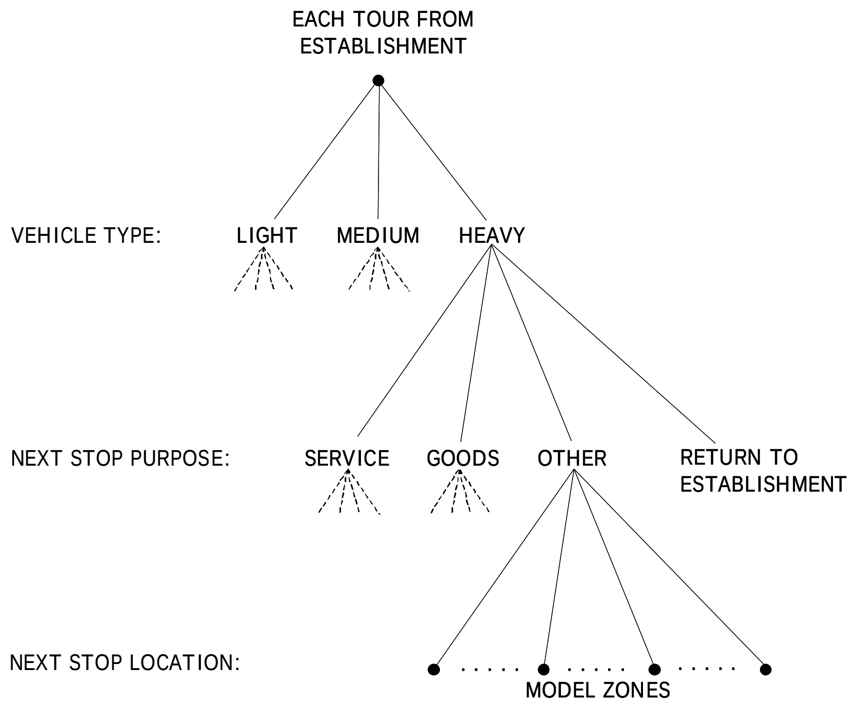

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Abstract

Tour-based models of urban commercial movements are being explored using a rich sample of disaggregate revealed choice data collected in Calgary in Canada. These models cover behaviour in the delivery of retail goods and certain categories of services using a set of logit models that include representation of various system attributes on the type of vehicle used and the number, purpose and distribution of stops. This work is ongoing at the time of writing. Some initial results are presented here; the results of further work will be presented at the conference.

Keywords

Commercial Movements; Goods Shipment; Service Delivery; Tour-based Modelling; Logit Choice Modelling; Transportation Demand Modelling and Forecasting; International Conference on Travel Behaviour Research; IATBR

Preferred citation

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1. Introduction

Calgary is a city in Alberta in Western Canada. In 2001 the population of the Calgary Region, including the city and areas about 30 kms beyond it in all directions, was just under 1 million.

In the past few years there has been much effort put into the development and application of tour-based and activity-based models of household travel behaviour. The idea in the modelling work described here is to test the applicability of similar models in goods and services delivery organised from a set distribution point or establishment. The intention is to use agent-based micro-simulation in the application of the resulting models as part of the transport modelling done in Calgary.

The choice data used in the estimation of the model parameters and associated testing of model forms have been drawn from a large survey of commercial movements arising from the point of production – where just over 3,300 establishments located in the Calgary Region in 2000 and 2001 were asked to describe the shipment of their products to consumers. The general approach in these surveys was different from the more ‘truck-based’ and ‘shipper-based’ approaches typically used. The idea was to focus on the producers and to draw on household travel survey techniques in the context of commercial movements and obtain to the extent possible the same sorts of information for goods and services movements from producers that is sought in household travel surveys from households. Goods shippers and goods depots were included as specific categories, so information about shipping *per se*, which some producers might not know in any detail, was also collected. These surveys provided, among other things, detailed descriptions of the behaviour of retail establishments in the delivery of retail goods and service establishments in the delivery of various categories of services.

The model is a series of connected logit models that represent different choice dimensions, working in order as follows:

- generation of tours (the number of tours out from the establishment);
- vehicle selection for each tour (from ‘light’, ‘medium’ and ‘heavy’ categories);
- next stop purpose for each vehicle category (from ‘service delivery’, ‘goods drop-off’, ‘other’ and ‘return to establishment’);
- next stop location for each stop purpose other than ‘return to establishment’ (from 1447 zones spanning the Calgary Region).

This paper first briefly describes the surveys and summarises the resulting choice data, and then focuses on some of the preliminary (and very recently-obtained) model estimation results concerning the second, third and fourth choice dimensions listed above, and what they indicate regarding goods and services delivery in an urban context. This work is still underway at the time of writing, but is beginning to show results. These initial results are presented here; the conference will provide an opportunity to present more complete results and further consideration of their implications.

2. The Survey and Data

2.1 Commodity Flow Study

The primary data source for this research is the 2001 Calgary Commodity Flow Study, a survey of commercial vehicle movement done for the City of Calgary's Forecasting Division. The study was conducted to permit a more advanced approach to modeling commercial vehicle movement in the Calgary region, and was done at around the same time as a similar survey of households.

The model, and the study, deal with locations by using a set of 1447 zones to describe Calgary and the surrounding countryside and outlying towns and cities, commonly called "the region".

The study comprised primarily a set of 24-hour trip diaries filled in by surveyed establishments. Every vehicle operated by a surveyed establishment reported the times and locations of every stop during the 24-hour study day, as well as information about the amount, value and type of goods handled or services provided. Additionally, information was collected on the vehicle itself (including configuration and GVW) and on the establishment, including numbers of employees in eight industry categories.

The establishment was considered to be the base of operations, and tours were recorded as being based on travel from this establishment, making one or more stops elsewhere, and then returning to this establishment.

2.2 Other data sources

Employment and zonal statistics were derived from a variety of sources, including the City of Calgary's own land use planning division and external consultants. Important sources of raw data include Statistics Canada, the City of Calgary Census and the Household Activity Survey done for the City at about the same time as the Commodity Flow Survey.

The 2001 Calgary Regional Travel Model, implemented in the EMME/2 package, was used to generate travel times, which are used in all levels of the model either as a direct travel time or incorporated into an accessibility measurement. The model incorporates personal travel, currently in the final stages of calibration and verification, and uses a trip table to load the networks with commercial vehicle traffic. Heavy and medium vehicles (larger commercial trucks) are restricted in their movements. By law in Calgary, they are required to travel on an arterial network of truck routes, and to minimize travel off the networks, driving the shortest amount necessary to perform their business. A penalty function was used to require applicable trucks to traverse the fewest non-truck-route links in the network, simulating the result of this bylaw.

2.3 Categorization, Sampling and Preparation

The commercial vehicle movement model is divided into a number of sectors representing different typical behaviours; this paper discusses the service and retail model component exclusively. Establishments listed their employment by industry category (agricultural, government, private service, transportation handling, industrial, warehousing, education and retail) as well as by space type (office, field, warehouse, etc.). This model investigated only establishments describing employment as primarily private service or retail; in other words, only establishments where at least 50% of the workers worked in the private service and retail areas combined.

For the location choice model, a subset of the 1447 zones were used. Ineligible zones (park-and-ride multimodal transit lots and external entry/exit points) were removed from consideration. Forty zones were selected using a striated random sampling method; the zones were divided into 19 query areas, separating areas of dense employment (the CBD and CBD fringe, the three industrial areas) from residential areas (two inner-city established residential areas, five newer suburban residential areas) and a combined "urban reserve" area including the very low-density undeveloped land immediately surrounding Calgary. Other query areas divided the surrounding region into three districts. Finally, three special query areas included the regional towns and cities as well as key employment nodes in Calgary (hospitals, post-secondary education and regional shopping facilities). Two zones were selected from each of these 19 query areas, with an additional two (for a total of four) selected from the query area that the actual stop was made in. In addition to these 40 striated random zones, an additional 40 zones were selected on a completely flat random basis from all zones. This total of eighty zones was felt to be representative enough to approximate the entire city and region. A future area of inquiry is the effect of these different sampling methods on location model estimation.

The final dataset was an extensive file; it entailed significant machine time to produce the entire table. The largest table, used for the location choice model, contained information about 11 different attributes for each of the 81 alternatives for zone choice. The table had a total of approximately 1200 fields and 17500 records, resulting in approximately 21 million individual data elements, and a file size of over 140 MB in a plain comma-separated text format.

2.4 Data used in model

The data elements used in the preliminary models described here are as follows:

Vehicle type – Vehicles were classified into three categories, based on their weight and configuration. Light vehicles include any vehicle with four tires and a GVW of less than 5450 kg, and include vehicles such as cars, vans and pick-ups. The majority of service and retail vehicles, about 90% were light vehicles. Medium vehicles include vehicles with six tires on the road, with a GVW of over 5450 kg, such as single unit trucks (cube vans). Heavy vehicles include any vehicle with over six tires on the road, with a GVW of over 5450 kg, and include semis (tractor-trailer) configurations (as well as semis without trailers) and heavy construction equipment. Light vehicles have unfettered access to the road system, where both medium and heavy trucks are restricted to truck routes. Heavy and medium vehicles therefore have different travel times and accessibilities than light vehicles.

Stop types – Stop purposes were classified into four purposes; Service, Goods, Other and Return. Service stops were stops made by vehicles for the delivery of services (for instance, a landscaper, plumber or security guard stopping at a location to mow the lawn, fix the sink or inspect the premises respectively). Service stops also include stops made to pick up supplies for the performance of a service, such as lawn food or plumbing pipe fittings. Goods stops were stops made to deliver or pick up goods for business purposes (for instance, a furniture store delivering ordered furniture) and included stops where goods were both picked up and dropped off at the same location (for instance, a water cooler delivery service delivering a weeks' supply of water and removing the previous weeks' bottles). Other stops were all stops not made for direct business purposes (including stops made for lunch, for fuelling, repairing and maintaining the vehicle, for banking, personal employee trips home, trips to meetings, and so on). Return to establishment stops were stops where the vehicle returned to the establishment for any reason, including the end of the work day or a need to resupply the vehicle with goods or supplies. For the stop purpose model, the previous stop type is used as a data element. A count of stops is also used, counting the number of stops previously made in each type on the current tour, as well as the total number of stops previously made on the tour.

Travel times – The stop purpose and stop location levels of the model incorporate travel times. In all cases, the vehicle type is used to provide an appropriate travel time. Light vehicles use the shortest travel time between zones, medium and heavy vehicles will travel to the truck route network in the fewest links, traverse the network in the shortest time, and then travel to the destination in the fewest links. The location model uses the travel times from the current location to the prospective location, as well as the travel time from the prospective location to return to the establishment (assumed to be the base of operations). The purpose model uses the travel time to return to the establishment, as well as the cumulative travel time for the vehicle between all of its' previous stops.

Accessibility terms – A logsum term was used to calculate zonal accessibility. The accessibility for zone i is:

$$\ln\left(\sum_j \frac{A_j}{\sum_j Aj} e^{-\lambda \cdot t_{ij}}\right)$$

where A_j is the attribute under consideration (such as population or employment), t_{ij} is the network travel time from zone i to zone j, and λ is a dispersion parameter from a logit destination choice model.

Accessibility is used in all levels of the model. For the vehicle choice model, accessibility at zone i is calculated using both the light vehicle travel times and the heavy and medium vehicle travel times, permitting response to a change in the relative conditions for the different vehicle types (a reduction in truck routes, for instance, would reduce heavy vehicle accessibility and not affect light vehicle accessibility). For the stop purpose and stop location models, accessibility is calculated using the appropriate vehicle type (i.e. if a light vehicle's movements are being considered, then the light vehicle travel time is used in the accessibility function).

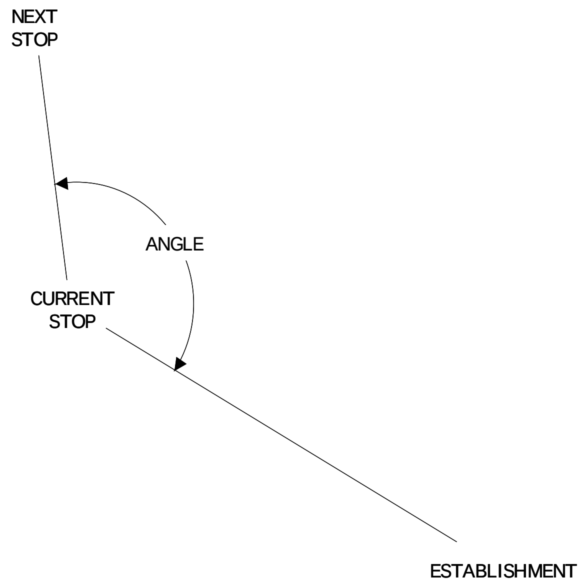
Establishment workers – The number of workers in each surveyed establishment was represented in a proportion of workers in the retail employment type, the proportion in the private service employment type and the proportion in all other employment types combined (government, industrial, agricultural, transport handling, warehousing, education). In practice, surveyed establishments almost entirely responded with all of their workers in only one of the eight types.

Zone type – Zones were categorized into five types; low-density, residential, retail shopping area, industrial area and employment node. These zone types were used in the stop location choice model. The categorization was based on the population and employment densities of the zones, as well as the relative mix of employment types. To briefly describe the five types, low-density were simply zones with a low density of both employment and population, and typically represent parks, farmland and undeveloped urban "greenfield" land. Residential zones were zones with much more population than employment, and so represent primarily low-density single family housing. Retail shopping areas are areas with significant employment concentration, and a high level of retail and private service employment. These represent areas such as enclosed shopping malls, "big-box" power retail, commercial strip retail development and intense mixed-use residential/retail areas. Industrial areas were areas with lower employment densities, and a mix of employment types that are not typically "white collar" (such as industrial, transportation handling and warehousing). These represent areas of industrial development, including industrial and low-density office parks, factories and manufacturing plants and warehouse and delivery hubs. Employment nodes are areas of either high density or overall "white collar" (such as education or private service) employment. These represent areas such as the high-density CBD office area, post-secondary education, hospitals and more intense commercial/industrial areas.

Zonal average income, population and employment – A smoothing and interpolating algorithm was used to produce zonal average incomes across all zones. This value is based on the average household income. The population and employment values used to calculate size terms used in the stop location model are simple zone-level totals of the number of people living in a zone and the number of jobs in a zone.

Enclosed angle – Used in stop location choice, this is the angle formed between the vector from the establishment to the current stop location and the vector from the current stop location to the destination location alternative. (see figure 1) The enclosed angle, measured in degrees, ranges from 180°, indicating a vehicle traveling directly away from the establishment to 0°, indicating a vehicle traveling directly toward the establishment.

Figure 1 Illustration of enclosed angle describing the positional relationship between the establishment and a pair of stops



3. Model Structure

The model will be applied by generating a synthetic population of business establishments, then applying each of the submodels in turn, using a random number generator to select specific actions from the range of possibilities. The result will be a list of trips made by commercial vehicles in the delivery of services and retail goods. This list will be organized into origin-destination matrices of vehicle movements for different times of day that will be combined with other such matrices for other categories of movements for assignment to a network. The resulting congested travel times will be fed back and the various demands re-calculated and re-loaded until convergence.

For this micro-simulation concerning the delivery of services and retail goods in particular, the basic structure of the choice models is as shown in Figure 2.

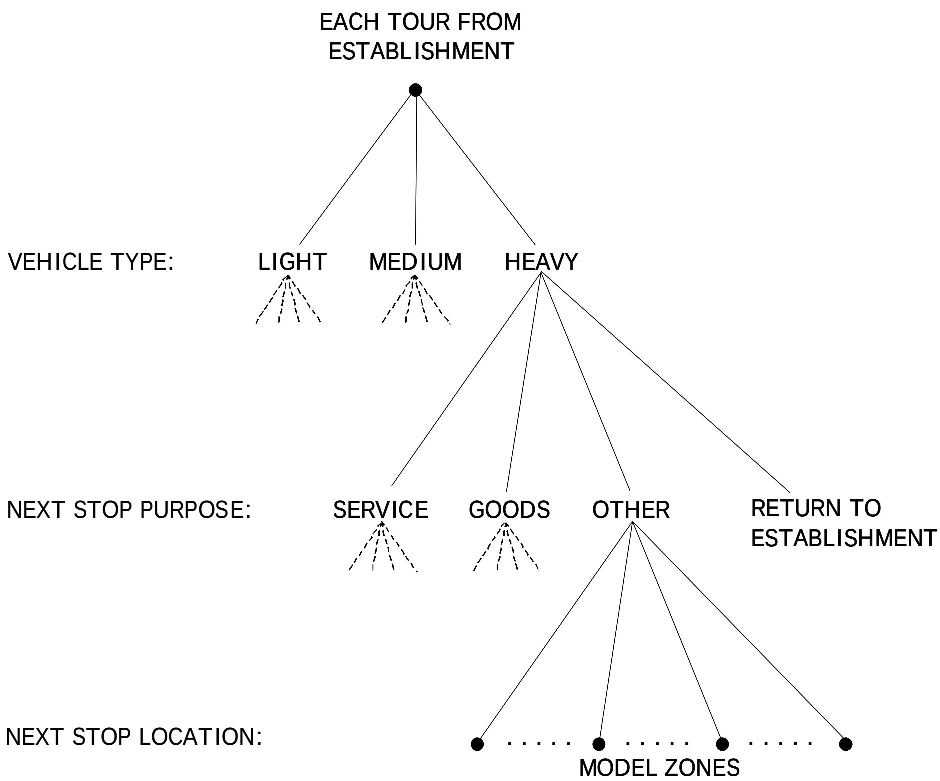
This structure is a series of connected single-level logit models. It is not quite a nested logit structure because (at least at this point) there are no logsum terms from lower levels being passed to upper levels. Instead, accessibility variables are included in the utility functions for the upper levels in order to provide representation of transport conditions on these choices.

This is consistent with much of the agent-based micro-simulation work being done concerning household travel, and is largely a practical necessity given the enormous computational burdens associated that would arise with such logsums.

The nature and order of the choice dimensions is different from that currently being used in much of the tour-based modelling of household travel – where each tour is assigned a 'primary destination' (according to some sort of pre-defined hierarchy among the activities and locations of stops), then a 'primary mode' and then further 'intermediate stops' and the mode(s) used for the individual trips between stops.

With the sorts of commercial tours being considered here, which are vehicle-based rather than person-based, mode choice (choice between vehicle types) is much less conditional on specific trip conditions. This means it makes sense to place vehicle type choice above stop location choice. The definition of a 'primary destination' is also problematic with commercial tours, which tend to include larger numbers of similar-purpose stops compared to household-person tours. Consequently, a structure that allows for number of stops on tours to grow as appropriate is used by having 'return to establishment' set against additional stop alternatives.

Figure 2 Model structure



Choice of purpose, between the alternatives 'deliver service', 'drop-off goods' and 'other' was included explicitly for each next stop because the data indicated that in some cases both 'deliver service' and 'drop-off goods' were included in the same tour. The majority of tours included either 'deliver service' and 'other' or 'drop-off goods' and 'other'. But there enough where both 'deliver service' and 'drop-off goods' were included that it was judged more appropriate to allow for choice of either for each stop, with terms included in the utility functions that can act to dampen the tendency to switch from one to the other, rather than to assign the tour as either 'service' or 'goods' from the outset and not allow any switching.

The generation of the tours by time of day is not included in Figure 2, and is not discussed here. The presentation here is limited to the results concerning choice of vehicle type, next stop purpose and next stop location given a list of tours by time of day. The presentation at the conference will be expanded to include the development of a list of tours by time of day.

The utility functions used in the logit models at each level are all linear-in-parameters, with some composite size terms included at the lowest level.

4. Model Results and Discussion

4.1 Vehicle Type Choice

The estimation results for the vehicle type choice model, at the highest level under consideration here, are presented in Table 1.

The signs, negative or positive, on the estimates are all consistent with expectations.

The estimation statistics indicate a good fit, but that the alternative specific constants are providing much of this good fit.

The relative values for the different accessibility terms indicate that increases in accessibility to employment (from the establishment location) correlate positively with heavy vehicle and medium vehicle use rather than light vehicle use whereas increases in accessibility to population correlate positively with medium vehicle and light vehicle use rather than heavy vehicle use. It is not clear from these results the extent to which these correlations are the result of vehicle use decisions at given locations rather than establishment location decisions made in response to travel and location conditions. But in terms of the policy responsiveness of the model overall, as transportation improvements act to increase accessibilities, this will alter the mix of commercial vehicles on the roads in the model results.

Table 1 Vehicle Type Choice

attribute associated with parameter	alternative	parameter estimate	absolute t-ratio
accessibility to population	light vehicle	0.4373	21.2
accessibility to population	medium vehicle	0.1782	7.6
accessibility to employment	medium vehicle	0.02998	1.9
proportion of workers in retail industry	medium vehicle	0.1582	2.6
alternative specific constant	medium vehicle	-4.497	33.4
accessibility to employment	heavy vehicle	0.09258	4.0
alternative specific constant	heavy vehicle	-6.138	31.4

estimation statistics

number of observations: 4,276
log-likelihood with zero coefficients: -30,748.5925
log-likelihood with constants only: -10,402.7825
log-likelihood with estimated parameters: -9,967.4416
rho2(0): 0.6758
rho2(c): 0.0419

Overall, light vehicle is chosen over 90% of the time, hence the substantial role of the constants. It would appear that further work should be done exploring factors that explain the variation in vehicle use. Additional indications of the employment composition and industry of establishments seem reasonable candidates.

As estimation work on the lower level models of stop purpose and stop location proceeds, it may be possible to bring expected maximums (logsums) from the lower level choices into the vehicle type choice model. Alternatively, the insight gained from the lower level estimations could be used to develop other measures that act as a predictor of the desireability of lower level options. In other words, it should be possible to improve this submodel by incorporating what is learned about how vehicle type conditions trip stop decisions.

4.2 Next Stop Purpose Choice for Light Vehicles

The estimation results for the choice of the purpose for the next stop for light vehicles, at the middle level under consideration here, are presented in Table 2.

The estimation results indicate a reasonably good fit, with the non-constant variables making a substantial contribution to this reasonably good fit.

Table 2 Next Stop Purpose Choice for Light Vehicles

attribute associated with parameter	alternative	parameter estimate	absolute t-ratio	normalized estimate
accessibility to population	service	0.03205	6.3	-5.4
accessibility to employment	service	0.02443	5.1	-4.1
proportion of workers in retail industry	service	-0.2501	11.6	42.1
alternative specific constant	service	2.128	30.5	-358.1
service to service transition constant	service	-2.860	80.7	481.3
goods to service transition constant	service	-9.757	31.1	1642.0
other to service transition constant	service	-2.823	56.3	475.1
accessibility to employment	goods	0.188	17.2	-31.6
proportion of workers in retail industry	goods	1.309	36.2	-220.3
alternative specific constant	goods	0.4321	4.6	-72.7
service to goods transition constant	goods	-8.529	33.4	1435.4
goods to goods transition constant	goods	-1.287	19.1	216.6
other to goods transition constant	goods	-2.902	38.2	488.4
accessibility to population	other	0.04493	5.0	-7.6
service to other transition constant	other	-3.421	77.6	575.7
goods to other transition constant	other	-4.390	50.1	738.8
other to other transition constant	other	-2.008	33.1	337.9
ln (number of previous stops for all purposes + 1)	return	-0.6035	18.0	101.6
ln (number of previous stops for service purpose + 1)	return	-0.2808	8.3	47.3
ln (number of previous stops for goods purpose + 1)	return	-0.7615	21.9	128.2
ln (number of previous stops for other purpose + 1)	return	0.3152	10.5	-53.0
light vehicle drive time to establishment (minutes)	return	-0.005942	5.8	1.0
total light vehicle drive time since start of tour (minutes)	return	0.005188	28.0	-0.9
alternative specific constant	return	-0.9065	12.2	152.6

estimation statistics

number of observations: 15,812
log-likelihood with zero coefficients: -141,790.5829
log-likelihood with constants only: -108,705.1046
log-likelihood with estimated parameters: -78,628.9386
rho2(0): 0.4455
rho2(c): 0.2767

The signs on the estimates are all consistent with expectations.

Of particular note are the signs on the estimates for the 'number of previous stops' variables for the 'return to establishment' purpose. The negative signs on the estimates for the 'all', 'service' and 'goods' numbers of previous stops indicate that as tours get longer (in terms of number of stops) there is a decreasing probability that these tours will end after a particular stop. The positive sign on the estimate for the 'other' number of previous stops indicates that as more ‘other’ stops are made there is an increasing probability that these tours will end after a particular stop. This difference acts to curtail the variation in the number of ‘other’ stops in tours relative to the number of ‘service’ and ‘goods’ stops, which is consistent with the understanding that a range of different types of commercial movements will give rise to wider variations in the number and timing of ‘service’ and ‘goods’ stops – which are more specific to the activities of the establishment and its industry category – than in the variation in the number and timing of ‘other’ stops – which are at least somewhat more related to the workers and vehicles (including lunch and rest breaks, vehicle refueling, etc) and thus are more homogenous.

There are large negative and positive estimates for the ‘transition constants’, which indicate the tendencies for one purpose to follow the next. In particular, all other things being equal, there are very weak tendencies for a goods stop to follow a service stop and for a service stop to follow a goods stop. The alternative specific constants are used to determine the purpose of the first stop, then the transition variables ensure that the probabilities for subsequent stops are consistent with the first.

The negative sign on the estimate for the light vehicle drive time to establishment for the ‘return’ purpose indicates there is a decreasing tendency to end the tour and return to the establishment rather than make another stop as the vehicle is further away from the establishment. This is as expected. There is also an increasing tendency to end the tour and return the establishment as the total travel time accumulated on the tour increases. This reflects the influence of the time budgets on tour patterns. The probability of returning decreases with increasing numbers of stop generally – in that there can be many short stops in some cases, but the total time accumulated in travelling between these stops (along with the time spent at them) has to fit within working hours generally.

In terms of the policy responsiveness of the model overall, as transportation improvements act to increase accessiblities and reduce travel times, this will act to increase the numbers of stops – moreso for ‘goods’ in particular all other things being equal via the accessibility terms in the utility functions for the ‘service’, ‘goods’ and ‘other’ alternatives and via the reduced total travel time accumulated in travelling between stops term in the utility function for the ‘return’ alternative, but also to increase the probability of return to establishment via the drive time to establishment term in the utility function for the ‘return’ alternative.

It might be appropriate to replace the transition variables for the previous stop with variables based on the *first* stop. This would allow the selection of the first stop to be a kind of "tour type" selection, and the subsequent stops types would be conditional on that tour type.

Alternatively, one could use a latent class model to select an unobserved categories of "tour type", and condition the stop type choice on the unobserved tour type.

4.3 Next Stop Purpose Choice for Medium and Heavy Vehicles

The estimation results for the choice of the purpose for the next stop for medium and heavy vehicles in particular, at the middle level under consideration here, are presented in Table 3. Separate estimations were performed for medium and heavy vehicles on their own, but there were not enough observations in either case to provide results that seemed reliable.

Table 3 Next Stop Purpose Choice for Medium and Heavy Vehicles

attribute associated with parameter	alternative	parameter estimate	absolute t-ratio	normalized estimate
accessibility to population	service	0.03656	2.7	-2.4
accessibility to employment	service	not included		
proportion of workers in retail industry	service	-1.066	9.8	70.0
alternative specific constant	service	2.565	17.7	-168.4
service to service transition constant	service	-2.662	21.7	174.8
goods to service transition constant	service	-8.15	25.8	535.1
other to service transition constant	service	-2.655	14.6	174.3
accessibility to employment	goods	0.05104	2.3	-3.4
proportion of workers in retail industry	goods	1.224	13.7	-80.4
alternative specific constant	goods	1.395	8.5	-91.6
service to goods transition constant	goods	-7.870	19.2	516.7
goods to goods transition constant	goods	-2.243	14.3	147.3
other to goods transition constant	goods	-2.929	13.3	192.3
accessibility to population	other	not included		
service to other transition constant	other	-3.587	22.0	235.5
goods to other transition constant	other	-4.770	21.5	313.2
other to other transition constant	other	-3.007	9.1	197.4
ln (number of previous stops for all purposes + 1)	return	-0.4576	5.0	30.0
ln (number of previous stops for service purpose + 1)	return	-5.417	5.3	355.7
ln (number of previous stops for goods purpose + 1)	return	-1.053	11	69.1
ln (number of previous stops for other purpose + 1)	return	0.1917	1.8	-12.6
light vehicle drive time to establishment (minutes)	return	-0.01523	5.7	1.0
total light vehicle drive time since start of tour (minutes)	return	0.01113	19.5	-0.7
alternative specific constant	return	-0.3088	2.7	20.3

estimation statistics

number of observations: 1,708
log-likelihood with zero coefficients: -15,355.0490
log-likelihood with constants only: -12,830.5434
log-likelihood with estimated parameters: -7,668.4988
rho2(0): 0.5006
rho2(c): 0.4023

The estimation results again indicate a good fit – better than the one for the corresponding model for light vehicles, with the non-constant variables again making a substantial contribution to this good fit.

The signs on the estimates match exactly those for the corresponding estimates for the light vehicle model, and the ratios among them are broadly similar. The same points could be made regarding the interpretation of these estimates.

But there are a few notable exceptions: some of the estimates in this case were not significantly different from 0, and thus were not included. The estimate for accessibility to employment for 'goods' is somewhat smaller, indicating a reduced influence; whereas the estimate for the number of previous stops for service purposes for 'return' is much more negative, indicating a much reduced tendency to end tours after a particular number service stops.

It is perhaps debatable whether there are enough differences between this model of next stop purpose for medium and heavy vehicles and the model of next stop purpose for light vehicles considered above to warrant two separate models – but it was felt appropriate to at least indicate the results for these two cases in this paper.

4.4 Next Stop Location Choice for Service

The estimation results for the choice of the location (zone) of the next stop when the purpose of the next stop is 'service delivery', at the lowest level under consideration here, are presented in Table 4.

The estimation statistics indicate an excellent fit – but this is for a dataset developed by randomly selecting 80 unchosen zone alternatives and combining it with the chosen alternative, so this indication regarding fit must be interpreted carefully.

The signs on all of the estimates are consistent with expectations – with notable exceptions concerning the accessibility terms. The negative signs on the estimates for the accessibility terms indicate that as the accessibility of an alternative next stop location increases it is less likely that it will be selected, all other things being equal. This seems unreasonable: those making deliveries should be headed into more accessible locations all other things being equal, because they are then well positioned to make their next stops. It may be that there are strong correlations in the data giving rise to these results. There may be a tendency to want to avoid more congested central locations all other things being equal. Or perhaps some of the area classifications interact with these accessibilities.

Table 4 Next Stop Location Choice When Next Stop Purpose is Service

attribute associated with parameter	alternative	parameter estimate	absolute t-ratio	normalized estimate
residential area classification	zone	0	n/a	0.0
retail shopping area classification	zone	0.3169	12.3	-3.4
industrial area classification	zone	-0.2121	1.0	2.3
employment node classification	zone	-0.1311	6.6	1.4
smoothed average income of residents; 0 if no residents	zone	5.651E-7	2.0	0.0
drive time from current stop (minutes)	zone	-0.09312	123.1	1.0
drive time from next stop to establishment (minutes)	zone	-0.01818	14.9	0.2
accessibility to population	zone	-0.07696	13.6	0.8
accessibility to employment	zone	-0.07640	13.1	0.8
angle from establishment to current stop to next stop (deg)	zone	-0.0004658	2.8	0.0
ln (population + 0.5237*employment)	zone	0.3104	48.5	-3.3
employment in composite size term immediately above	zone	0.5237	5.2	

estimation statistics

number of observations: 10,273
log-likelihood with zero coefficients: -292,916.5416
log-likelihood with constants only: n/a
log-likelihood with estimated parameters: -28,099.0649
rho2(0): 0.9041
rho2(c): n/a

The estimates for the area type classifications are consistent with expectations. Service stops tend to occur in retail shopping areas and in residential areas more than in industrial or employment node areas. The positive value on the estimate for the average zonal income term is sensible: higher income areas tend to consume more services.

The negative sign on the estimate for the drive time from current stop (to the next stop alternative) term indicates an aversion to increased driving times, consistent with an effort to be efficient in the delivery of services. The negative sign (and somewhat smaller absolute magnitude) on the estimate for the drive time from next stop to establishment indicates a (somewhat weaker) tendency to keep within the areas around the establishment. This together with the negative sign on the estimate for the angle measure indicate a tendency to work back towards the establishment, all other things being equal.

The relative values of the estimates for the population and employment size terms (contained within the ln term) indicate that employment size is about half as influential as population size – consistent with the other indications that service stops are more influenced by population than employment.

In terms of the policy responsiveness of the model overall, as transportation improvements act to increase accessiblities and reduce travel times, this will act to decrease the extent to which stops are made in more accessible locations (unexpected as indicated above) and extend the range of stop locations and distances between stops.

4.5 Next Stop Location Choice for Goods

The estimation results for the choice of the location (zone) of the next stop when the purpose of the next stop is 'goods drop-off', at the lowest level under consideration here, are presented in Table 5.

Table 5 Next Stop Location Choice When Next Stop Purpose is Goods

attribute associated with parameter	alternative	parameter estimate	absolute t-ratio	normalized estimate
residential area classification	zone	0	n/a	0.0
retail shopping area classification	zone	-0.09531	1.8	1.1
industrial area classification	zone	0.04802	1.3	-0.5
employment node classification	zone	not included		
smoothed average income of residents; 0 if no residents	zone	not included		
drive time from current stop (minutes)	zone	-0.09000	53.9	1.0
drive time from next stop to establishment (minutes)	zone	-0.02704	11.1	0.3
accessibility to population	zone	-0.08417	7.5	0.9
accessibility to employment	zone	-0.07032	5.2	0.8
angle from establishment to current stop to next stop (deg)	zone	0.0007420	2.1	0.0
ln (population + 0.9165*employment)	zone	0.2652	17.6	-2.9
employment in composite size term immediately above	zone	0.9165	3.9	

estimation statistics

number of observations: 2,253
log-likelihood with zero coefficients: -62,996.6267
log-likelihood with constants only: n/a
log-likelihood with estimated parameters: -11,508.2529
rho2(0): 0.9216
rho2(c): n/a

Again, the estimation statistics indicate an excellent fit – but for a dataset developed by randomly selecting 80 unchosen zone alternatives and combining it with the chosen alternative.

Again, all the sign are consistent with expectations – with the same notable exceptions concerning the accessibility terms, and with the exception of the estimate for the angle term.

The positive sign on the estimate for the angle term in this case suggests that the pattern of goods stops (this case) tends to be different from the pattern of service stops (the previous case). There is not the same effort with goods stops to try to move in a direction back towards the establishment. There is still a tendency to keep within the area of the establishment, as indicated by the negative sign on the estimate for the drive time from next stop to establishment term. But there would appear to be a tendency for a different sort of stop pattern than with service purpose stops. This could be because for goods movements, there is a desire to empty the truck on the way out so that the longer return journey can be made more efficiently with an empty vehicle. With service movements the vehicle might not empty in the same way (in fact, in some cases it might fill up with refuse,) and so there wouldn't be the same incentive to go to the close locations first to empty the truck.

Some of the estimates for terms in this case contrast with those developed for stop location choice for service visits. Comparatively, industrial areas are more attractive to retail goods movement than for service visits, where retail shopping areas are less attractive to these goods trips. Employment nodes were found to not be significantly more or less attractive than residential areas. Similarly, the average income was an important factor in attracting service visits, but was found to be not significantly important in attracting goods visits.

Drive times and accessibilities seem to affect goods and service trips similarly. The coefficient for employment in the composite size term (ln(population+0.9165*employment)) is larger than the employment coefficient for service visits, indicating a trend of greater attraction to areas of higher employment.

4.6 Next Stop Location Choice for Other

The estimation results for the choice of the location (zone) of the next stop when the purpose of the next stop is ‘other’, at the lowest level under consideration here, are presented in Table 6.

Once again, the estimation statistics indicate an excellent fit – but for a dataset developed by randomly selecting 80 unchosen zone alternatives and combining it with the chosen alternative.

Again, all the sign are consistent with expectations – with the same notable exceptions concerning the accessibility terms.

Table 6 Next Stop Location Choice When Next Stop Purpose is Other

attribute associated with parameter	alternative	parameter estimate	absolute t-ratio	normalized estimate
residential area classification	zone	0	n/a	0.0
retail shopping area classification	zone	0.1719	2.6	-2.0
industrial area classification	zone	-0.7271	12.4	8.3
employment node classification	zone	-0.7957	15.0	9.0
smoothed average income of residents; 0 if no residents	zone	-6.5547E-6	7.8	0.0
drive time from current stop (minutes)	zone	-0.08808	36.1	1.0
drive time from next stop to establishment (minutes)	zone	-0.02997	8.4	0.3
accessibility to population	zone	not included		
accessibility to employment	zone	-0.10690	6.8	1.2
angle from establishment to current stop to next stop (deg)	zone	-0.002586	4.5	0.0
ln (population + 4.418*employment)	zone	0.2574	11.5	-2.9
employment in composite size term immediately above	zone	4.4180	5.7	

estimation statistics

number of observations: 1,087
log-likelihood with zero coefficients: -31,095.8261
log-likelihood with constants only: n/a
log-likelihood with estimated parameters: -2,617.9022
rho2(0): 0.9158
rho2(c): n/a

The estimation results are comparable to those for service and goods visits, with some very noteworthy differences. The area classification played a similar role to service visits, with ‘other’ trips being significantly attracted to retail shopping areas and finding industrial and employment node areas much less attractive than residential areas. It is worth mentioning that many of the small local shopping centres (such as a “strip mall” with a gas station, convenience store, quick-service restaurant and one or two other merchants) were not disaggregated as separate zones, but rather left in with their suburban residential surroundings in residential area zones. Many ‘other’ visits, seemingly attracted to residential areas, may actually be attracted to these small commercial areas.

Areas of higher income were actually found to be less attractive to vehicles making ‘other’ trips, where they were more attractive to service vehicles and unimportant to vehicles making goods trips. This may well prove to be an artefact of correlation with another factor such as zone categorisation or network accessibility, but it may also be a search for less expensive services (meals, vehicle repairs, fuel and maintenance).

Drive time, angle and accessibility produce similar results in the estimated equation for ‘other’ trips as for service visits; there is a general trend to return towards the establishment and to minimise travel time.

The size term is a very strong indicator of the motivator of ‘other’ trips; the value of one job of employment is 4.4x that of one person resident in a zone. ‘Other’ trips seem to be attracted to areas of employment, especially retail employment. This fits in with the general conception of ‘other’ stops comprising largely meal and vehicle fuel/service stops.

5. Conclusions

This paper describes some initial testing of the idea of using tour-based treatments similar to those now being used to model household travel behaviour in the modelling of certain forms of commercial movements. As indicated, the result are very encouraging, even if still very preliminary. They definitely point to a new way ahead in modelling and understanding urban commercial movements.

One of the initial premises of this work is that there are two fundamental methods of organizing and accomplishing commercial movements. One is ‘tour-based’, where vehicles operate out from an establishment in tours, make stops along the tour for service delivery and/or goods pick-up and drop-off, and eventually return to the establishment. The other is ‘visit-based’, where vehicles come to establishments and pick-up or drop-off goods and then move on to other locations in order to facilitate the transport onwards of the goods that have been picked-up until they are dropped-off. The work described here focuses on the first of these methods. In the work described here the split between these two methods was done in terms of establishment industry category: ‘tour-based’ operation was drawn from establishments in the services and retail goods industry categories. Service establishments always used the ‘tour-based’ method; but some retail establishments used the ‘visit-based’ method, and thus were not included. There was some sense that perhaps it might be more effective to use vehicle ownership rather than industry category as a guide to method of operation – in that it seems reasonable to expect that use of ‘own account’ vehicles is consistent with ‘tour-based’ operation and use of ‘for-hire’ vehicles is consistent with ‘visit-based’ operation. But it was found in the data that in some cases ‘for-hire’ vehicles were being used exclusively by one establishment in a ‘tour-based’ operation. It would appear that in the survey the descriptor ‘for-hire’ was sometimes used to indicate when a vehicle was leased rather than owned or when a driver worked as a contractor rather than as an employee.

As a result, the distinction based on establishment industry category was more appropriate given that it is more consistent with the available employment statistics and future forecasts.

The measure of network impedance should be a composite measure that includes both drive time and drive distance multiplied by an appropriate factor, not just drive time as has been done in the work thus far. Further work will develop and use such a measure. The new measure of network impedance would also be used to calculate new accessibility measures.

We are anticipating testing a number of possible additional formulations. First, it may be that the enclosed angle and accessibility affect stops differently depending on what the stop number is in the tour. It may be, for instance, that early stops would be attracted to more accessible locations, to be well positioned for later stops, but that later stops are attracted to less accessible locations to avoid some of the negative effects correlated with accessibility, such as congestion, stop and go traffic, and parking charges. As well, early stops might tend to move away from the establishment, and later stops might move towards the establishment. If estimations support this hypothesis, then the number of stops on the tour might need to be included as a separate submodel in its own right, with its own estimation, so that the parameters in the choice of stop location submodel can be conditional upon the total number of stops in the tour.

The unexpected sign on the accessibility values are initially troubling. But these are logsum terms from a destination choice model that is not being used in this model. Perhaps that destination choice model is not appropriate for goods movements, and a different one should be used. Ideally such accessibility calculations should be replaced by logsum calculations from the next stop models, to ensure consistently between the levels of the model. As we become more comfortable with our formulations for the next stop calculation the logsums can be calculated, and applied at the higher levels in a sequential estimation process.

The probabilities of choosing goods or service stops may be more related to the tour itself, rather than to the attributes of the next and previous stops. "Tour type" could be included as a separate variable, with "no goods stops", "no service stops", and "mixed stops" as alternatives. Alternatively, the tour types could be a latent class variable, and the set of them could be estimated using more sophisticated estimation techniques.

These are preliminary results; there is a lot of additional room for refinement, and we will be working on this in the near future. But these results begin to show how goods and services are attracted to different types of zones, how different vehicle types condition stop choices, and how the locations, length and nature of the tour respond to transportation conditions and transportation policy. Perhaps more importantly, these results show that a tour-based approach to modeling service and retail vehicle movement is a practical one, and can be applied in a real-world model. A dynamic approach to commercial vehicle modeling that interacts with personal travel can and should be a part of an urban transport modeling strategy.

We look forward to reporting on more of what we are finding when we present our material at the conference.

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