 to 5 kms	16.2	15.1	12.9	12.6
5 to 20 kms	30.9	21.4	26.1	27.9
+ 20 kms	38.3	33.3	37.2	48.6
Speed Standard Deviation				
Trip Distance	**5:30 to 7:30**	**7:30 to 9:00**	**9:00 to 11:00**	**11:00 to 16:00**
0 to 5 kms	5.53	9.40	6.49	7.01
5 to 20 kms	5.83	5.72	12.55	12.11
+20 kms	6.94	6.02	11.50	17.00
Speed Coefficient of Variation				
Trip Distance	**5:30 to 7:30**	**7:30 to 9:00**	**9:00 to 11:00**	**11:00 to 16:00**
0 to 5 kms	0.34	0.62	0.50	0.56
5 to 20 kms	0.18	0.27	0.48	0.43
+ 20 kms	0.18	0.18	0.31	0.35

Table 2 - Speed Average, Standard Deviation, and Coefficient of Variation by Trip Distance and Departure Time

Table 2 also shows the speed standard deviation arranged by trip distance and time of day. It is observed that the speed standard deviation is lower during the congestion period than after 9:00 am. The data suggests that even though the speed travel time is lower during rush hour it is nonetheless subject to less variation.

Lastly, Table 2 shows the coefficient of variation, ratio between standard deviation and average, arranged by trip distance and time of the day. Short trips have the largest coefficient of variation in all cases. One explanation for this is the larger variation in the type of local areas traveled by short trips. Part of the variation can also be attributed to the driver's tendency to round arrival or departure times to five minute intervals. This rounding has a higher impact on short distance trips than for longer distances.

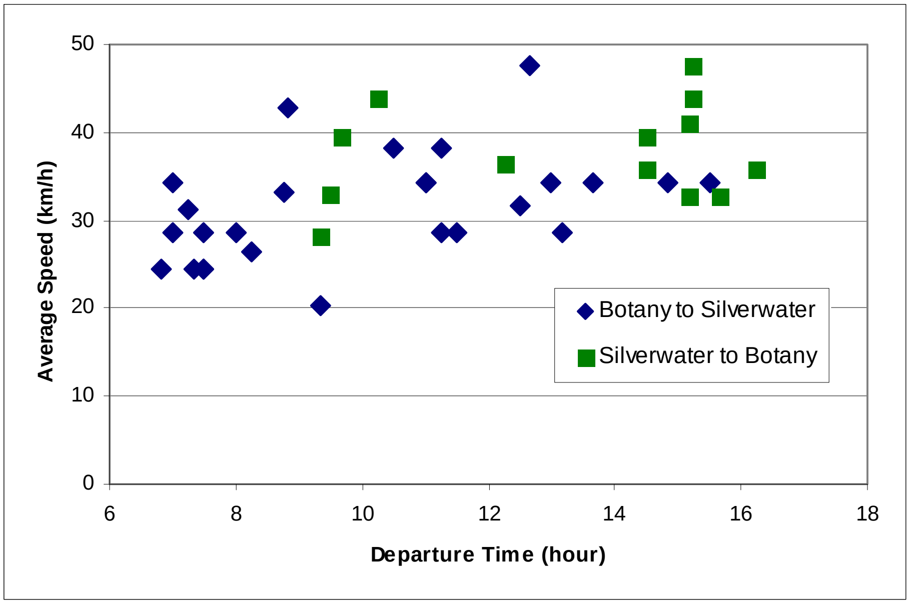

Figure 7. Average Speed between Botany (depot) and Silverwater

Figure 7 represents the speed observations for the connecting link between the Depot and the suburb of Silverwater. In the figure it is possible to observe that the speed in the 7:30-8:30am period tends to be lower than during the rest of the day. During the morning rush hour the average speed is 26.2 kilometers per hour (km/h) while speed average for the full day is 32.2 km/h. Figure 7 also shows that directional effects can be important, with return trips from Silverwater to Botany having a higher average speed than trips from Botany to Silverwater. The importance of directional effects and its effect on route design and customer sequencing was also confirmed by interviews with the driver. Preferably, the route sends drivers against the peak traffic in the morning (the majority of commuters are moving towards the city) and afternoon (the majority of commuters are dispersing towards the outer suburbs).

A useful classification of tours can be obtained based on percentage time driving and average distance traveled per customer. Tours can be divided into three classes: (I) average distance per customer less than 40 kilometers and percentage time driving *less* than 50%, (II) average distance per customer less than 40 kilometers and percentage time driving *more* than 50%, and (III) average distance per customer *more* than 40 kilometers and percentage time driving *more* than 50%; summary data for each class is shown in Table 3.

Tour Class	% Time Driving	Dist. per stop (km)	Stops per Tour	Tour Duration (hr)	Tour Distance (km)	Tour Speed (km/hr)	Effective Tour Speed (km/hr)
Class I	43%	13.3	7.5	8.2	88.0	24.9	11.1
Class II	58%	21.1	6.4	7.2	117.4	26.7	17.2
Class III	65%	59.6	3.9	8.3	206.3	36.4	26.0

Table 3 – Tour Characteristics by Type (Averages)

Class I tours have many stops and spend a high percentage of the tour time at the customers' sites (i.e, a low percentage of the tour time is spent driving). The tour distance is short because customers are located close to each other but the tour duration is high because many customers are served. The driving speed is low because the percentage of local and access roads/streets used increases with the number of customers visited. The effective tour speed (tour distance divided by total tour duration) is affected by the time spent at the customers and is significantly lower than the driving speed (tour distance divided by total tour driving). Despite of the low speed, tours are highly efficient[3] from the distributor perspective because many customers are served driving a short distance and spending a low percentage of the tour on the road.

Class III tours have few stops and spend a high percentage of the tour time on the network (driving). The tour distance is long because customers are away from each other, or the depot is far from the distribution area, or both. As a result, tour duration is high and very few customers can be served. The driving speed is high because the percentage of local and access roads/streets used is small and main highways are used to connect the depot with the distribution area. The effective tour speed (tour distance divided by total tour duration) is significantly higher than for Class I tours. Despite the high speed, tours are highly inefficient from the distributor's perspective because few customers are served despite driving a long distance and spending a high percentage of the tour on the road. Comparing delivery costs, Class III tours have a

[3] Maintaining the same service level, i.e. without decreasing the time spent at the customers, the distributor minimizes its operating costs by reducing the distance driven and the time spent on the road.

delivery cost per customer that is approximately 3 times higher than Class III tours. Class I and III tours have only one common characteristic: tours have a high duration. Either because there are many customers or they are located far away. the tour length constraint is binding, i.e. generally there is no redundant or "slack" capacity to add one more customers to the tour.

Except for tour duration, Class II tour characteristics are midway between the corresponding characteristics of Class I and III tours. In Class II tours the tour duration constraint is generally not binding and more customers could be added to the tour. Class II tours are not as efficient as Class I tours, however, they are unavoidable since each daily route and sequence of customers depends on what freight is available on a particular day for delivery. For further insights, analysis, and modeling of congestion impacts on tours the reader is referred to Figliozzi (2007b).

The relationships between trip length and speed shown in Table 2 can be extended to the relationship between tour length and average tour speed as shown in Figure 8; long trips are more likely to use freeways or primary highways and therefore have a higher travel speed. The R^2 of the linear regression between tour length and average travel speed is 0.56. An even higher correlation is found between the driving time per customer and the distance traveled per customer. As shown in Figure 9 the R^2 of the regression between driving time per customer and distance traveled per customer is equal to 0.84.

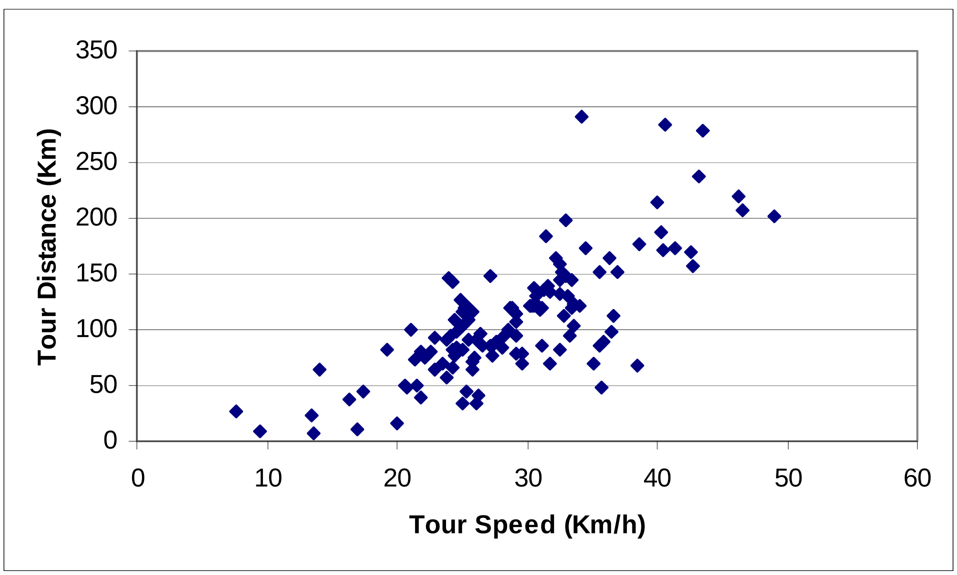

Figure 8. Tour Distance vs. Tour Speed

The relationship between distance and time traveled in real-life is very strong despite the "noise" introduced by network links with diverse geometric design, traffic control, and speed limits. This explains why continuous approximations to routing problems can be an effective analytical tool to model routing problems at a planning or strategic level (Figliozzi, 2008). The R^2 between tour length and driving time is equal to 0.73, which is still a strong relationship. The decrease in R^2 from 0.84 to 0.73 is explained by the lack of control for tour class. The number of customers per tour is correlated with the characteristics of the network links traveled, e.g. Class I tours have a high proportion of local or access links whereas Class III tours have a high proportion of freeways or arterial roads. Disaggregating by class, there is an increase in the correlation between tour distance and tour driving time.

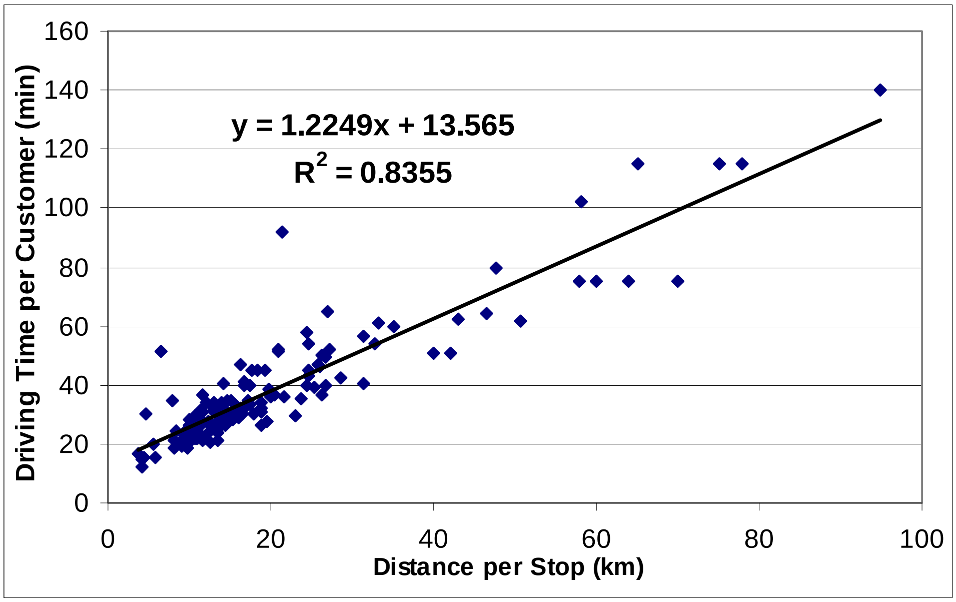

Figure 9. Driving Time and Distance Traveled per Customer Visited

6. Congestion, Travel Time Correlations, and Sample Size

This section discusses issues related to congestion, travel time correlations, and sample size. Sample size undoubtedly affects the level of detail or granularity achievable in the congestion analysis. Despite the use of several months of complete routing data, congestion analysis proved to be a difficult task. In particular, it was not possible to obtain congestion data for *all* depot-customer and inter-customer travel times. Five factors that complicated this analysis are listed here:

(a) The sheer number of possible origin destination (OD) pairs: As 190 customers were visited, the possible number of origin-destination links between customers is 17,955.

(b) Time of day breakdown: distinguishing between peak and non-peak periods.

(c) Departure time vs. arrival time: long trips may fall in both rush and non-peak periods. For example, a trip that started at 8:30 am during the rush hour period and finished at 11:30 am during the non-rush hour period.

(d) Directional effects: morning and evening rush hours can have different impacts whether heavy traffic is moving towards the CBD or away.

(e) Alternate routes: No information was available on potential travel times for alternative routes.

(f) At the tour level, variation of customer demands precludes the direct comparison of tour travel times: Tours may take place in the same suburb but the variation of the daily number of stops, location and delivery size make each tour almost unique. In fact, in the eight-month period no complete tour was repeated; either the customers or the customer sequence changed.

Therefore, in order to analyze the effects of congestion on travel speed the data was aggregated by trip length and time of day, as shown in the previous section. Although this is convenient to illustrate the level of congestion for policy makers or planners, it is not desirable for the daily optimization of tours. Ideally, a sufficient amount of data would be available in order to develop a reasonably good approximation of the travel time distribution for each individual link. This is necessary to accurately approximate the travel time variation of a tour or route.

An adequate number of observations to estimate speed standard deviations were obtained for the most frequently traveled depot-customer pairs. This data also demonstrated a positive correlation between travel times. Given the tour sequence depot→customer A→customer B, if a higher than average travel time takes place for the link depot→customer A, then a higher than average travel time between customer A and customer B is likely. Due to the limited amount of repeated triplets (e.g. depot→customer A→customer B) in the eight-month data we were unable to estimate more than two correlations; the correlations ranged from 0.2 to 0.3. Correlations are particularly difficult to estimate because they require a repeated number of identical three-customer sequences, whereas speed or travel time standard deviations require only repeated two-customer sequences. The order is influential; correlation for depot→A→ B may be significantly different from the correlation for B →A→depot. Besides, network characteristics, time of day, and directional effects are likely to influence the value of travel time correlations though we were unable to test this hypothesis due to the lack of data.

7. Conclusions

Detailed disaggregated truck activity data can provide a wealth of valuable information for transportation planners. The tour analyses provided insightful disaggregated information about urban truck activities. The percentage of empty trips was found to have no significant relationship with tour length or percentage of empty distance traveled. A relationship between trip length, tour length and travel speed was found. Travel between different industrial suburbs explains the shape of multimodal trip length distributions. Variations in daily demand explain the normal-like shape of the tour trip distribution.

Significant levels of congestion were found from the analysis of speed and travel time variability. As expected, the morning peak hour period showed the highest level of congestion. Between the depot and frequently visited customers it was possible to detect a positive correlation among travel times. It was discussed that large amounts of complete tour data are needed to estimate congestion levels and travel time correlations. Aggregation by trip length and time of day seems a sensible approach to analyze tour data between a depot and its delivery or service areas. Three different tour patterns where identified as a function of percentage of tour time driving and average tour distance per customer visited.

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