Developing a Conceptual Framework for the Integration of Urban with International Freight Transportation Models

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Introduction

A number of stylized facts conspire to create the need for freight transportation models that are able to link urban freight transportation with the international movement of goods. These stylized facts are as follows.

First, the most acute problems associated with transportation are generally localized in cities and urban areas. To be sure, there are also sections of the highway systems in the US and Canada that suffer from large amounts of traffic congestion such as the I-95 corridor in the Northeast that are not urban *per se*. These sections of the interstate highway system are, however, generally found near large population centers.

Second, in recent years, the contribution of freight transportation to overall traffic demand at all geographical scales has been recognized as being important and has become a focus of research. Third, and coupled with this, is the fact that the amount of freight transportation is expected to increase significantly into the future as a result of trade liberalization and contemporary logistics and production techniques. As such, the link between international trade, freight transportation (urban freight transportation in particular) and the effect of this transportation on existing transportation problems is quickly becoming more germane.

Fourth and finally, while there exist methods of modeling freight transportation at the international level as well as at the regional, state and urban levels, urban models that currently exist have not been integrated with the international level models. As such, it is not possible to ask questions of the type “by how much would congestion increase in Montreal if there were a 10% increase in textile imports into Canada from

China?" Given the expected increased contribution of freight transportation to transportation more generally as well as in cities, and the fact that the most acute problems of transportation take place in cities, being able to answer questions of this type are of critical importance for the future and represent a crucial direction for future research. As such, the purpose of the work described in this paper is to develop a conceptual framework that could actually be used to integrate an urban freight transportation model of Montreal, Quebec, Canada with models describing the international movement of goods.

In order to be able to better define and understand the problem of freight model integration, the paper begins with a quick description of models that have been developed and/or applied to freight transportation followed by a relatively detailed consideration of geographical scale of freight transportation data and models. With this description it is then explained what the authors mean by freight model integration and shown that such integration does not currently exist between urban and international models. This is followed by a brief description how the authors conceive of possible freight model integration which is then followed by a description of ongoing work at McGill University aimed at integrating urban with international freight models for the city of Montreal and the country of Canada.

Freight Models, Geographical Scale and Integration

Freight Models

In order to understand what it means for freight models to integrate, the first thing to understand is just what the authors mean when they are referring to freight models. As can be seen from the (growing) literature describing freight transportation modeling (see for example (Holguín-Veras, List, Meyburg, Ozbay, Passwell, Teng, and

Yahalom 2001;Regan and Garrido 2001;Shankar and Pendyala 2001;Zlapoter and Austrian 1989;Cambridge Systematics, Leeper, Sydec, Corsi, and Grimm 1997;Southworth 2002;Friesz 2000)) there are many different analysis techniques applied to freight issues or data that have been considered as making up part of freight modeling.

Based on this literature, freight models can range from the relatively simple to the very complex. An example of one of the simpler freight models is the Economic Indicator Variables procedure for deriving forecasts of freight transport demand as described in Cambridge Systematics, et al. (1997). Examples of more complex freight transportation models include multistage network models, such as the relatively little used spatial-price equilibrium models as described by Harker (1987) or the much more commonly used freight adaptations of the traditional four-stage model (e.g. (Souleyrette, Hans, and Pathak 1996), (Cambridge Systematics 1992) or (URS Greiner Woodward Clyde 2000)).

This large number of techniques can be collected under the rubric of ‘model’ because fundamentally, a freight transportation model is a method through which to try to describe and/or predict freight transportation phenomena, generally, freight transportation traffic. It is necessary to make this explicit in its own right and out of thoroughness, but also in order to emphasize the class of freight models that we are interested in integrating.

In order to understand the types of models we are interested in, it is useful to consider what is probably the most common modeling technique in freight modeling (particularly at the metropolitan and state level), namely applying the traditional four-stage urban transportation planning model to freight. Since most readers will be very familiar with this model (or modeling framework), we will not belabour its explanation here (for a more thorough explanation please refer to Southworth (2002), D'Este (2000) or Ortùzar & Willumsen (2001).

The goal of the four stage urban transportation model (heretofore referred to as the FSM) is to be able to explain/predict freight traffic movements between discrete geographical units over a road network for a particular geographical region. As such, the region of interest is divided into Traffic Analysis Zones (TAZs), occasionally referred to as Freight Analysis Zones (FAZs). That it is called the four stage model can sometimes be a misnomer in the sense that depending upon whether freight flows or trips are the initial unit of analysis, there can be five stages.

The first of the four stages is to estimate the amount of freight *generated* in, or received by (*attracted* to) each of the zones covered in the model (Freight Generation and Attraction). It should be noted that freight movements can be estimated as either freight commodity flows or as actual vehicle trips. The second stage is to *distribute* the freight movements (flows or trips) across the entire region covered by the model (Freight Trip or Flow Distribution). That is, in this stage, the originating zones of the attracted freight movements are estimated, as are the destination zones of the generated flows. In the third stage, the mode by which freight is carried is estimated assigning the flows to rail, road, etc. or in metropolitan applications to types of vehicles. This stage is referred to as Freight Mode Choice Modeling. The need for the following stage is dependent upon the whether freight vehicle trips are estimated directly. If they are, this stage is not required. If, however, the initial unit of analysis of freight movements are commodity flows, this stage is required and involves converting freight flows into vehicular loads in preparation for the final stage. As such this stage can be referred to as Freight Flow to Vehicle Load Conversion. The final stage (Assignment) of the model takes the vehicle trips and assigns these trips to the travel network in order to estimate vehicle flows along roads, rail lines, etc.

Apart from the fact that the four stage model is so commonly used in freight research, it is also worth examining it a bit more closely because it gives a basis from which to start when characterizing the types of models that we are trying to integrate. There are two characteristics of the FSM that are useful in order to be able to understand the problem of integration, as well as the models types we are trying to integrate.

The first critical characteristic of the FSM is how the four stages of the model are an intuitive breakdown of what is required to get to the end product of the model. That is, in order to be able to arrive at a model that can assign traffic over a network, we need to know where freight trips begin and end (Generation and Attraction), by what means they are moved (Mode Split), how many vehicles these movements represent (if needed – Freight Flow to Vehicle Load Conversion), and what routes they take on their journey (Assignment).

The second critical characteristic is the fact that *the* four stage model is, in fact, not one, but multiple models used in (differing) combination with the result of reaching the final goal defined above. We say that the FSM can be used with different combinations of the models because, for example and as explained above, sometimes the stage of vehicle load conversion is not necessary. Similarly, if it were the case that there were a comprehensive origin destination freight survey undertaken (e.g. (City of Edmonton 2003)), then the only stages of the model left might be mode split and assignment.

It should also be mentioned that in the same way that there are multiple models within the FSM framework, there are also a number of ways by which each of the stages of the FSM can be modeled. For example, the distribution stage of the FSM is done most commonly through the use of "gravity models" (see for an example (Black 1999) or through regional input-output analysis (see for an example (Fischer, Ang-Olson, and La 2000)).

In order to understand the types of models we are trying to integrate, as well as what we mean by integration, it is necessary to be familiar with the breadth of models that exist as well as the main characteristics of the FSM, but it is not enough. Before being able to explain this, it is necessary first to explore concepts relating to the geographical scale of data and models. We begin by exploring geographical scale itself.

Geographical Scale

Because of the importance of the geographic dimension in understanding model integration, we take the time here to explore the concept of scale for both freight models as well as freight data. We begin by emphasizing the use of geographical scale along the strict geographical/cartographical notion of scale. Namely, the somewhat unintuitive notion that the small scale refers to large geographical areas and the large scale refers to small geographical areas.

Consider for example 2 maps. The first, a standard map of the United States covering two 11 by 14 inch pages is a smaller scale map of 1:12,000,000 where each unit on the map represents 12 million units on the ground. At this scale and size, each inch represents 190 miles on the ground. The second map, which would also fit onto two 11 by 14 inch pages of the Census Metropolitan area of Montreal (about 60 miles east-west by 50 miles north-south) would be a larger scale map of around 1:185,000. At this scale and size, each inch represents only 3 miles on the ground.

As such, when we refer to the scale of data or the scale of models, it is this definition we are using. Larger scale data are more detailed data, describing small geographical units, such as zip codes. Similarly, larger scale models are models of relatively small areas such as cities, relative to smaller scale models that might represent whole countries.

The Geographical Scale of Data

As with all models, freight transportation models require inputs and through the application of the models, outputs are produced. The outputs depend on the model but as alluded to above, the output for the models we are concerned with, are freight movements between geographical units covered by the model.

Naturally, the initial inputs to these models also vary but are essentially of two types. The first type is actual flows of commodities between the TAZs covered by the models. It should be noted that such data generally capture freight flows and not vehicle trips. Such data might come from commodity surveys such as the US Commodity Flow Survey (CFS) data or the City of Edmonton Commodity Flow

Survey Project (2003). These data can include mode information as well. As a result, having such data can obviate the need for the generation and distribution stages. If there is also mode information, the third stage can be obviated as well. If it contains information on actual vehicle movements, then the only stage left might be assignment. This type of data is generally preferred to the second type of data.

Unlike the first type of input data to freight models, actual freight flows between zonal units covered by the model are not available. In this case, there are two ways to deal with the problem of lacking input data.

One way to overcome this problem is to estimate productions and attractions of the zonal units covered by the models based upon the characteristics of the zones themselves. As such, the input data are socioeconomic data relating to the zones used in the model. This is the more common stage of Generation as described above when describing the FSM, an example of which would be the approach described in the Quick Response Freight Manual (Cambridge Systematics Inc., Comsis Corporation, and University of Wisconsin 1996). This is also generally the approach adopted when vehicle trip models are used (i.e. the initial generation stage generates vehicle trips ((Holguín-Veras, List, Meyburg, Ozbay, Passwell, Teng, and Yahalom 2001)). Once this Generation stage is accomplished, the other stages of the model can be followed.

Another method to overcome this problem that is used when modeling freight commodity flow data is to disaggregate data from smaller scale geographical units to larger scale units. The general method used can be described as by Jack Faucett

Associates (1998) as cited in (Holguín-Veras, List, Meyburg, Ozbay, Passwell, Teng, and Yahalom 2001).

> The starting point is a known region-to-region table of commodity flow tonnage based on economic output forecasts and established regional trade patterns. The region-to-region flows, depicting inbound and outbound flow patterns, are disaggregated to the zonal level based on economic data, reflective of the intensity of production and consuming industries.

As such, the input data are smaller scale commodity flow data along with economic and demographic data of the TAZs of the model. This stage is analogous to the generation stage and can then be followed by the other stages of the model in question.

This approach to dealing with the lack of data at the appropriate scale is linked to an important issue in data availability and collection. That is, that there is a tension in data collection more generally, but which is also particularly relevant to freight transportation data. It is sometimes said in economics that the only thing for which there is not a diminishing marginal rate of utility is money. We would argue that in freight transportation research, the same can be said for the increasing geographical scale of data. I.e. the larger the geographical scale of data, the better, because it is more precise and also because data could always be aggregated. Disaggregating data, however, is more complicated than aggregating, and the resulting data are less reliable. So it is that county level data are preferred to state-level data and zip code level data are preferred to county-level data, etc. The problem, of course, is that data at a larger geographical scale are more expensive to collect since there are many more units at which to collect data (i.e. there are many more zip codes than counties).

A consequence of this is that data at a smaller geographical scale are more common and more widely available than data at a larger geographical scale. As a result, the disaggregation of data is a useful technique, and a necessary concept in order to understand, what we mean by integration. Another critical element, however, is the geographical scale of models.

The Geographical Scale of Models

A sense for the diversity of freight models was described above. What was not mentioned was that there have also been a fairly large number of freight modeling reviews to capture these models. Examples of some of the main reviews as mentioned above are (Holguín-Veras, List, Meyburg, Ozbay, Passwell, Teng, and Yahalom 2001;Harker 1987;Regan and Garrido 2001;Shankar and Pendyala 2001;Zlapoter and Austrian 1989;Cambridge Systematics, Leeper, Sydec, Corsi, and Grimm 1997;Southworth 2002;Friesz 2000;Fang, Harrison, and Mahmassani 1996)). An interesting feature of these reviews is that there are almost as many model classifications as there are reviews, with different reviews focusing on different classes of models.

To give some examples, Zlapoter and Austrian (1989) focus on econometric freight transportation demand modeling where they divide the models reviewed into aggregate and disaggregate studies based on the form of the data used in the models. Harker (1987) provides a survey of network equilibrium models considering Spatial Price Equilibrium Models, Strategic Freight Network Equilibrium Models as well as others. Fang, Harrison and Mahmassani (1996) divide mode split and freight demand models into econometric and network based models. Shankar and Pendyala consider trend and time series analysis, elasticity methods, network models of logistics, aggregate and disaggregate demand models and economic input-output methods. Southworth (2002) considers primarily the different models used in the various stages of the FSM.

One trend in freight model description and classification is that models are being classified along a geographical dimension. Two recent examples: Regan and Garrido (2001) classify models between urban, intercity and international models; the newly founded FMIP classifies models (or modeling studies) into national and international, state and regional and metropolitan and local freight modeling studies. As a starting point, it is relatively straightforward to apply the concept of scale to models. Large scale models cover relatively small areas, whereas small scale models relatively large areas. However, it is worth nuancing the notion of the scale of a model.

The first nuance that is useful is that through geographical classifications of models, one gets the impression that urban models require different modeling techniques than regional or international models. While it is true that some models are better suited to different scales of analysis, often the models themselves that are used at different scales are not appreciably different, but rather what differentiates them is more where they are applied than it is the models themselves. As a quick example, we can consider the fact that the FSM or variants of it have been used extensively in urban analyses (e.g. Phoenix (Cambridge Systematics 1992)) as well as at the state level (e.g. Indiana (Black 1999). As such it is perhaps better to think of models as being *applied* to a given geographical level as opposed to thinking of them necessarily as urban, regional or international models. For ease of explanation, we continue referring to urban, regional, etc. models, but emphasize the notion that these are indeed urban, regional, etc. *applications* of these models.

The second nuance to make is that the scale of models is defined primarily by two things. The size of the zones at the focus of the analysis as well as what the focus of the analysis is.

The goal of models is to be able to answer numerous questions related to freight movements, questions such as “Is there enough capacity for future flows?” Implicit to this is the question of “where?” “Is there enough capacity in this city, state or country?” As such, one of the key determinants of the scale of the model is the focus of the analysis, be it a city, a state or a country.

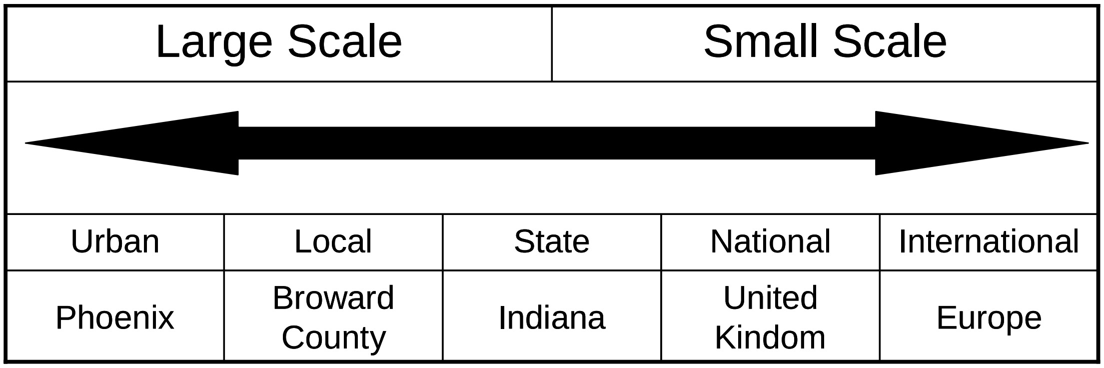
In order for the analysis to be useful in answering the questions of interest for the location of interest, there needs to be enough detail. If the interest is interstate highway movements, it might be possible to restrict detail to relatively large TAZs. If the interest is bottlenecks on a city road network, the TAZs would have to be much smaller. That having been said, it is not the case that all TAZs are of the same scale or level of detail. In order to be able to understand all the factors influencing the movement of freight at a particular level of detail in a particular location, it is necessary to consider movements from surrounding areas and how they will influence the location of interest. The further away from the center of the analysis, the less important is level of detail of these zones. If they are believed to have an important influence, they need to be added to the model. The result is that models generally contain TAZs of different levels of detail or scale. Those TAZs with greater detail are referred to as *internal*. Those with less detail but still in the model are referred to as *external*.

This notion is captured in the description of the Cross-Cascade Corridor in Washington State. Here the area of interest is an east-west corridor through mid-Washington State connecting Seattle to Spokane (HDR Engineering, Hunt, Abraham, Transystems Corporation, and Berk & Associates 2002). The model itself covers 61 zones, ranging from 25 sub-county zones, 30 county level zones and 6 *external* zones with two in Canada, and one *overseas* zone. Despite the fact that these external zones are included in the model, this model is still referred to as local. Similarly, the Florida Statewide Intermodal Highway Freight Model (as described in a study on Broward County, Florida (Cambridge Systematics 2002)) has 508 TAZs covering the entire state, and a few "external zones representing the balance of North America outside Florida." Again, despite the fact that the balance of North America outside Florida is represented in the model, the model remains a Statewide model. The reasons for the inclusion of external zones are obvious – freight movements for TAZs within the model are influenced by zones outside of the model.

To sum up, we can say that models are applied to a given geographical focus. The geographical focus of the model implicitly determines the level of detail required by the models. Those areas (or zones) that are the primary focus of the model are *internal* to the model and determine the scale of data needed for the model and thereby the scale of the model. The zones that influence the model but are not the primary focus of the model are *external* to the model.

As such, it is now possible to envision the geographical scale of models along a continuum with urban applications of models to particular cities on one end and international applications models to multinational areas at the other (see Figure 1).

Figure 1 - The Geographical Scale of Models



Some examples of the different applications of models at various scales have already been mentioned above (Phoenix, Broward County and the State of Indiana). This is not to suggest that there have not been even smaller scale applications. Examples of smaller scale models include the Great Britain Freight Model (MDS-Transmodal Limited 2003) or the Swedish Model for Goods Transport (SAMPLAN 2001) or at the international level European models of freight transportation such as (Demilie, Jourquin, and Beuthe 1997) or (Tavasszy 1997).

Model Integration

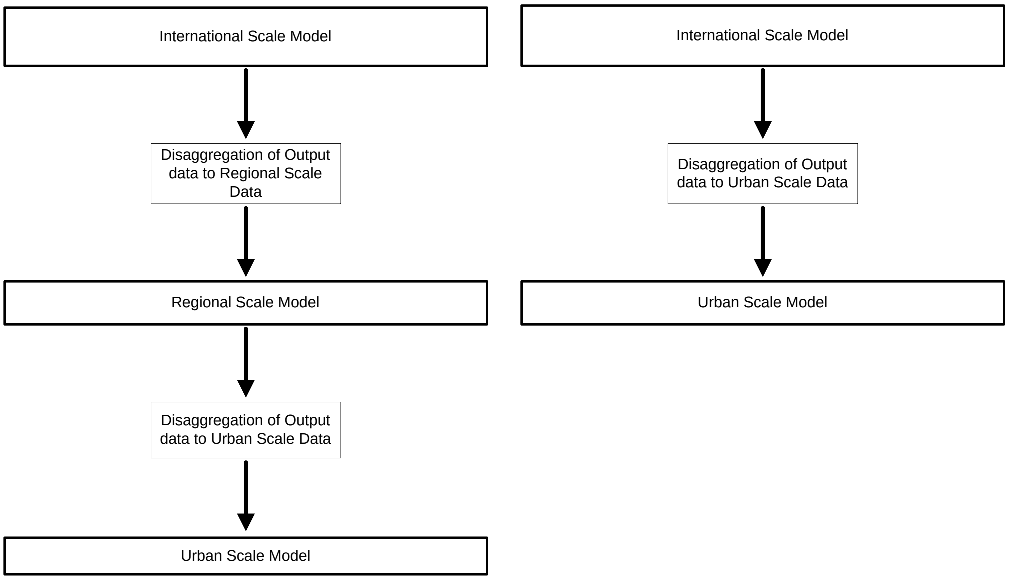
Having a better understanding of the conceptual stages in freight transportation modeling as well as a more precise understanding of the geographical scale of data and models, we can now explore the issue of model integration. To be more explicit, the purpose here is to describe what is meant by the integration of models applied at different geographical scales, heretofore “model integration.” Effectively, by model integration, we mean that the output of smaller scale models serves as an input into larger scale models. In particular, we are interested in the integration of small scale (international) models with large scale urban models. More specifically, we see integration as being a multi-stage approach whereby the output of smaller scale models is disaggregated into larger scale zonal units so that this newly disaggregated data can be used by larger scale models to predict freight movements.

To our knowledge, there has not been an attempt to do this. One possible exception is the “Conceptual Framework” as outlined in Shankar and Pendyala (2001). They describe a method by which to model freight movements from originating firms up through a series of models and then back down to the firm level in other locations. Upon writing this paper, it was not known whether this framework had been applied.

The final structure of this modeling framework is obviously by no means defined. What seems clear is that the largest scale model comprises of an urban model that will use the output of data from a smaller scale model as the starting point (i.e. productions and attractions) and then distribute, assign mode, convert flows to vehicles and then assign routes across the network. Given that integrating models is the main purpose of the work, it is likely that the largest scale model will be a relatively standard treatment at the urban level so that a version of the FSM should be envisioned.

With respect to the smaller scale model(s) that could be used for the final goal of providing data to disaggregate to the urban model, any number of scenarios could be imagined. It might be the case that an international model would provide data usable through disaggregation to a regional level model and that the output of that model could then be further disaggregated for use in the final model. It might also be the case that an international model would have enough geographical detail to be able to integrate directly with the urban model. As such, the structure of the modeling framework is by no means set (please see Figure 2 for a schema of possible integrative frameworks).

Figure 2 - Examples of Theoretical Possible Integrative Frameworks



Moreover, it is not necessary that any of the smaller scale models (smaller than the urban model) comprise all of the stages of the FSM. That is, it is not necessary that an international model produce estimates of the vehicle flows along a highway network to be used by larger scale models. In fact, the most crucial stages that any given smaller scale model would need to have would be generation and distribution, because it is only after these stages that its outputs could then be used by a larger scale model. As well, for each intermediate step (integration of a larger with a smaller scale model) there would also need to be a step of disaggregation, analogous to generation. Naturally, the existence of trade flow data to a particular scale would obviate the need for a model at that scale. No international model would be necessary if, for example, data were available on commodity flows between foreign countries and individual provinces, but rather only a provincial level model to distribute these commodity flows across the province of Quebec.

As such, the models we are considering have three characteristics. First, they are generally multi-stage (in that they are themselves comprised of sub-models). If they are not multi-stage then they are models that could be used in a multi-stage modeling process with the goal of producing estimates of freight movements between zones. Second, they are geographic in the sense that they are comprised of discrete geographical units between which freight flows are predicted. Third, they generally have networks over which freight is assigned to move between the different geographical units of the model, although as mentioned above, this is not necessary.

As such, the class of models that could be considered for integration includes freight applications of the traditional four stage model (see for example (Cambridge Systematics 2005b;Cambridge Systematics 1992)), network equilibrium models ((Harker 1987;Friesz 2000;Crainic, Florian, Guélat, and Spiess 1990), and spatial input-output freight models (see e.g. (Vilain, Liu, and Aimen 1999;Harris and Liu 1998;Fischer, Ang-Olson, and La 2000)) including land-use models (see e.g. (HDR Engineering, Hunt, Abraham, Transystems Corporation, and Berk & Associates 2002)).

The Inclusion of International Level Information in Urban Model Applications

Since the focus of this paper is how to integrate urban models with international level models, the focus of the analysis here is on urban applications and the degree to which they incorporate international level data.

It may be argued that since some urban or local scale models incorporate smaller scale data or even data from other models that try to incorporate smaller scales, that this is sufficient to incorporate an international element into models. As examples of such models we are thinking of the work undertaken for the North Jersey Transportation Planning Authority (NJTPA) (Cambridge Systematics 2005a) or in the Cross-Cascade Corridor (HDR Engineering, Hunt, Abraham, Transystems Corporation, and Berk & Associates 2002).

There are two reasons for which these studies or models do not entirely integrate the urban with the international. The first is that while these models may very well capture a great deal of international commodity flows, they do not capture them all. In the case of the NJTPA international container arrivals to the US are assigned through the New York/New Jersey Comprehensive Port Improvement Plan (CPIP) (cited on page 72 of the NJTPA report) to the ports covered in the study, but this does not include all international traffic. Although it might be the case that we are mistaken in the case of the Cross-Cascade corridor (it was unclear from the documentation available at the time of writing), it is believed that its “overseas” category is more focused towards the pacific and of not enough geographic detail to be able to isolate trade flows originating and destined to a particular country.

The second reason is that even these models that incorporate an international element have a smaller scale focus than a traditional urban model and are aimed at predicting freight movements on major highways at a regional level and not down to the micro level of traditional urban passenger models. It should be noted that the idea of integrating (at least) smaller scale local with urban model applications is not necessarily a novel idea – it is mentioned as a possibility for further model development in both the Cross-Cascade study, as well as in the Broward County study

(Cambridge Systematics 2002). To the knowledge of the authors, however, integration with the urban scale has not been done.

Towards the Integration of Urban with Smaller Scale Models at McGill

McGill University is located in Montreal, Canada. Montreal is the second largest city in Canada, home to one of the largest ports in the country and is also a manufacturing and distribution hub. It is also located in the heart of the most densely populated region in Canada, containing almost half of Canada’s population. This region known as the Quebec City – Windsor corridor is the most important freight transportation corridor of the country.

Research on urban passenger, as well as freight, transportation is undertaken in the School of Urban Planning and the Department of Geography at McGill. On the freight side, McGill has the only intercity carrier choice model for the Quebec City – Windsor Corridor and one of the only urban freight models in the country. On the passenger side, it also has a very well developed and fine grained urban transportation model that includes a well developed road, as well as public transportation, network. Moreover, the School of Urban Planning is the home of the new *Laboratory on Integrated Land Use and Modeling* that has received funding from the Canadian federal government, as well as a mandate to work on freight transportation issues. Good working relationships with municipal, regional, provincial and federal transportation agencies complete the necessary requirements for the successful development of a conceptual framework to be able to link international freight movements with movement at the urban scale in Montreal.

The broad brushstrokes of the modeling framework, as well as possible designs were outlined above. The precise form of the framework cannot be determined, however, before a great deal of research that will be elaborated over the next year. Apart from research that still needs to be done, the final form of the framework will also be determined by one overriding factor.

This critical factor is the fact that the goal of the research is to develop a framework that could actually be applied in a following stage of research. That is, it is not a hypothetical conceptual framework, but one that could be used to link urban (Montreal) freight movements to smaller scale international movements or model applications. As a result, ground work is required to establish what avenues would be open for the development of a usable modeling framework. The factors that will determine those avenues are data availability and the facility with which different models can be applied.

Data will affect the choice of model applications along two dimensions, namely input data and data required to allow the model to function. By input data we mean data that are manipulated or transformed by the model itself. For example, a gravity model requires attracted and generated flows by TAZ, or at least the socioeconomic data by zone to be able to produce estimates of these, in order to be able to distribute freight flows between all the TAZs. If these data are not available, it would not be possible to use a gravity model for distribution. Similarly, and as mentioned above, if there turned out to be international commodity flow data that had a relatively fine level of resolution (to the provincial level, for example) then there would be no need for a model that could distribute international commodity flow data to the provincial level.

The second type of data can be thought of as operating data that are needed so that the model can transform the input data. As an example consider a regional input-output model. In order for these models to function to distribute commodity flows over the geographical units of analysis, it is necessary to have a large number of 'technical coefficients.' These coefficients describe the requirements of each industry in each TAZ for the output of all other industries in all other TAZs. Without these coefficients (or these *data*) it is not possible for the model to work. Another example would be the requirement for a transportation network when trying to assign freight traffic to roads and highways.

The other constraining factor in model selection and framework development will be the ease with which models can be applied. That is, since this is an attempt to develop a workable framework and not an attempt to develop or test new modeling techniques *per se*, favour will be given to models that can be applied without a tremendous amount of work in addition to the actual use of the models themselves. This also has two dimensions. The first is related to data and is simply that models will be chosen that do not have tremendous data requirements for which data does not already exist. For example it is unlikely that a regional input-output model would be used if it were the case that there were no relatively easily available technical coefficients. I.e. it would not be within the scope of the work to develop technical coefficients so that input-output analysis could be used.

Second, while there may be several theoretical possibilities to model freight movements at a given geographical scale, rarely applied or little developed techniques are unlikely to be used. As an example, it could be argued that the way of the future for urban freight modeling is microsimulation models such as in Taniguchi and Thompson (2002) or Hunt and Stefan (2003), however, it is unlikely that they would be considered in the framework given the relatively limited experience with the application of these models.

As such, in order to be able develop and finalize such a framework, preliminary research will need to be undertaken along three main directions. The first, and to which research for this paper contributes a large amount, is research on the full breadth of models and modeling techniques that have been (or could be) used in a framework or hierarchy of models. The second direction of research will be on the types of models that exist and/or have been applied to the geographical focus of the analysis and to evaluate whether any such models could be used. An example might be the regional freight transportation model applied to the Canadian provinces of Ontario and Quebec and as described in Crainic, Florian, Guélat and Spiess (1990). The final stage will be to evaluate and research what data (both input data as well as data necessary to allow models to function) are available and at what scale for the regions of interest (international, national, regional and urban). Experience with freight modeling at McGill in the Quebec City-Windsor corridor as well as in urban Montreal means that a fair bit of this work has already been done.

Once all of these pieces have been gathered, it will then be possible to evaluate a possible framework that could be used to integrate different freight models to be able to link the international movement of goods with freight movements at the urban level. The natural next step would be to apply this framework and to ask questions of the sort “By how much would freight traffic increase on the road network in Montreal if textile imports from China were to increase by 10%.”

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