A Commercial Movement Modelling Strategy for Alberta's Major Cities

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ABSTRACT

In recognition of the expected benefits to transportation planning, a system for modelling commercial movements is being developed in a joint effort involving the Cities of Edmonton and Calgary and Alberta Transportation. This effort includes an extensive set of surveys considering commercial movements. Interviews were conducted at business establishments and with vehicle drivers in the two urban areas in order to provide observations of relevant behaviour required for establishing a more complete understanding of the nature of this component of travel and for model development and calibration. The system of models incorporates a novel agent-based micro-simulation framework, using a tour-based approach, based on what has been learned from the data. It accounts for truck routes, responds to truck restrictions and related policy and provides insight into commercial vehicle movements. All commercial vehicle types are represented, including light vehicles used for commercial purposes (pick-ups, vans and passenger cars), heavier single unit and multi-unit configurations and fleet vehicles (such as police cruisers, garbage trucks and government service and maintenance vehicles). This modelling system is being incorporated within the two EMME/2 models covering the Calgary and Edmonton Regions, with the micro-simulation processes being done in external Java applications. Some initial model results are available.

1.0 INTRODUCTION

Commercial vehicle movements are a significant portion of travel in urban areas. It is estimated that about 10 to 15 percent of urban vehicle trips are made for commercial purposes. But the impacts of commercial vehicles are likely to be even greater than this: Personal vehicle trips traverse the entire network, whereas commercial vehicles (and especially the larger trucks) tend to concentrate vehicle movements in industrial and commercial areas, and more during the middle of the work day rather than in the AM and PM peaks. Additionally, when compared with the personal vehicle fleet, larger trucks can have more significant impacts per vehicle in key areas such as road congestion and traffic flow, greenhouse gas and pollutant emissions and pavement wear. Higher values of time are also typically attributed to commercial vehicles, so this sector should be considered separately in order to properly calculate the benefits of travel time savings.

The Calgary and Edmonton census metropolitan regions each have populations around one million. Together they represent nearly two thirds of the population in the Province of Alberta. Key strategic highway and railway routes for commercial traffic run through each city. Both Edmonton and Calgary have developed state-of-the-art regional travel models, focussing on personal travel patterns on a typical fall weekday. These models use an aggregate, equilibrium framework, but have been calibrated using disaggregate behaviour data obtained from comprehensive surveys of household travel and activity behaviour. The weekday personal travel market is segmented into 25 person / purpose categories; and for each travel segment nested logit models are used to predict daily trip generation and destination choice, time of day of travel, and mode choice (Hunt, 2003; Hunt et al, 1998).

However, the treatment of commercial vehicle movements is very limited in these models – based essentially on a scaling of truck flows derived from link count data. A limited treatment of commercial movements is typical of virtually all models of this sort, despite the importance of these movements as indicated above. Back in 1998, representatives of the transportation departments of the cities of Edmonton and Calgary, and the Province of Alberta, met to discuss urban travel modelling issues. The need for improved commercial vehicle travel models in both the Edmonton and Calgary regions was identified as particularly important. It was also recognised that it would be most beneficial to pursue such improvements using a common, consistent and cooperative approach among all three parties. Consequently, from 1999 onwards, the two cities, with the active staff and financial support of Alberta Transportation, have undertaken a coordinated program of data collection and model development concerning urban region commercial movements.

2.0 APPROACH

2.1 Team Approach

There is a long history of mutually beneficial support in transportation modelling activities between Calgary and Edmonton, with many cases where a close two-way exchange of information has allowed one city to draw on the successful application of a given approach by the other, along with some more direct sharing of experiences and skills through staff exchanges and common technical advising. This is evidenced by various relevant joint publications describing such common activities (Abraham et al, 2001; Hunt et al, 1994, 2001, 2003). Alberta Transportation also supports the development of a regional-level coverage – extending well beyond the city boundaries – in both models.

The work described here was felt to warrant an even closer team effort, not just because of the successful history of mutual support, but also because of:

- concerns about the data and sample size challenges that would arise given the inherent large degree of heterogeneity in commercial movements;

- the regional and inter-city-corridor aspects relevant to the Province of Alberta, rather than either of the cities;
- the potential for direct linkages in freight flows between the two cities to result in relevant information about flows in one city to be collected in the survey in the other city; and
- a need for a coordinated effort at gaining endorsements for the project (particularly the data collection) from relevant province-wide motor-carrier associations and provincial bodies.

The closer team approach in this case, along with the sharing of experience, included:

- the development and application of essentially the same survey design and instruments;
- the sharing of a description of the geography in each city and the rest of the Province; and
- the pooling of data for certain elements of behavioural analysis and model estimation.

As the work progressed, a further 'split and share' approach was adopted. In a first stage the focus in Edmonton would be on the development of the aggregate data set and associated descriptions of commercial movements in total while the focus in Calgary would be on the development of the modelling system and its integration with the existing Regional Travel Model. In a second stage, drawing on the experience of the other, Edmonton would undertake the development of the modelling system and Calgary would develop the descriptions of commercial movements in total. At the time of writing, the first stage has been completed in both cities.

2.2 Modelling Approach

The most common methods for urban commercial vehicle modelling are the expanded OD-matrix techniques. With these techniques, a base year matrix of commercial vehicles is developed. This is typically based on ground counts, but could also be survey-based. This matrix is then expanded to represent a steady-state, which is scaled for future years. (Ortúzar and Willumsen, 1994). This general approach has several problems; the most obvious one is the lack of policy response. Additionally, relying totally on ground count data would exclude the half of commercial movements that are made with light commercial vehicles. These models are only really useful for providing "background traffic", where personal vehicle modelling is the goal and commercial vehicles are of no interest to the modelling agency.

The second major method used in urban commercial vehicle modelling is to use a variant on the traditional four-step aggregate approach. These models utilise the four traditional steps of trip generation, mode choice, trip distribution and network assignment. (Cambridge Systematics et al, 1996). Mode choice is often neglected entirely; frequently only larger vehicles are considered. This approach emphasises trips rather than tours, which is not the best way to consider urban commercial vehicle movement. Additionally, most models done with this method tend to use simple "standard" coefficients to handle tour generation and trip distribution, and often neglect service trips, focussing on goods movement alone.

While most jurisdictions use one of the previous two modelling approaches for commercial vehicles (or neglect them entirely), a number of more novel approaches are being developed. The philosophy of supply chain modelling, more prevalent in Europe than North America, attempts to model the suppliers, warehouses and consumers of products in individual supply chains. (Boerkamps et al, 2000). This approach is useful for examining a limited range of industries (say, in an area dominated by one type of company), but would require substantial data to produce a comprehensive model for a typically diverse North American urban area. Some models use a spatially disaggregate input-output paradigm, which does a very good job of representing the commodity flows in the economy. (Hunt and Abraham, 2001) This provides good data for commercial vehicle models, but the model typically downplays or simplifies important elements of the urban commercial vehicle phenomenon, such as trip chaining and less than load hauling.

The microsimulation approach has recently become the state-of-the-art in household travel modelling (Jonnalagadda et al, 2001). It is more flexible and powerful, but requires disaggregate data and a more detailed modelling framework. Some of the benefits of a microsimulation approach are the ability to model various aspects of choice behaviour explicitly, aggregate results in any manner desired, and the flexibility to create any number of specific constraints.

For the Calgary and Edmonton commercial movement models, a hybrid approach was developed with a tour-based microsimulation included. The total set of commercial vehicle movements was divided into three groups, each modelled separately; tour-based movements, fleet-allocator movements and external-internal movements. The majority of movements are modelled with the tour-based model, with the two other movements being modelled with methods that use the available data.

External-internal movements, comprising a small fraction of the total, are made by commercial vehicles with at least one trip end outside the model area. The external-internal movements model uses singly-constrained gravity models to assign the internal ends of trips being made by trucks crossing the model area boundary. This model only includes trucks – and excludes those commercial trips with at least one end external by light vehicles – because the external cordon survey done to collect the information used to develop this model only considered trucks; light vehicles were not stopped.

Fleet allocators represent roughly one third of all commercial vehicle movements. Fleet allocators primarily dispatch vehicles to cover an area or to travel road links, rather than handle a specific shipment. Examples include newspaper delivery, garbage and recycling pickup, road and parks maintenance, mail and courier service, taxi, police and rental car fleets. At this point the fleet allocator model uses an aggregate generation and gravity-style distribution framework.

The remaining two thirds of trips are modelled using a tour-based microsimulation. This model identified the attributes of individual tours, including stop purpose, vehicle type, time of day and the stop locations. It uses a series of logit models to simulate the decisions made with a touring vehicle. Because of the microsimulation element, results can be aggregated in any way to analyse tours for different industries, time periods or other results as needed.

3.0 SURVEYS

Major commercial movement data collection efforts were conducted in both Calgary and Edmonton to support the development of the associated commercial movement models described above.

3.1 Survey Design and Implementation

Past experience has shown that the systematic study of goods and services movements in urban areas is very challenging. This is due to a number of issues. The primary issue is the considerable heterogeneity within the population of such movements. In some studies the strong focus is placed on just those movements by the trucking (transport and handling) industry, which is made up of a large number of very different sorts of privately-owned businesses making numerous and complex movements and by no means covers all of the movements being made.

A novel survey approach was designed for the work reported here in order to avoid some of these issues, seeking to (a) concentrate on the activities of all business establishments; (b) pursue a large survey sample; and (c) minimise survey burden for respondents. Features of the design included:

- covering all establishments involved in the shipment of both goods and services, including transportation depots;
- seeking information on individual shipments of goods and services on one weekday;
- covering only outbound movements generated by a given establishment – except for transportation depots, where both inbound and outbound are covered;
- including a special separate interview for fleet allocators, where the approach was to observe just the fleet allocation process and results, seeking indications of the vehicle movements in terms of route patterns and/or coverage areas;
- offering direct assistance, including face-to-face contacts, training, and staff for data collection;
- including an External Truck / Commodity Survey to intercept trucks entering and leaving the Region, to ensure complete coverage of the movements of interest; and
- obtaining the support of organisations involved in goods and services movement, including the Alberta Motor Transport Association and regional economic development agencies.

The spatial components of the various types of goods and services vehicle movements occurring in urban areas, and captured by the survey approach, are summarised in Figure 1.

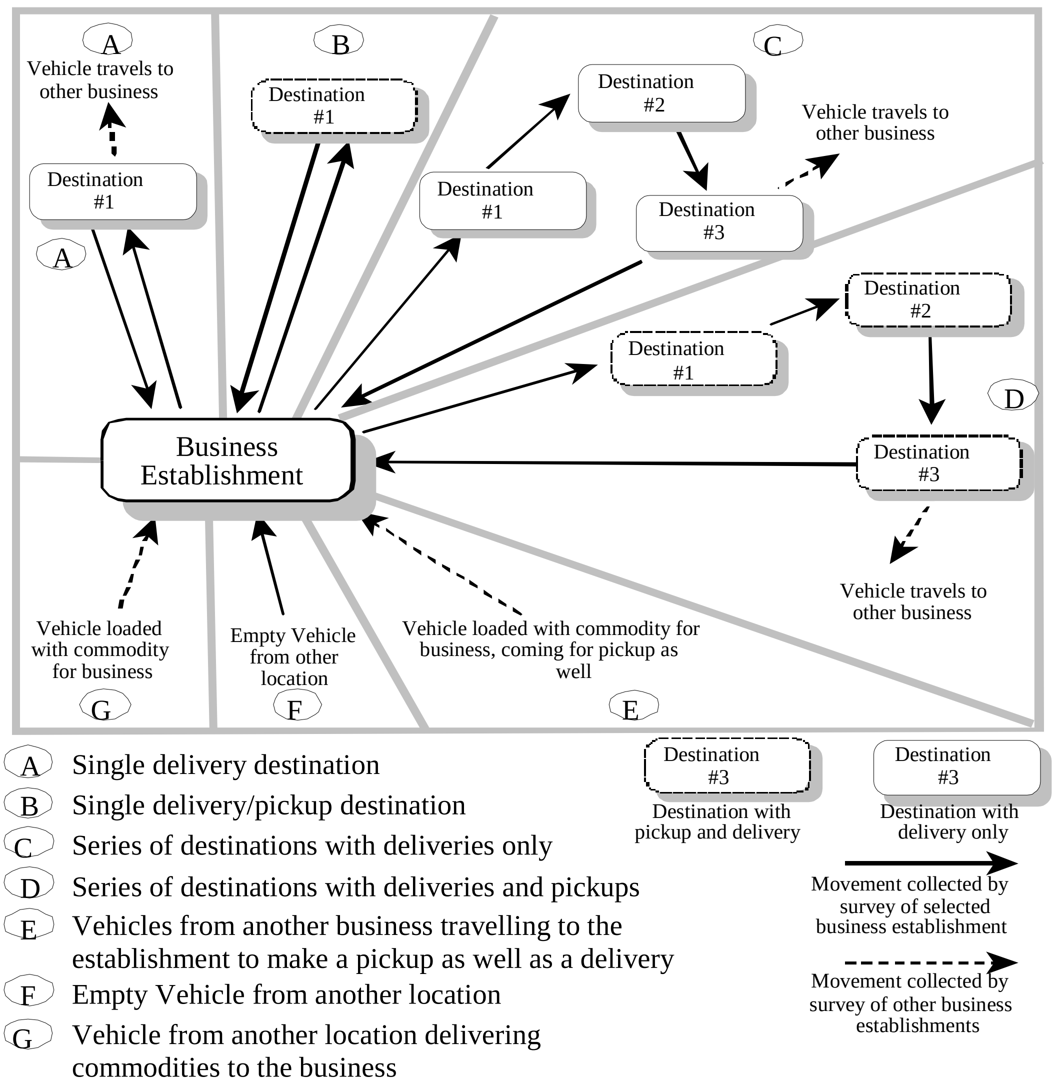

Figure 1: Range of goods and services vehicle movements in urban areas

Based on the above concepts a common program of surveys was designed and developed for both cities. This data collection program included:

- **Commodity Flow Study of business establishments,** obtaining descriptions of the basic patterns of goods and services flows and the corresponding nature of the vehicle movements generated by business establishments in the shipment of goods and services from production to consumption location. This survey was performed in the Calgary Region in the fall of 2000 at just over 3,000 business establishments; and in the Edmonton Region in the fall of 2001 / spring 2002 at just over 4,300 business establishments (Hunt et al, 2004).
- **Fleet Allocator Survey,** obtaining somewhat less structured descriptions of the relevant fleet allocation process and results from those fleet allocator establishments identified in the Region Commodity Flow Study, including routes and/or coverage areas, frequency of operation, fleet size and vehicle characteristics and vehicle kilometres travelled per vehicle and in total.
- **External Truck Survey,** obtaining data on the movement of commercial goods by trucks on Provincial highways in and out of each Region. The Calgary Region External Truck Survey was performed in the fall of 2000, surveying over 6,000 truck movements, at 16 highway locations; and in the Edmonton Region in the fall of 2001, similarly surveying over 6,400 truck movements at 24 locations (Hunt et al, 2004).

In addition, vehicle classification counts were undertaken at sites on highways and major arterial roadways throughout both regions; to provide observed truck flows on individual links for use in verification of the sample expansion and in model calibration.

3.2 Survey Expansion

The Commodity Flow and Fleet Allocator Surveys obtained data for only a sample of all the goods and service movements on a given day. These sample data must be expanded to represent the corresponding 'population' of goods and service movements.

The expansion process involved scaling the observed values for each establishment across three independent variables:

- establishment size, measured in terms of the number of employees;
- standard industry category (SIC); and
- geographic location.

The individual expansion factor for each establishment is the ratio of the number of employees in the population over the number of employees in the same category in the sample.

In order to collect the required information on the total employment in relevant categories, an additional survey (called the 'Total Employment Survey') was undertaken in order to obtain relevant employment by occupation from all establishments in the region, whether or not they shipped goods or services.

Figure 2 illustrates the expansion process, which was complicated by the need to account for the employment at establishments that did versus the employment as establishments that did not ship goods or services.

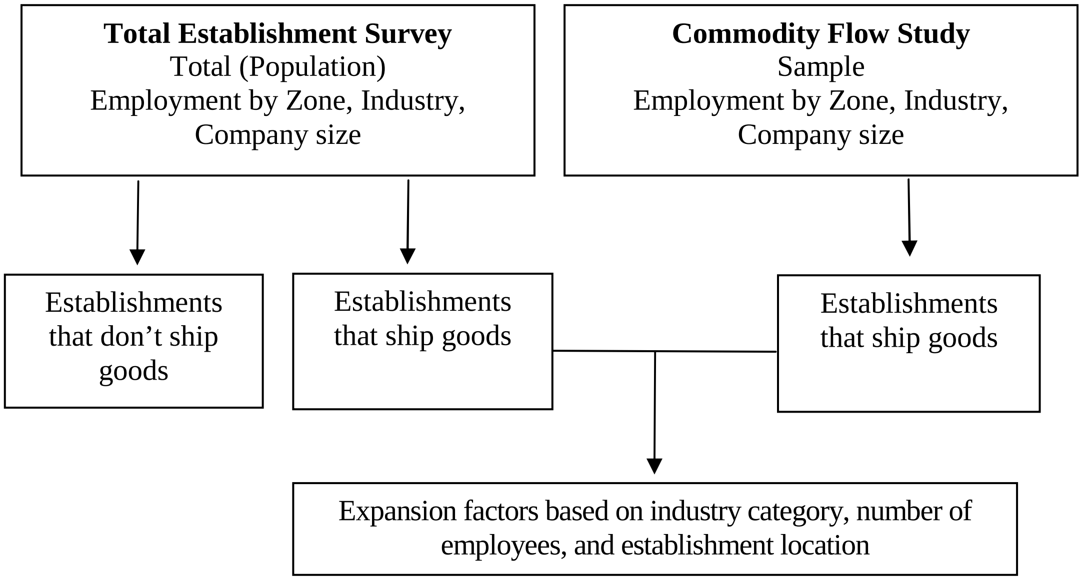

Figure 2: Process to expand survey sample to represent 'population' of goods and services movements

3.3 Aggregate Commodity Flows (in Edmonton)

Shown below are examples of the distributions of characteristics for the movement of goods and services in Edmonton, based on the expanded sample, as reported in the project report (City of Edmonton, 2003).

Vehicle Characteristics: The vehicles used to deliver goods and services fall into three general categories; passenger vehicles (cars, pickup trucks), single-unit trucks and multi-unit trucks. On a typical weekday, about 23,400 vehicles are used to deliver goods and services throughout the Edmonton Region. These include about 13,500 passenger vehicles, 4,900 single-unit trucks and 5,100 multi-unit trucks. Establishments in the industrial and transportation handling industries use nearly 80% of all multi-unit trucks. Wholesale and industrial establishments use more than 55% of all single-unit trucks whereas private services and industrial establishments use about 60% of the passenger vehicles.

The majority of the nearly 10,000 single unit and multi-unit trucks that are used to deliver goods and services on a typical weekday have a gross-vehicular weight (GVW) of between 12,000 kg and 60,000 kg. Figure 3 shows the distribution of GVWs for these vehicles.

Trip Generation by Vehicle Type: Approximately 165,000 commercial vehicle trips are generated in a typical day, with about 128,000 originating within the City of Edmonton, 17,000 within Sherwood Park and St. Albert and 19,000 in the remainder of the Region. It is notable that not all of the surveyed establishments were engaged in shipping goods or services on their assigned survey day, even though they did 'normally' ship goods/services: Only about 75% of the establishments that ship goods or services did so on their survey day. Passenger vehicles are the predominant vehicle type, accounting for nearly 60% of all vehicle trips. Single-unit trucks are used for approximately 30% of all trips, with multi-unit trucks accounting for the remaining 10%.

Trips by Category: Figure 4 and 5 show the distribution of trips by category of goods or services carried. Printed matter, fabricated metal, and food or kindred were the most common goods types. Transportation services, municipal government and personal / miscellaneous services were the most common service categories. Transportation service trips are predominantly made by courier companies.

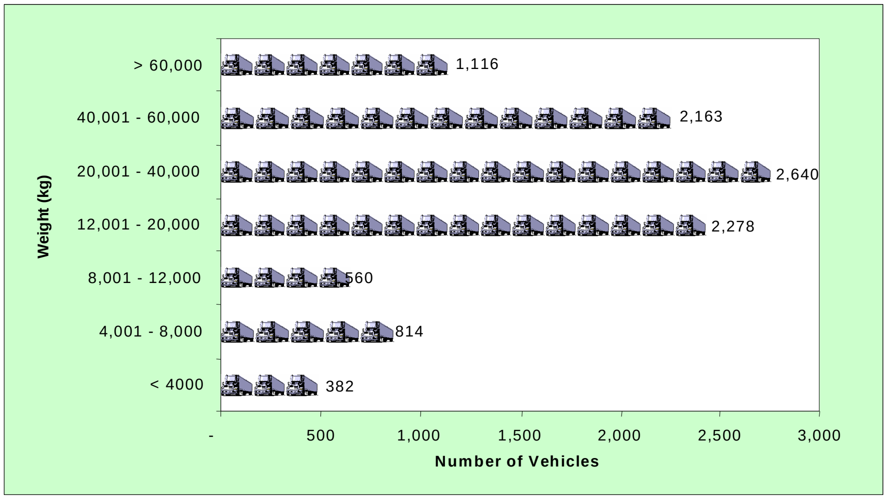

Figure 3: Distribution of gross vehicular weights

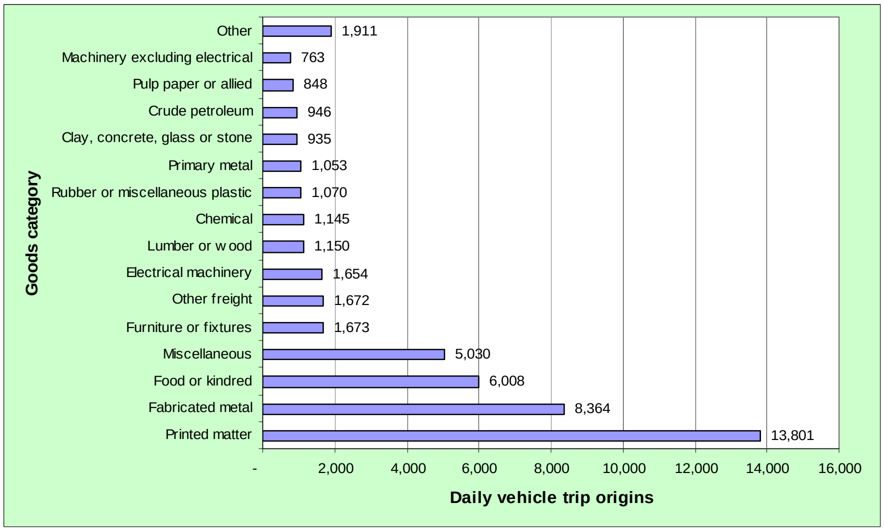

Figure 4: Daily vehicle trips by goods category

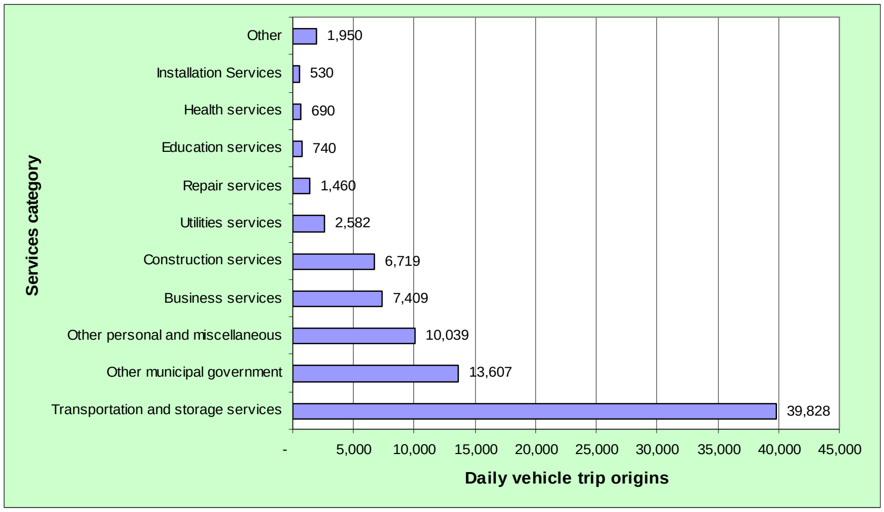

Figure 5: Daily vehicle trips by service category

Spatial Pattern of Origins and Destinations: Just over 93% of commercial movements in the Edmonton Region both start and end within the Region, and only 2% are external to external. Figure 6 shows the pattern of vehicle movements between origins and destinations for trips within the urban built-up area, including Edmonton, St. Albert and Sherwood Park.

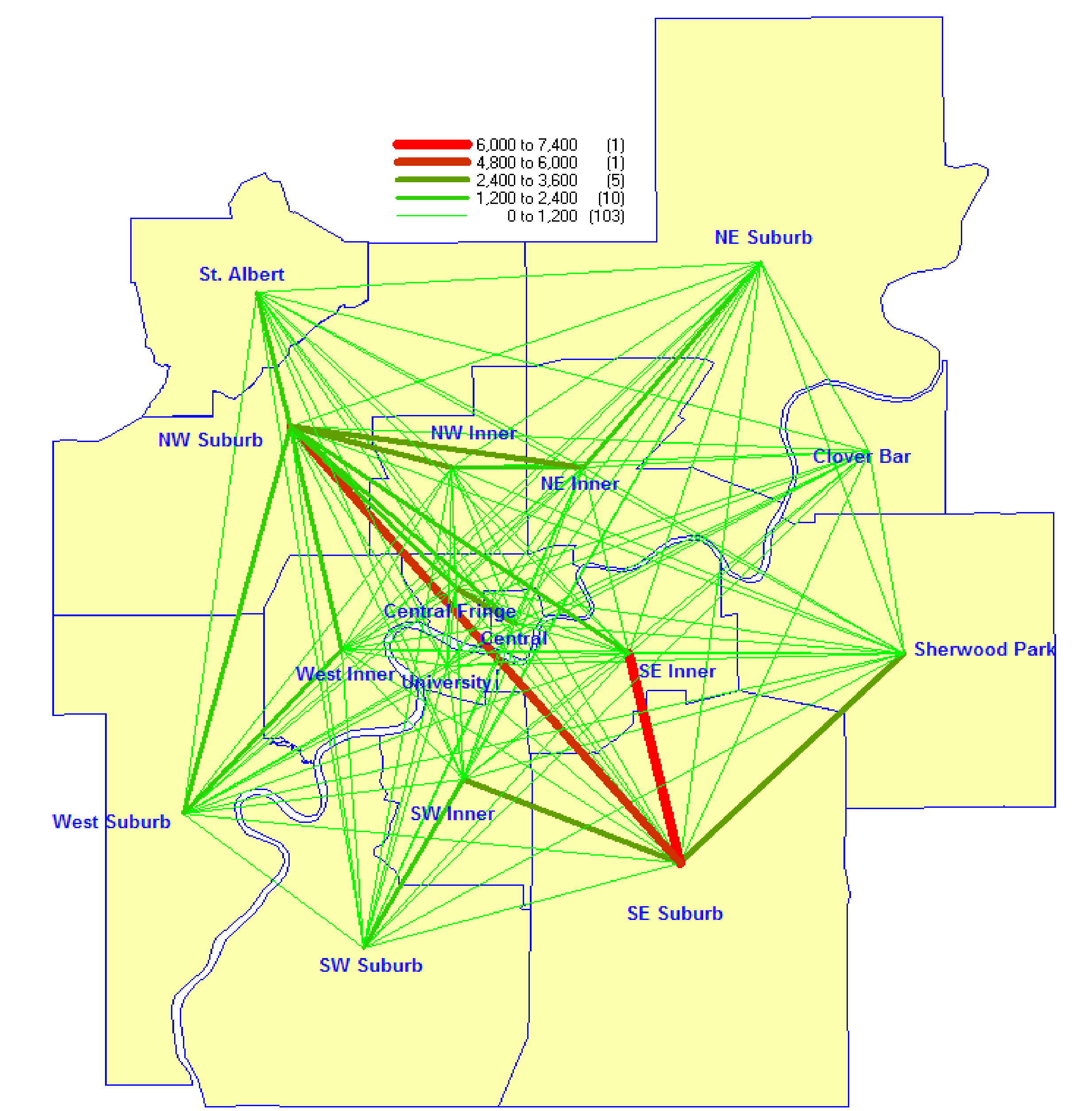

Figure 6: Pattern of commercial vehicle trips within the Edmonton Urban Area

Based on the results of the External Truck Survey, approximately 16,000 trucks enter or exit the Edmonton Region over the 24 hours of a typical weekday, carrying approximately 660,000 metric tones. Further findings regarding this volume of trucks include:

- 40% cross between 8:00AM and 4:00PM, with the peak half-hour volume occurring between 5:30PM and 6:00PM;
- 72% are owned by the company producing the goods being shipped;

- 77% are multi-unit and the remaining 23% are single-unit;
- 36% are empty and 19% are carrying manufactured goods, machinery, or equipment;
- 62% are carrying a single commodity and only 2% are carrying more than one commodity; and
- 42% have one trip end (either origin or destination) in the City of Edmonton, 37% have one trip end in the Edmonton Region and 21% are making external to external trips.

The expanded pattern of truck movements from the two surveys was loaded to the node-and-link representation of the roadway network of the Edmonton Region in the Edmonton regional travel model. This loading respected the current truck route restrictions on the network, particularly in the City of Edmonton, where trucks greater than 8 tonnes have to use designated truck routes.

The resulting truck flows on the model network are shown in Figure 7. The width of the 'bar' on each roadway is proportional to the volume of trucks using the roadway over 24 hours.

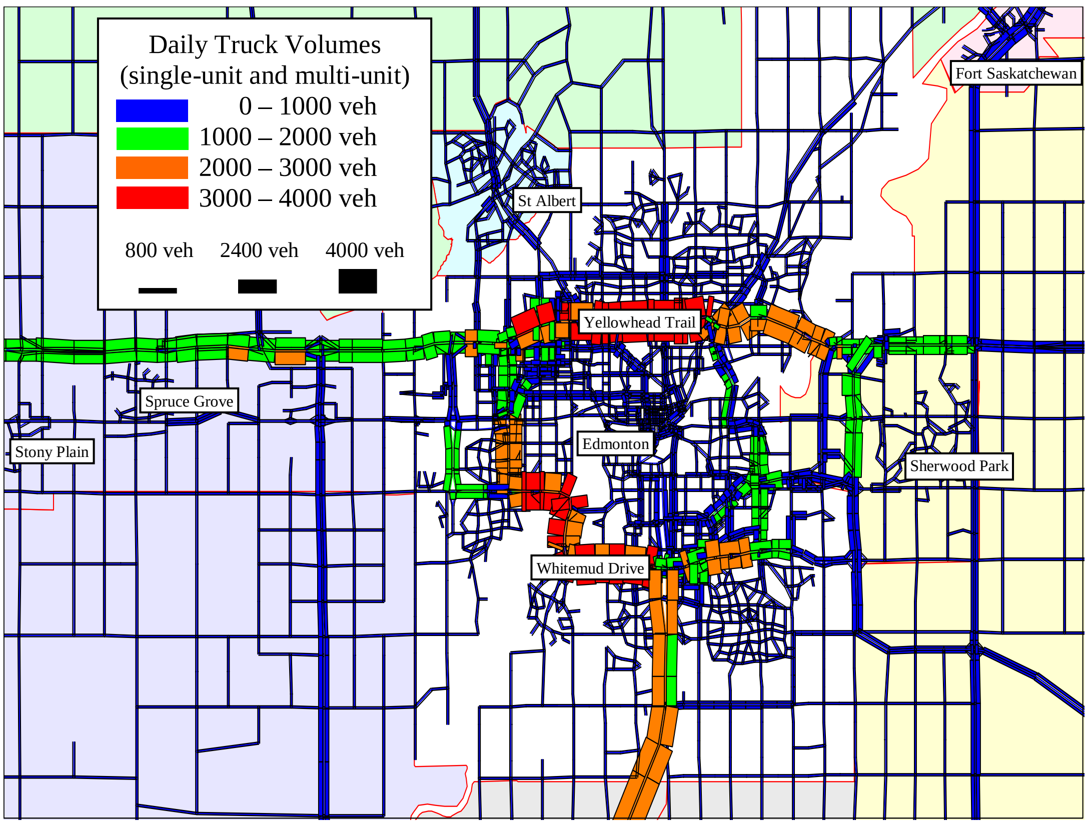

Figure 7: Truck flows on roadways when the survey-derived pattern of trips is assigned to the Edmonton Regional Model network

These assigned truck flows were found to match very closely the corresponding observed values obtained from vehicle classification counts. For both the single-unit and multi-unit truck categories the overall match between survey and corresponding observed values was within 5%, with individual directional values ranging from -25% to +25%. Because these vehicle classification counts are obtained independent of the surveys, this close match is a strong indication of the validity of the surveys.

4.0 MODEL (IN CALGARY)

4.1 Major Philosophical Underpinnings

The Calgary commercial vehicle model operates based upon three vehicle classes; light, medium and heavy. Light vehicles are passenger vehicles (cars, vans, pickup trucks), and operate over the entire road network. Medium vehicles are single-unit vehicles with six tires, and heavy vehicles are multi-unit vehicles with more than six tires. Both medium and heavy vehicles are subject to truck route restrictions in Calgary.

To handle time, the Calgary commercial vehicle model uses five time periods; AM and PM peaks, plus the offpeak periods that occur between midnight and the AM peak (‘early offpeak’), between the two peaks (‘midday offpeak’), and between the PM peak and midnight (‘late offpeak’). The microsimulation model is capable of creating tours that cross midnight. A single tour is only limited to 24 hours from when it begins, which should never occur within a single urban area. Trips and stops are assigned exact times, so the time periods are not fixed and the results could be aggregated differently; for instance, by 5 minute intervals if necessary.

A concept of purpose is also included in this model; much as work and school in a household personal travel model, the model purposes represent different major types of activities, which imply different types of companies, different influences and different choice structures. The four purposes are ‘goods’, which includes handling goods; ‘service’, which is the performance of service (or goods handling to perform a service, such as a plumber picking up supplies); ‘other’, which comprises all non-business purposes, such as driver breaks, meals, vehicle fuelling or business banking; and ‘return’, which represents the return trip to the business establishment, either at the end of the day or during the day, for any reason.

A final major philosophical component of the Calgary commercial vehicle model is the segregation of companies into 5 industry categories, which are ‘private services’ (which includes ‘government’ and ‘education’), ‘retail’, ‘industrial’ (which includes ‘agricultural’), ‘wholesaling’ and ‘transport and handling’. Each of these five industries for the most part has unique coefficients throughout the model, so the model produces very different behaviours and reactions to policy changes for these different categories. The model also has a slightly different structure for ‘transport and handling’, most notably in that the ‘goods’ and ‘services’ stop and tour purposes are combined into a single ‘business’ purpose, because ‘transport and handling’ firms provide the service of handling goods, which blurs the definitions.

4.2 Structure Of Tour-Based Model

The tour-based model uses a Monte Carlo microsimulation process to generate a list of individual tours, including for each tour the type of vehicle used and the attributes of the individual trips made, including the start and end time and the origin and destination location zones.

Tour-based microsimulation models of household travel typically use a ‘rubberbanding’ technique, where the attributes of the primary stop in a home-based tour (the work stop or the most distant shopping stop if there is no work stop) are determined first and then the number and attributes of any additional stops on the tour are treated as extensions/modifications of the trips between the home and the primary stop. For instance, an ‘intermediate stop’ for exercise might be inserted into the journey back from work to home. This ‘rubberbanding’ technique seems less well-suited to the representation of commercial vehicle tours, where there are often a comparatively larger number of compulsory stops out from the establishment without any basis for the identification of a ‘primary-intermediate’ hierarchy. As a result, the design of the Calgary commercial vehicle model considers each potential stop on a tour sequentially: tours ‘grow’ with the determination to continue the tour or return to the establishment re-considered after each stop.

The overall model process flow is shown in Figure 8.

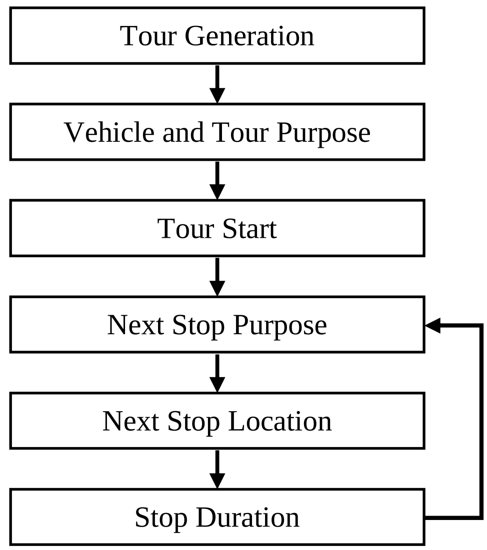

Figure 8: Structure of Calgary commercial vehicle model.

The modules in the process work together to determine the various elements of individual tours. These modules are:

- **Tour Generation:** The aggregate number of tours generated by each industry category is determined first for each time period in each model zone. These aggregate numbers of tours are used to form lists of discrete tours considered in the rest of the model. Tour generation rate (tours per employee in an industry) is determined based upon a regression that uses zonal attributes such as land use and accessibility. This rate is multiplied by the number of employees in the relevant industry in the zone to produce a total number of tours generated. This total number is allocated among the five time period alternatives using logit models where the utility functions include zonal attributes such as employment composition, accessibility to population and employment and alternative specific constants.
- **Tour Start Time:** In order to include representation of the influence of time of day and to handle trips that cross time periods, the microsimulator keeps track of trip start and end times and allocates trips to totals as they are generated. This means that tours need to be assigned an exact start time within the time period. A Monte Carlo process is used to assign this time, with sampling distributions based on observed start times differentiated by industry and time period.
- **Tour Purpose and Vehicle Type:** Each tour is then assigned both a primary purpose and a vehicle type simultaneously. This is done using a Monte Carlo process where the selection probabilities are determined using single-level logit models based on industry type with utility functions that include land use, establishment location and accessibility attributes. The alternatives for the primary purpose are to (a) handle goods, (b) perform services or (c) undertake other non-business purposes. The alternatives for vehicle type are, as shown above, (a) light, (b) medium or (c) heavy.

The trips in the tour are then identified in an iterative process. For a given tour, only one vehicle type and one primary purpose are selected, but at least one and possibly more stop locations and purposes are selected, with the previous and current stops influencing the decisions on the next stop. To implement this, the following three elements are iterative:

- **Next Stop Purpose:** The purpose is selected for each subsequent stop, from the alternatives (a) goods, (b) service, (c) other or (d) return to establishment. If the primary purpose of the tour is to handle goods, then the service alternative is not available for stops on the tour. Similarly, if the primary purpose is to perform services, then the goods alternative is not available for stops; and if the primary purpose is to undertake other non-business purposes, then neither the goods nor the services alternatives are available. If the purpose selected for the subsequent stop is return to establishment, then the next stop location is already known, the final trip is made and the microsimulator moves on to the next tour. Again, a Monte Carlo process is used to select the purpose for each next stop, with the selection probabilities determined using single-level logit models with utility functions that include the number of stops made in the different purposes on the existing tour, the total elapsed time of the tour, and the distance to the establishment.
- **Next Stop Location:** Once the purpose of the next stop is selected, and it is not return to establishment, then the location of the next stop is selected. Again, a Monte Carlo process is used with the selection probabilities – across the full set of 1,447 model zones – determined using a logit model with a utility function that includes a wide range of attributes, such as zonal employment and population, land use type, generalised cost of travel, return generalised cost to establishment and an angle measure which represents whether a stop is heading towards or away from the establishment The drive time to the next stop is also used to advance the clock keeping track of the start and end times for the trips included in the tour.
- **Stop Duration:** The duration of each next stop being made by the vehicle is established and used to advance the clock keeping track of the start and end times. A Monte Carlo process is used to determine the duration of the stop, with sampling distributions based on observed durations. The microsimulator then returns to the next stop purpose module and iterates.

The commercial movements considered in the tour-based microsimulation are divided into 13 segments, based on establishment industry, vehicle type and tour or stop purpose. Example segments include 'retail making service tour/stop', 'wholesale light vehicle handling goods' and 'other'. The values of the parameters in the various logit model utility functions and the shapes of the sampling distributions that are used in these modules vary according to the segment being considered.

4.3 Implementation of Tour-Based Model

One notable issue with commercial vehicle modelling is the impact of truck routes; these affect medium and heavy vehicles, funnelling them onto major routes and requiring more circuitous routes than necessary. The Calgary truck route policy requires trucks to travel on designated truck routes unless making a stop, where they are required to take the shortest route into and out of the neighbourhood. Industrial areas are free travel areas, with all roads effectively having truck route status. This policy is replicated in the model, which improves accuracy and adds a desirable policy responsiveness.

A generalised cost model is used to establish a penalty on all non-truck routes; by making this penalty suitably large, the path choice algorithm first minimises off-route travel, and then takes optimal routes between the entry and exit points of the truck route system. The penalty is quantized, with 1000 minutes travel time added for every 100m of link length (with link length rounded up to the nearest 100m). This results in two features; (a) trucks take the shortest path off of the truck route within 50m, rather than the one with the fewest links, and (b) the modulus operator can be used to re-establish the travel time before the penalties were added; this time is essential for both the generalised cost function, and for the proper accounting for time within the microsimulator.

The microsimulator itself is a specially written Java program. The software was constructed as a general purpose microsimulator, however, and it is heavily configurable to handle additional model restrictions or changes. The microsimulator interacts with the regional travel model, as well as the external and fleet-allocator models, all of which are implemented within EMME/2. The tours themselves are also generated within EMME/2, but the remainder of the microsimulation occurs within the microsimulator. Final results are aggregated and then passed back to EMME/2 in the form of nine trip tables, for light, medium and heavy vehicles during the AM peak, PM peak and combined offpeak. The microsimulator is configurable to provide results in different forms (such as separate tables by 30 minute time slices, or by industry). The Java environment runs quickly; an overnight run simulates about 1.3 million tours, comprising 6.5 million trips and representing 35 days of commercial travel.

It is important to avoid the possible problems that might result from a disaggregate Monte Carlo model producing slightly different trip tables with each run, and interfacing with a steady-state aggregate model. The solution is simple: the generated tours are multiplied by 10, and the resulting trip tables divided by 10 after the microsimulation to produce the proper result. This smoothes out the majority of variance; in one test of two runs, identical except for the random number seed, the link volumes were in most cases identical – the largest difference was under 20 vehicles. This has the additional benefit of reducing rounding errors resulting from generating tours in 1,447 geographic zones by 5 time periods and 5 industries.

4.4 Estimation and Calibration of Tour-Based Model

The parameters for the logit choice models were estimated on a data set representing roughly 35,000 trips. The location choice data set alone was 450 MB of comma-delimited text. Because of the large data sets, t-test results in excess of 100 were frequently seen. The Monte Carlo models for stop duration and tour start time were derived using curve fit software, with R^2 values in excess of 0.98 for all but three curves and all R^2 values above 0.9.

Following the estimation process, a series of calibrations were performed. The microsimulation nature of the model means that all of the elements are interdependent; for instance, if the tour generation is adjusted, establishment locations are changed, which affects the decision to return to establishment and therefore tour lengths. This interdependence necessitates an iterative calibration process where several different elements are adjusted simultaneously.

The model was calibrated to match five sets of targets:
- Tour generation by industry and geographic area;
- Tour length (number of stops in a tour);
- Vehicle type and tour purpose proportions;
- Total trip destinations for 13 super-zones, including intra-zonal proportions; and
- Number of trips within the AM, PM and combined offpeak periods.

Fits were within 5% of observed values in all cases, and many are within a fraction of a percent.

4.5 Fleet Allocator Model

The initial intention with the fleet allocator model was to establish a simulation of the fleet allocation process that would capture the relevant influences and provide an accurate trip table of vehicle movements for these fleets. A review of the Operations Research literature identified the Clarke-Wright Algorithm (Clarke and Wright, 1964) as a potential basis for such a simulation, providing a rule-based process for identifying a capacity and time-constrained, nearly-optimal minimum-cost allocation of fleet movements and an associated estimate of total vehicle kilometers travelled that included both within-zone and between-zone components. The algorithm was incorporated within the EMME/2 implementation of the regional travel model, but in testing was found to run far too slowly for practical application.

At this point a basic, aggregate generation and gravity-style distribution process was established to provide a representation of fleet allocator vehicle movements. The model parameters were calibrated to reproduce the aggregate trips and vehicle-kilometers statistics for fleet allocators, and then later adjusted as part of the calibration of the total commercial vehicle movements model as described in Section 4.7 below.

The further investigation of a faster implementation of the Clarke-Wright Algorithm or the implementation of a similar but faster algorithm is left to future development work.

4.6 External Vehicle Model

The external-internal movements model uses singly-constrained, logit-style gravity models to assign to model zones the internal ends of trips being made by trucks crossing the model area boundary. In each model the utility function for each zone includes the ‘industrial’ and/or ‘transport and handling’ employment in the zone (as an attractor) and the travel cost between the zone and the entry/exit point. There are four such gravity-style models, one for each of the following:

- medium trucks entering (where the gravity model assigns the destination zone);
- heavy trucks entering (where the gravity model assigns the destination zone);
- medium trucks exiting (where the gravity model assigns the origin zone); and
- heavy trucks exiting (where the gravity model assigns the origin zone).

In addition, small fixed proportions (around 6%) of entering trucks in both the medium and heavy categories are assigned to go straight through to exit points in proportion to the exit volumes based on the observed pattern of such movements.

These gravity-style models are applied to forecast volumes for the medium and heavy trucks entering and exiting at each external cordon point developed by extrapolating corresponding observed count volumes. They provide a small background traffic that is loaded to the road network and can change routes but is otherwise not policy sensitive.

Light vehicle commercial trips with at least one end external are not included – because the required data were not available. But, the volume of such trips is expected to be comparatively small, on the order of a few percent at most. And the treatment of vehicles trips with at least one end external in the regional travel model (ostensibly being made by households) is such that it includes the light vehicle commercial trips with at least one end external. So the lack of representation of light vehicle commercial trips in this component model is not a serious shortcoming. It merely results in a very slight underestimation of the impacts of policy alternatives accruing to light vehicle commercial trips.

4.7 Overall Results

The total commercial vehicle movements model was further adjusted to match screenline ground count as a final stage in calibration. Because there is no way to determine from ground counts if a given light vehicle is operating for commercial or personal purposes, this calibration was based on ground counts of medium and heavy vehicles. One of the reasons behind our definitions of these vehicle types, in fact, was to ensure that they were clearly identifiable by those doing the ground counts.

First, screenline totals were developed across a dozen screenlines, including cordon counts of the city boundary and CBD. The tour-based model, calibrated as above in five ways to match the survey data, was taken as accurate. The external trips were also taken as accurate, primarily because they are such a small portion of the total that it would be difficult to get a reasonable result by adjusting them. The fleet allocator trips are then adjusted using super-zone K-factors to provide a match with the screenline values. Once this is complete, the adjustments made to the medium vehicles are then applied to the light vehicle fleet allocator model, to provide the best-guess adjustments to these totals. The light vehicle commercial vehicle totals are then added to the personal vehicle model totals, and compared to the personal vehicle model screenlines. The model output is currently reasonably close, and we are improving the match.

Figures 9 and 10 provide selected flow maps from the model. The width of the link indicates the commercial vehicle volume on the link, but note that this scale is different for the maps – there is overall more light vehicle traffic than heavy vehicle traffic. Industrial areas are shaded in light grey, and the CBD is the dense network in the centre of the model region. The heavy vehicle traffic can be seen to be concentrated in the industrial areas and along major truck corridors, whereas the light vehicle traffic is more dispersed.

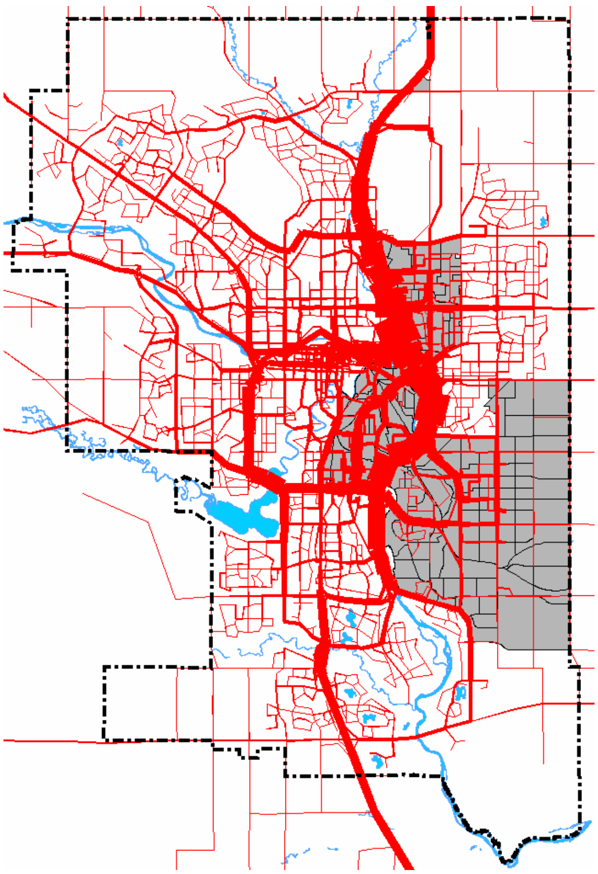

Figure 9: Light vehicle model flow volumes.

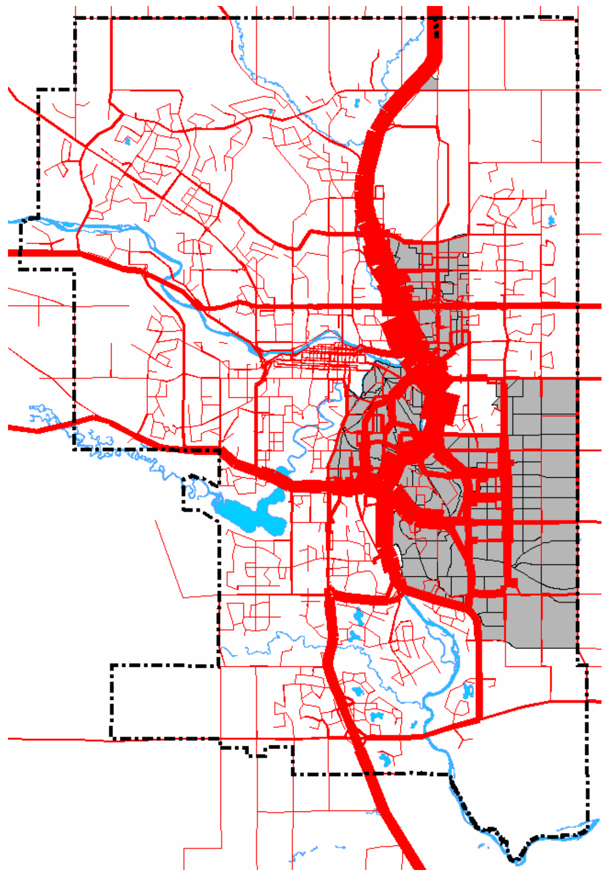

Figure 10: Heavy vehicle model flow volumes.

The impact of truck route restrictions on heavy trucks flows can also been seen in the south-central portions of the maps, where there are a variety of arterial roadways that carry sizable light vehicle flows and almost no heavy vehicle flows, because such arterials can only be used by heavy vehicles as part of the minimum-distance access or egress to the surrounding areas. There are also a number of collector distributor roads throughout the city that carry some light vehicle traffic and no heavy vehicle traffic, again, because heavy vehicles can only use these roads for access and egress.

5.0 CONCLUSIONS

5.1. Major Findings

The nature of urban commercial vehicle movement is generally poorly understood; the principles governing larger regional models are often assumed to apply to urban areas. This discounts many important elements, including the importance of trip chaining and less-than-load hauling, the significance of service delivery as a motivator for travel, and the role of light commercial vehicles. Applying the freight-only, large-truck view of commercial movements in urban areas leads to the neglect of the half of commercial trips made in light vehicles and the two-thirds of trips made for service delivery. Urban commercial movement is different from both urban household movement and regional commercial movement, and requires different modelling approaches.

The urban commercial movements model described here is a successful demonstration of several principles. It has produced a stable microsimulation, one that coexists with and appropriately supplements a deterministic aggregate model. As discussed above, by using a tour-based microsimulation, it is possible to simulate many subtle influences between a wide variety of elements in a tour, and to use the previous stops on a tour to inform future stops.

Solutions have been developed to a number of tricky problems arising in the modelling of commercial movements. The potential for double counting with transport and handling movements has been identified and a straightforward solution adopted. Truck routes have been included in a way that incorporates a representation of policy but still permits generalized cost analysis. Workable techniques for handling both aggregate and disaggregate modelling within the same model platform have been developed. In addition, the logit choice model estimation results on their own have provided clear indications of the elements that influence the decisions involved in commercial vehicle movement.

The resulting commercial vehicle movement model facilitates the analysis of both (a) the impacts of commercial vehicles on the transport system and (b) the impacts of potential policy options and infrastructure changes on commercial vehicle movements and the costs and benefits of commercial transport. This has relevance in a wide variety of areas, including emissions, congestion, pavement design, commercial development and truck route policy.

5.2. Things That Went Well

The joint approach to the work, with the Cities of Calgary and Edmonton and Alberta Transportation working as a team with coordinated survey and modelling components, was very successful – and helped make the project a success. As modelling efforts become more comprehensive and data requirements become more extensive, it was clear that the collaborative efforts by the team helped to clarify ideas, refine and improve data collection efforts, encourage greater participation by respondents, reduce workload, speed-up production and avoid mistakes.

The innovative approach developed to represent truck route regulations in Calgary, using a generalized cost function along with travel time penalties, was very successful. It worked to restrict medium and heavy trucks to designated truck routes while still allowing them to access every zone using a minimum distance on non-truck routes consistent with the regulations.

5.3. Things That Did Not Go So Well

Commercial vehicle movements are complex and heterogeneous. Data describing these movements is similarly complex and heterogeneous. There are many different establishment and commodity types, vehicle types, and many other elements. Additionally, there are no definitive 'population' totals for business firms or business establishments for use in survey expansion. All this made the development of relevant categories of data, the associated refinement of data and the expansion of the survey very difficult. Problems with a lack of information about the totals numbers of business establishments that did or did not ship eventually led to additional work being done to gather employment information from the population of both types of firms.

Most of the elements in the tour-based model are very effective, and the model represents a significant advance. But the stop duration module has some shortcomings. There are aspects of the interactions between stop duration and other elements, such as the durations of previous stops and the difference between first and subsequent stops, that this current model does not represent. A more complete representation of this aspect of commercial tours would appropriately enhance the policy responsiveness and detailed-level accuracy of the model.

Fleet allocators also warrant more attention than they have been given to this point. Operational run-time issues forced the 'stop-gap' implementation of an aggregate, generation and gravity-style distribution model rather that one based on a more direct representation of fleet allocation behaviour available with the Clarke-Wright Algorithm.

It was beyond the scope of this model, but it is clear that there are important links between transport, commodity flows and land use. A more complete spatially disaggregated input-output land use and transport model would provide a much richer modelling environment to inform the decisions made by the commercial vehicle model.

5.4. Implications and Appropriate Directions For Future Work

The model described here is a significant improvement on the state-of-the-art and its application in practice. But, as mentioned above, there is still work to be done in both Calgary and Edmonton – let alone the work to be done in other jurisdictions wishing to establish a similar modelling solution.

Until this point in the project, Calgary has been developing the commercial vehicle movements model for implementation within the broader regional transportation model framework while Edmonton has analysed the survey data and reported aggregate descriptions of commercial movements. The next step is to trade model structure for aggregate report so both centres have complete models and aggregate statistics.

There are two areas where improvement is clearly warranted: the fleet allocator model and the treatment of stop duration in the tour-based microsimulation models. Efforts are now underway to establish a faster implementation of the Clarke-Wright Algorithm as a basis for developing a more sophisticated fleet allocator model that the current aggregate generation and gravity-style distribution model. The Java-based microsimulation approach used for the tour-based model may well be the way forward on this issue.

Stop duration requires additional study to determine a better modelling strategy. It would appear that both logit choice model and hazard-duration model approaches hold promise, and will be investigated, as will the question of what sorts of data are needed to best inform the a representation of stop duration. It is expected that the individual and total durations of previous stops as well as the number of previous stops have the most influence, along with stop purpose, vehicle type and industry type, while elements such as time of day, land use and network travel times may also have more indirect but still potentially important influences.

Overall, the tour-based microsimulation approach has proven to be very successful: it delivers stable and robust answers, calculates quickly, gives great flexibility and permits very subtle influences and interactions to be modelled. On this basis, it is expected that the same sort of microsimulation approach will be used in the model of weekend household travel to be developed for Calgary in the near future – in part because of the similarities between weekend travel and commercial movements travel, where there are comparatively longer tours made with no single primary stop being evident.

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