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Compendium of Tour-Based Freight Modeling Literature

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OAK RIDGE NATIONAL LABORATORY
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COMPENDIUM OF TOUR-BASED FREIGHT MODELING LITERATURE

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CONTENTS

1. INTRODUCTION

Transportation officials, metropolitan planning organizations (MPOs), and companies of varying size can all benefit from freight movement data. Obtaining freight movement data and route choice information is crucial to planning, improving current and future transportation infrastructure, locating businesses, improving efforts to streamline goods movement, especially urban goods movement, and reducing energy usage within freight transportation. Obtaining data on freight movements can also help in better planning transportation infrastructure to improve safety. Also, with increasing demands and changing consumption habits, mobility being offered as a service, and with new technologies such as 3-D printing, the landscape of freight planning is changing, as businesses compete to meet the needs of a growing customer base, while transportation planners aim at meeting these needs by maintaining and updating the transportation infrastructure.

For decades, transportation research has focused on passenger travel behavior. Much of this research has examined route decision choice and, more recently, trip chaining of personal vehicles, both individually and collectively. Discrete choice modeling has commonly been used to better understand passenger movement and predict route decisions based on geographic and demographic data from Census data and personal surveys, and micro-simulation has been used to model estimated movements through the transportation network. However, there is a growing interest in examining freight movements, and although previous research has been done to look at freight route choice regarding individual trips, there is increasing interest in freight tours.

2. TRIP VERSUS TOUR-BASED MODELING

Trip-based freight modeling is much more prevalent in the literature, as the route choice from origin (warehouse or manufacturing center) to destination (distribution center or customer) is often modeled to estimate trip production and attraction. However, there is recent interest in modeling freight tours as a means by which intermediate route choice decisions are examined. Doustmohammadi (2016) suggests that tour-based models are more suitable for considering intermediate stops and the effect that these stops have on vehicle miles traveled (VMT), which is an important consideration regarding energy usage. Trip-based models fail to include complexities and details, especially prevalent trip-chaining behavior. Although the traditional four-step travel demand model has typically been used to model passenger movements, it fails to capture information regarding the interdependency of multiple trips within tours, and thus, is not necessarily suitable for modeling freight tours within an area. "The traditional four-step approach assumes that trips are independent, and that trips between an origin-destination (OD) pair are only related to the zonal attributes and the travel impedance of the corresponding OD pair" (Wang and Holguin-Veras, 2008).

Many sources of both passenger and freight trip-based modeling are based on aggregate-level data. Aggregate models tend to calculate link and route flows by adding up individual movements, rather than relying on more basic behavioral assumptions. This type of modeling is typically less data-intensive, takes less time, and, thus, many studies have used aggregate-level data. In terms of freight models, using aggregate-level data assumes that drivers' choices are guided by a dispatcher or logistics manager and that the discrete choices are not independent of each other.

Models that use disaggregate data, on the other hand, are more suitable for modeling tour behavior and route choice, because they consider underlying decisions and nuisances within the tour of trips that the previous models are lacking. These models focus on individual vehicle movements to try to estimate the underlying decision-making process. This type of modeling is much more data-intensive, and typically relies on travel diary data and detailed information on individual behavior and choices, which can be difficult to obtain and process. According to Figliozzi et al (2007) there are five data types used to develop regional or local freight models: vehicle fleet data, vehicle flows, commodity flows, major freight generators, and major freight corridor data. These data types are necessary for both trip and tour-based freight modeling.

The design and structure of the Maricopa Association of Governments (MAG) tour-based freight model is a good example of existing tour-based models. The objective of the MAG model is similar to other tour-based models in that it estimates tours of truck trips by industry and by truck type (light-duty and heavy-duty). In the MAG model, as shown in Figure 1, choice models were developed after analyzing shipment data from various businesses. Tour generation is estimated by zone, and typically relies on zonal land use data. Individual truck movements are then aggregated to the zone level. The following diagram outlines the six choice models developed within the MAG model. These choice models are commonly used in other existing truck tour models found in the literature.

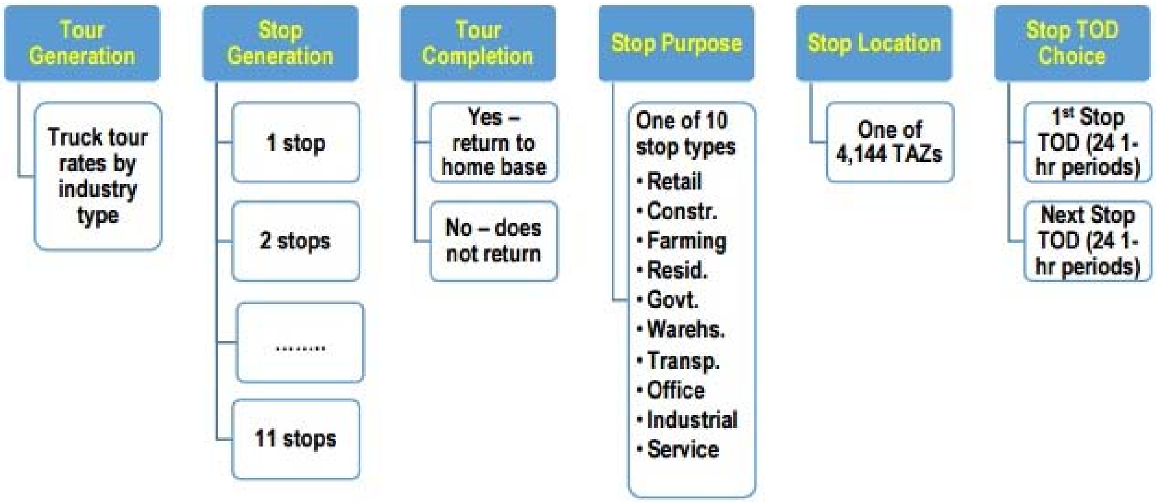

Figure 1. Discrete Choice Model Types (Source: MAG, 2017)

3. DATA SOURCES IN EXISTING TOUR-BASED MODELS

As shown in Table 1, there are several sources of data that can be used in generating route and stop choice models within freight tours, and these sources vary depending on the size and scope of the research, and the availability of data. According to Figliozzi et al (2007), confidentiality issues usually cause limitations in collecting complete and detailed freight data. In many trip-based freight studies, as well as tour-based freight studies, travel diaries and travel survey data are commonly used. The difficulty with using this type of data is in the reliability of the data: there are often reporting errors, missing data, and companies and drivers often refuse to record data for the survey due to privacy concerns.

Global Positioning System (GPS) data has been used in several studies, when it is available. The American Transportation Research Institute (ATRI) provided truck GPS data for several tour-based freight models in the literature. However, it was found that there were technical issues with using GPS data, such as losing satellite connection. Also, GPS data lacks information regarding the vehicle type, company information, among other proprietary information. Doustmohammadi (2016) stated that there are drawbacks to using GPS data, namely that it is biased because it's from a sample of the population, and it lacks vehicle type and ownership to preserve anonymity. Greaves and Figliozzi (2008) stated that GPS data can be used to complement survey data, but likely will never be a replacement for traditional data sources depicting route choice.

In numerous freight studies, driver and establishment surveys along with GPS data were used to examine stop location and duration, and time constraints associated with the remaining route when constructing tours. Details regarding the business of origin, commodity types, destination business, and characteristics of the business, such as number of employees, were also examined. Data at the traffic analysis zone (TAZ) and Census block level, such as socioeconomic and demographic data (income, education) were also used to apply zonal-level attributes to examine route choice between origin and destination pairs.

Donnelly et al (2010) used a variety of data sources to develop a micro-simulation model. The data sources and usage are similar to other studies. Commodity Flow Survey (CFS) data were used to generate value-to-ton ratios, mode shares by commodity type, and long-distance trip lengths. Vehicle Inventory and Use Survey (VIUS) data were used to generate average weekly miles for various commodities and truck classes, distribution of carrier types and truck types for each commodity, and average stops per week. Driver surveys were used to obtain average and total shipment weights for truck types. Data obtained from firms containing employment numbers helped in generating attributes specific to firm types and destination choice factors. Actual truck count data also helped in estimating imports and exports, and in model validation. These methods for obtaining data needed for micro-simulation and other model types were commonly found throughout the literature.

Table 1. Data Types

Data Type	Pros	Cons
Driver Surveys	Firsthand accounts of routes and route choice	Lacks certain details due to privacy concerns; often contain mistakes
Establishment Surveys	Contains employment information, commodity production, and building details	Lacks certain details due to privacy concerns
Zonal-Level Data	Contains demographic, business sector, and land use data	Allows for general estimation
GPS Data	Contains accurate route data (unless signal loss or user error occurs)	Lacks truck type, commodity type, and pertinent business and route choice information; biased because it's obtained from a sample
Transportation Network-Level Data	Contains estimates of freight flows for large areas	Not always suitable for local area estimation

4. MODEL TYPES

According to Holguin-Veras et al (2013), and shown in Table 2, there are currently three main methods used in tour-based freight models. These three model types include: micro-simulation, hybrid, and analytical. Both hybrid and analytical models attempt to estimate both production and attraction factors, while hybrid and micro-simulation models attempt to model representative tours.

Table 2. Model Types Distinction

Micro-Simulation Model	Hybrid- Micro-Simulation/Discrete Choice Model	Analytical Model
Models freight flows on a transportation network; generates random numbers to simulate individual movements within the network	Combination of micro-simulation and discrete choice modeling; discrete choice modeling relies on data on individual behavior to estimate route choice decisions; the results of discrete choice models are used as input for the micro-simulation	Models based on behavioral assumptions, economic principals, or statistical phenomena

4.1 MICRO-SIMULATION AND HYBRID MODELS

Several of the literature sources on tour-based freight modeling use micro-simulation to model individual freight movements. Micro-simulation models are commonly found in traffic engineering and transportation network research as they are useful in modeling flows through a network by combining least cost path analysis with network congestion levels. In several of the literature sources, micro-simulation is combined with discrete choice models. In these hybrid models, regression and logit models are used to determine stop locations and durations, and micro-simulation is then used to model the movements on the network.

Agent-based models are also found in several of the sources of literature on tour-based freight modeling. These model the behavior of individual agents and then aggregate the agents to model the larger system behavior. Agent-based freight models consider the individual, autonomous movements of freight and the effect that these movements have on the entire freight network, and the transportation network in general. Donnelly et al (2010) developed an agent-based micro-simulation tour-based freight model for Oregon, as part of the Oregon Statewide Integrated Model (SWIM2). Economic drivers, mode choice, presence of trans-shipments, exports/imports, shipment generation based on information from individual firms, destination choice, carrier and vehicle choice, and tour optimization specifications (shortest path), were all considered in this model. The purpose of the study was to model freight flows by commodity and truck type. Because it was agent-based, and involved micro-simulation, it modeled individual shipments of specific commodity types with varying truck dimensions to provide a detailed representation of freight flows within Oregon.

Gliebe et al (2007) developed a disaggregate micro-simulation model for Ohio using establishment survey data collected by the Ohio Department of Transportation (DOT). The model, which was called the Disaggregate Choice Model (DCM), used binary choice, multinomial logit, and probabilistic drawing from empirical data to develop a dynamic activity choice model. In this particular type of model, activities and locations are assigned to each vehicle, and destination alternatives are assigned varying levels of attractiveness, which ultimately determines the individual driver's choice in choosing the alternative. This type of model was appropriate for estimating locations for tour stops or destinations based on tour purpose.

Stefan and Hunt (2005) developed a disaggregate tour model for Calgary, Alberta, Canada using agent-based micro-simulation and Monte Carlo techniques, in which the Monte Carlo probabilities for logit model coefficients are estimated using data on observed behavior. The model, which was called the Commercial Vehicle Model (CVM), differed from the Disaggregate Choice Model (DCM) by selecting a stop duration based on a distribution of stop durations specific to that particular activity associated with the stop.

Boerkamps et al (1999) developed a micro-simulation model called GoodTrip, which modeled intra-city freight tours. For the case study, goods shipments for the City of Groningen, Netherlands were obtained through survey data. GoodTrip used the locations of consumers, supermarkets, hypermarkets, distribution centers, and producers as network nodes. A shortest path routine was used to assign tours by mode to the transportation network. The objective of the study was to look at the reduction in city-wide emissions by locating an urban distribution center (UDC), or central short-term goods storage facility, within the city to reduce intra-city tour mileage.

GPS provides a way to collect very detailed data on freight movements. Although obtainment of proprietary shipment data from a parcel delivery service is rare, ATRI and travel data measurement companies are often the sources of GPS data used in tour-based freight models. Kuppam et al (2013) used ATRI GPS travel logs of truck tours from companies collected by MAG, and truck GPS data obtained from StreetLight, as part of the development of the Mega-Regional Multi-Modal Agent-Based Behavioral Freight Model, which was also a hybrid model. A multinomial logit model was used to assign utility to stop choices to determine stop frequencies of tours. A binomial logit model was used to estimate whether a truck returns to its origin. A multinomial logit model was developed to predict the land use type, although GPS data could have also been used to determine land use types. Based on the results from this study, the authors concluded with the recommendation of using GPS data for developing truck tour-based models.

Doustmohammadi (2016) also used GPS data obtained from ATRI for the Birmingham, Alabama region to develop a tour-based model to compare with the Birmingham MPO's trip-based model. The methodology used was similar to Kuppam et al (2013). The model considered tour origins per TAZ. It also used socioeconomic data for TAZs as predictor variables. ArcGIS was used to model the zonal boundaries and road network. Percent root mean squared error was calculated for the original trip-based model and the tour-based model to determine model accuracy: the tour-based model was more accurate. The trip-based model underestimated afternoon rush-hour and nightly truck traffic and overestimated morning and midday truck traffic. The authors of the study found that modeling discrete tours was more accurate than modeling zonal averages.

Outwater et al (2012), along with Resource Systems Group Inc., with the Chicago Metropolitan Agency for Planning (CMAP) and the University of Illinois at Chicago developed a hybrid model. This study had a national focus, looking at supply chain buyer-supplier pairs, and then allocated these freight movements for the pairs using the Freight Analysis Framework (FAF) network. They obtained survey data from a variety of sources, including: the Phoenix Internal Truck Travel Survey, Texas Regional Commercial Vehicle Survey and Model from the Texas Department of Transportation (TX DOT), Toronto: Region of Peel Commercial Vehicle Survey, Tokyo Metropolitan Goods Movement Survey and Model, and the Portland, Oregon MOSAIC Model (which used data from the Canadian National Roadside Survey, surveys from Michigan and Oregon using the Surface Transportation Board's Carload Waybill Sample for rail, and data from the Commodity Flow Survey (CFS) and Vehicle Inventory and Use Survey (VIUS) for carrier types). A multinomial logit model was developed to determine mode and path selection consideration times, costs, shipment characteristics, and distribution channel characteristics. The output of the national-level model included shipments by mode and path for origin-destination pairs in the U.S. Origin-destination pairs from the national model were used in the Chicago regional-scale model as internal and external shipments into the region.

4.2 DISCRETE CHOICE MODELS

Ruan et al (2012) developed a discrete choice model without the use of micro-simulation, and also used data from the Texas Regional Commercial Vehicle Survey looking specifically at the San Antonio region to develop a tour-chaining model. Tour types were defined as: single direct, peddling (multiple tours with multiple stops), multiple direct (vehicle makes multiple direct OD runs), multiple peddling, and mixed (multiple tours with direct and peddling). Discrete choice models were developed considering 1) daily tour chaining (single direct, single peddling, multiple direct, multiple peddling and mixed) using multinomial logit and nested logit models and 2) individual tour with choice of direct or peddling, using binary logistic regression. The methods used in this study considered tour chaining, rather than individual tours, in order to uncover the interrelatedness of individual tours in a day.

4.3 ANALYTICAL MODELS

There are varying types of analytical models found in the tour-based freight modeling literature. Entropy maximization, gravity models, equilibrium models, and various regression models were all found in the literature. The model type used obviously depended upon the data availability, but also the scope.

4.4 ENTROPY MAXIMIZATION MODELS

In several of the tour-based freight modeling literature sources, entropy maximization models are found to be useful in modeling production and attraction factors in the transportation network. Wang et al (2008) used data obtained from the Denver Regional Council of Governments (DRCOG) to develop an aggregate entropy maximization tour-based model. The data were collected for the Denver Metropolitan area using a travel behavior inventory survey of businesses. The survey considered business characteristics, vehicle ownership, and commercial vehicle travel to estimate tours. The aggregated tour flows for the study area were used to estimate the number of trips by TAZ and total impedance, which were to be used as inputs for the model. Individual tour data were used to determine coefficients for the set of constraints in the model. The researchers used entropy maximization to estimate trip production and attraction factors at each node within the network.

Holguin-Veras et al (2005) also developed an aggregate-level entropy maximization model using commercial vehicle data collected by DRCOG to estimate a trip matrix. The model estimated tours at three levels: micro (individual trips to and from a location, creating a tour), meso (number of tour flows), and macro (total trips produced at a node, and attracted at another node). Observed trip chain patterns, vehicle categories and trip purposes, number of trip chains and number of stops per trip chain, length of trip chain, and conditional probabilities of trip purposes were all estimated in the model.

You (2012) also developed an entropy maximization model estimating tours with origins and destinations at the Ports of Los Angeles and Long Beach, California. The study found that the tour-based entropy maximization model using GPS data considered the direction of freight movements, and was suitable for converting trip data to tours. It was also suggested that the Inverse Selective Vehicle Routing Problem is suitable for building an urban truck distribution model using GPS data.

4.5 GRAVITY MODELS

Gravity models have been widely used in freight network modeling, and trip and tour-based modeling literature and are suitable for modeling the relationship between places, such as traffic analysis zones (TAZs). With gravity models, it is assumed that there is a negative relationship between attraction and distance. Kim et al (2011) developed a gravity model considering destination attractiveness and costs of trips between TAZs in and around Seoul, South Korea. For this study, survey data of truck trips and data from 248 TAZs from 2005 were obtained from the Korea Transport Institute. Truck trip data was separated into primary and intermediate trips. Socioeconomic data, land-use attributes, and geographic characteristics for each TAZ were obtained. Land use characteristics for each TAZ were considered, such as the existence of industrial complexes or bodies of water. The results from the model suggested that trip distance, accessibility, and the presence of an industrial complex were important explanatory variables.

Figliozzi (2007) constructed a vehicle tour routing problem, which examined vehicle tours relative to their routing constraints using several datasets used in previous tour-based modeling studies. One key finding from this study was that deadheading, or the return trip to a warehouse with an empty trailer, did not decrease efficiency of tours. This study found that the distribution of trip lengths and the average trip length, the distance from the warehouse or central distribution center to the destination location, and the number of stops in the tour were all associated with tour types.

Greaves and Figliozzi (2008) successfully used GPS data in a study of Melbourne, Australia. In this particular study, one week of passive GPS data from 30 trucks delivering office supplies, paper, restaurant foods, quarry materials, and general freight were used to determine routes and obtain average tour lengths and speeds. The GPS data were processed and modeled with Caliper's TransCAD software to calculate a shortest path to determine the tour routes. TransCAD software was commonly used to develop tour-based models, especially modeling TAZs, and was useful in micro-simulation of freight flows along the road network.

Figliozzi et al (2007) analyzed a dataset of LTL (less than truckload) delivery tours in an area of Sydney, Australia. The data were analyzed with respect to periods of congestion within Sydney to examine effects on route choice. The distribution of empty trips within tours, tour length, and average speed of trips within tours were also examined.

In a similar analysis using a different location, Beziat et al (2015) analyzed survey data from drivers and businesses within the City of Paris, France. Driver surveys, establishment surveys, and additional information regarding commodity types were obtained. Regression models were developed to examine the influence of commodity types and business characteristics on the number of stops within tours and the length between stops.

4.6 EQUILIBRIUM MODELS

Equilibrium models, which attempt to model flows and costs on the transportation network, and are commonly found in traffic assignment modeling, were also found in the tour-based freight modeling literature. In 2016, as part of the Strategic Highway Research Program (SHRP2 C20) Freight Demand Modeling and Data Improvement Strategic Plan through the Federal Highway Administration, Winston-Salem, North Carolina's MPO began leading the Piedmont Triad Regional Model (PTRM) Team: Piedmont Authority for Regional Transportation (PART), along with the North Carolina Department of Transportation (NCDOT), and neighboring MPOs to develop a freight node database for the region using targeted freight facility survey data in order to develop a tour-based freight model. The PTRM is a multi-modal four-step travel demand model used by local planning agencies. The freight node database currently includes: location of facilities (with help from business listings and chamber of commerce data), number of employees (North American Industry Classification System), and business sector type. The project team conducted a random sampling of the facilities and obtained completed survey results from 151 of the 968 facilities in their database. The survey data contained information regarding average number of employees, building square footage, number of truck bays (using aerial images), and daily truck traffic. The study is ongoing, and the survey data, along with economic forecast data, and freight flows from the FAF will be used to develop equilibrium and dynamic traffic assignment models.

Table 3. Summary of Existing Sources

Author(s)	Year	Model Type	Data Type	Data Source	Application
Beziat et al	2015	Analytical	Driver and establishment surveys	City	Paris, France
Boerkamps et al	1999	Micro-simulation	Establishment surveys	City	Groningen, Netherlands
Donnelly et al	2010	Micro-simulation	Driver and establishment surveys; commodity flow survey	City	Portland, Oregan
Doustmohammadi	2016	Hybrid	GPS	ATRI	Birmingham, Alabama
Figliozzi	2007	Analytical	Variety	Previous source	General
Figliozzi et al	2007	Analytical	Truck routes from freight forwarder	Freight in forwarder in Sydney	Sydney, Australia
Bliebe et al	2007	Micro-simulation	Establishment surveys	Ohio DOT	Ohio
Greaves et al	2008	Analytical	GPS	Company data	Melbourne, Australia
Holguin-Veras et al	2005	Analytical	Commercial vehicle survey data	DRCOG	Denver, Colorado
Kim et al	2011	Analytical	Driver and establishment surveys	Korea Transport Institute	Seoul, South Korea
Kuppam et al	2013	Hybrid	GPS	ATRI/MAG	Phoenix, Arizona
Outwater et al	2012	Hybrid	Establishment and commodity surveys; FAF data	MAG, TXDOT, Toronto, Canada Portland, Oregon	Chicago, Illinois
Ruan et al	2012	Discrete Choice	Commercial vehicle survey data	TXDOT	San Antonio, Texas
Wang et al	2008	Analytical	Establishment surveys	DRCOG	Denver, Colorado
Winston-Salem MPO	2016	Analytical	Driver and establishment surveys; FAF	PART, NCDOT	Winston-Salem, North Carolina
You et al	2012	Analytical	GPS; establishment surveys	Ports of L.A. and Long Beach, California	Ports of L.A. and Long Beach, California

5. SUMMARY OF FINDINGS FROM THE LITERATURE

There are multiple methods for developing a tour-based freight model, and the model framework ultimately depends on the goal of the model (size and scope of study area) and the availability of data, as shown in Figure 2. In many of the studies outlined in this literature review, proprietary shipping data from companies were not available, and thus, researchers used methods to estimate routes and potential locations for stops within freight tours based on business, economic, Census, freight flow, and personal survey data at varying geographic scales.

As shown in Table 3, based on the findings from the literature, hybrid models appear to be the method of choice: using both micro-simulation and the development of discrete choice models to determine stop preferences. GPS travel log data obtained from ATRI and other travel data measurement companies were also commonly used throughout the literature as a to evaluate accounts of route choice to supplement actual stop location data obtained from surveys. Access to actual proprietary shipping data from companies within a city or region will obviously provide researchers with more accurate depictions of route choice and stops to develop realistic tour-based models. In doing so, transportation planners can then use these tour-based models to thoroughly examine the transportation infrastructure, and better determine long-term effects on the natural and built environment.

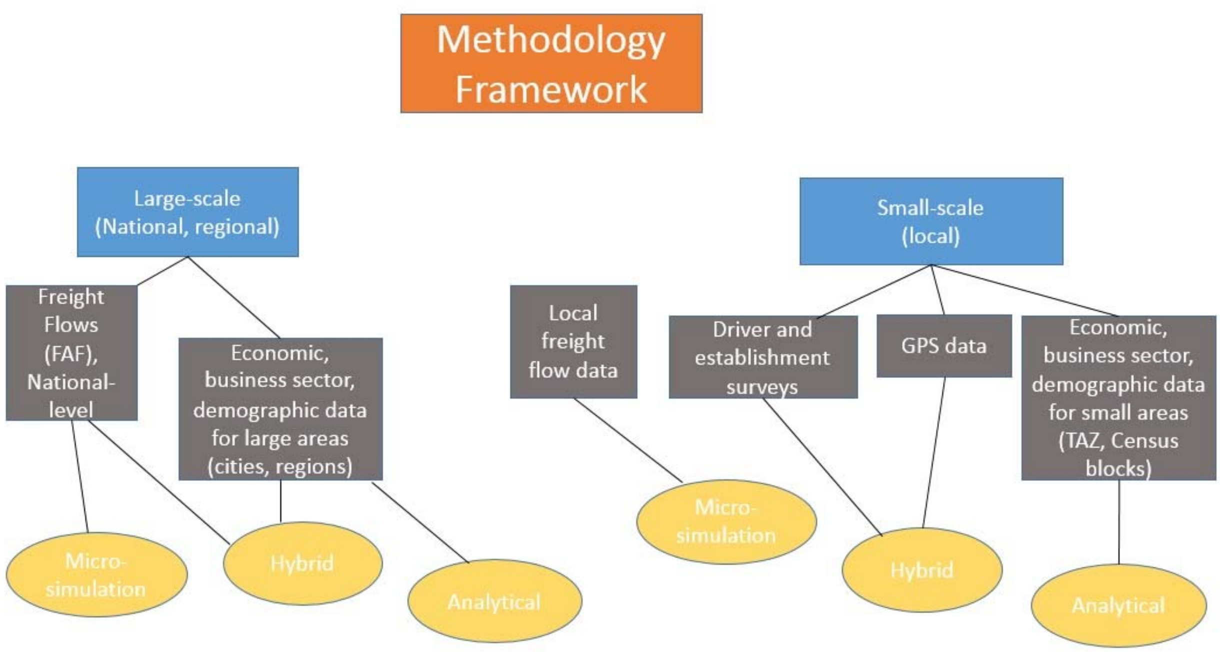

Figure 2. Scope of Models and Data Types

5.1 THE IMPACT OF CHANGING TECHNOLOGIES

Although there is not an abundance of literature on tour-based freight modeling and implementation, there are many examples to draw from when developing a methodology framework. Although the sources mentioned previously vary in the data used and models developed, there is an overarching theme present: modeling traditional freight movements with existing or outdated technology. What is currently lacking in the literature is the consideration of changes in the manufacturing and movement of goods, changes in service, and especially in changes in vehicle types and technologies, as well as how changes in existing freight routing decision variables can affect safety. These issues need to be considered in future tour-based freight modeling efforts.

5.2 3-D PRINTING

In terms of changes in manufacturing affecting the existing freight network and modeling practices, additive manufacturing, or 3-D printing, should be considered. As advances in 3-D printing technologies help in making ownership, maintenance, usability, and availability of 3-D printing facilities more commonplace, consideration should be given to how this will affect overall freight movements. The shipment of many types of manufactured components will decrease, while the shipment of printers, parts, and even plastic pellets will increase as the use of these devices and services expands. How this will affect the manufacturing of items should be considered. Existing facilities and data regarding the expected growth of these types of facilities and the products produced by 3-D printing should be examined to determine potential expansion and influence on the current freight network and tour generation.

5.3 MOBILITY AS A SERVICE

With the growing popularity of online shopping and the use of services such as Amazon Prime, door-to-door deliveries are steadily increasing as many people are opting to do the majority of their shopping online as opposed to shopping at brick-and-mortar stores. New companies are emerging such as Roadie and other Uber-style delivery companies, where mobility is offered as a service, and should be considered when modeling freight tours. Changes to existing companies' freight delivery methods, even having employees deliver items purchased online to customers nearby on their way home from work (as recently proposed by Walmart), will also affect the freight network.

Alternatives, such as those previously mentioned, are being used to cut costs for businesses, and can appeal to customers by reducing purchase costs and even eliminate shipping costs for the customer. These methods also tend to align with efforts to reduce emissions, by creating the opportunity to move goods more efficiently (by someone who is already en-route to a given destination) and by using alternative transportation (Roadie uses bicycles for some intra-city deliveries). These new approaches appeal to both businesses and customers wanting to reduce their carbon footprint. These services also appeal to those who want more immediate shipping options from nearby businesses. All of these issues should be considered when developing tour-based freight models, as they have an effect on the current freight network, and have an effect on a local level (neighborhoods) rather than simply considering shipments from warehouse to store or other distribution center. These new services can be incorporated into current methods to improve efficiency and in efforts to reduce emissions during tours.

5.4 NEW FREIGHT MODES AND TECHNOLOGIES

Another consideration that is lacking from the current freight tour literature is the development of new transportation technologies and the effect of these technologies on the existing freight network and freight movements. Electric vehicle usage is increasing, and will significantly decrease emissions. The use of electric vehicles for freight movements should be considered, especially for local tours. How the increasing usage of these vehicle types affects emissions locally and regionally, determining the location of charging stations and how this affects route choice decisions, and the effects that these vehicle types have on neighborhoods (possibly reducing air and noise pollution levels) should all be considered when developing local-level tour models. Autonomous vehicle usage should also be considered, as advancements in autonomous vehicle technology will likely lead to more of these vehicle types being used for deliveries and long-haul freight shipments in the near future, which will have an effect on efficiency and travel times, as autonomous trucks will not have the rest periods that are required for long haul truck trips.

Recent advancements in the development and implementation of drones for delivery purposes should also be considered in the literature. As companies like Amazon and UPS are experimenting with the use of drones for local deliveries, these technologies should be incorporated into advanced models as they are considered for making door-to-door deliveries during tours. The next generation of freight models should be able to analyze how drone usage will affect emissions, energy usage, and efficiency of completion of tours.

5.5 SAFETY CONCERNS

As the frequency of freight movements increases, mitigating the negative effects on the existing transportation infrastructure needs to be addressed, at national, regional, and local scales. Ways to reduce truck and passenger vehicular collisions should be examined, and this can be done by considering new freight modes and incorporating new safety practices. As demand increases, and online shopping and door-to-door deliveries increase, while shopping at brick-and-mortar stores decrease, this increased freight traffic affects congestion, adds to wear and tear on the existing transportation infrastructure, increases pollution levels, and even increases the risk of pedestrian vehicle incidents in neighborhoods and areas frequented by pedestrians and bicyclists. As shown in Figure 3, these issues need to be taken into consideration when examining routing decisions and when making changes to the current freight network infrastructure.

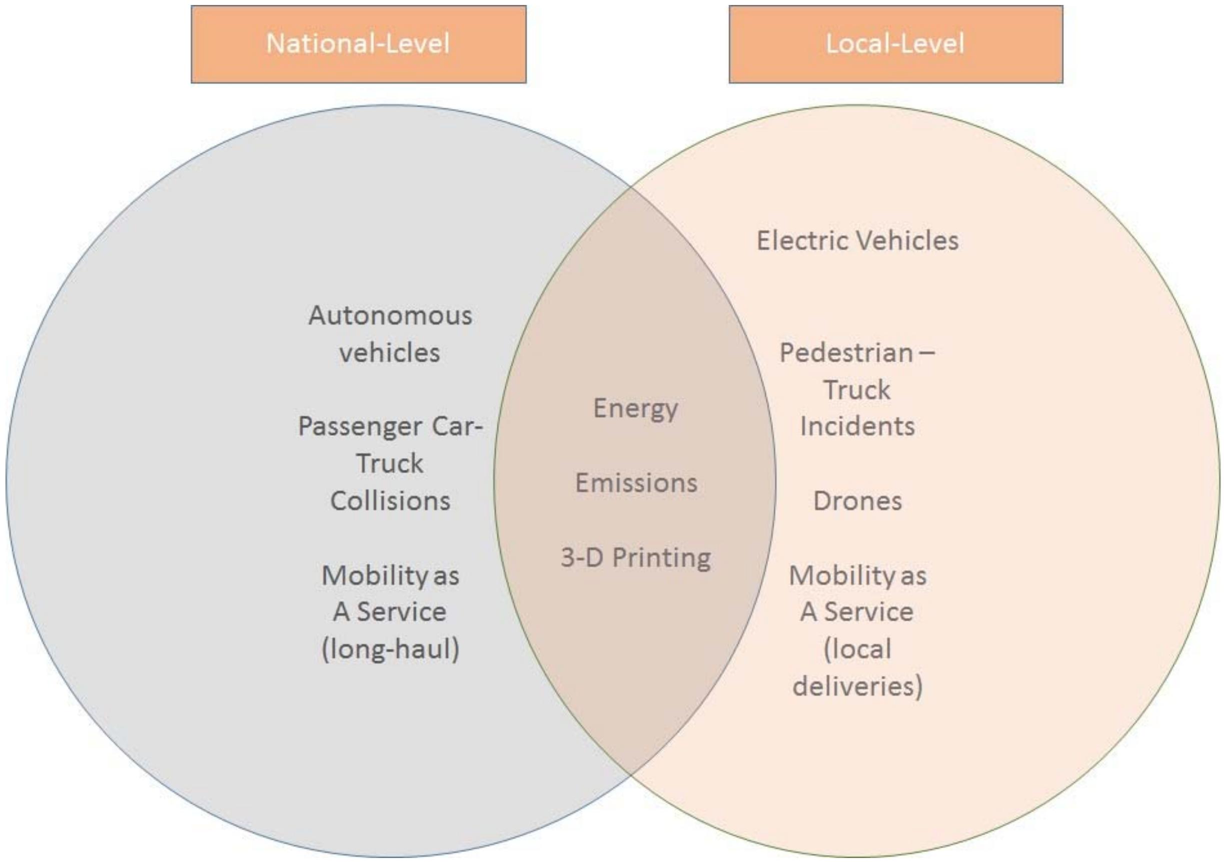

Figure 3. Considerations at National and Local Level

6. CONCLUSION

Tour-based freight modeling, although only recently becoming part of the transportation and freight modeling literature, is crucial to transportation planning and engineering. Whereas trip-based freight models adhered to the traditional four-step travel demand model and were commonly used in modeling passenger vehicle movements, the importance of modeling tours has been realized as a means by which the underlying route decision process is modeled.

An abundance of surveys, GPS data, and economic and business profile data are available for model development, but proprietary data from shippers would improve model development and aid in accurately depicting freight movements at varying geographic scales. As is evident in the literature, the model type used will ultimately depend on the scope of the research and the availability of data. Currently, micro-simulation, hybrid (micro-simulation and discrete choice modeling), and analytical models are the three main model types used in tour-based freight modeling, with hybrid being the most common.

Although there are several sources of tour-based freight models that an MPO or other planning entity can refer to when developing a model for another location, these sources are still missing pertinent information regarding changing manufacturing practices, evolving vehicle technologies, improved delivery systems and technology, and crucial safety issues. Considerations should be given to these issues in order to better model the existing, and quickly changing economic landscape.

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