Freight and Land Use Travel Demand Evaluation: Final Report

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16. Abstract This report identifies and documents best practices and tools for better understanding and analyzing how land use, local economic development, and demographic factors drive freight movement, trip generation, and freight demand analysis. The report includes a literature review.		
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EXECUTIVE SUMMARY

The transportation planning profession is experiencing a paradigm shift in the way programs and projects are developed, evaluated, implemented, and maintained for all travel modes and purposes. The most recent Federal transportation and authorizing legislation, the Fixing America's Surface Transportation (FAST) Act, placed greater emphasis on freight and goods movement. Freight transportation drives economic prosperity. Transportation and land use planners, practitioners, and decisionmakers are looking for ways to maximize productivity while also considering the effects of technological and societal trends (e.g., e-commerce and an overall increased demand for goods movement). These stakeholders must also consider how to effectively utilize improved supply chain data. Finally, stakeholders need to better understand economic trends impacting private sector operations/business models to develop and implement effective multimodal transportation policies, programs, and projects.

This report identifies and documents best practices and tools for better understanding and analyzing how land use, local economic development, and demographic factors drive freight movement, trip generation, and freight demand analysis. The primary intended audience is transportation and land use planners, travel demand modelers, and transportation engineers at multiple levels of government.

Some of the recommendations from this project will be incorporated into an update to the Federal Highway Administration (FHWA) Quick Response Freight Manual (QRFM). The QRFM provides information on the freight transportation system and factors affecting freight demand, helps locate available data and freight-related forecasts, and guides the application of this information for developing freight forecasts. It provides techniques and transferable parameters for freight modeling and freight site planning.

This project encompassed a series of activities, each of which built upon previous findings to provide a comprehensive understanding of the state of the practice. These activities reflect different stakeholder views that were solicited during the process. Stakeholders provided perspectives on an array of topics, ranging from challenges and gaps to suggestions about key products and attributes for future development.

The project's key findings include the following:

The QRFM was a helpful resource and practical research catalyst, but should be updated to reflect contemporary issues and trends. Historically, the QFRM has been one of the FHWA's key freight documents and a driver/foundation for the last ten years of freight travel demand analysis. However, the QRFM's substantive content and format need to be updated to reflect changes in the practice as well as the growing audience for freight issues and decisionmaking.

Most analytical needs for freight data and research are well-documented, but there is less clarity and agreement on how to address the gaps. One of the first steps in the second Strategic Highway Research Program (SHRP2) Freight Modeling and Data Improvement Program was to develop a comprehensive list of needs by freight travel demand users and those who make freight-related decisions. The SHRP2 Program developed new tools to address some of these needs. A future QRFM update could address these issues and support ongoing freight research efforts.

The definition of what constitutes freight is changing. The advent of e-commerce and on-demand deliveries has dramatically changed Americans' lives as well as the freight industry and planning fields. Many freight practitioners are experiencing challenges in how to best capture, analyze, and apply data on new trends for more effective decisionmaking.

Integrated land use, transportation, and economic modeling frameworks continue to advance, but knowledge and adoption challenges remain. Freight demand models have typically been based on population, employment, and industry-level forecasts. New models are emerging to better integrate land use, transportation, and economic activity. Widespread use of these advanced modeling tools remains a data and operational challenge.

Successful freight analysis and planning requires more diverse and broader sets of stakeholders. A more diverse group of stakeholders is needed to address challenges, including local transportation and land use planners, private industry, and elected officials.

Future products should present a set of emerging practice options, not just best practices. Given the diverse scales and contexts, it is important to not provide a "one-size-fits-all" approach, but rather sets of solutions.

From these findings and stakeholder input, a series of topics were developed, and detailed in this report:

1. Topic A covered the overall integration of land use and freight planning.

2. Topic B addressed last-mile considerations.

3. Topic C included freight modeling framework issues.

4. Topic D concerned the application and integration of public and private data sources.

5. Topic O includes elements not necessarily integral to the four topics listed above, but rather reflected new materials and practices that are ready for inclusion in the QRFM.

Each topic summarizes the relevance of certain subjects to the land use/demographics focus of this project. The purpose is to highlight best practices for understanding how land use, local economic development, and demographic factors drive freight trip generation and freight movement. The report also identifies best practices and tools for analyzing freight demand at a range of scales from statewide or regional modeling to local transportation analysis. Where general consensus exists on guidance that is ready to be put into practice, recommendations are provided on source materials that might be included in the QRFM. Where the sense is that further research and development is needed before a tool or approach can be put into widespread practice, that information is described as well.

This report serves as a strategic action plan to improve the integration of land use and demographic factors with freight demand analysis. It serves as a resource for continuing efforts by FHWA and its partners in the community of practice to improve planning for goods movement.

SECTION 1: INTRODUCTION

The ways in which freight and goods movement occur are changing, as are the tools used by the private and public sectors to define and measure performance. Goods movement is recognized as a principal driver of economic prosperity, but in an increasingly information-based economy, the traditional definition of what constitutes freight is changing. Advancements in data collection and analysis have vastly expanded analytic capabilities; often there is too much data, rather than not enough. This has resulted in an explosion of information, giving a greater array of robust, data-driven, analytic tools; a wider distribution of tools, and increased communication of analytic results to broader audiences (see Table 1).

Table 1: Current Context for Goods Movement and Land Use Planning

CURRENT PLANNING CONTEXT	
INFORMATION EXPLOSION	
	-New Data
	-More Practitioners
	-Larger Audience
GOODS MOVEMENT STATE OF THE PRACTICE	
	-Telematics
	-Technology
	-Societal Trends
	-Economic / Freight Trends
	-Improved Freight Data
LAND USE / DEMOGRAPHICS	
	-"Ds" Relationship to Freight (Density, Diversity, Design)

Planning and designing the built environment is viewed increasingly as a means for enhancing transportation system efficiency through more effective multimodal use. The importance of a context-sensitive approach to integrating land use and transportation applies to the assessment of freight travel demand and the provision of transportation supply. Previous studies have addressed how the "Ds" of land use (e.g., density, diversity, and design) affect auto trip and vehicle miles traveled (VMT) generation. Far less information exists regarding truck trip generation.

In the last decades, goods movement practices have led to land use changes such as increased development of intermodal logistics hubs, larger regional distribution centers, and freight-oriented development around gateways such as airports, intermodal rail, and ports. Some communities are promoting economic development centers that cluster freight and logistics with other related industries and supportive businesses.

This report describes the findings of a project led by the Federal Highway Administration (FHWA) to consider the current state of the practice for integrating goods movement and land use planning. This report—and its companion literature review— summarize the types of planning approaches and tools that are expected to help planners implement sound freight planning policies, plans, and projects. This report focuses on integrating land use and socioeconomic trends into transportation planning processes. Section 1 describes the project purpose and approach. Other sections and chapters describe the findings and proposed

approaches for FHWA and partner agencies to implement more effective freight planning practices.

PROJECT PURPOSE

The purpose of this Freight and Land Use Travel Demand Evaluation study was to identify and document best practices and tools for analyzing how land use, local economic development, and demographic factors drive freight movement, trip generation, and freight demand analysis. Research efforts include defining the need for improved freight and land use modeling techniques that are of the greatest value, and considering the most effective format for new freight data products.

This study serves as a resource for continuing efforts by FHWA and its partners in the community of practice to improve planning for goods movement, such as the forthcoming update to the Quick Response Freight Manual (QRFM).

PROJECT APPROACH

The study authors acknowledge there is extensive research on personal travel with a more limited set of similar studies on goods movement. This project focused on a combination of research activities supplemented by various stakeholder outreach activities, including a virtual meeting with practitioners and expert working session. A summary of stakeholder outreach activities is presented below. Additional details on the project approach are included in Appendix A.

- *Outreach during the 2017 Transportation Research Board (TRB) Annual Meeting*–This outreach solicited input and marketed the next event (i.e., Virtual Meeting #1).

- *Virtual Meeting #1*–Held as part of FHWA's monthly freight webinar series, this meeting was an informational webinar supplemented with open discussion to validate the literature review findings and understand the challenges practitioners are facing that were not previously captured.

- *Expert Working Session*–Presented a draft set of topic matrices to freight planning experts. This meeting focused on reviewing the research and refining the best practices and tools based upon their collective expertise.

- *Virtual Meeting #2*–Provided experts from the working session mentioned above an opportunity to review and comment on the draft final technical report and its findings.

TECHNICAL REPORT ORGANIZATION

This document reflects the findings from all project activities. The subsequent sections include:

Key Findings–Includes important synthesized findings from the different activities that formed the development of the topic matrices.

Topic Matrices–Provides summaries of both practice-ready materials for inclusion into the QRFM update as well as key gaps in best practices and how those gaps might be filled.

Recommendations and Next Steps–Provides final thoughts and specific ideas for the QRFM update.

*Appendice*s–Includes important supportive information.

SECTION 2: KEY PROJECT FINDINGS

This project began with a literature review and moved on to the expert working session, each phase building on previous activities to provide a clearer understanding of the state of the practice. The findings presented in this section reflect all of these activities, as well as the different stakeholder views solicited as part of the project efforts. These views provided perspectives on challenges and gaps as well as products for future development.

THE QRFM REQUIRES UPDATING

The current QRFM was developed in 2007 and requires updating to capture changes in the transportation and freight industries. While gaps in freight data still exist, there have been significant strides in data collection methods and sources as well as technological advances in the freight industry, including some of the initiatives listed in Table 2.

Table 2: The Research/Synthesis Cycle

THE RESEARCH/SYNTHESIS CYCLE
QRFM published as landmark document (2007)
Syntheses of information identified current status/need (2008-2010)
Second Strategic Highway Program (SHRP2) Freight Demand Modeling and Data Improvement (C20) organized the next wave of research (2012-2016)
SHRP2 studies were completed (2016-2017) and will be ready for "synthesis" in projects like the QRFM update

The QRFM is oriented toward Federal, State, and metropolitan agency audiences; however, the concepts of freight-efficient land uses and context-sensitive trip generation are also valuable to local land use planning and zoning authorities. These users' needs vary widely given their agencies' different geographic scales, strategic priorities, and other factors. As such, it is important to rethink the audience for the QRFM and package it in a form that is useful to all users from the State to local levels.

Since the last QRFM, a wave of technological progress has changed the way people find, consume, and use information. Plans need to incorporate data visualization that connect to users in ways that adapt to their needs, not simply used to make data look good and read well. The current QRFM is an extensive document that exists as a PDF on a website. This format is not user-friendly and can be difficult to navigate when a user is quickly looking for information on a certain topic.

Following the 2007 QRFM release, a series of syntheses released between 2008 and 2010 focused on applications such as freight travel forecasting. These syntheses formed the basis for later National Cooperative Highway Research Program (NCHRP) projects, since identified as additional foundation literature. During the next wave of research conducted as part of the SHRP2 C20 effort between 2012 and 2016, the emphasis shifted toward land use and demographic-sensitive context related to freight and goods movement. Understanding this

evolution in research and practice helps reveal how the outputs of this project can lead to new developments; it also provides a good framework for the project's recommendations.

With the next QRFM update, it will be important to think about who the new users will be over the next decade as well as the QRFM's overall format and content. An updated QRFM can affect the direction of the freight transportation industry and freight planning more generally. Stakeholders participating in this project's outreach activities suggested that the QRFM present information via a more interactive audience-based approach that would allow them to search for guidance related to their freight planning needs or application. An interactive manual that is more graphically rich will better enable users to quickly understand what is important to them.

From a content perspective, disseminating practical user guidance for freight demand modeling faces some version of "future shock" associated with an accelerating pace of change. Most QRFM users are tasked with using freight demand projections to help make transportation facility recommendations for projects that are expected to have a lifespan of several decades. However, the vehicles that will use these facilities will probably have a lifespan of years rather than decades. The technologies that will govern freight distribution may have a lifespan of months rather than years. The QRFM must communicate the challenges of integrating decisionmaking across these temporal scales so that infrastructure investments can sustain several cycles of unpredictable technology changes.

Another consideration is the degree to which research and development is perceived as independent from practitioner support. A general cyclical trend has occurred during the past decade: the QRFM serves as the end of one phase of research, while SHRP2 and other synthesis papers serve as the beginning of the next phase. Tools developed to support practitioners, such as the QRFM, need to evolve as advancements are made through these research and development cycles.

Specific recommendations for the QRFM update are outlined in sections 3 and 4 of this document.

GAPS ARE SIGNIFICANT; THERE IS INSUFFICIENT INFORMATION AVAILABLE ON HOW TO ADDRESS THEM

One output of SHRP2 C20 research has been a comprehensive list of needs articulated by freight travel demand modelers and freight decisionmakers. This list includes needs to develop:

Data

- o   Standardized data sources with common definitions

- o   Statistical sampling of truck shipments

- o   Methods for surveying businesses to obtain local freight trip generation rates, including use of technology such as Global Positioning System (GPS) and mobile apps

- o   Data development to understand the nature, volume, and trends of intermodal transfers

- o Industry-level freight data development at a subregional level and within urban areas
- o Use of intelligent transportation systems (ITS) resources to generate data for freight modeling

Models

- o Standardized analytic tools and applications
- o Inclusion of behavior-based elements in freight models
- o Truck touring models for urban goods delivery
- o Development of a universal multimodal, network-based model for various geographic scales
- o Incorporation of local land use policies and controls for better local forecasting accuracy

Applications

- o Improved understanding of interactions between freight activity and various economic influences and macroeconomic trends
- o Development of a process to routinely generate new data sources and problem-solving methods
- o Development of benefit-cost analysis tools that go beyond traditional financial measures
- o Development of funding assessments resulting from freight forecasts
- o Creation of technical guidance and support toolkits to support the infrastructure design process

Much of the research for this project provided information on where/what the gaps are in understanding the land use and freight interaction. NCFRP Report 37, *Using Commodity Flow Survey Microdata and Other Establishment Data to Estimate the Generation of Freight, Freight Trips, and Service Trips: Guidebook,* fills a practical gap in this information. Many practitioners are also using current resources to develop contextual and customized solutions to their challenges, contributing to a wide diversity of applications that do not necessarily align with one another or make best use of leveraging resources/information.

FREIGHT MOVEMENT TRENDS ARE EVOLVING QUICKLY

Freight movement trends are changing. Ten years ago, households might get one or two packages a month. Now, with the advent of on-demand deliveries, these same households may receive one or two packages a day, ranging from e-commerce deliveries to other same-day local grocery deliveries. Households have now become part of the larger production-consumption (PC) link in a way they were not a decade ago. Traditionally, the freight portion of the goods movement paradigm ended with delivery of goods to a retail establishment; after that point, "home-based

shopping" travel by residents would be used to purchase the goods from retailers. Now, however, much "last-mile" delivery ends directly with the consumer, so that households are considered the end point of the freight supply chain.

In addition, these changes may also be playing out differently depending on geographic context (rural versus urban). Preliminary data suggests that shopping and home-delivery trips are neither perfect complements nor perfect substitutes. People travel to stores for "experiential retail," to inspect goods they will buy online. In other cases, consumers only buy certain items at stores or online.

Current freight and land use datasets, tools, and analyses may not reflect these trends accurately. For example, "e-commerce-enabled freight" is one potential gap; these trips are not represented in existing passenger demand models, which focus heavily on individuals' trips made to fulfill daily out-of-home activity needs. The models also do not address how distance is perhaps less important than the time factor for this type of household-level decisionmaking. Survey mechanisms in particular are also insufficient; many questions about household freight are simply not asked. Some Metropolitan Planning Organizations (MPOs) with more technical resources may be exploring new ways to capture this data. Ultimately, more local surveys are needed to help connect existing models to local activities. Furthermore, national collection also is difficult. What level of accuracy is needed? How do we improve the availability and visibility of data among agencies and between the public and private sectors? Are commonly sourced datasets available at smaller geographic scales?

The state of the practice is evolving toward behavioral-based freight models (BBFM) that can more precisely reflect truck-touring behavior associated with e-commerce goods movement and treat them as light truck trips in a manner similar to service-trip generation (STG) and route assignment. This has become the default approach and is described in greater detail in a FHWA report on behavioral supply chain modeling guidance.[1]

An alternative, or perhaps complementary, approach would be to treat household deliveries as part of a "home-based other" trip generated by the residential unit itself (rather than the people who reside in the unit). Household surveys may still be the best source to collect information related to service trips and residential deliveries. Estimates at the household level are usually more accurate, due to lower degree of household type variation and the value in household surveys for a variety of other socioeconomic and trip-making behavior. Thinking about the need for services (such as pool service, home repairs, appliance replacement, etc.) and goods (grocery, apparel, household furniture, etc.), it is likely that some of the freight demand can be explained or predicted by household and personal attributes. This can lead to new ways to standardize questions related to consumption of services and goods as part of the household profile. It can also support efforts to determine reliable trip rates by type of goods and services in the future. NCHRP Project 08-117, *Impact of Transformational Technologies on Land Uses*, is anticipated to start during 2018 and includes an effort to consider the last-mile effect of getting goods to the

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[1] FHWA, *Behavioral/Agent-Based Supply Chain Modeling Research Synthesis and Guide*, 2017.

customer. This may be one useful avenue for exploring the concept of the "freight/life" paradigm.

NEW MODELING FRAMEWORKS ARE BEING DEVELOPED

Freight demand models have typically been based on population, employment, and industry-level forecasts. New frameworks are emerging to better integrate land use, transportation, and economic activity. These newer modeling frameworks are designed to address several areas of interest:

Goods movement activities throughout the "production-consumption" linkage–an improved understanding of the continuum of freight activities from production through warehousing and distribution to final delivery.

The changing nature of what constitutes freight–residential deliveries are increasingly important as a factor in both local decisionmaking from a site and community design perspective as well as in supply chain modeling with larger regional, megaregional, and national implications.

Land use differences–the ways in which rural, suburban, and urban contexts differ and how those differences are being shaped by redevelopment of older industrial districts.

Industry differences–land use codes such as the North American Industry Classification System (NAICS) or Institute of Transportation Engineers (ITE) land use types provide one level of information regarding economic development, but other nuances remain in the industry. For instance, not all warehouse or distribution land uses are the same, nor do they generate the same types of freight impacts.

Scalable data approaches–connecting freight forecasting and supply chain decisions at site, corridor, regional, and national levels.

To improve goods movement within and to communities, it is critical to understanding how land use and economic decisions can affect freight activity and how data models can reflect these interrelations.

Additional challenges and needs related to modeling frameworks have been identified, including:

Developing commonly sourced data sets that can be used on smaller geographic scales.

Improving the availability and visibility of data among agencies and between the public and private sectors, especially in helping to coordinate data licensing agreement limitations.

Capturing local context information more effectively and using it successfully for regional conversations. In particular, what are the sources for local land use data? What can those sources tell us about current and future freight demand?

Better categorizing industry gaps in existing freight datasets, particularly those related to localized economic activities (e.g., local food systems activities).

Developing a more universal, open-source freight modeling tool, as many users must piece together data or improvise with available resources.

Dealing with intermodal connections and issues. This may include international corridor issues and may include all other modes—aviation, maritime/port, etc.—and interfacing with multimodal considerations, including those around public transport.

Understanding issues in predominantly rural or "bridge" States where there may be significant freight trips that do not have origins or destinations within the State.

Understanding localized truck context and issues such as parking, platooning, changes in urban delivery systems, manufacturing industrial centers, etc.

Enacting emerging policy mechanisms such as freight ordinances to help connect regional and local freight activities and impacts.

BBFMs help illuminate the activities of freight movement and urban delivery systems by taking into account the decisions each operator must make. These depend on an array of factors, such as the nature of the goods being moved, the location of each trip within the supply chain from production to consumption, and the context of the communities where the trips occur.

More sophisticated and integrated modeling frameworks continue to be developed and disseminated, but a new phase of research and development is now underway:

FHWA is undertaking exploratory advanced research on a national BBFM project aimed at utilizing the Commodity Flow Survey (CFS) to the highest extent and incorporating international elements.

The SHRP2 program is working on an analytic approach that will be the foundation for an effective land use and freight framework and related models.

National Cooperative Freight Research Program (NCFRP) Project 49, *Understanding and Using New Data Sources to Address Urban and Metropolitan Freight Challenges*, includes new strategies and examples of new information-gathering techniques and data fusion (e.g., using multiple datasets to develop a stronger contextual freight understanding; examples include artificial intelligence, computer visioning, radar/light detection and ranging (LiDAR)/sensors, and surveillance technology).

STAKEHOLDER ENGAGEMENT IS CRITICAL

Engagement with a broad set of stakeholders is required to identify key issues (which includes developing new data sources) and implement solutions. The following stakeholder groups are of particular importance for these efforts:

Local transportation and land use planners and practitioners–These professionals analyze current and future impacts associated with development, but freight is sometimes overlooked in these discussions. Currently there is limited information or guidance around how to adapt local planning processes to include freight-specific considerations.

Private freight industry and freight data providers–Privately held information and decisionmaking insights can greatly enhance public conversations. Private sector freight

stakeholders might include traditional carriers, but also larger trucking and rail organizations as well as data providers.

Elected officials (local, State, Federal)–There is a need to better understand what information elected officials require to support freight planning and its outcomes.

Emerging freight actors–These include organizations like e-retailers at a national level and more localized delivery service organizations with an emerging role in freight discussions.

Including representatives from the above (and other) stakeholder groups in the freight analysis/planning conversation will support more effective coordination, governance, and decisionmaking. For example, such inclusion could help an MPO articulate more effectively to the public the changing nature of freight or influence and collaborate with local planners to support freight activities. It could also help to develop and enhance the conversation about economic competitiveness, as was done in a successful pilot by the Maricopa Association of Governments.[2]

TARGETED COMMUNICATION IS ESSENTIAL

Planners need to have a wide set of options—best practices for a city transportation planner may not be the same as those for a State Department of Transportation (DOT) planner or an MPO planner. However, all planners undertake analyses and make decisions that are intrinsically freight-related. In addition to developing future freight tools, effort should be applied to developing a set of emerging practice options and best practices suited for various contexts, agencies, and stakeholders.

Guidance on best practices for freight modeling should focus on effectively conveying a story to a specific audience. Key communications concepts (in many cases summarizing elements described above) include:

Anticipate "what if" questions by utilizing a scenario planning approach to better articulate and address the uncertainties underlying practitioners' and planners' assumptions.

Describe the problem in terms that are important to the audience; many decisionmakers are not particularly concerned with truck volume or delays as a performance measure. On the other hand they may be interested in related outcomes within their jurisdictions such as economic success (as assessed by outcome measures such as jobs creation, value of goods delivered or property tax increases) and quality of life (assessed by outcome measures such as reduced civic complaints about truck traffic on residential streets).

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[2] For more information, see http://azmag.gov/Portals/0/Documents/MagContent/TRANS_2017-02-13_SHRP2-TRANS_2017-06-06-C20-MAG-Next-Generation-Freight-Demand-Model-Update.pdf.

Apply compelling visualization tools to make the problem and the solution come alive to the audience. This communications approach should be applied either in conjunction with or independent from the application of innovative data sources and modeling tools.

SECTION 3: TOPICS

This section presents a summary of freight planning topics relevant to land use and demographic considerations. The overall purpose of this summary is to: 1) highlight best practices and tools for analyzing freight demand at a range of scales from statewide or regional modeling to local transportation analysis; and 2) document best practices and tools for understanding how land use, local economic development, and demographic factors drive freight movement and trip generation.

Five topics are covered, each of which corresponds to key gaps identified in the literature review:

Topic A: overall integration of land use and freight planning

Topic B: last-mile considerations

Topic C: freight modeling framework issues

Topic D: application and integration of public and private data sources

Topic E: elements that were not necessarily integral to the four key gaps identified in the literature review, but rather reflected new materials and practices that were ready for adoption

Matrices were used as discussion tools during the expert working session to suggest materials that are ready for widespread practice. The matrices also identified key areas where expert discussion was needed to generate consensus on industry challenges, or where additional coordination is desired to develop guidance on practices that are ready for adoption. See Appendix B for the complete topic matrices.

TOPIC A: INTEGRATION OF LAND USE AND FREIGHT PLANNING

The integration of land use and freight planning underpins goods movement and travel demand management—from the econometric approaches used by private industry to match supply and demand to the planning, design, and operations tools used to define transportation system investments. Understanding relationships between land use inputs and goods movement outputs benefits from improved data sources, analytical research, and database management. In turn, those relationships provide the ability to consider more subtle elements, such as the effects freight demand and goods movement trends might have on influencing land use planning and tailoring analyses toward industry-specific needs.

This topic summarizes perhaps the most compelling study element: how freight demand is affected by land use (see Figure 1). Important considerations related to this element are discussed below.
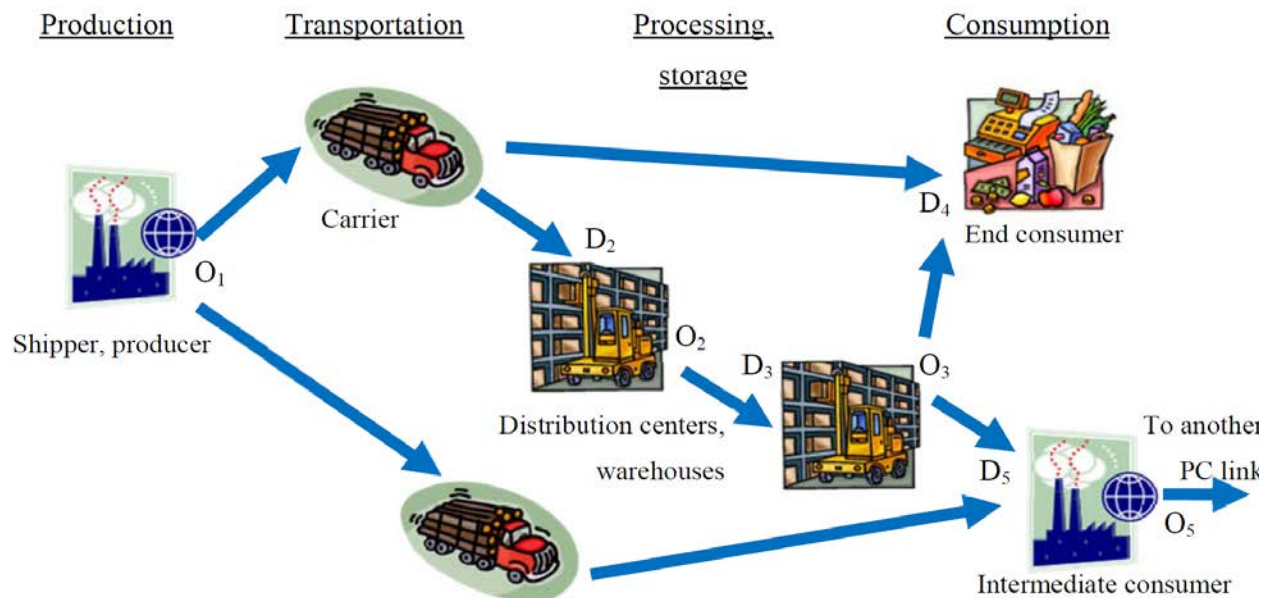
Figure 1: NCFRP Report 37 Provides Insight into Trip Generation for Different Elements of the PC Link
Source: NCFRP Report 37

When analyzing trip generation relative to freight, it should be considered in terms of freight generation (FG), freight trip generation (FTG), and service-trip generation (STG). A key concept is that FG and FTG are two different measurements.

- FG is derived from freight production-consumption (PC) and is typically measured in tons. This is the sum of freight attraction (the amount of cargo that is brought to the establishment to be processed, stored, or sold to customers) and freight production (the amount of cargo sent out of the establishment for use at another establishment).

- FTG is the number of freight vehicle trips generated by an establishment. It is typically modeled by converting FG to truck trips based and logistical decisions for shipment size, frequency of deliveries, vehicle size, and modes used. The models are used to derive trip generation based on commercial establishment land use type generating trips and the relationship between those subject sites, their commercial partners upstream and downstream within the PC link, and the land use and transportation system elements surrounding those freight-generating sites.

- STG is the number of vehicle trips generated in performing services at an establishment.

Application of NCFRP Freight Trip Generation Data

NCFRP Report 37 improves estimated freight generation using commodity flow data that facilitates trip generation assessment as a function of characteristics such as establishment size and type of economic activity performed (see Figure 2). The models provided FG, FTG, and STG rates per employee for each classification of commercial establishment based upon NAICS codes. Models are provided for establishment-level FTG (both production and attraction) and STG (attraction). For many of the industry classes, the models are non-linear to represent the scale of economies of production (i.e., the larger the establishment, the higher the productivity for a unit of labor). The research found that using industrial classification systems for estimating FG and FTG rates is more effective than using standard land use classification systems. The amount of cargo consumed and produced at an establishment are the inputs and outputs of an economic process, respectively, making employment and the industry sector better predictors than variables like square footage.

Freight Trip Generation Estimates for the Commercial Center in Troy, NY

Freight Trip Attraction (FTA)

ID	NAICS Description	Actual NAICS	Model Used		FTE	Deliveries Received/Day	
			NAICS	Geography		Linear Model	Non-linear Model
1	Retail Trade	44	44	CR	11.2	3.21	3.91
2		44	44	CR	3.15	2.37	2.44
3		44	44	CR	7	2.77	3.28
4		44	44	CR	4.15	2.48	2.70
5		44	44	CR	1.9	2.24	2.02
6		45	45	CR	4.25	1.11	2.29
7		45	45	CR	12.75	3.34	3.82
8		45	45	CR	4.8	1.26	2.42
9	Accommodation and Food Service	72	72	CR	21	1.14	1.64
10		72	72	CR	9.5	1.14	1.08
11		72	72	CR	4.8	1.14	0.76
12		72	72	CR	4.9	1.14	0.77
13		72	72	CR	3.8	1.14	0.67
	All FIS				93.2	24.49	27.79
	FTA (1 delivery = 1 vehicle trip)					24.49	27.79

Freight Trip Production (FTP)

ID	NAICS Description	Actual NAICS	Model Used		FTE	Shipments Out/Day	
			NAICS	Geography		Linear Model	Non-linear Model
1	Retail Trade	44	44	CR	11.2	4.68	5.79
2		44	44	CR	3.15	1.32	2.61
3		44	44	CR	7	2.93	4.31
4		44	44	CR	4.15	1.73	3.11
5		44	44	CR	1.9	0.79	1.90
6		45	44, 45	CR	4.25	1.84	3.09
7		45	44, 45	CR	12.75	5.51	6.33
8		45	44, 45	CR	4.8	2.07	3.34
9	Accommodation and Food Service	72	72	NYC + CR	21	2.39	3.86
10		72	72	NYC + CR	9.5	1.08	2.21
11		72	72	NYC + CR	4.8	0.55	1.36
12		72	72	NYC + CR	4.9	0.56	1.38
13		72	72	NYC + CR	3.8	0.43	1.16
	All FIS				93.2	25.89	40.46
	FTA (1 delivery = 1 vehicle trip)					12.94	20.23

Figure 2: Example Freight Trip Generation Problem Described in NCFRP Report 37
Source: NCFRP Report 37

These models estimate FG at the establishment level based upon employment; however, employment data from the Census Bureau is at the ZIP code or county level. Also, planning forecasts by the MPOs and States are made at the Traffic Analysis Zone (TAZ) level. This requires aggregation and disaggregation of data between the establishment level and the TAZ level for analysis. Also, if the State or region's total FG is going to be compared with the CFS, this comparison requires further aggregation up to the regional or State level.

Another important factor is that FG, FTG, and STG rates may vary from region to region and from State to State, in part depending on differences specific to commodities in the flow, requiring local calibration. This is explored further in Topic C.

The models and data will aid practitioners in improved FG, FTG, and STG analyses for travel demand modeling. This can also be used to facilitate more precise traffic impact analyses, better curb space management, and more properly sized loading/unloading areas.

NCFRP Report 37 contains several hundred pages of tabular information that reflect a robust and deep data source, but one that may be challenging for the first-time user to absorb. The QRFM should summarize the findings of NCFRP Report 37 and provide directions to particular elements that may be most accessible to practitioners not well versed in the research subject matter, including:

The illustrative examples in Chapter 9 that organize the databases to solve a given problem, such as in the creation of Table 120 (included as Figure 2 above) to demonstrate the development of commercial parking needs for a commercial center.

Online databases that allow the user to search based upon NAICS codes or land use.

While NCFRP Report 37 provides very useful information for commercial site trip generation from both production (i.e., the manufacturer) and attraction (i.e., the retailer) ends, the research on household trip attractions for service trips is still lacking. Additional research would be beneficial on:

The total amount of freight trip ends at the residential attraction level, both through household survey queries regarding the amount and type of home deliveries as well as through more intensive service trip provider information on household deliveries.

The types of household characteristics (persons per household, age of residents, income, etc.) that may affect service trip generation at the household level.

Approach for Applying Context-Sensitive Land Use to NCFRP Report 37 Trip Generation Rates

Local land use context substantially influences total vehicular trip rates, resulting in new tools such as those developed by the U.S. Environmental Protection Agency (EPA) as part of their Mixed-Use Development (MXD) trip generation analysis approach and as documented in NCHRP Report 758, *Trip Generation Rates for Transportation Impact Analysis of Infill Developments*. In some cases, integrating the establishment size and economic activity independent variables of NCFRP Report 37 with the EPA MXD Trip Generation or NCHRP Report 758 approaches may improve the accuracy of FTG and STG model estimations. These

approaches recognize that land use variables such as density, diversity, design, distance to transit, and distance to a regional core (often described as the "Ds") affect localized trip generation rates. ITE is currently investigating incorporating a more sophisticated level of context-sensitivity into its published trip-generation rates. Many jurisdictions have adopted context-sensitive adjustments for total trip generation rates in their development impact analysis processes. The development of truck trip generation rates (whether for freight or service), however, remains relatively unexplored in the traditional traffic impact analysis process used by most jurisdictions.

Land use context (i.e., the "Ds") is to a certain extent implicitly reflected in NCFRP Report 37 formulas for trip generation rates. This is largely because those formulas incorporate facility size (as reflected by number of employees) and type (as reflected by NAICS codes), and the number of truck deliveries or service deliveries is not sensitive to other contextual land use elements. In other words, even if a restaurant employing a staff of 50 generates fewer vehicle trips by patrons if located in a higher density community or closer to transit, the number of goods and service deliveries will not be sensitive to those variables.

However, NCFRP Report 37 notes that, in describing the connections between the freight system and land use, it is important to distinguish between two separate aspects: 1) how land use at the establishment level influences FTG; and 2) how freight activity and land use interact with each other at the system level. The main emphasis of NCFRP Report 37 was that the impact of land use on FTG and the spatial distribution of freight and land use activities may warrant additional consideration.

NCFRP Report 37 Trip Generation Database

The resources in NCFRP Report 37 are quite robust and contain a fair amount of technical complexity. The comparison of different types of freight demand models in a database as described by NCHRP Report 739 is a FTG software tool, currently under development, which replaces the comparative assessment of freight demand models described by NCHRP Report 739.[3]

The software, developed by the Rensselaer Polytechnic Institute (RPI), applies FTG models at the ZIP-code and two-digit NAICS-code levels. The NCFRP Report 37 databases provide independent data regarding the warehousing component of the PC link, thereby helping practitioners differentiate between manufacturing, warehousing, distribution, and final delivery. The QRFM update will need to coordinate with database development efforts to provide a logical cross-reference and a simplified summary of access to the software and its user guide.

The advent of e-commerce has increased the complexity of the relationship between manufacturing and the ultimate destination for individual goods delivery. Long-standing definitional boundaries are being blurred and may need to be redrawn. The expert working session included a constructive discussion of the semantic and technical differences between the

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[3] For more information on the FTG software tool see https://coe-sufs.org/wordpress/ncfrp33/appendix/ftg.

types of goods movement that might be considered "freight" and those that are more "life" oriented, as described in section 2 of this report.

Freight Villages Concepts and the Effect on Trip Generation

Freight villages are clusters of transportation and logistics facilities that are co-located and coordinated for synergies with an intermodal terminal and may also be referred to as intermodal distribution centers, inland ports, logistics centers, or trade gateways. The genesis for this analysis is the degree to which the freight village concept, relating to the size and location of goods delivery staging centers, could affect truck trip generation and total travel. These typically include distribution centers, warehousing, value-added industries, services, and other supportive land uses with access to intermodal connections such as highways, rail, freight airports, or possibly marine ports.

Freight villages promote synergies in logistics processes (e.g., haulage, storage, and packaging) and infrastructure (e.g., connections to networks, transshipment equipment, railway sidings, etc.). Freight villages could reduce congestion at both the regional and local levels through increased intermodal transportation, internalized trip-making for intermediate goods processing steps due to colocation of industry, and improved staging for urban distribution. Freight villages could impact FTG; however, a great deal of uncertainty exists as to whether the level of synergy due to colocation can be sufficient to realize significant changes in FTG. Practitioners might consider that:

Freight villages may provide more efficient intermodal transportation options, improving the competitiveness of other non-highway transportation modes. Shifting freight from truck to rail can reduce VMT and have a positive impact on regional congestion.

Colocation with industry can minimize intermediate trips between companies and the intermodal terminal. If manufacturers, suppliers, and distribution centers can be located on the same site, this could lower congestion at the local level by avoiding trips that would otherwise occur on the road network outside of the freight village.

Centers used for consolidation and distribution could conceivably result in fewer truck trips and more efficient urban deliveries. However, the final delivery of goods to stores and consumers is still made overwhelmingly by trucks, with delivery patterns oriented toward private company ownership rather than by trip-making efficiency, and it is unclear whether these benefits can be realized in practice.

Freight intensity in the vicinity of a freight village can cause local congestion that may spill over into the surrounding region. Intermodal transportation naturally entails the growth of truck activity around terminals, as the initial and final segments of most freight movements still need to be handled by trucks.

"Freight sprawl" caused by industrial and logistics relocation to exurban greenfield areas outside of urban areas can cause dispersal of freight generators away from the urbanized core, affecting regional transportation and logistics patterns.

Strategic Planning for Freight Locational Planning

Analysis of the movement of both people and goods can benefit from scenario planning that evaluates both land use and transportation-system actions on travel needs. The expert working session included a robust discussion on the value of strategic planning at the national, regional, local, and site levels.

(Mega)Regional Planning

In 2016-2017, FHWA conducted a series of megaregion workshops that brought together local, State, and Federal transportation decisionmakers to identify how States, MPOs, and other planning partners can better coordinate freight planning, and identify common approaches to address traffic congestion and aging infrastructure at a megaregion level. The megaregion workshops identified many technical and institutional opportunities as well as constraints for implementing a more holistic approach to large-scale movement of people and goods.

At the broadest scale, the I-10 Corridor workshop brought together State government and USDOT leadership to identify a shared vision of connecting several megaregions, establishing a megaregional concept of operations, and developing an action plan for a 1,000-mile span of the corridor. Actions discussed ranged from turning data into corridor-wide traveler information, identifying new policies and technologies, and streamlining goods movement regarding permitting, weigh-in-motion, truck parking, and enforcement. For example, at the Piedmont megaregion workshop, participants focused on freight and goods movement bottlenecks. Attendees recognized the need to better link Atlanta to the Ports of Savannah and Charleston, yet those two port cities are not consistently considered part of the Piedmont megaregion. This concern about boundaries relates to the concept of "problem sheds" discussed at the Mid-South megaregion workshop, indicating the need for a nimble and problem-oriented approach to connecting stakeholders, depending on the scale and scope of the issue being addressed. Each of these workshops helped develop or strengthen interagency and interdisciplinary relationships and set the stage for implementing specific megaregional transportation solutions.

Subarea Planning

At the subarea level, studies are showing that both passenger and freight travel becomes more efficient in terms of VMT per capita (and related environmental externalities) when land uses become more compact and diverse, even though truck delays increase somewhat (an outcome similar to that found in most studies of person movement and smart growth environments). Wygonik et al. demonstrated the effects of smart growth land use in the Puget Sound Council of Governments' region in their 2017 TRB paper, *Forecasting Tools for Analyzing Urban Land Use Patterns and Truck Movement*.[4] Several suggestions for quick-response approaches are suitable for adoption, including:

Considering suitability in terms of accessibility to designated freight corridors and intermodal connectors, land use compatibility, freight impact on area traffic congestion, and facility design and operations.

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[4] For more information, see https://trrjournalonline.trb.org/doi/10.3141/2547-11.

Increasing terminal times in locations where truck circulation, parking, or loading is more challenging due to development density and land cost.

Considering use of special generator zones for major warehousing facilities such as freight villages.

Applying time-of-day adjustments to reflect both the goods movement market propensity to avoid congested times as well as policies developed to further encourage off-peak period deliveries.

Site Level Planning

At the site level, additional detail is needed to ensure local development codes adequately consider goods movement. For instance, truck trip generation has typically focused on commercial uses due to the emphasis of goods distribution by commercial entities wherein the final destination is a retail store or other service (such as a hotel or a restaurant). The increase in e-commerce has increased the importance of accommodating goods movement for residential properties, particularly in denser urban areas where a high ratio of residential dwelling units to total curb space exacerbates the need for curb space management.

NCHRP Report 844, *Guide for Integrating Goods and Services Movement by Commercial Vehicles in Smart Growth Environments*, summarizes a wide range of strategies for accommodating goods movement demand and operations given the context-sensitivity of particularly freight-sensitive land uses with a focus on issues for areas in the process of transitioning from freight-intensive to mixed use. Figure 3 illustrates the types of development framing goods movement and livability objectives referenced in NCHRP Report 844.
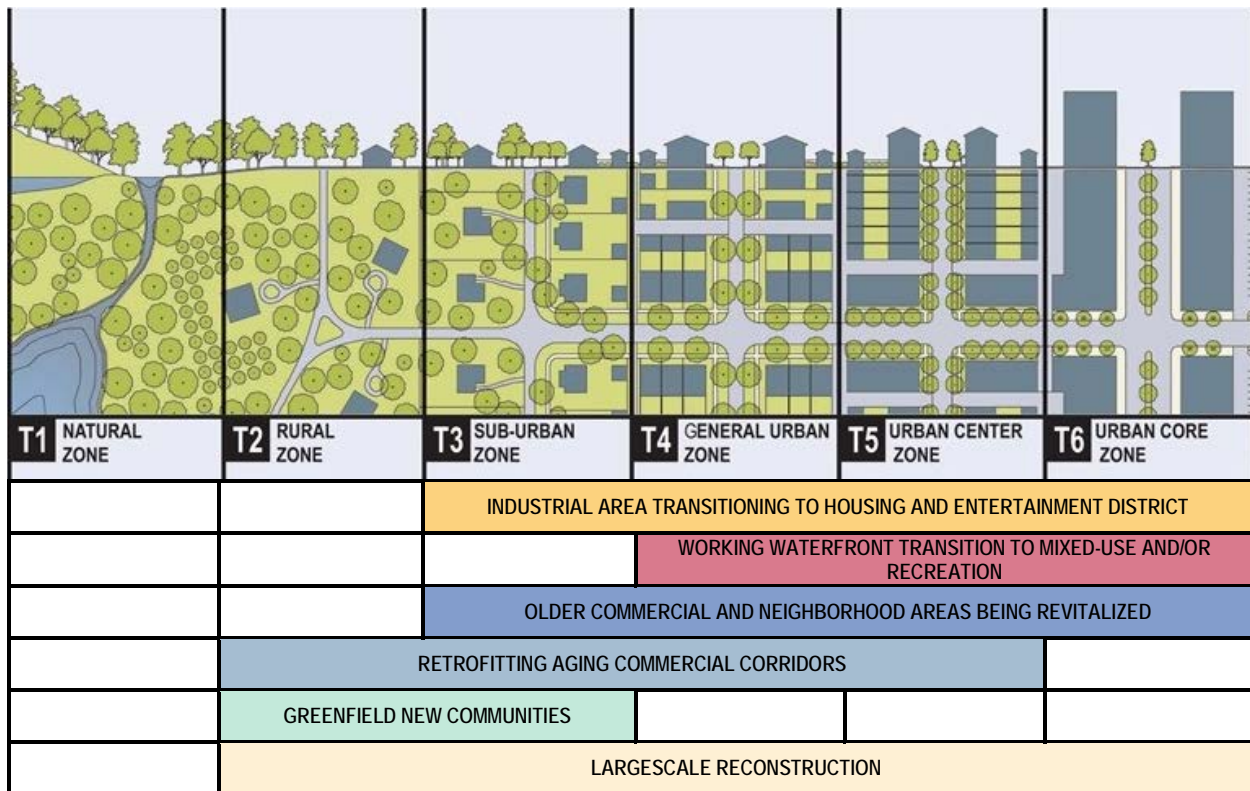
Figure 3: Relationship of Smart Growth Classification to the Rural-to-Urban Transect
Source: NCHRP Project 08-96

How-To Guide for Inventorying Freight-Generating Facilities

The improved understanding of trip generation and land use increases the importance of maintaining a good inventory of the types and locations of freight-generating land uses. As part of the SHRP2 C20 Implementation Assistance Program, the Winston-Salem MPO conducted a survey of freight facilities to support development of a tour-based truck model. Surveys of some of the identified freight nodes were conducted to verify node information as well as to gain additional insights into freight operations and characteristics. One of the additional data points that the surveys created was a correlation between daily truck trips (i.e., number of trucks entering the facility per day) and the number of truck bays present at a freight facility). This insight gave planners a technique to develop a rough estimate of truck trips that may start or end at a given facility.

This project provides a practice-ready approach for synthesizing standardized geodatabases supplemented with field data from both observed conditions (using tools such as Google Earth) and facility management surveys. This type of database provides a geographic representation of all identified freight nodes and can be classified by various descriptive variables such as facility type, category, commodity, number of truck bays, building square footage, and number of employees. The survey data helped establish or refine relationships between building square footage, full-time employment, the number of truck bays, and the number of truck trips. The process is readily transferable to agencies at State, regional, or local levels seeking better

information on freight-intensive land uses. This information can be useful in identifying areas of high freight concentration for the purposes of informing land use planning, economic development, or transportation improvement priorities.

Integrating Land Use and Goods and Services Movement

The NCHRP Report 844 summarizes a wide range of strategies for accommodating demand for goods movement and operations given the context-sensitivity of particularly freight-sensitive land uses. It also focuses on issues for areas in the process of transitioning from freight-intensive to mixed use. It is expected that the topic could be added as part of a new QRFM.

In particular, Table 2.2 in NCHRP Report 844 recognizes six specific types of both new development and redevelopment that affect how goods movement may be developed or retrofitted:

1. Industrial areas in transition
2. Working waterfronts in transition
3. Older commercial areas being revitalized
4. Aging commercial corridors
5. Greenfields
6. Large-scale reconstruction

Table 3.1 in NCHRP Report 844 summarizes the types of strategies to best achieve goods movement objectives with minimal adverse effects, including setting the stage, creating places and streets, operating with minimal impacts, and ongoing monitoring.

NCHRP Report 844 also provides useful case studies for implementing progressive strategies. Additional research will be useful to better understand how these strategies might affect freight demand from a quantitative perspective. However, the report provides a good foundation for applying planning and freight demand management strategies within different land uses contexts.

In a similar vein, the April 2012 FHWA's *Freight and Land Use Handbook* was not initially considered a foundational document as it focuses more on policy and planning than on quantitative analytic solutions.[5] This handbook would also provide broader planning concepts for the QRFM update.

Issues Associated with Unique Commodities

Most trip generation and travel forecasting processes and approaches are designed to address conditions that recur on a typical basis, such as average daily (or weekday) traffic, peak commuting hour conditions, the 30th highest hour of traffic over a given year, or the hourly or weekly trips generated by a given quantity of a certain land use type. For most long-range transportation planning purposes, seasonal variations are addressed by avoiding atypical conditions (such as holidays or snowstorms). Most goods movement references, such as NCFRP

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[5] For more information on the FHWA *Freight and Land Use Handbook*, see https://ops.fhwa.dot.gov/publications/fhwahop12006/.

Report 37, continue to serve this need of the average demand for the typical experience. However, many goods movement demands have seasonal variations that may affect travel demand to varying degrees (Figure 4).
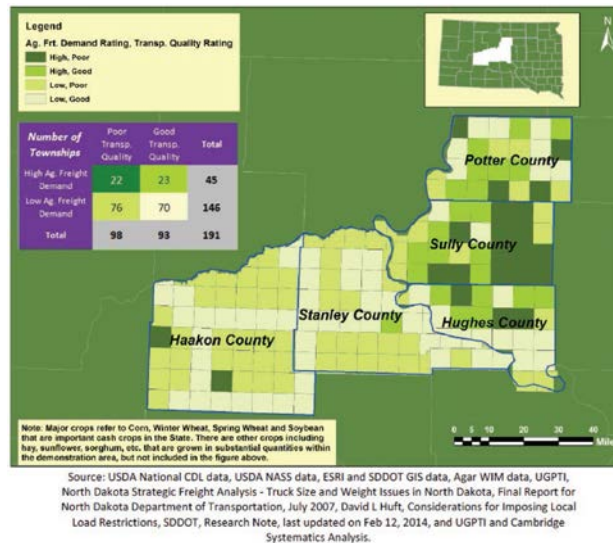
Figure 4: Example of Seasonal Estimates of Equivalent Single Axle Loads
Source: SHRP2 C20

The SHRP2 C20 program included assessments of industry-specific variability in freight demand. The South Dakota DOT Agricultural Freight Data Improvement Study (2016) included:

Innovative agricultural freight-related data sources were identified, such as the Agricultural Marketing Service, the National Agricultural Statistics Service, and the United States Department of Agriculture, that can be utilized for planning purposes over a horizon ranging from days to months, seasons, and years.

Innovative data collection methods such as unmanned aerial vehicles and smartphones offer significant promise for cost-effective means to filling large gaps in data on local roadway traffic counts and surface condition.

A compendium of conventional and unconventional agricultural freight data related to major crops and livestock facilities. The demonstration included trip generation estimates for four major crop types and two types of livestock facilities, and testing of various planning scenarios, including facility siting and public roadway closures.

The South Dakota model uses agricultural data as an input to estimate freight-related transportation demand, knitting together agricultural and transportation data sources to achieve a common baseline for analysis. The spreadsheet facilitates filling in gaps of data available in the public realm and plug-and-play using the existing spreadsheet tool with local data. This study is available at: http://nasconetwork.com/Websites/nasconetwork/files/Content/4850034/SD2014-09_Final_Report.pdf.

Freight Roadway Design Considerations

As indicated in NCHRP Report 844, the integration of goods movement and livability is increasingly relevant as many communities move away from greenfield development and segregated land uses to a greater reliance on mixing uses (facilitated by tools such as form-based zoning) and redeveloping in a more compact and transportation-efficient form. The Puget Sound Regional Council study described above demonstrated that more compact land use forms reduce both personal and goods movement VMT per capita. At the same time, these forms can bring increased total travel demand and can exacerbate design conflicts between different modes of transportation—such as trucks and bicyclists—that have very different operating characteristics. A system-wide approach to transportation with local and regional community objectives for economic development and goods movement balanced with livability can be tailored to provide more context-sensitive solutions for land use planning and transportation facility design. This can be accomplished by looking at the overall network and identifying the function of each roadway in terms of the land uses and traffic it is intended to serve so that it can be matched with appropriate context-sensitive design standards.
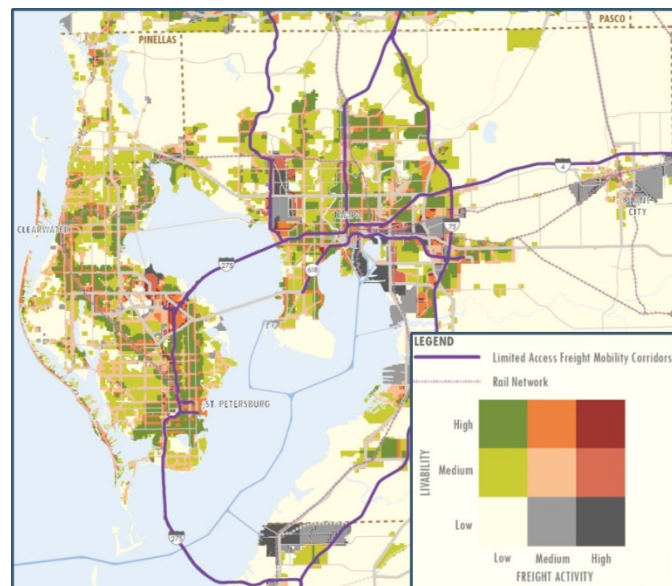
Figure 5: The Development of Transportation and Land Use Policy Can Be Informed by Both Freight-Intensive Uses and Project Freight Flows
Source: Florida DOT, District 7, FRDC

The Freight Roadway Design Considerations (FRDC) document developed by Florida DOT District 7 provides guidance to transportation planning and engineering practitioners for balancing livability and goods movement needs in a context-sensitive manner. The FRDC implements one recommended element of the 2013 Tampa Bay Regional Strategic Freight Plan available at: https://tampabayfreight.com/strategic-plan/tampa-bay-strategic-freight-plan/. This element is to develop a new approach to the roadway design process that considers freight activity and land use compatibility analysis. The FRDC benefitted from a literature review of current practices and guidance from an internal review group and interagency coordination and

commentary on draft materials throughout the development of the Tampa Bay Regional Strategic Plan. The FRDC provides guidance on identifying roadway context, understanding and clarifying design intent, and selecting among a series of design strategies to help integrate goods movement into the development of complete streets. Figure 5 illustrates the development of transportation and land use policies that can be informed by freight-intensive uses and project freight flows.

Local Transportation Impact Analysis Approaches

Currently, local jurisdictions incorporate goods movement considerations into impact analyses on a somewhat ad hoc basis. Most U.S. local jurisdictions have an established process for conducting what are conventionally termed "traffic impact studies" for new developments. These studies identify needed elements of a development's site access and circulation as well as offsite improvements to accommodate site-generated travel demand. Most jurisdictions generally follow guidance provided by the Institute of Transportation Engineers (ITE) in its 2010 *Recommended Practice on Transportation Impact Analyses for Site Development* (TIASD). The TIASD advises that truck impacts be considered explicitly (as contrasted with being combined with auto impacts) for land uses that would generate a significant number of truck trips (with the suggestion that separate truck analyses might be appropriate for Port/Terminal and Industrial/Agricultural land uses). This guidance applies to the various components of the site analysis, including access, loading and circulation; trip generation and distribution; and the consideration of heavy vehicle performance characteristics in the assessment of Level of Service or Quality of Service measures of effectiveness.

ITE is in the process of updating its recommended practice, which will be titled *Recommended Practice on Multimodal Transportation Impact Assessment.* An improved consideration of goods movement is expected to be included in the update including:

Site-level and context-sensitive trip generation.

Guidance on more specific development thresholds across non-industrial land use and transect types (such as 100 high-rise dwelling units in an urban core environment) that might warrant quantitative analysis of truck trip generation or loading zone demand.

Guidance on thresholds of development or curb space availability that might trigger the need for local agency recommendations for loading zone as part of site development approval.

TOPIC B: LAST-MILE CONSIDERATIONS

Consideration of the last-mile is a basic concern in the integration of land use and freight planning, particularly given:

Increased urbanization and mixing of land uses in most metropolitan areas.

A delivery paradigm shifting to more dispersed activity, including those professional goods and services delivered directly to residential addresses in lieu of brick-and-mortar retail sites and the innovative (but sometimes disruptive) technologies and markets that are growing to support that evolution.

Pressures to meet market expectations while managing potentially adverse community effects of greater freight traffic.

Topic B covers: 1) the significant gap in last-mile understanding; and 2) a last mile analysis methodology ready to be adopted as a widespread practice.

Synthesis on Data Use and Application in Last-Mile Delivery Techniques

The growth of e-commerce and omni-channel fulfillment (which describes the process from the time a customer orders a product to the time the merchandise is delivered to that end-user through a combination of channels) has led to increased focus on the traffic impact of last mile deliveries. Last-mile deliveries present both challenges and opportunities for the private and public sectors, especially in terms of travel time and recurring/non-recurring costs. A public-private feedback loop appears to be developing wherein:

The public sector establishes policies affecting last-mile delivery at a site or at the neighborhood level. For example, policies might cover access and circulation design and operations, loading zone requirements, and curb space management.

The private sector adapts to the policies set by the public sector and tests the boundaries of optimum performance. Considerations that come into play include customer satisfaction and the costs to the company of violating the policies.

The public sector adjusts its policies in reaction to both commercial (e.g., business and tourism climates) and residential concerns (e.g., livability concerns raised by residents).

Such a feedback loop appears to be sustainable in terms of societal and technological perspectives. From the societal perspective, the high dollar value of last-mile efficiency is confirmed by statistics. From the technology perspective, pilot testing of automated delivery devices, from drop boxes to unmanned drones, is being developed on an iterative basis as communities explore regulatory changes to support an appropriate pace of innovation.

In a 2017 TRB paper (17-04295), *Enabling the Freight Traffic Controller for Collaborative Multidrop Urban Logistics: Practical and Theoretical Challenges*, Cherrett et al. suggest a collaborative "freight traffic control" paradigm that helps private companies share data and strategies that are either managed, or at least encouraged, by the public sector. The paper presents a case study of a proposed clustering and routing strategy for deliveries in central London. This case study demonstrates this strategy's potential for reduced costs and negative externalities, but also demonstrates the challenges associated with the decisionmaking process. While more data on urban deliveries and routing has vastly improved travel time and curb space management potential, many human factors considerations can affect the last-mile delivery process. These range from the degree to which clients make their schedules more malleable to account for variable "just-in-time" pickup to the degree with which local officials will enforce curb space management (or other innovative parking approaches).

The last-mile delivery topic is broad and under constant evolution, with sufficient nuances in definitional, societal, technological, and economic arenas to warrant an independent synthesis on last-mile delivery techniques. This synthesis could be developed through NCHRP to contribute

to the QRFM update or developed independently by FHWA (and perhaps at a more cursory level) as part of QRFM. NCHRP 08-117, *Impact of Transformational Technologies on Land Use and Transportation*, will cover the impact of transformational technologies starting in 2018, including the retail last-mile element in its tentative work scope, and could also be a resource for this effort.

Transferable Last-Mile Analysis from Broward County

The SHRP2 C20 implementation assistance project in Broward County, Florida, focused on petroleum commodity flows. The Florida DOT District 4 assessed petroleum flow data to understand the supply and demand chain for petroleum commodities distributed from Port Everglades (PEV) to the 12 counties of southern Florida. A methodology was developed for estimating fuel consumption based on local factors such as land use, socioeconomic, roadway, and traffic inputs. The analysis also provided a viable solution to resolve the issue of "last-mile" petroleum information that is lacking in the current TRANSEARCH database.
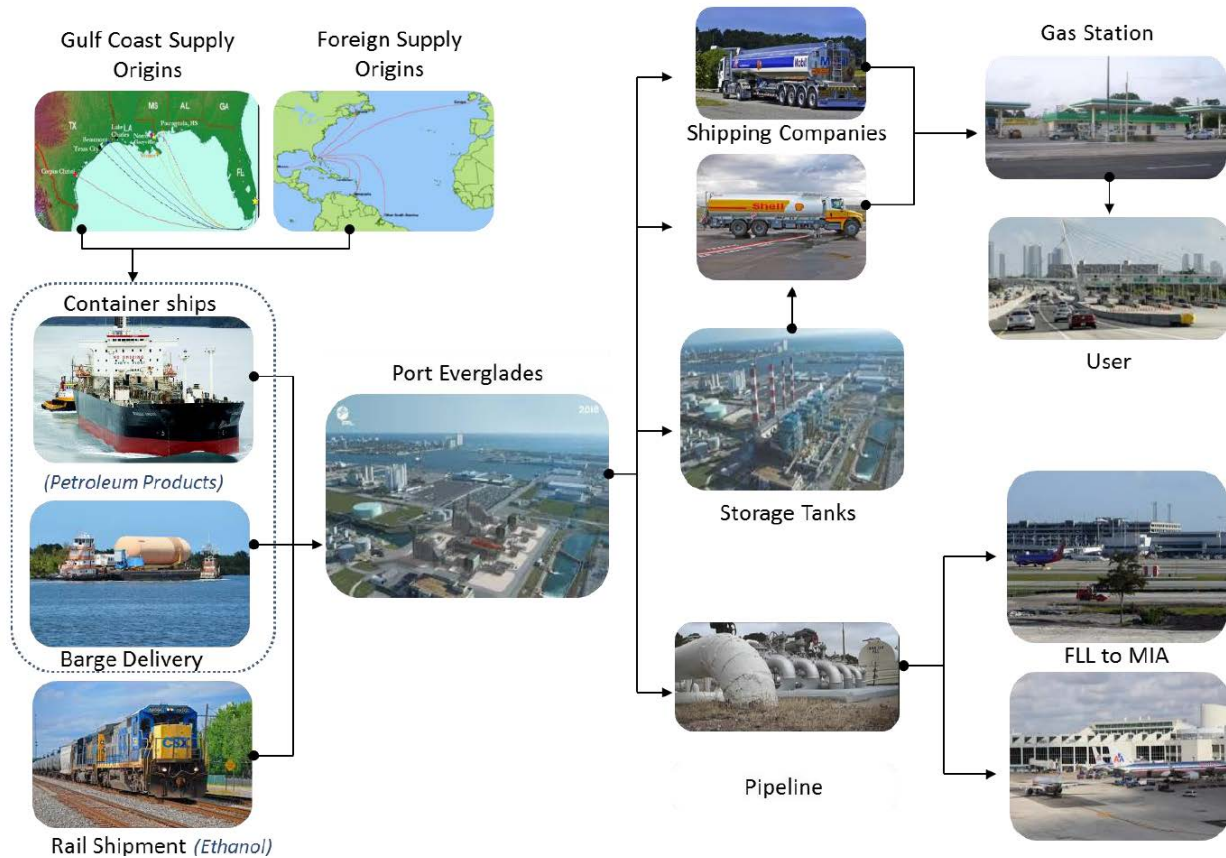
Figure 6: Summary of Southeast Florida Petroleum Commodity Flows
Source: SHRP2

The analysis first applied truck-GPS data from the American Transportation Research Institute (ATRI) to derive petroleum tankers' truck travel path (or route) information. Using a three-step

approach, this data was used to describe the routes tanker trucks take from PEV to their final delivery points, including intermediate stops, as they distribute fuel to retail service stations:

1. Identify petroleum tanker trucks originating at PEV.

2. Derive the trip chains of trucks originating at PEV.

3. Derive truck travel paths for the trucks traveling between PEV and gas stations.

To help close the gaps between TRANSEARCH database limitations and the tanker trucks that were not part of the ATRI instrumentation pilot, a methodology was developed to estimate the trip assignments and analyze the relationship between Broward County petroleum commodity consumption and available local data, including land use, socioeconomic, roadway, and traffic data (Figure 6). This approach, calibrated in part to the ATRI-instrumentation data, created a model to first predict fuel sales at retail locations based on gas station location, population and employment density, and household income (the four significant variables out of 23 variables tested). This information was used to predict fuel sales, which could then be used to estimate fuel deliveries and truck VMT. This approach, relying on sales volume rather than either retail facility size or employment, can be incorporated in QRFM update as part of a hybrid modeling process.

TOPIC C: MODELING FRAMEWORK

Topic C covers the range of modeling tools practitioners use to conduct robust goods movement studies. The current state of the practice in all travel demand modeling tools is changing from conventional "four-step" travel demand models to Activity-Based Model (ABM) frameworks. This approach offers more flexibility to describe linked-trip behaviors and reflects a wider range of behaviors by different travelers who may have various reasons for optimizing their travel needs.

Advanced behavioral-based freight models (BBFMs) that consider supply chain and delivery systems are being developed to provide a more complete understanding of freight movement and forecasting (see Figure 7). These models are disaggregate models that incorporate supply chain procedures of firms and truck touring aspects. Advanced BBFMs contain several common components, summarized below:

- Firm synthesis, including freight production and consumption

- Commodity flows, including buyer-supplier matching and commodity flow allocation

- Transportation/logistics, including distribution channel, vehicle choice and shipment size

- Modal assignment

- Network flows, including truck touring models
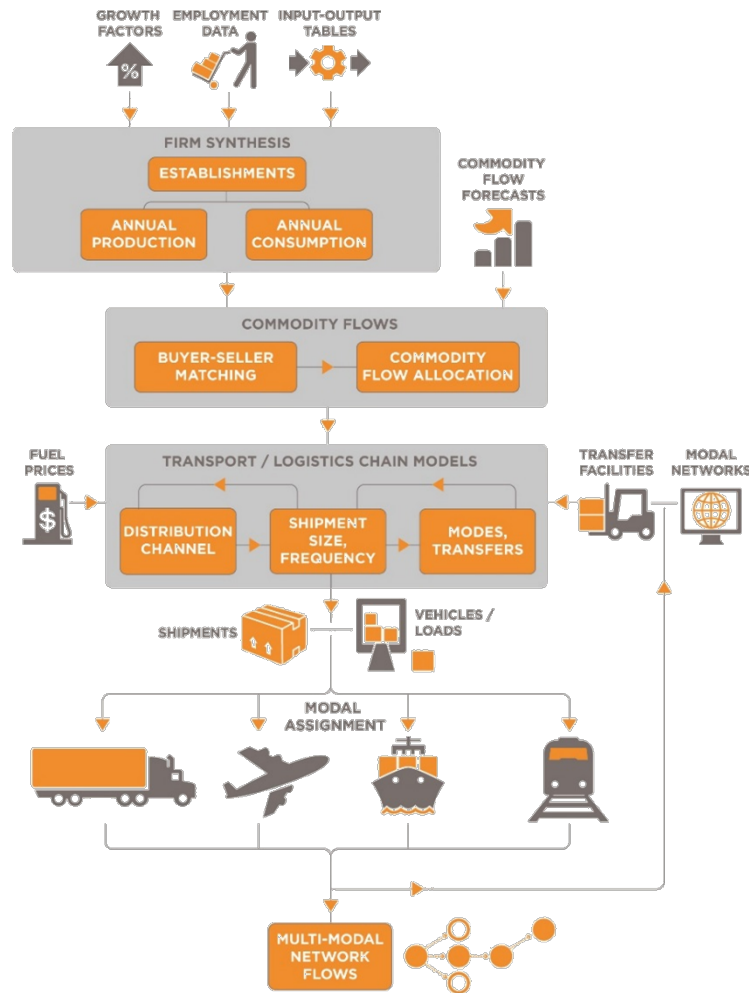
Figure 7. Behavioral Supply Chain Modeling Process
Source: RSG, University of Maryland, and Vision Engineering and Planning, 2017

Synthesis on Applying Lessons Learned from ABM to Four Step/Hybrid Models (with Focus of Land Use/Demographics as Inputs)

ABMs describe a shift from the traditional "four-step" model to one in which the decisions of individual travelers are evaluated in a probabilistic fashion. The traditional four-step model includes trip generation, trip distribution, mode split, and traffic assignment at a traffic analysis zone level for discrete but unconnected trips between a single origin and a single destination. The AMB model, however, examines continuing activity from one place to another over an extended time period, usually a typical weekday.

The primary advantage of an ABM approach is that it more realistically reflects the relationships among multiple trip purposes and locations throughout the day (i.e., a person who leaves a personal car at home when traveling to the office during the morning peak will therefore not use the personal car for a midday errand). A key constraint of the ABM approach is that it is more

data-intensive than a four-step model approach. ABMs are being developed nationwide, predominantly by MPOs or State agencies that have relatively robust model development programming capacity.

The state of the practice in ABM is somewhat more advanced for person-movement than for goods movement. Several jurisdictions are making great strides in development of similar BBFMs that focus on businesses supply chains and freight movement (see Figure 8).
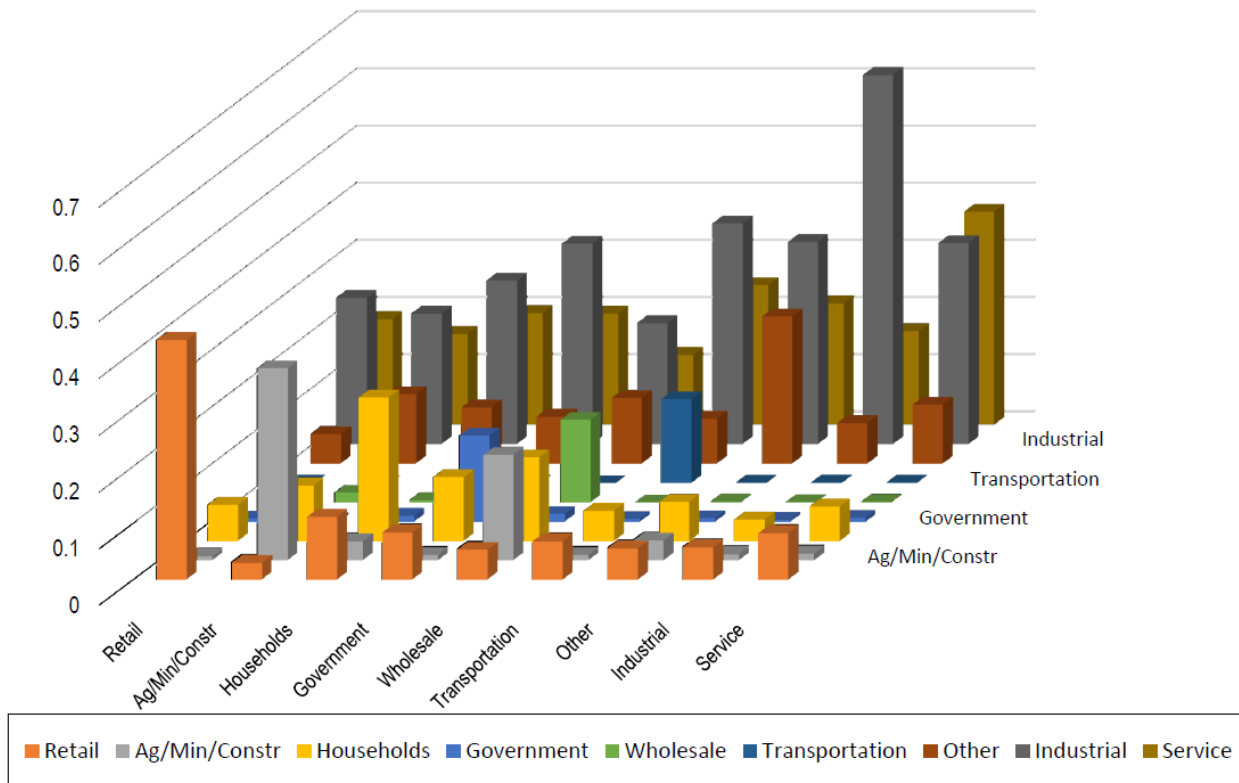
Figure 8: BBFM Representation of Industry-Specific Relationships across the PC Linkage
Source: SHRP2

The QRFM update should have a new chapter on BBFM techniques, logically situated as a modeling approach type equivalent to four-step models, commodity models, and hybrid approaches.

The challenge for the QRFM in addressing BBFM approaches will be twofold:

Highlighting the benefits of BBFM through summary materials and case studies to help promote greater dissemination of BBFM development and application technology, and

Synthesizing lessons learned from BBFM applications to help transfer key findings and quick-response approaches that might be suitable for those who are years away from applying a BBFM.

The *Behavioral/Agent-Based Supply Chain Modeling Research Synthesis and Guide* was developed by FHWA in parallel to this study and will help the QRFM address these objectives.

Freight Case Studies as Part of BBFM Deployment

The SHRP2 C20 process included four useful case studies on BBFM; three at the regional level (Phoenix, Arizona; Baltimore, Maryland; Portland, Oregon) and another related to statewide application (Wisconsin).

In the Phoenix region, the Maricopa Association of Governments (MAG), the Pima Association of Governments, and the Arizona DOT collaborated to develop a regional freight model that can be integrated within regional and statewide travel forecasting models to support decisionmaking and analysis across the Sun Corridor megaregion. To develop the megaregional freight model, the project team first completed a comprehensive review of freight data sources to determine what data were available and appropriate for the model.

The megaregional freight model includes independent components for firm synthesis, supply chain analysis, mode choice, and truck touring. The first two components help tailor the functional and geographic relationships among different industries. The latter two components help tailor the assignment of FTG and STG to reflect truck tours chaining several deliveries throughout the day.

The goal for the model was to better replicate the economic behaviors of establishments, shippers, and carriers by modeling travel and tour formations. The model hierarchy includes three layers, each containing one or more models:

- Financial layer: describes the production, consumption, and evolution of businesses, including a Firm Synthesis Model.

- Logistics layer: determines the transfer of goods between buyers and suppliers, including a Supplier Selection Model that generates buyers and sellers for shipments.

- Physical transportation layer: estimates truck activity for origin and destination of local goods movement using GPS data, including two models: 1) a Supply Chain Model that describes how goods are moved from origin to destination; 2) a Truck Tour-Based Model that captures any touring behavior (i.e., making multiple deliveries in a single day) by trucks in the region. Figure 9 illustrates a Truck Tour-Based Model structure used for this approach.
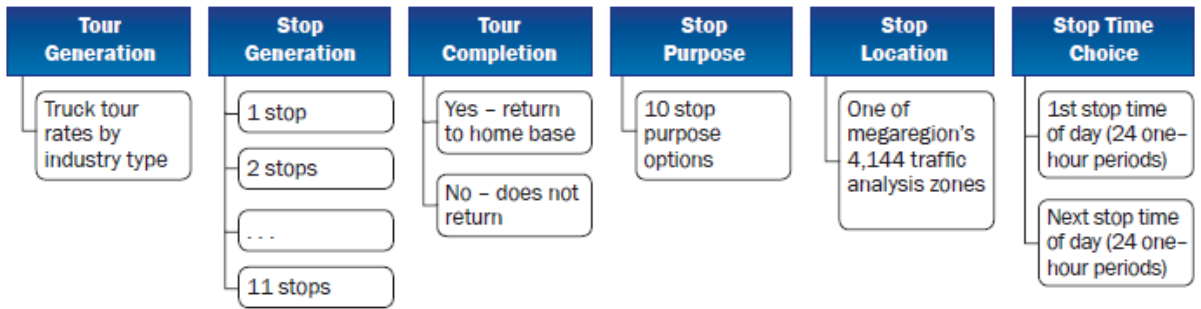
Tour Generation	Stop Generation	Tour Completion	Stop Purpose	Stop Location	Stop Time Choice
Truck tour rates by industry type	1 stop 2 stops . . . 11 stops	Yes – return to home base No – does not return	10 stop purpose options	One of megaregion's 4,144 traffic analysis zones	1st stop time of day (24 one-hour periods) Next stop time of day (24 one-hour periods)

Figure 9: Truck Tour-Based Model Structure from Behavior-Based Modeling
Source: MAG

At the statewide level, the Wisconsin DOT (WisDOT) developed a proof-of-concept BBFM and compared it to the prior statewide freight model.

The WisDOT team sought to transfer the behavioral-based freight model approach developed by the Chicago Metropolitan Agency for Planning (CMAP), and identified several valuable lessons in model development and application. First, WisDOT found that some changes were needed to adjust the regional data used to validate the CMAP model to better reflect nationally available data. WisDOT also found that the BBFM improved the assessment of freight mode shift to rail for the introduction of new intermodal terminals. For routine truck touring models, however, the BBFM results were not materially different in terms of predicting truck volumes on State roadways on a statewide scale (a primary function of the statewide model). These useful lessons learned will help agencies consider the cost effectiveness of BBFMs. These advanced BBFMs may be of greatest value to metropolitan agencies evaluating a range of scenarios at a more disaggregated scale in a more urban environment where network granularity is more sensitive to the types of nuances BBFM tools provide.

Baltimore Metropolitan Council and Portland Metro Freight Modeling Systems

The Maryland State Highway Administration (SHA) and Baltimore Metropolitan Council (BMC) model is a two-agency freight model developed as part of the Freight and Commercial Vehicle Model Development project (the model work was completed in part with FHWA funding provided to SHA and BMC under a SHRP2 C20 Implementation Assistance Program grant). The SHA/BMC model included components that function at different geographical scales.

The larger, national-scale model is designed for integration with the Maryland Statewide Model (MSTM) maintained by SHA. It is a supply chain model that simulates the transport of freight between supplier and buyer businesses in the United States, focusing on movements that include Maryland. This model produces a list of commodity shipments sorted by mode and converts them to daily truck trip tables that can be assigned to the national and statewide networks in MSTM along with trip tables from the passenger model component of MSTM.

The freight truck-touring model (FTTM) simulates truck movements within the Baltimore region that deliver and pick up freight shipments at businesses. The FTTM is a tour-based model and builds a set of truck tours. These tours include transfer points at which the shipment is handled

before delivery/after pick up for shipments with a more complex supply chain (i.e., a warehouse, distribution center, or consolidation center) and the suppliers and buyer of shipments where those are within the model region. The shipment list from the National Supply Chain Model (NSCM) is used as the demand input for the FTTM and describes the magnitude and location of delivery and pick-up activity in the region that must be connected by truck movements.

The commercial vehicle touring model (CVTM) for non-freight-carrying trucks simulates the remainder of the travel of light, medium, and heavy trucks for commercial service purposes (i.e., providing services and goods delivery to households and services to businesses). Like FTTM, the CVTM is a tour-based model, but demand is derived from the characteristics of the business establishments and households in the region and is not affected by the supply chain model. CVTM simulates truck and light-duty vehicle movements based on demand for services and goods from certain industries, while FTTM simulates truck tours based on commodity flows.

In Oregon, Portland Metro received a SHRP2 C20 grant and is currently developing a new behavior-based freight and commercial vehicle modeling system. The Portland Metro freight model is based on a combined supply chain and tour-based framework. This framework comprises several steps that simulate the transport of freight between each supplier and buyer business in the United States. The model has three major components:

- NSCM: Connects the Portland region with the rest of the Nation and includes global freight flows based on FAF data.

- Tour-Based Freight Truck Model: Encompasses freight delivery and pick-up movements, which converts shipments generated by the supply chain model into local truck trips.

- Tour-Based Non-freight Commercial Service Model: Generates trips based on local land uses for both commercial and residential customers.

The Tour-Based Freight Truck Model and Tour-Based Non-freight Commercial Service Model are similar to the SHA/BMC freight model described above and were calibrated using local data collected during the Portland model project.

Portland Metro developed an "establishment survey" to collect behavioral freight data that focused on travel across four counties in Portland Metro's modeling area. The survey was distributed to non-freight service providers (e.g., construction contractors) and firms associated with short-distance light- and medium-truck goods movement. GPS data for truck trips was also provided by local distribution businesses and supplemented by commercial GPS data from data vendors. Because the establishment survey collected the required data, the model allows planners to estimate the movement of service vehicles separately from typical freight vehicles.

Commodity Flow Playbook

The QRFM is designed to help practitioners quickly gain a big-picture perspective of potential resources to help address their immediate freight planning challenges. Often, the types of challenges and the range of potential resources can appear daunting. NCFRP 26, *Guidebook for Developing Subnational Commodity Flow Data*, is a useful approach for tackling problems that apply beyond the subnational commodity flow topic.

NCFRP 26 uses football terminology to help users construct a "game plan" from among the many plays or methods they have available to them. The game plan will be tailored to each user's specific circumstances and the problems they are trying to solve. In many cases, users will want to combine methods to take advantage of the strengths and compensate for the weaknesses of individual approaches. NCFRP 26 helps users diagnose their problem and data needs, identify their resources and skills, and explore their relationship with the private-sector freight community (the source of potentially useful data) to help craft the right game plan for their situation. NCFRP 26 provides some real-life examples of problems that planners deal with that require commodity flow data. Further, NCFRP 26 uses those examples to illustrate the thought process involved in developing an approach and selecting appropriate commodity flow data development methods.

In helping users structure a game plan for tackling commodity flow data problems, NCFRP 26 enables users to:

- Understand the nature of a problem and the types of data needed.

- Understand available capabilities and resources, including a self-diagnosis questionnaire to help identify opportunities for in-house solutions and issues that might best be addressed through interagency partnerships or consulting services.

- Follow a systematic approach for using available data and less expensive techniques to help target new primary data collection methods.

Example #2 in NCFRP 26 specifically addresses the development of an advanced freight modeling system (the subject of topic matrix C). The playbook concept could be applied to solving any freight problem and could be a useful framing tool to improve the usability of the QRFM.

Port Everglades Petroleum Commodity Flow Survey

The SHRP2 C20 project undertaken by Florida DOT also serves as a model for considering different truck types and commodity flow types in a modeling approach. This item provides an opportunity for practitioners to consider customizing more standard techniques, modifying them to apply more precisely to locally important issues.

While the Broward County last-mile analysis methodology describes the linkage between land uses, sales revenues, and observed flows, the PEV Petroleum Commodity Flow Survey focuses on aspects of data that address commodity flow forecasting and the vehicle conversion step of the process (as described in Section 5-9 of the QRFM).

Additionally, the PEV Petroleum Commodity Flow Survey summarizes the state of the practice, benefits, and limitations of a wide range of truck data collection techniques, suitable for Chapter 10 of the QRFM.

Freight Analysis Framework (FAF)

The Freight Analysis Framework (FAF), produced through a partnership between the Bureau of Transportation Statistics (BTS) and FHWA, integrates data from a variety of sources to create a

comprehensive picture of freight movement among states and major metropolitan areas by all modes of transportation. Starting with data from the Commodity Flow Survey (CFS), international trade data from the Census Bureau, and data from agriculture, extraction, utility, construction, and service sectors, FAF provides estimates for tonnage and value by regions of origin and destination, commodity type, and mode for the base year and forecast years.

FAF4 data analysis and visualization tools have been significantly enhanced in the past decade, facilitating development of products that help address more directly economic outcomes of interest to decisionmakers. Figure 10 illustrates a sample visual output of FAF4 analysis, demonstrating the economic input of Florida's freight flows.
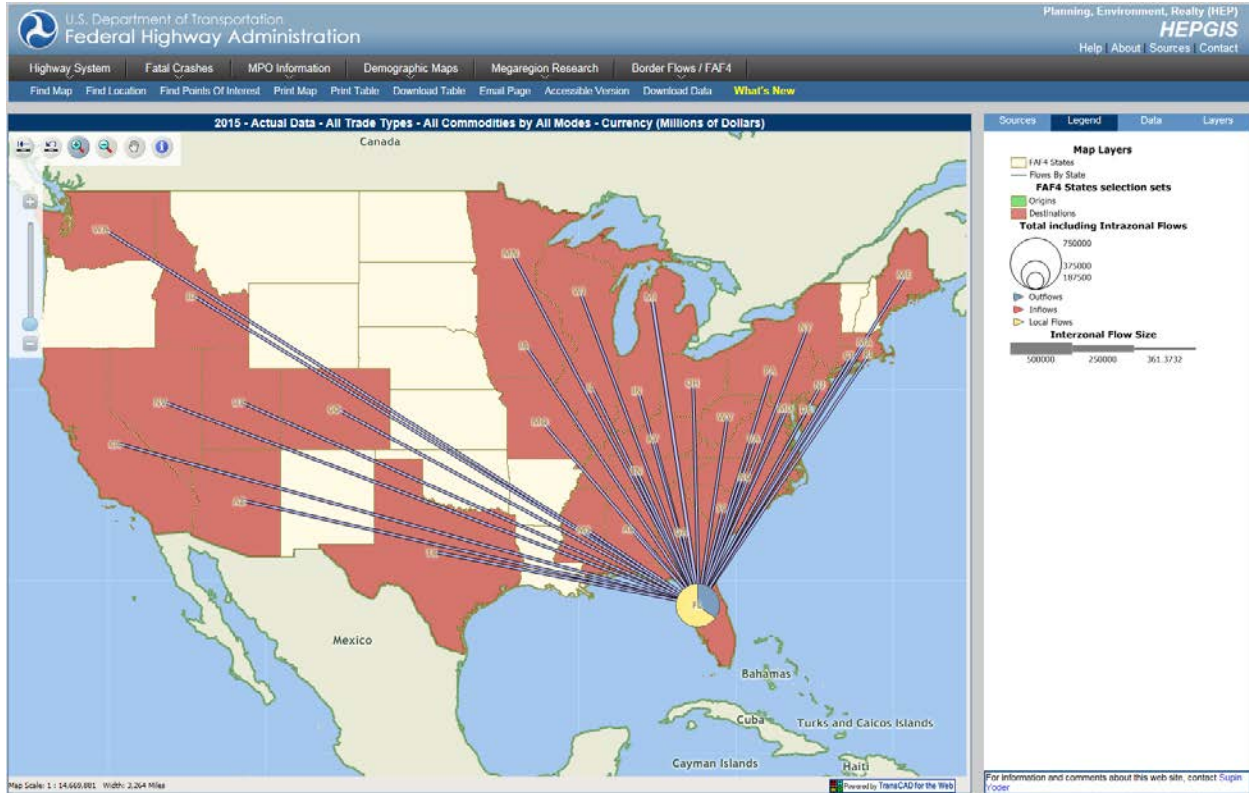
Figure 10: Example of FAF4 Data Visualization Describing Economic Impact
Source: FHWA

TOPIC D: PUBLIC AND PRIVATE DATA SOURCES

Key initiatives under this topic include the following:

Update the current listing of best data sources from NCFRP 25, *Freight Trip Generation and Land Use,* by building on the work done in SHRP2 C20 projects and filling gaps identified in that research.

Develop a national strategic plan for freight data-sharing to leverage private sector decisionmaking resources and make these more readily available to the public sector.

Facilitate understanding within the community of practice (including both public and private sector practitioners) of the increasingly disparate time horizons affecting goods movement decisionmaking. Explore how the private and public sectors respond to that demand with policies, pricing, and traditional and innovative approaches to increasing supply chain capacities.

Topic D also provides additional resources for consideration.

Current Listing of Best Data Sources

NCFRP Report 25 provides guidelines for sharing freight data, primarily between public and private freight stakeholders. The report recognizes the difficulties in obtaining data from private entities as well as the significant costs associated with data collection, and provides examples of how to overcome these barriers. Additionally, the report highlights 18 different public and commercial data sources that can be assessed by practitioners without restrictions (see Table 3). It should also be presented in the context of the value of blending public and private data sources as described elsewhere throughout Topic D.

Table 3: Summary of Freight Data Sources as of 2013
Source: NCFRP Report 25

Database	Source and URL
Airline Traffic, Airfare, and Airline On-time Data	USDOT Bureau of Transportation Statistics (BTS) Publicly available at www.bts.gov
Border Crossing Data	USDOT BTS Publicly available at www.bts.gov
Commodity Flow Survey (CFS)	USDOT BTS Publicly available at www.bts.gov
Freight Analysis Framework (FAF-3)	USDOT FHWA Publicly available at www.ops.fhwa.dot.gov/freight/freight_analysis/faf/faf3/netwkdbflow
Industry Trade Data and Analysis	U.S. Department of Commerce International Trade Administration Publicly available at www.trade.gov/data.asp
Intermodal Data and Statistics	Intermodal Association of North America - Multiple report and products – some for a fee. See https://www.intermodal.org/resource-center/data-statistics

Database	Source and URL
Maritime Statistics Reports and Survey Series and Fleet Statistics	USDOT Maritime Administration. Publicly available at https://www.marad.dot.gov/resources/data-statistics/
Port/Import/Export Reporting Service (PIERS)	Available for a fee from Journal of Commerce at https://ihsmarkit.com/products/piers.html
Rail Waybill Sample Surface Transportation Board	Publicly available at https://www.stb.gov/stb/industry/econ_waybill.html
Rail Industry Operating Statistics	Association of American Railroads https://www.aar.org/data-center/ - Multiple products – some publicly available and some only available to members
Rail Industry Reference Files	RAILINC Corporation multiple products, some publicly available and some available to subscribers only at www.railinc.com/ References and Files tab
State of the Trucking Industry	American Trucking Associations - Only available to the subscribers. See www.trucking.org/StateIndustry/Pages/default.aspx
Ton Miles of Truck Shipments by State	USDOT FHWA Publicly available at www.ops.fhwa.dot.gov/freight/freight_analysis/nat_ freight_stats/docs/09factsfigures/
Transborder Surface Freight Data	USDOT BTS Publicly available at www.bts.gov
TRANSEARCH	IHS Global Insight - Available for a fee at http://www.ihsglobalinsight.com/ProductsServices/ProductDetail838.htm
TranStats – The Intermodal Transportation Database	USDOT BTS Publicly available at www.transtats.bts.gov
Waterborne Commerce of the U.S.	U.S. Army Corps of Engineers - publicly available at https://www.iwr.usace.army.mil/about/technical-centers/wcsc-waterborne-commerce-statistics-center/

Strategic Plan for Freight Shipping Data Development and Sharing

Data confidentiality is a concern voiced by shippers and carriers. Given small margins on typical freight transportation services, shippers and carriers are often cautious about giving away their competitive advantage if competing firms have access to their data. At the national level, regulations such as Title 13 of the U.S. Code directing private firm participation in the Economic Census helps ensure the relevance of the CFS. As data interests become more fine-grained, however, balancing private and public sector interests becomes more challenging. For example, the SHRP2 C20 project team working in the Albany, NY, region was able to collect data after developing a non-disclosure agreement (NDA) with each participating firm. The process of

developing and executing the NDA took substantial time and effort before data collection could begin.

A national strategic plan for freight shipping data would help standardize the development of more localized yet transferable metadata. This effort would require a public-private partnership (at least in the informal sense of the term) to balance the costs (of both fiscal and proprietary natures) and benefits (in terms of smoother goods movement policy and project implementation). Conceptual elements could borrow from both institutional frameworks such as NAICS code evolution as well as industry self-promotion techniques, such as Leadership in Environmental and Energy Design certification, to find an appropriate balance between incentivizing and compelling private sector participation. This strategic plan would also need to anticipate and incorporate technological and societal changes that would keep the database sufficiently nimble over time, a subject explored further in topic matrix D.

Aligning Private Sector Shipping Needs with Public Sector Policies and Investments

Investment decisions in transportation infrastructure and services have long benefitted from robust data collection, compilation, and analysis. For the past several decades, this process has generally been led and managed by the public sector. Examples include demographic data such as those provided by the U.S. Census Bureau; travel flow information from traffic counts (both permanent stations and temporary project-level observations) and traveler surveys; and performance measures such as level of service and cost-benefit ratios. The public sector has also defined the rules and regulations for transportation system investments, ranging from National Environmental Policy Act (NEPA) impact analysis to best practices by agencies such as the American Association of State Highway and Transportation Officials, ITE, and TRB guidance. Major transportation system investments might have a useful life of several decades, so the process by which investment decisions are made has similarly valued analysis attributes such as authority, reliability, and transferability over attributes such as innovation and speed.

The information explosion discussed earlier in this report has shifted the data analytics paradigm. Recent advancements in transportation data collection have led to improved data quality, greater temporal coverage, wider geographical coverage, and differing population characteristics. New data sources, such as probe vehicles, GPS, crowd-sourced data (e.g., INRIX, HERE, Google, TomTom, Waze, etc.), Bluetooth, cellular data, and other emerging data sources could generate conventional performance measures needed for both traditional analytic methods as well as new measures for gauging factors such as reliability and resilience.

The information explosion has also illuminated the differences in evaluation timelines between transportation system providers and transportation system users. Other important factors to consider on this topic include:

Major transportation system infrastructure investments such as new roads, rail lines, and ports still have a useful life of 30 or 40 years and high capital costs that are supported in part by that lengthy amortization period.

Rolling stock such as trucks and railcars still have a useful life of 10 to 20 years, in part due to the certainty of the investment in the infrastructure they use.

Unlike infrastructure and rolling stock, the shelf life of data-intensive technologies driving market demand such as product innovations, supply chain management, product information distribution and customer feedback methods, and purchase transactions is continually shrinking and might best be measured in weeks or months rather than years.

The discrepancies between the relatively stable shelf life of the transportation system and rolling stock and that of the economic markets creates a challenge in aligning private shipper needs with public sector policies and investments. Market economies creating and using data are focused on near-term rates of return on investment; the state of the practice in the private sector today is almost certain to be obsolete in five to ten years.

Additional challenges associated with private sector data include cost, limited availability with strict use policies and NDAs, and privacy concerns. The public sector must also ensure that new and innovative data sources meet acceptable quality criteria; these include timelines, coverage, accuracy, continuity, and provenance. Despite the myriad challenges, transportation agencies negotiate with private vendors to obtain consistent, timely, quality data for planning purposes. Practitioners are bombarded with information; for example, the National Performance Management Research Data Set (NPMRDS) provides an important data resource and many State DOTs and MPOs purchase their own freight databases. However, in many cases these efforts are still insufficient to support decisionmaking on data spending.

NCHRP 49-14, *Methods to Acquire Proprietary Data for Transportation Applications*, will develop a synthesis of the benefits and limitations of non-traditional data for transportation applications. The project will identify available data sources at various levels (private and public sector), consider methods and tools such as data fusion techniques to apply innovative data sources to more traditional performance measure evaluation, and summarize how agencies might integrate new data sources to either complement or replace existing transportation data sets.

Truck Data Collection Survey Instruments

Additional materials for truck data collection include the development of automated data collection and interview techniques. These are described in more detail below.

Automated Vehicle Locator Resources
The Florida DOT SHRP2 C20 project on petroleum flows in southeast Florida included a summary of the strengths and weaknesses of vehicle detection technology characteristics associated with tanker truck identification. Table 4 provides excerpts from this summary to identify vehicle detection technology characteristics. A number of these methods could potentially be used to collect data on truck and freight movements.

Table 4: Excerpt of Vehicle Detection Technology Characteristics from Florida DOT SHRP2 Analysis
Source: SHRP2

Technology	Definition and Operation Theory	Vehicle Classification Detecting Methods	Potential for Tanker Truck Detection
Video Image Processing	Video image processor systems detect vehicles by interpreting video image and convert signals into traffic flow data. Video image processing can be trained to recognize vehicles' classification and identification based on the digital imagery that is presented.	Analyze video images: can classify vehicle by length, edges, and combinations of features and sizes.	High
Laser Scanner/LiDAR	A transmitted pulsed or continuous light which is used to image objects, utilized three dimensional (3D) data which extracts road data from classification.	Create 3D images: can classify vehicles by length, edges, shapes, features, and sizes.	High
License Plate Recognition	Captures photographic video or images of license plates, which are processed through a series of algorithms to capture and identify the license plate image.	Analyze license plates photos or images: detect vehicle classification based on registration information.	High
Transponders	Detects vehicles and collect data when they pass through transponder stations.	Analyze vehicle registration database: detect vehicle classification based on registration information.	High
Inductive Loop	A sensor capable of detecting vehicle passage and presence. There are two basic undercarriage loop classifier technologies. One uses the "signature" from existing loops to determine classification by matching the shape of that loop to expected profiles. The other uses specific types of loops to detect changes in inductance associated with wheels, and uses that information to detect and measure axles.	Analyze complex information: can classify vehicles by length, axles, and loop signatures.	Low
Weigh-in-Motion	Detects vehicle by presence of an axle as well as the pressure put on the device.	Classify vehicles by axles and weight.	Low

Technology	Definition and Operation Theory	Vehicle Classification Detecting Methods	Potential for Tanker Truck Detection
Microwave Doppler	The constant frequency signal (with respect to time) allows vehicle speed to be measured using the Doppler principle. Accordingly, the frequency of the received signal is decreased by a vehicle moving away from the radar and increased by a vehicle moving toward the radar. Vehicle passage or count is denoted by the presence of the frequency shift.	Classify vehicles by length	Low
Microwave Radar	Vehicle detection devices that transmit electromagnetic energy from an antenna towards vehicles traveling the roadway. When a vehicle passes through the antenna beam, a portion of the transmitted energy is reflected back towards the antenna. The energy then enters a receiver where the detection is made and traffic flow data, such as volume, speed, and vehicle length are calculated.	Classify vehicles by length	Low
Magnetometer (two-axis fluxgate magnetometer	Passive devices that detect the presence of a ferrous metal object through the perturbation (known as a magnetic anomaly) it causes in the Earth's magnetic field. Its output is connected to an electronics unit.	Classify vehicles by length	Low
Piezo/ Quartz Sensor	An axle detection sensor embedded in the roadway, which produces a signal when an axle/tire comes across it.	Classify vehicles by axles	Low
Passive infrared	A device whose infrared-sensitive element detects and converts the reflected and emitted energy from vehicles, road surfaces, and other objects into electrical signals.	Classify vehicles by axles	Low
Magnetic Detector (induction or search coil magnetometer)	A device that detects changes in the Earth's magnetic field caused by the movement of a ferrous metal vehicle in or near its detection area. It is placed under or in the roadway to detect the passage of a vehicle over the sensor. These sensors generally detect only moving vehicles. Their output is connected to an electronics unit.	Cannot classify vehicles	N/A

Technology	Definition and Operation Theory	Vehicle Classification Detecting Methods	Potential for Tanker Truck Detection
Air switch/ Road tube	A tube installed perpendicular to traffic, in which a burst of air pressure produces an electrical signal as a vehicle's tires pass over the tube.	Cannot classify vehicles	N/A
Ultrasonic	Transmits pressure waves of sound energy at a frequency between 25 and 50 kHz, which is above the human audible range. Most ultrasonic sensors operate with pulse waveforms and provide vehicle count, presence, and occupancy information.	Cannot classify vehicles	N/A
Passive Acoustic Array Sensors	Measures vehicle passage, presence, and speed by detecting acoustic energy or audible sounds produced by vehicular traffic from a variety of sources within each vehicle and from the interaction of a vehicle's tires with the road.	Cannot classify vehicles	N/A

Truck Data Collection Survey Techniques

The ITE *Trip Generation Handbook* is one of the foundational resources for this project. As described in the annotated bibliography, the ITE *Trip Generation Handbook* is a best practice that is periodically updated and adopted by ITE through a rigorous peer-review process. The third edition of the ITE *Trip Generation Handbook* covers a wide range of topics beyond goods movement. Thomas, Yarbrouh, Anderson, Harris, and Harrison (Transportation Research Record 2160, 2010, p. 163) recommended to ITE an application for a truck data collection survey. The Winston-Salem MPO SHRP2 C20 implementation assistance project in the Piedmont Triad applied this type of survey and provides a current example that would be appropriate for inclusion in the QRFM as a case study.

2017 CFS

The CFS is undertaken through a partnership between the U.S. Census Bureau and BTS. The CFS was initiated in 1993 and is conducted every five years (years ending in "2" and "7") as part of the Economic Census. The CFS produces data on the movement of goods in the United States. It provides information on commodities shipped, their value, weight, and mode of transportation, as well as the origin and destination of shipments of commodities from manufacturing, mining, wholesale, and selected retail and services establishments. The continued application of a steady approach provides both a snapshot of relatively current conditions as well as a baseline for longitudinal trendline analysis.

The CFS captures data on shipments originating from selected types of business establishments located in the 50 States and the District of Columbia. The establishments are asked to provide shipment information about a sample of their individual outbound shipments during a pre-specified, one-week period. For shipments that include more than one commodity, respondents

are instructed to report the commodity that makes up the greatest percentage of the shipment's weight.

The current QRFM summarized the results of the 2002 CFS, noting that the coarse aggregation of the CFS database (the national data is aggregated into 114 zones) limits application CFS data. Since then, the CFS has been substantially disaggregated; the 2012 CFS included 3,143 zones. The 2017 CFS results are expected to be published in 2019. The content of the QRFM should be broadening to incorporate more explanatory materials. These materials would help decisionmakers and practitioners gain a more holistic perspective of the range of tools available.

Review of Freight Data Sets

Freight data collection is often fragmented and uncoordinated, and is often not well defined. Data standards can vary greatly across freight data sources, making it difficult to integrate available data. Further, Federal agencies have recently made national freight datasets available to the public; the data are typically not available on the sub-regional scale needed for effective local freight planning.

As part of the SHRP2 C20 program, the Capital District Transportation Committee (CDTC), the MPO for the greater Albany-Schenectady-Troy New York area, assembled a project team and developed a process to effectively collect, integrate, and maintain freight-related data from multiple sources, including innovative, easily obtainable private data and commonly used public databases. The project team identified existing freight data at the national, State, and local levels, and it designed and conducted data collection activities to obtain new freight data for the CDTC region. Figure 11 provides freight dataset characteristics from the Capital District study that facilitate data mining for local freight planning purposes.

Table 27: Variables Included in the Databases

No.	Database	Parameter					Industry			Frequency				Mode							Aggregation						Policy					
		Freight trips	Freight generation	Ton-miles	Value	Service trips	NAICS	SCTG	STCC	5 years	Yearly	Quarterly	Hourly	Types of trucks	Trucks	Rail	Water	Air	Pipeline	Multi-modal	Import/Exports	State	County	ZIPcode	Census Tract	Along highways	Weight limit	Landuse/Demographic	Network	Traffic	Toll	Crashes
	Publicly available data																															
1	Commodity Flow Survey (CFS)		✓	✓	✓		✓	✓		✓					✓	✓	✓	✓	✓	✓		✓								✓		
2	FAF3 Origin-Destination		✓	✓	✓			✓		✓					✓	✓	✓		✓	✓	✓	✓								✓		
3	Smart location data						✓				2nd version													✓	✓			✓				
4	Employment data										✓													✓								
	Need to be obtained from different agencies																															
1	511 NY data feed												✓																	✓		✓
2	Capital Region updated network		✓								2006-07															✓			✓	✓		
3	Commercial Census data		✓				✓				Periodically			✓												✓						✓
4	HERE speed data											✓			✓											✓			✓	✓		
5	MIST speed and volume data										✓														✓				✓	✓		
6	TRANSEARCH commodity flow		✓	✓	✓				✓		✓													✓						✓		
7	Economic data (in GIS format)										✓											✓	✓					✓	✓			
8	E-ZPass data	✓										✓	✓													✓			✓	✓	✓	
9	Oversize/overweight permiting	✓	✓								✓														✓							
10	TRANSMIT data	✓	✓										✓													✓	✓		✓	✓	✓	
11	Truck crash data										✓		✓										✓									✓
12	Truck traffic counts	✓										✓	✓													✓			✓	✓		
13	Weight-In-Motion (WIM)	✓										✓	✓													✓	✓			✓		
	New datasets																															
1	GPS	✓				✓	✓					✓	✓	✓		✓								✓						✓		
2	In-Depth-Interviews	✓	✓				✓								✓	✓	✓	✓						✓				✓	✓	✓	✓	✓
3	FTG, FG, STA models	✓	✓			✓	✓							✓										✓						✓		

Figure 11: The Capital District Study Examined Freight Data Set Characteristics that Facilitate Data Mining for Local Freight Planning Purposes

Source: CDTC

The Capital District study focused on creating a dynamic freight database that would allow for aggregation of data at the local level. The study characterizes a comprehensive list of potential freight datasets, sources, processes for obtaining data, compatibility with research, level of disaggregation, advantages, and limitations.

The study included publicly available information as well as data from shippers and carriers in the region, as well as survey and in-depth interview responses. Together, this information helped CDTC understand freight shipment patterns in the region and provided insight into the decisionmaking processes by these businesses. A major positive outcome of this project was identifying the availability of processed data that will readily support any level of aggregation. For example, the project showed that the CFS and FAF can support national-level analyses; EZ-Pass or truck count data can model interstate flows; and freight trip generation, freight generation, and service trip models can support ZIP code-level analyses. In addition to obtaining and preparing the database, the project team calibrated models to estimate the freight flows (trips, generation, and services) at the ZIP code level.

TOPIC O: OTHER TOPICS

Several elements that are appropriate for inclusion into QRFM did not fall neatly into topics A through D. These elements were included below.

Summary of the State of the Practice

The final report for the SHRP2 C20 strategic plan provided a useful 15-page summary of the state of the practice.[6] Different components of this plan can now be updated for the SHRP2 C20 projects and products, including:

Economic flow models

Land use and economic input-output models

Commodity-based models

Trip based models

Localized estimation routines

Aggregate/trendline measures

Quick response procedures

Scenario Planning Guidance

Scenario planning is an increasingly important topic given that any transportation forecasting process has a range of uncertain and uncontrollable input variables. Additionally, investment decisions should encompass the widest possible range of likely futures as reflected in a risk-management approach to forecasting. For this particular "thinking beyond the QRFM" topic, one of the foundational documents, NCHRP Report 750, *Strategic Issues Facing Transportation Volume 1: Scenario Planning for Freight Transportation Infrastructure Investment*, is dedicated to the topic of scenario planning for freight transportation investment.

NCHRP Report 750 Volume 1 outlines the Schwartz Eight-Step Method for Scenario Planning, which describes the following approach:

1. Identify focal issue

2. Identify key local factors

3. Identify driving forces

4. Rank driving forces by importance and uncertainty

5. Select scenario logic

6. Flesh out scenarios

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[6] For more information on the strategic plan, see http://www.trb.org/Main/Blurbs/167629.aspx.

7. Apply the scenarios and uncover implications

8. Identify leading indicators and signposts

This report provides specific examples on freight scenarios that have been used to examine alternative outcomes and their implications in company decisions. The 2010 Future Freight Flow symposium process is described in detail as an example of procedural approaches to scenario planning workshop development.

Megaregional Planning Considerations

Megaregions increasingly reflect economic interdependencies across regional and State boundaries throughout the United States. Transportation remains an integral part of these systems, ensuring efficient flow of people, goods, and services. Effectively managing these systems across jurisdictional boundaries remains a challenge. Specifically, many megaregions struggle with identifying key issues of concern and taking action to implement specific project priorities to enhance or improve transportation conditions. These areas continue to have a strong need to create new models for implementing megaregional transportation solutions that reflect agreed upon project priorities and system performance goals.

The first round of 2016-2017 megaregion workshops helped FHWA and local partners explore technical and institutional opportunities and constraints associated with more holistic engagement in large-scale movement of people and goods.

At the broadest scale, the I-10 Corridor workshop provided an opportunity for State DOT leadership to share a vision to connect several megaregions and establish a concept of operations. Workshop participants also identified the need to develop an action plan for continued planning and operations over a 1,000-mile span. Suggested action strategies ranged from turning data into corridor-wide traveler information to policies and technologies that would further streamline goods movement (e.g., through permitting, weigh-in-motion, truck parking, and enforcement tactics).

A key concern expressed in the Piedmont megaregion workshop was how best to link Atlanta to the Ports of Savannah and Charleston, yet many megaregion definitions don't include those two port cities in the Piedmont megaregion. The concept of "problem sheds" discussed at the Mid-South megaregion workshop may help focus attention on the importance of a more nimble approach to connecting stakeholders depending on the scale and scope of the issue being addressed. Maintaining precise or fixed boundaries are not required to form useful and opportunistic partnerships to address the identified regional issues. The area of these "problem sheds" will vary based upon the issue and the relevant regional partners. Overall, each of the megaregion workshops helped develop or strengthen interagency and interdisciplinary relationships. They also helped set the stage for implementing specific megaregional transportation solutions.

The concept of scenario planning for megaregions was examined by Weidner et al. in a 2013 TRB paper 13-2236, *Exercising a Mega-Region Analysis Framework in the Chesapeake Bay Area*, which examined a high energy-price scenario for a multi-State, multi-MPO area in the mid-Atlantic region. The scenario demonstrates the value of having a planning application at a

geographic scale below the national commodity flow model that can link economic, land use, transport, and fiscal models. This can help MPOs and others within a megaregion better examine the unanticipated effects of their decisionmaking for that megaregion. The applicability of this type of model to the QRFM will depend on how potential users of the manual interact with megaregions. This type of model may be of greatest value to transportation agency coalitions such as the I-95 Corridor Coalition.

An outcome of this research was an identified need for practitioners to better understand strategic, institutional, and other linkages between their own agencies, partner agencies, and private sector entities within the goods movement community. The concept of megaregional coordination is similar (although not limited to goods movement or economic development). This involves finding common ground and synergies among new partners for whom collaboration is mutually beneficial.

Value of Reliability

Reliability is a topic area of recognized importance and value to the freight industry for both operations and planning. In the past, the lack of consistent data limited the ability of many practitioners to assemble meaningful metrics associated with transportation system reliability. Subsequent work by Xia Jin et al. at Florida International University identified the value of reliability at roughly 50 percent greater than travel time.[7] This effort builds upon prior meta-analyses by the same team in a 2016 TRB paper 16-2051, *Comprehensive Review and Meta-analysis of Stated-Preference Studies for Valuation of Travel Time Reliability in Freight Transport*. Reliability has also been a major focus of the MAP-21 National Freight Performance Measure through the Truck Travel Time Reliability Index.

Visualization Techniques

Understanding and communicating the significance of freight data is critical to planning for future transportation capacity, operation, preservation, safety and security, energy, and economic investment needs. The advent of new data sources and more robust analytic tools does not change the importance of turning data into information, and transforming that information into wisdom to inform decisions. In fact, the explosion of data increases the importance of separating "the signal from the noise," both in terms of performing data analysis and summarizing actionable intelligence. Using visualization techniques to tell a compelling story is often a hallmark of new data and analytic applications, but should be recognized as being independent from those applications.

Transportation agencies can enhance their freight transportation planning and decisionmaking by using visualization tools, which provide a powerful means of communicating complex concepts and data. Visualization tools can also be used to provide a powerful means of communicating freight performance measures. Visualization of data can help freight stakeholders understand geographic information such as truck touring routes; temporal information such as time of day

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[7] For more information, see http://amonline.trb.org/63532-trb-1.3393340/t005-1.3409009/475-1.3409319/17-00847-1.3403384/17-00847-1.3409326?qr=1.

delivery patterns or seasonal variability; and physical information such as the effect of alternative curb space management approaches on goods delivery.

In addition, visualization techniques can be used to develop more robust forecasting models while communicating concepts and analyses to decisionmakers. Visualization can help explain a variety of freight-related variables that may be inputs to or outcomes from an analytic technique, providing a "common language" to promote a greater understanding and more productive dialogue among modelers, planners, researchers, the private sector, decisionmakers, and other stakeholders.

In addition to the SHRP2 C20 resources described elsewhere throughout this report, the TRB Committee on Visualization (ABJ95) provides a useful clearinghouse for visualization technique considerations.

SECTION 4: SUMMARY OF KEY FINDINGS

This project documented best practices and tools for understanding and analyzing how land use, local economic development, and demographic factors drive freight movement, trip generation, and freight demand analysis. This information was gathered through a combination of activities that included a literature review and stakeholder outreach. Key findings include the following:

Recent models have improved estimated freight generation using commodity flow data that estimates trip generation as a function of characteristics such as establishment size employment, and type of economic activity performed.

The improved understanding of trip generation and land use increases the importance of maintaining a good inventory of the types and locations of freight-generating land uses.

The advent of e-commerce has increased the complexity of the relationship between manufacturing and the ultimate destination for individual goods delivery.

Local land use context may influence freight generation and the spatial distribution of freight and land use activities may warrant additional consideration.

There is a range of strategies for accommodating demand for goods movement and operations given the context-sensitivity of particularly freight-sensitive land uses.

The integration of goods movement and livability is increasingly relevant as many communities move away from greenfield development and segregated land uses to a greater reliance on mixing uses and redeveloping in a more compact and transportation-efficient form.

Consideration of the last-mile is a basic concern in the integration of land use and freight planning, particularly given increased urbanization and mixing of land uses, increased e-commerce delivery directly to residences, and managing potentially adverse community effects of greater freight traffic.

Practices for local and regional Transportation Impact Assessments can be improved through consideration of goods movement, including site freight trip generation by business type, consideration of freight trip attraction for non-industrial uses, and curb loading zone availability in urban environments.

Analysis of the movement of both people and goods can benefit from scenario planning that evaluates both land use and transportation system actions on travel needs.

The current state of the practice in travel demand modeling tools is changing from conventional "four-step" travel demand models to advanced BBFMs that consider supply chain and delivery systems are being developed to provide a more complete understanding of freight movement and forecasting. The SHRP2 C20 process included four useful case studies on BBFMs; three at the regional level (Phoenix, Arizona; Baltimore, Maryland; Portland, Oregon) and another related to statewide application (Wisconsin).

Investment decisions in transportation infrastructure and services have long benefitted from a robust data collection, compilation, and analysis. Recent advancements in transportation data

collection have led to improved data quality, greater temporal coverage, wider geographical coverage, and differing population characteristics. A strategic plan for fusing the wide range of public freight data and encouraging private data-sharing can help further the understanding of the relationship between freight trip generation and land use, particularly at the local and regional level.

This report also included insights that relate specifically to integrating land use, demographics, and economic discussions into the QRFM.

This appendix provides details on the project approach. The approach involved conducting a literature review and several stakeholder outreach activities to obtain input on draft project documents**.**

LITERATURE REVIEW RESEARCH

The initial literature compilation gathered relevant material from reasonable sources, including existing works in progress and information from published and unpublished reports, to prepare a broad synthesis of best practices and guidelines related to freight trip generation. The output of this activity was a literature review.

One critical document framed this literature review—the 2007 QRFM. Like the original QRFM published in 1996, this manual provides background information on the freight transportation system and factors affecting freight demand. In the last decade, significant advances have occurred in tracking freight movement, in the state of the practice for behavior-based supply chain modeling, and in developing processes for taking into account land use and demographic considerations. Within freight planning, the QRFM—despite being out of date—remains a foundational document that helped the study team organize the literature review findings into two categories. The first category is literature that was considered an update of QRFM information and could be incorporated into appropriate sections or chapters. The second category explores opportunities beyond the QRFM to address broader topics such as scenario planning applications, land use/zoning applications, megaregions, and freight resiliency.

Key resources and technical information included in the literature review for this project include the following:

QRFM published as landmark document (2007)

SHRP2 C20 Freight Demand Modeling and Data Improvement

NCFRP Report 24: *Smart Growth and Urban Goods Movement*

NCFRP Report 25: *Freight Data Sharing Guidebook*

NCFRP Report 26: *Subnational Commodity Flow Data*

NCFRP Report 37: U*sing Commodity Flow Survey Microdata and Other Establishment Data to Estimate the Generation of Freight, Freight Trips, and Service Trips: Guidebook*

NCHRP Report 739: *Freight Trip Generation and Land Use*

NCHRP Report 750 Strategic Issues Facing Transportation Volume 1: Scenario Planning for Freight Transportation Infrastructure Investment

Information gathered also addressed broader topics associated with freight demand, including considerations outlined in the current planning context (discussed in section 1 of this report and highlighted in Table 1):

While current Federal, State, and metropolitan commodity flow analyses are primarily oriented toward institutional boundaries, a megaregional topology may be a more appropriate scale for contemplating broader economic diversification.

The QRFM is primarily oriented toward the same Federal, State, and metropolitan agency audiences, but the concepts of freight-efficient land uses and context-sensitive trip-generation are also valuable to local land use planning and zoning authorities. The update to the QRFM should be scalable for use from a statewide level down to the local site level.

The information explosion and emphasis on interdisciplinary performance measures make scenario planning an increasingly valuable tool for considering alternative investment approaches.

The evolving nature of freight logistics as it relates to development of industry, distribution centers, and delivery of goods and services needs to be understood in terms of its effect on land use and FG.

The literature review was not exhaustive, but rather is meant to document emerging best practices and new approaches and serve as a foundation for stakeholder outreach activities (described below).

STAKEHOLDER OUTREACH ACTIVITIES

The goal of outreach activities was to better understand nuances and situational needs of the study participants in a way that would help concurrently inspire and educate them. These activities included:

Outreach during the 2017 Transportation Research Board (TRB) Annual Meeting–This outreach solicited input and marketed the next event (i.e., Virtual Meeting #1).

Virtual Meeting #1–Held as part of FHWA's monthly freight webinar series, this meeting was an informational webinar supplemented with open discussion to validate the literature review findings and understand the challenges practitioners are facing that were not previously captured.

Expert Working Session–Presented a draft set of topic matrices to freight planning experts for refinement and more detailed discussion.

Virtual Meeting #2–Provided experts from the expert working session mentioned above an opportunity to review and comment on the draft final technical report and its findings.

Together, these activities helped develop and refine the key findings and topic matrices contained in this technical report. Additional details on these activities follow below.

TRB Annual Meeting–January 8-12, 2017

During the TRB Annual Meeting in Washington, DC, project team members attended more than 10 key TRB freight committee meetings to inform and solicit initial thoughts on key freight issues, and encourage participation in Virtual Meeting #1.

Virtual Meeting #1–April 19, 2017

The goal of the first virtual meeting, held as part of the April "Talking Freight" webinar series hosted by FHWA, was to engage a broad group of interested stakeholders and practitioners to explore new trends in freight travel demand evaluation as they occur in different communities and contexts. This meeting included select presentations with complementary discussion time. These presentations included:

Where are we now?–State of the Practice in Incorporating Land Use and Demographic Trends into Freight Trip Demand

Where are we going?–Advances in Freight Travel Demand Evaluation

How do we get there?–FHWA Freight Resources: Existing and Forthcoming

The webinar summarized high-level issues identified early in the literature scan and garnered feedback to confirm areas of greatest practitioner interest. Throughout the course of the webinar, the study team facilitated conversation and conducted polls to gather feedback from the audience on the topics discussed. The goal was to learn whether the findings matched practitioners' experiences.

The webinar helped practitioners explore the gaps and challenges they face in many different communities and contexts. These gaps and challenges span a variety of disciplines (such as transportation, land use planning, and economics) and goods movement stakeholders (such as owners, manufacturers, shippers, and service providers).

A total of 221 participants attended Virtual Meeting #1. Webinar attendees came from a variety of backgrounds in both public and private organizations across the Nation and represented both urban and rural areas.

Expert Working Session–August 8, 2017

FHWA also hosted an expert working session at U.S. DOT headquarters in Washington, DC. Attendees at the expert working session included freight demand modeling practitioners from state DOTs, MPOs, consultants, and academia. While the Annual Meeting outreach and Virtual Meeting #1 were meant to engage a broad group of potential stakeholders, the expert working session focused on mining the collective expertise of more than 10 freight researchers and planning practitioners. The goal of this session was to introduce the draft topic matrices and refine and add detail as provided through participant leadership, expertise, and engagement. The session attendees were asked to:

Consider how to close industry gaps reflected in the initial project literature review

Assess practice-readiness

Suggest case studies

Identify missing topics

Build momentum for next steps

This conversation was supported through a pre-session briefing package that included summaries of the draft topic matrices, as well as a compendium of high-level resources that provided important framing context.

Virtual Meeting #2–December 6, 2017

The second virtual meeting provided experts from the August working session with an opportunity to review and comment on the draft final technical report and its findings. The key recommendations from this meeting were threefold:

1. Emphasizing the dual nature of the report—identifying both practice-ready QRFM content and actions to close knowledge gaps.
2. Suggesting formatting and readability enhancements to the topic matrices.
3. Proposing a new conclusion that connects this report to the QRFM update.

Attendees of this meeting believed this report provided a very good summary of the practices and key issues that freight and transportation practitioners were struggling with. The attendees also identified key needs for next steps for advancement by FHWA and other transportation planning and research agencies.

APPENDIX B: TOPIC MATRICES

Table 5: Topic A: Overall Integration of Land Use and Freight Planning

ID #	WHAT?	WHERE?	
		…is the source information?	…should this go in QRFM3?
A-1	NCFRP Report 37 trip production data	NCFRP Report 37	Chapter 6 - hybrid approaches?
A-2	Approach for applying context-sensitive land use (i.e., transect - both outside and within Special Districts) to NCFRP Report 37 trip generation rates	NCFRP Report 37	
A-3	NCFRP Report 37 trip generation database	NCFRP Report 37	Chapter 6 - hybrid approaches?
A-4	"Freight villages" / intermodal/inland ports as special districts (effect on tripgen - how do FG/unit or FTG/unit rates change?)	NCFRP Report 37	
A-5	Strategic plan for freight-intensive locational planning	NCFRP Report 24, NCHRP 08-96	
A-6	How-to guide for inventorying freight-generating facilities	SHRP2 C20 - Winston Salem	Chapter 10.2 - Data Collection
A-7	NCHRP 08-96: Integrating Goods and Services Movement by Commercial Vehicles in Smart Growth Environments	NCHRP Project 08-96	New Chapter 14 on Facility Context
A-8	Transferable spreadsheet tool for aligning agricultural/transportation issues such as unique commodities and seasonal variation	SHRP2 C20 - South Dakota DOT, Washington DOT	Chapter 11 - Application Issues
A-9	FDOT Freight Roadway Design Considerations	TRB (17-1016, Hunter)	New Chapter 14 on Facility Context
A-10	Local Traffic Impact Study (corridor, site) planning	ITE Recommended Practices	Section 4.4

Table 6: Topic B: Last Mile Considerations

ID #	WHAT?	WHERE?	
		…is the source information?	…should this go in QRFM3?
B-1	GAP: Synthesis on data use and application in last-mile delivery techniques (from omni-channel fulfillment scheduling to AV/drone technology) and STG with SU trucks	Example: TRB 17-04295 (Cherrett)	
B-2	Broward County "Last Mile" Analysis Methodology	SHRP2 C20 Florida DOT (Section 5.4)	Chapter 6 - Hybrid Approaches

Table 7: Topic C: Modeling Framework

ID #	WHAT?	WHERE?	
		…is the source information?	…should this go in QRFM3?
C-1	GAP: Synthesis: Applying lessons learned from freight ABM to four-step/hybrid models (with focus of land use/demographics as inputs)	SHRP2 C20	New Chapter (between 5 and 6)
C-2	Activity Based Model status (Maricopa Association of Governments Case Study, plus additions of others Baltimore, Sacramento, Wisconsin, Portland, Columbus?)	SHRP2 C20	New Chapter (between 5 and 6)
C-3	Baltimore Metropolitan Council C20 Freight Modeling System	SHRP2 C20	New Chapter (between 5 and 6)
C-4	Commodity Flow "Playbook"	NCFRP Report 26 Chapter 6	Chapter 5 - Commodity Models
C-5	Port Everglade Petroleum Commodity Flow Pilot Study	SHRP2 C20 (Table 4-2)	Chapter 5 - Commodity Models
C-6	FAF4 Model / Documentation	FHWA	Chapter 5.9

Table 8: Topic D: Public and Private Data Sources

ID #	WHAT?	WHERE?	
		…is the source information?	…should this go in QRFM3?
D-1	GAP: Current listing of best data sources	NCFRP Report 25 - Table 3.2, SHRP2 C20 Capital Region	Chapter 5 - Models, 10 - Data
D-2	Strategic plan for freight shipping data development and sharing	NCFRP Report 25, supplement Table 3.1?	
D-3	GAP: White paper: Aligning private sector shipping needs with public sector policies and investments	NCFRP Report 25	
D-4	Truck data collection survey instruments	ITE Trip Generation Handbook (TRR 2160)	Chapter 10.2 - Data Collection
D-5	2017 Commodity Flow Survey (BTS)	Census/BTS	Chapter 5.7
D-6	Review of freight data sets	SHRP2 C20 Capital District MPO (Tables 1 and 27)	Chapters 9, 10

Table 9: Other Topics

ID #	WHAT?	WHERE?	
		…is the source information?	…should this go in QRFM3?
O-1	Summary of state of the practice from SHRP2 C20 Final Report (2013) as introduction	SHRP2 C20 Final Report (p. 23-38 and conclusions)	New Summary Chapter in Part B
O-2	Scenario planning (including community/regional plan development/adoption effect on FG, and MOEs)	NCHRP Report 750 Volume 1 (p. 8-10)	Chapter 11 - Application Issues
O-3	Megaregion planning considerations (Chesapeake megaregion example)	TRB paper 13-2336 (Weidner)	Chapter 6 - hybrid approaches
O-4	Value of reliability	TRB paper 17-00847 (Lin)	Chapter 11 - Application Issues
O-5	Visualization Techniques	TRB AppCons 17 (Smith/Piedmont Triad), (Guerrero, Bi-State MPO IL/IA)	Chapter 11 - Application Issues

**APPENDIX C: FREIGHT/LAND USE TRAVEL DEMAND EVALUATION
LITERATURE REVIEW**

July 2017

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SECTION 1: OVERVIEW

PROJECT PURPOSE

The overall purpose of the Freight and Land Use Travel Demand Evaluation study was to define the need for improved information, identify types of new technical content that are of the greatest value, and consider the most effective format for new freight and land use data products. The study involved conducting a literature review (summarized in this report) and peer exchanges.

The purpose of the literature review was to determine how land use, local economic development, and demographic factors drive freight movement, trip generation, and freight demand analysis. This information is expected to provide freight and transportation practitioners with improved processes and tools that better reflect the relationship between freight movement and land use.

Based on the information collected via literature review, interviews, and the peer exchanges, key insights were summarized and developed into a technical report, which describes opportunities for improving the estimation of freight trip generation (FTG) rates that recognize a multimodal perspective and variability in FTG due to differences in land use. The technical report also explores how business and demographic changes, real and expected, may trigger changes in freight and logistical movements. Further, the technical report shows how these changes are captured in freight demand modeling and recommends enhancement to resources needed for a full update to the Quick Response Freight Manual (QRFM).

STRUCTURE

This document contains the following information:

- **Section 2** describes the project approach, including integrating the literature review and peer exchange.

- **Section 3** presents key findings of the literature scan.

- **Section 4** summarizes key gaps and opportunities as identified from the literature scan.

- **Appendix A** contains an annotated bibliography of sources reviewed in the scan.

STATE OF THE PRACTICE AND TRENDS

The second iteration of QRFM was published in September 2007. Like its 1996 predecessor, the QRFM provided background information on the freight transportation system and factors affecting freight demand. The QRFM provides information that helps planners:

- Understand key issues;
- Locate available data and freight-related forecasts; and
- Apply this information in developing forecasts for freight vehicle trip tables.

In the last decade, significant strides have been made in tracking freight movement, advancing a behavior-based supply chain modeling state of the practice, and incorporating land use and demographic considerations into travel demand analysis.

Information Explosion

The transportation planning profession is experiencing a paradigm shift in the way programs and projects are developed, evaluated, implemented, and maintained for all travel modes. Rapid advances in communication technology have ushered in an era characterized by big data. This has resulted in an explosion of information, given a greater array of robust, data-driven, analytic tools; a wider distribution of such tools, and increased communication of analytic results to broader audiences.

The transportation industry will benefit from these technology advances. There will be increased opportunities for improved knowledge within the traditional transportation industry and emerging cross-disciplinary partnerships, including with professionals in non-transportation fields such as economic development and public health.

At the same time, the transportation planning professional risks being inundated with information from peers and other stakeholders. It becomes more challenging, but even more important to be able to distinguish among the myriad of data sources to focus on information that will inform sound decisionmaking.

Goods Movement State of the Practice

The two most recent pieces of Federal transportation authorizing legislation, the Moving Ahead for Progress in the 21st Century (MAP 21) and the Fixing America's Surface Transportation (FAST) Act, placed greater emphasis on freight and goods movement. Freight transportation is a principal driver of economic prosperity. Yet, analytical tools for evaluating and forecasting freight movement are lagging as compared to those used to assess passenger movement. The need for improved FTG tools is compounded by recent and emerging goods movement trends that significantly affect how the private sector does business. In particular, these trends include:

- Cargo telematics approaches employed by firms such as Transfix and INRIX.

- Technological trends, which include automated vehicles and emerging delivery services such as drones.

- Societal trends such as e-retailing and the needs of aging baby boomers and millennials.

- Economic/freight trends such as intermodal logistics centers and the post-Panamax economy (post-Panamax refers to container vessels that are too large to navigate through the original dimensions of the Panama Canal locks).

- Improved freight data, including the effects of multimodal shares and intermodal transfers between sea, air, rail, as well long-haul, last-mile, distribution, and service vehicle trips.

It is important for land use and transportation planners to understand these macro and micro economic trends to help improve, develop, and implement effective multimodal transportation system policies, programs, and projects.

Land Use and Demographic Considerations

The same economic and societal trends driving the information explosion and the evolution of goods movement also influence how local and regional governments engage in land use planning and development. Planning and design of the built environment are increasingly viewed as ways to increase transportation system efficiency through a more effective multimodal approach. In addition, just-in-time deliveries and increased deliveries from e-commerce have led to more frequent shipment of goods, increasing truck vehicle miles traveled (VMT) and urban congestion. The importance of a context-sensitive approach to integrating land use and transportation applies to the assessment of freight travel demand and the provision of transportation supply. Many studies have addressed how the "Ds" of land use (density, diversity, design), affect auto trips and VMT. Far less information exists regarding truck trip generation.

Current industry trends for moving freight have created land use changes with increased development of intermodal logistics hubs, larger regional distribution centers, and freight-oriented development around gateways such as airports and ports. Some communities are promoting economic development centers that cluster freight and logistics with other related industries and supportive businesses.

NEXT STEPS FOR CONSIDERATION

Additional user feedback will help define the final product for a potential update of QRFM. Initial scoping for the project began with a hypothesis that the updated QRFM would be a stand-alone technical report to update the previous QRFM. However, project team review led to a conclusion that the updated QRFM would most effectively serve the freight demand community if it were developed as a living web document. The web version of the QRFM will be updated periodically as land use and travel demand conditions evolve and new freight mobility and accessibility challenges arise. This will allow the document to be adapted by future generations and remain relevant in the ever-changing transportation and freight industries.

There may also be opportunities to link QRFM resources with continued cross-training through online libraries, webinars, or podcasts sponsored by the Federal Highway Administration (FHWA) through mechanisms such as the Travel Model Improvement Program (TMIP)/Freight Model Improvement Program (FMIP) and Talking Freight initiatives, or via cross-training alliances with groups like the American Association of State Highway and Transportation Officials (AASHTO), Transportation Research Board (TRB), Institute of Transportation Engineers (ITE), or American Planning Association (APA). The beta tool from National Cooperative Freight Research Program (NCFRP) Project 48 is a useful resource in the development of this project, and also as part of the package of resources incorporated in the final report: https://ncfrp48-stage.icfwebservices.com/NCFRP48/reports/#/route2 (credentials are required to access website).

The updated QRFM could also be branded with key infographics or flow diagrams. The "production-consumption (PC)" link graphic shown in Figure 1 is an iconic tool for helping define the evolving reflection of supply-chain relationships in the development of freight generation (FG), FTG, and service trip generation (STG) concepts described in National Cooperative Highway Research Program (NCHRP) Report 739 and the pre-publication edition of NCFRP Report 37 (additional details are described in section 3 and the annotated bibliography within this document).
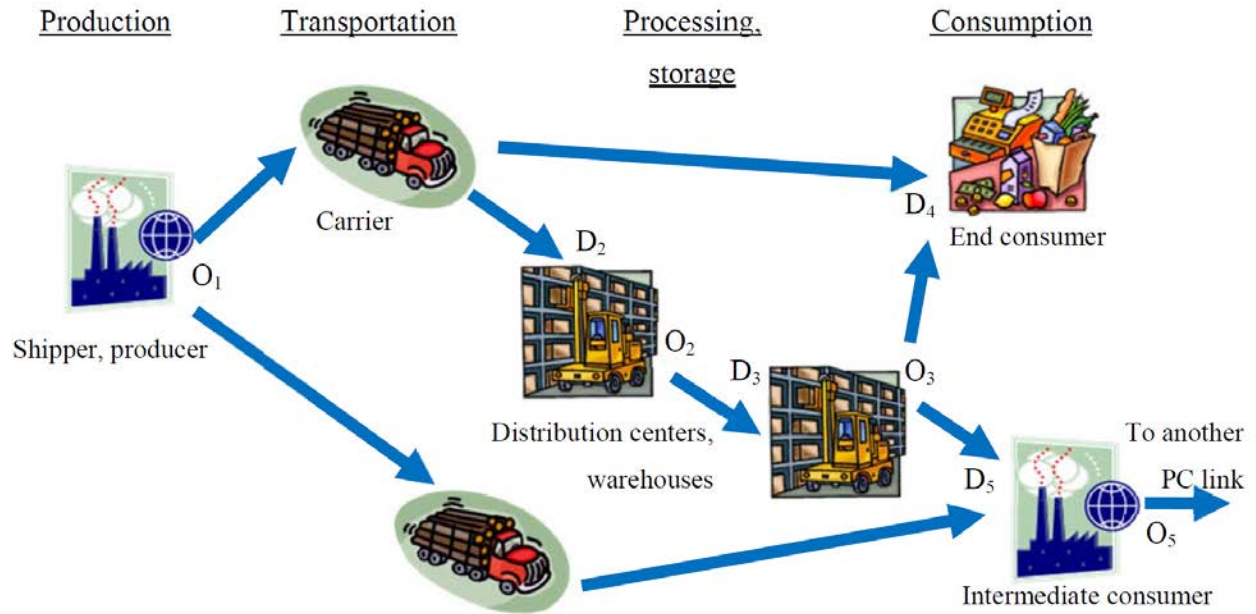
Figure 12: PC Link
Source: NCFRP Report 37

SECTION 2: STUDY APPROACH

Extensive research on personal travel exists, but there is a relative gap in studies on goods movement. To help better assess these gap areas, this literature review sought to:

- Explore if available information on context sensitivity could be incorporated in appropriate QRFM sections or chapters.

- Explore if broader topics such as scenario planning applications, land use/zoning applications, megaregions, and freight resiliency could be incorporated into QRFM.

The intent of the iterative approach was to respond to the needs and interests of stakeholders gleaned through outreach approaches (described below).

INITIAL LITERATURE COMPILATION

The initial literature compilation gathered relevant literature from all reasonable sources, including existing works in progress, and both published and unpublished reports. The intent was to prepare a broad synthesis of FTG best practices and guidelines.

Information was also gathered on broader topics beyond the QRFM associated with freight demand. As a result of this information-gathering process, the team found that:

- While current Federal, State, and metropolitan commodity flow analyses are primarily oriented toward institutional boundaries, a megaregional topology may be a more appropriate scale for contemplating broader economic diversification.

- The QRFM is primarily oriented toward the same Federal, State, and metropolitan agency audiences, but the concepts of freight-efficient land uses and context-sensitive trip-generation are also valuable to local agencies with land use planning and zoning authority.

- The information explosion and emphasis on interdisciplinary performance measures make scenario planning an increasingly valuable tool for considering alternative investment approaches.

- There is a need to better understand how evolving freight logistics—and corresponding development of industry, distribution centers, and delivery of goods and services—needs impacts land use and freight generation.

SUMMARY OF OUTREACH

Several stakeholder/peer outreach and coordination events were conducted involving a range of freight practitioners (these are also described in more detail in the technical report that accompanies this literature review). The goal of these events was to glean more insights on the nuances and situational needs of participants in to help inspire and educate them. In developing and facilitating these events, the study team sought to:

- Articulate clearly the event's objectives to ensure that the right participants were invited and engaged.

- Provide opportunities for participants to discuss topics that supported their own work.

- Leverage diverse techniques, media, and tools to maximize information gathering.

- Seek a common understanding of documented gaps and needs as a basis for robust discussion.

Virtual Meeting #1–April 19, 2017

The first virtual meeting, held as part of the April Talking Freight webinar series hosted by FHWA, explored gaps and challenges that freight practitioners face in many different communities and contexts. These challenges span a variety of disciplines (such as transportation, land use planning, and economics) and have impacts on an array of stakeholders (including freight owners/operators, goods manufacturers/shippers, and freight service providers). The webinar summarized high-level issues identified early in the literature scan and gathered feedback to confirm areas of highest practitioner interest.

Expert Working Session–August 8, 2017

This session was hosted by FHWA at U.S. Department of Transportation (USDOT) headquarters in Washington, DC Key objectives were to:

- Detail and expand upon a collective understanding of the state of the practice for using multimodal approaches to analyze land use and demographic changes and incorporate them into FTG rates.

- Develop a next steps Action Agenda to identify important technical needs as well as strategies to address gaps.

- Identify specific enhancements to the QRFM.

Virtual Meeting #2–December 6, 2017

The second virtual meeting provided an opportunity for practitioners to review the project's draft final technical report and its findings before finalization.

SECTION 3: LITERATURE SCAN

The literature scan researched foundational resources and supplementary material to assess the state of practice in research and development/applications for freight demand evaluation using information produced since the QRFM was published. The literature scan will guide the development of detailed discussions with key stakeholders and aid in identifying user needs.

Much information exists on current gaps; however, not much is available in terms of how to close those gaps. Additionally, in an environment where new techniques are ever-evolving, the question becomes, "What is the best way to document the state of the practice?"

There is a continuing cycle of research and synthesis (see Table 10), which is described in more detail on the next page. The QRFM was produced in 2007 as the results of prior research were incorporated into similar synthesis documents. Additionally, NCHRP and second Strategic Highway Research Program (SHRP2) Capacity 20 (C20) program efforts have aimed to develop the next generation of research needs. Both SHRP2 initiatives and FTG analyses (summarized in NCFRP Report 37) reflect key advances in the freight planning process.

Table 10: Research Cycle and Foundational Resources

THE RESEARCH /SYNTHESIS CYCLE
QRFM published as landmark document (2007)
Syntheses of information identified current status/need (2008-2010)
SHRP2 C20 organized next wave of research (2012-2016)
SHRP2 studies are now being completed (2016-2017) and will be ready for "synthesis" in products like QRFM update
FOUNDATIONAL RESOURCES
ITE *Trip Generation Handbook*, 3rd Edition
NCFRP Report 24: *Smart Growth and Urban Goods Movement*
NCFRP Report 25: *Freight Data Sharing Guidebook*
NCFRP Report 26: *Subnational Commodity Flow Data*
NCFRP Report 37: *Using Commodity Flow Survey Microdata and Other Establishment Data to Estimate the Generation of Freight, Freight Trips, and Service Trips: Guidebook*
NCHRP Report 739: *Freight Trip Generation and Land Use*
NCHRP Report 750: *Strategic Issues Facing Transportation, Volume 1: Scenario Planning for Freight Transportation Infrastructure Investment*
NCHRP Project 08-96: *Integration of Freight Considerations into Smart Growth Design*

QRFM (2007)

Model Types

The QRFM describes several types of models:

- **Four-Step Travel Forecasting:** Addresses how the traditional "four-step" transportation forecasting process (trip generation, trip distribution, mode split, and network assignment) is used to forecast goods movement in traditional urban transportation planning models, in State transportation planning models, and in site planning.

- **Commodity Modeling:** Discusses how commodity flow surveys can be used in freight forecasting in place of traditional trip tables.

- **Economic Activity Modeling:** Discusses how freight forecasting can be included within more comprehensive economic/land use/ecological models.

- **Hybrid Modeling:** Discusses how different freight models can be combined with multimodal commodity methods to better understand goods movement flows.

Model Application

QRFM Chapters 8-11 focus on application-ready updates from recent research reports including:

- **Model validation:** Considers how to calibrate freight models and forecasts, and how to validate models.

- **Existing data sources:** Discusses the availability of data, the content of that data, and the advantages and disadvantages of using existing freight data.

- **Data collection methods:** Discusses why existing data may be insufficient and why new data sources may be required to support freight modeling.

- **Application issues:** Discusses why freight forecasts are needed, their attributes, and how forecasts are used in the transportation planning process.

Case Studies

This section of the QRFM covers how methodological and data issues were addressed at various government levels and in different regions, including by States and multistate partnerships, large and small urban areas, and individual sites such as ports, airports, industrial parks, and intermodal railroad terminals. Models discussed include:

- Southern California Association of Governments heavy-duty truck model (Los Angeles, California).

- Freight Action Strategy truck forecasting model (Seattle, Washington).

- San Joaquin Valley truck model (Central California).

NCHRP SYNTHESES

TRB released a series of relevant summary documents after publication of the QRFM. These documents generally supported both the current state of the practice as reflected in QRFM and helped define a framework for the subsequent wave of travel demand-related research advanced by SHRP2. Relevant summary NCHRP documents include the following:

- NCHRP Synthesis 384 (2008), Forecasting Metropolitan and Commercial Freight Travel

- NCHRP Synthesis 406 (2010), Advance Practices in Travel Forecasting

- NCHRP Synthesis 410 (2010), Freight Transportation Surveys

These reports contributed to the base of freight travel demand literature, but have not been explicitly included in this literature review as their contents are reflected and updated in subsequent NCHRP and NCFRP reports developed after 2010.

SHRP AND SHRP2 INITIATIVES

In the 1987 highway bill, U.S. Congress authorized the original SHRP as a five-year, $150-million research program. At that time, the U.S. transportation and public works system was in the public spotlight due to its state of deterioration. SHRP was proposed as a highway research program that would concentrate efforts on a short list of high-value activities. These fell under four major technical research areas, including:

- Improved performance of asphalt materials

- Improved concrete and the protection of reinforced concrete structures

- Efficient methods of highway maintenance, including control of snow and ice

- Long-term durability of pavements

SHRP2 was authorized in 2005. Its focus was to find strategic solutions to three national transportation challenges:

- Improving highway safety

- Reducing congestion

- Improving methods for renewing roads and bridges

There has been a recommendation for a future SHRP comprised of several primary research program areas:

- Accelerating the renewal of America's highways

- Making significant improvement in highway safety

- Providing a highway system with reliable travel times

SHRP2 C20–Freight Demand Modeling and Data Improvement (2013)

The SHRP2 C20 initiative assesses the state of the practice of freight demand modeling and freight data as related to highway capacity planning and programming. While passenger travel modeling is moving toward more activity-based modeling techniques, freight demand models have remained relatively unchanged. However, new information technology advances have greatly improved how transportation planners access freight data.

Land Use and Demographic Considerations with QRFM Elements

Table 2 (on the next page) identifies land use and demographic considerations with QRFM elements.

Element B: Establish techniques and standard practices to review and evaluate freight forecasts. This element directly addresses the objective of improving and expanding upon the current state of the practice.

Elements D, E, H, I, and J address topics beyond the QRFM:

- **Element D:** Develop methods that predict mode shift and highway capacity implications of various what-if scenarios (scenario planning).

- **Element E:** Develop a range of freight forecasting methods and tools that address decisionmaking needs that can be applied at all levels (national, regional, State, metropolitan planning organization (MPO), municipal (geographic scales).

- **Element H:** Determine how economic, demographic, and other factors and conditions drive freight patterns and characteristics. Document economic and demographic changes related to freight choices (economic/demographic trends).

- **Element I:** Develop freight data sources for application at subregional levels (geographic scales).

- **Element J:** Develop and standardize a portfolio of core freight data sources and data sets that supports planning, programming, and project prioritization (data sources).

Table ES.3. Sample Research Initiatives

Sample Research Initiatives[a]	Research Dimensions			Strategic Objectives						
	Knowledge	Models	Data	1. Improve and expand knowledge base.	2. Develop modeling methods to reflect actual supply chain management practices.	3. Develop modeling methods based on sound economic and demographic principles.	4. Develop standard freight data to smaller geographic scales.	5. Maximize use of freight tools by public sector for planning and programming.	6. Improve availability and visibility of data between public and private sectors.	7. Develop new and enhanced visualization tools and techniques.
A: Determine the freight and logistics knowledge and skill requirements for transportation decision makers and professional and technical personnel. Develop the associated learning systems to address knowledge and skill deficits.	●			■						
B: Establish techniques and standard practices to review and evaluate freight forecasts.		●		■	□	□				
C: Establish modeling approaches for behavior-based freight movement.	●	●			■					
D: Develop methods that predict mode shift and highway capacity implications of various what-if scenarios.	●	●			■	■				
E: Develop a range of freight forecasting methods and tools that address decision-making needs and that can be applied at all levels (national, regional, state, metropolitan planning organization, municipal).		●	●		■	■	□			
F: Develop robust tools for freight cost–benefit analysis that go beyond financial considerations to the full range of benefits, costs, and externalities.	●	●				□		■		
G: Establish analytic approaches that describe how elements of the freight transportation system operate and perform and how they affect the larger overall transportation system.	●	●				■		□		
H: Determine how economic, demographic, and other factors and conditions drive freight patterns and characteristics. Document economic and demographic changes related to freight choices.	●					■				
I: Develop freight data resources for application at subregional levels.			●		□	□	■			
J: Establish, pool, and standardize a portfolio of core freight data sources and data sets that supports planning, programming, and project prioritization.			●				■	■	□	
K: Develop procedures for applying freight forecasting to the design of transportation infrastructure, particularly pavement and bridges.		●						■		
L: Advance research to effectively integrate logistics practices (private sector) with transportation policy, planning, and programming (public sector).	●				□			■	■	
M: Develop visualization tools for freight planning and modeling through a two-pronged approach of discovery and addressing known decision-making needs.	●	●	●							■

Note: Directly Addresses Objective ■; Indirectly Addresses Objective □.

[a] The sample research initiatives outlined as part of the SHRP 2 C20 research project demonstrate how the strategic objectives could be advanced. Each initiative also applies to one or more of the three research dimensions (indicated by ●).

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Freight Decisionmaking Needs and Gaps

SHRP2 has also advanced research on behavior/agent-based supply chain modeling that will allow State DOTs and MPOs to better understand freight travel behavior as it relates to industry decisionmaking processes used for logistics and freight movement.

Table 3 highlights freight decisionmaking needs, gaps between those needs and the current modeling and data practices, and data and modeling requirements to meet those needs. Essentially, it is a comprehensive list of knowledge gaps.

Table 12: Freight Decisionmaking Needs and Gaps from SHRP2
Source: SHRP2

Table ES.2. Freight Decision-Making Needs and Gaps

Decision-Making Needs	Gaps Between Needs and Current Practices	Data or Modeling Requirements to Close Gaps
Standardized data sources with common definitions	• Various data sources collected through different programs result in extensive inconsistencies.	• Homogeneous data for ease of incorporation into freight models and for consistency of freight models in different regions. • Reduction in data manipulation to improve accuracy.
Statistical sampling of truck shipments	• Detailed knowledge of truck movements in local areas. • Understanding of current truck activity by different industry segments (long-haul, local, drayage).	• An ongoing standard data-collection program to gather local truck movements. • Compilation of truck data to a level comparable to rail industry data (i.e., Carload Waybill Sample).
Standardized analytic tools and applications	• Range of various tools that require unique data sets.	• Consistency in modeling approaches and data needs for similar geographic scales.
Inclusion of behavior-based elements in freight models	• Current practices use truck movements and commodity flows, but should be based on the behaviors, economic principles, and business practices that dictate the movement of freight. • Current modeling tools do not accurately reflect real-world supply chains and logistics practices.	• Determination of the influencing behavioral factors that affect freight movement and ongoing data collection to inform models. • Behavior-based freight modeling tools to take advantage of newly collected data sets for various geographic analyses. • Incorporation of intermodal transfers, consolidation and distribution practices, and other shipper and carrier practices in modeling tools.
Data development to understand the nature, volume, and trends of intermodal transfers	• Public sector access to intermodal transfer data of containers, bulk material, and roll-on–roll-off cargo is lacking for most transfer facilities other than those of large ports and rail yards.	• Data sets developed through collaboration with the private sector to inform the planning practice knowledge base and models on intermodal transfers. • Protocols to collect data on a regular basis.
Industry-level freight data development at a subregional level and within urban areas	• Freight data are generally not industry-specific, which translates into forecasts that are not sensitive to the unique industry trends that are critical to regions that rely heavily on specific industries.	• Industry-level forecasts that are sensitive to the unique factors of different industries. • Tools and data at a disaggregated level (local) that can be aggregated for larger geographic analyses. • Tools and models to take advantage of the new data sets.
Incorporation of local land use policies and controls for better local forecasting accuracy	• Current freight data and models lack local detail related to the generation of freight activity, which hampers local efforts to effectively plan for the last mile.	• Enhanced understanding of land use decisions and their implications on freight activity. • Resources for local organizations to incorporate land use considerations into freight planning data and models.
Development of a correlation between freight activity and various economic influences and macroeconomic trends	• Freight models are typically based on population-, employment-, and industry-level productivity forecasts, with no consideration for the impacts of other economic factors.	• Enhanced models that incorporate a wide array of economic factors in forecasting freight demand.
Better accuracy of freight forecasts	• Freight models rarely (if ever) are reviewed to check the accuracy of their forecasts, calling into question their reliability and validity.	• A systematic approach for freight model and data owners to review and evaluate forecasts (every 3 to 5 years) and adjust models and data methods accordingly.
Development of a process to routinely generate new data sources and problem-solving methods	• The improvement of freight planning nationally depends on continuing innovation and steady progress in the development of models, analytic tools, and knowledge acquisition.	• A value-adding and sustainable process to generate new and innovative ideas. • Acknowledgment of failed practices that can contribute to the knowledge base of practitioners.
Use of ITS resources to generate data for freight modeling	• Technologies that can be used to collect freight data have not been used to their potential. • Data can provide a wealth of information related to current conditions and diversions as a result of traffic incidents.	• An understanding of the information needed by the modeling community and the standard to which it can be used. • An accessible data bank for freight modeling developed with the cooperation of GPS device providers, ITS infrastructure owners, and other data providers.
Development of a universal multimodal, network-based model for various geographic scales	• The fragmentation of modeling techniques and data means that practitioners typically must develop or improvise data and models for their own applications. • Agencies with fewer resources are not able to adequately analyze freight movements. • Some freight transport modes are analyzed more than others because they have more data available for analysis.	• An open-source data bank and universal freight modeling tool is the ultimate goal. • A level playing field among different modes of freight transportation in terms of quantity and accuracy of data and complexity of modeling tools.
Development of benefit–cost analysis tools that go beyond traditional financial measures	• Analysis of the benefits of project-based scenarios lacks the precision required for those decisions, including direct and indirect impacts, costs, and benefits.	• Tools that incorporate a comprehensive analysis of the factors associated with infrastructure development, expansion, and enhancement specifically related to freight.
Development of funding assessments resulting from freight forecasts	• Transportation funding scenarios and what-if analyses are limited in their ability to forecast revenues associated with freight movement.	• Estimated costs and potential funding sources that can be justified based on credible freight forecasts.
Creation of tools to support the infrastructure design process	• Infrastructure design, unless specific to freight, rarely focuses efforts on how best to accommodate freight movements.	• Incorporation of freight forecasts into infrastructure design related to vehicle size and weight and future freight activity (i.e., tonnage) by mode.
Development of knowledge and skills among the freight planning community as a foundation for improved analysis	• The freight planning community is relatively small and knowledge transfer is challenging. • Talented innovators who can lead new approaches to freight transportation planning are pursuing careers in other industries.	• A comprehensive knowledge base for planning professionals that includes the wide range of subject areas related to freight transportation. • Greater recognition or formal standing of freight planning as a profession with an associated body of knowledge.

SHRP2 C20 Subsequent Studies

The SHRP2 Implementation Assistance Program has funded pilot projects in 11 States to develop state-of-the-art tools for freight modeling and data analysis. This includes development of behavior/agent-based supply chain models, methods for understanding freight delivery patterns in urban areas, testing emerging technologies to collect data on freight traffic, interactive mapping and visualization of freight data, platforms for sharing data on a regional level, and tools for greater insight into the linkage between industry and infrastructure needs.

Four pilot projects focus on modeling and seven focus on data. Several of these studies are expected to be directly applicable to QRFM. Other studies show some potential for new techniques, or may just provide good sources for up-to-date case study information; the ones at the bottom of the list tend to focus less on travel demand practices but may also have potential as case studies. Table 13 provides additional information about the 11 pilot projects.

Table 13: SHRP2 C20 Pilot Projects

Recipient	Project Type	Project Status	QRFM Applicability	Notes
FL Department of Transportation	Data	Complete	Yes	Successful methodology for estimating fuel consumption based on local factors (i.e., land use, socio-economic, roadway, traffic inputs)
Capital District Transportation Committee (NY)	Data	Complete	Yes	Land use data model components
SD Department of Transportation	Data	Complete	Yes	Agricultural and land use data used as part of methodology to develop improved traffic counts
Maricopa Association of Governments (AZ)	Modeling	Substantially Complete	Yes	Land use data model components
Maryland State Highway Administration	Modeling	Substantially Complete	Yes	Land use data model components
City of Winston-Salem (NC)	Data	Complete	Yes	Development of freight facility database for use in informing land use planning, economic development or transportation improvement priorities
Metro (Portland) Metropolitan Planning Organization (OR)	Modeling	In Progress	Yes	Land use data model components
WA Department of Transportation (WA)	Data	Complete	Yes	Used interviews and questionnaires to collect business characteristics like route and mode choice and supported truck trip modeling by collecting truck

Recipient	Project Type	Project Status	QRFM Applicability	Notes
				count data at food distribution facilities under a variety of land use scenarios
Mid-America Regional Council (MO)	Data	Complete	Case Study Potential	Low applicability potential
Delaware Valley Regional Planning Commission (PA)	Data	Complete	Case Study Potential	Freight data clearinghouse enhancement and plotted major freight facilities in the region, but land use data was not a major project input or output
WI Department of Transportation	Modeling	Complete	Case Study Potential	Low applicability potential

NCFRP REPORT 24: *SMART GROWTH AND URBAN GOODS MOVEMENT* (2013)

NCFRP Report 24 summarizes contemporary literature on the impacts of smart growth on goods movement and identifies areas for further research. The effort included outreach to a variety of goods movement practitioners and urban planners. The Puget Sound region was used as a testbed for incorporating several emerging practices for goods movement and smart growth scenario planning.

NCFRP REPORT 25: *FREIGHT DATA SHARING GUIDEBOOK* (2013)

NCFRP Report 25 provides a series of guidelines for sharing freight data, primarily between public and private freight stakeholders. The report recognizes the difficulties of obtaining data from private entities as well as the significant costs associated with data collection. The report provides examples of how to overcome these barriers. Additionally, it highlights 18 different public and commercial data sources that practitioners can access without restrictions.

NCHRP REPORT 739: *FREIGHT TRIP GENERATION AND LAND USE* (2012)

NCHRP Report 739 identified the need to make an important distinction between FG, FTG, and STG. FG is an expression of economic activity performed at a business establishment. Input materials are processed and transformed generating an output that, in most cases, is transported elsewhere for further processing, storage, distribution, or consumption. In contrast, FTG is the result of the logistic decisions concerning how best to transport the FG in terms of shipment size, frequency of deliveries, and the vehicle/mode used. STG is the travel made by local service industry personnel, such as craftsman and technicians who deliver, install, and maintain goods or services at their final destinations. The separation of FTG and STG by industry is important for understanding and predicting total freight travel demand. For instance, a fabricating plant that makes bathroom fixtures has a high ratio of FTG to STG, whereas a local plumber has a high ratio of STG to FTG.

NCFRP REPORT 37: *USING COMMODITY FLOW SURVEY MICRODATA AND OTHER ESTABLISHMENT DATA TO ESTIMATE THE GENERATION OF FREIGHT, FREIGHT TRIPS, AND SERVICE TRIPS: GUIDEBOOK* **(2017)**

NCFRP Report 37 describes how industry-specific land classification systems such as the Standard Industrial Codes (SIC) or North American Industry Classification System (NAICS) provide a much better framework for forecasting freight generation (total flow of goods) than do more generalized codes, for example those defined by ITE for total vehicle trip generation or use in MPO forecasts (i.e., office, commercial, industrial jobs).

NCFRP Report 37 describes how industry-specific codes better link FTG (the flow of goods expressed in terms of vehicle trips) and service trip generation (truck trips generated primarily to provide services rather than delivering goods). New models to reflect these approaches have been developed through studies sponsored by TRB, with a focus on the New York City and Albany regions. The comparison of different types of freight demand models in a database (as described by NCHRR Report 739) is now being replaced by a single FTG software tool. This tool is in development and can be accessed here:

https://coe-sufs.org/wordpress/ncfrp33/appendix/ftg/.

Developed by the Rensselaer Polytechnic Institute, the software applies FTG models at the ZIP code and two-digit NAICS code levels and made available during 2017.

ITE *TRIP GENERATION HANDBOOK* (2014)

The ITE *Trip Generation Handbook* provides guidance for site-specific trip generation with a special focus on person and vehicle trips by land use code. The handbook provides guidance on NCRFP Report 26 and NCHRP Report 739/NCFRP Report 19.

ADDITIONAL RESOURCES FOR "THINKING BEYOND QRFM"

The foundational documents described in this report form the primary basis for considering updates to the QRFM. The following additional areas of interest reflect subjects that were not addressed in the QRFM, but are of increasing interest to the transportation industry. The initial exploration of these topics in the literature review includes best practices from other agencies, references to the QRFM in peer-reviewed literature beyond the foundational resources, and current agency and institutional consideration of the broader topics described as "thinking beyond QRFM." The initial findings below were expanded on during the peer exchanges.

Automated and Connected Vehicles (AV/CV)

The topic of automated vehicles for goods movement has generated significant research on a wide range of topics including highway safety, institutional and legal policies, just-in-time deliveries, and regulations enforcement. The initial review of the foundational literature indicates that industry consensus has not yet resulted in practical guidance for the application of AV/CV technologies into goods movement forecasting or transportation planning practices. The peer

exchange events included this as an area of focus; there is a need to confirm the hypothesis that the specific role (or absence thereof) of the truck driver is not yet valued as a discriminator in freight travel demand analysis. Such analysis would be needed for more effective jurisdictional programmatic or facility planning. To evaluate this hypothesis, the definition of "automated" vehicle can be extended to concepts like last-mile deliveries by drones and robots.

Congestion Pricing

The QRFM recognized that users may need to realize tolls could create a dampening effect on demand. However it did not provide guidance on this issue beyond the use of time and cost impedance variables common to statewide or metropolitan travel demand models. Congestion pricing for facilities (such as with managed lanes) is an area of increased importance for truck trip assignment, considering the increased use of tolling for revenue generation and travel demand management both by location and time of day. This is an area where both attitudinal research and operational research has been robust, but the initial literature scan did not find compelling consensus on emerging or best practices specific to the freight industry.

FTG Survey Recommended Practices

The ITE *Trip Generation Handbook* is one of the foundational resources for this project. As described in the annotated bibliography, the handbook is a best practice that is periodically updated and adopted by ITE through a rigorous peer-review process. The 10th edition of the ITE *Trip Generation Handbook* was released in 2017. The ITE *Trip Generation Handbook* covers a wide range of topics beyond goods movement. One of the key freight recommendations is an application for a truck data collection survey, as from Thompson, Yarbrouh, Anderson, Harris, and Harrison in Transportation Research Record Number 2160 (p. 163) published in 2010.

Land Use Context

Two key documents provide useful context for considering the integration of land use context into the freight planning process. NCHRP Project 08-96 summarizes a wide range of strategies for accommodating goods movement demand and operations given the context-sensitivity of particularly freight-sensitive land uses (see Figure 13). It focuses on strategies for areas that are in the process of transitioning from freight-intensive to mixed use.

Related work has been done by Brian Hunter et al. at on identifying freight roadway design considerations (2017 TRB paper 17-01016; this was recognized as a bst paper by TRB Committee AT025). This work also builds upon the City of Portland *Street Design Guidelines* (2008) for Trucks, and elements from Massachusetts DOT on encroachments and Virginia DOT on design vehicle concepts.
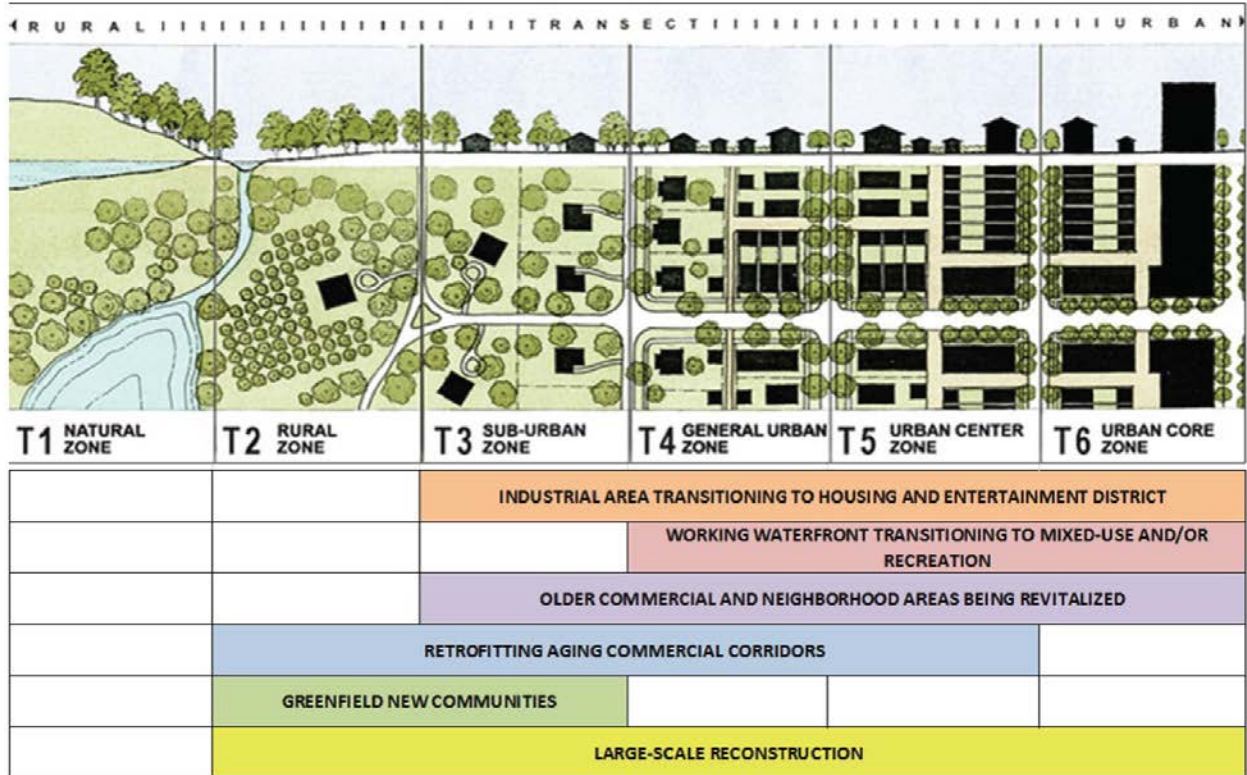
Figure 13: Relationship of Smart Growth Classification to the Rural-to-Urban Transect
Source: NCHRP Project 08-96

Megaregions

The concept of scenario planning for megaregions was examined by Weidner et al. in 2013 TRB paper 13-2236 examining a high energy price scenario for a multistate, multi-MPO region in the mid-Atlantic region. This examination demonstrated the value of scenarios for planning applications below the national commodity flow model. It also showed the ability of megaregion scenarios to link economic, land use, transport, and fiscal models. Overall it showed how decisions made by an MPO within a megaregion can have otherwise unanticipated effects elsewhere in the same megaregion. The applicability of this type of model to the QRFM will depend on the degree to which potential QRFM users gain value in the megaregion scale, which may be of greatest value to coalitions of transportation agencies such as the I-95 Corridor Coalition.

Reliability

Reliability is a topic of growing importance. While data are becoming increasingly more detailed and observed data are more precisely captured, this may still be limited in terms of its value to the freight industry for operations and planning. The QRFM states that reliability has increasingly been viewed as an important element to travelers, but does not provide guidance on how reliability might be incorporated into goods movement planning. Subsequent work by Xia Jin et al. at Florida International University on identifying stated value of reliability (at roughly

50 percent greater than travel time) was recognized as a best paper by TRB Committee AT015 (2017 TRB paper 17-00847). This effort builds upon prior meta-analysis by the same team in 2016 TRB paper 16-2051.

Scenario Planning

Scenario planning is a topic of increasing importance given the recognition that any transportation forecasting process has a range of uncertain, and often uncontrollable input variables and that investment decisions should encompass the widest range of likely futures as reflected in a risk-management approach to forecasting. For this particular topic, one of the foundational documents, NCHRP Report 750 Volume 1, is dedicated to the topic of scenario planning for freight transportation investment. That report is further described in the annotated bibliography.

Other QRFM References and Potential Case Studies

Additional resources were identified through the compendium of TRB annual meeting papers and presentations that cite the QRFM II and may serve as case studies for key topics and/or case studies for use in the next edition of the QRFM. Table 14 describes those additional resources.

Table 14: Additional Resources for QRFM References

Title	Author	TRB Paper Number	Key Topics
Arizona Statewide Travel Markets	Erhardt, Parsons Brinkerhof	TRB: 12-2109	Freight Analysis Framework application, use of 4-step models
Distribution Analysis - Virginia Freight	Duanmu et al., Old Dominion University	TRB: 12-2782	Commodity-based gravity model
Structural commodity generation - California statewide model	Ranaiefar et al., University of California Irvine	TRB: 13-1962	Structural equations model (SEM)
South Carolina Statewide Model Development	Amar et al., CDM Smith	TRB: 16-5539	Integration of MPO models into a statewide model
Spatial Firm Demographic Microsimulator: Development and Validation for Phoenix and Tucson Mega-region, Arizona	Ravulaparthy et al., Maricopa Association of Governments and Cambridge Systematics	TRB: 17-4964	Effect of spatial consideration on freight

SECTION 4: KEY TAKEAWAYS

Based upon the findings of the literature review, the following key takeaways were identified.

STRENGTHS, EXISTING PRACTICE, AND CONTEXT

QRFM has served as a foundational document in the freight transportation community. Following the 2007 release of QRFM, a series of syntheses, released between 2008 and 2010, focused on applications such as freight travel forecasting. These syntheses formed the basis for later NCHRP reports identified as additional foundation literature. During the next wave of research conducted as part of SHRP2 C20 (between 2012 and 2016), there was a shifting emphasis toward land use and demographic-sensitive context as it relates to freight and goods movement. Understanding this evolution in research and practice helps to show how the outputs of this project can lead to new developments as practitioners are engaged. This can also offer a good model for recommendations from this project.

A subsequent output of SHRP2 C20 research has been a comprehensive and succinct list of needs by freight travel demand users and those who make decisions related to freight, including:

- Standardized data sources with common definitions.

- Statistical sampling of truck shipments.

- Methods for surveying businesses to obtain local FTG rates, including use of technology such as Global Positioning Systems and mobile apps.

- Standardized analytic tools and applications.

- Inclusion of behavior-based elements in freight models.

- Truck touring models for urban goods delivery.

- Data development to understand the nature, volume, and trends of intermodal transfers.

- Industry-level freight data development at a subregional level and within urban areas.

- Incorporation of local land use policies and controls for better local forecasting accuracy.

- Development of a correlation between freight activity and various economic influences and macroeconomic trends.

- Better accuracy of freight forecasts.

- Development of a process to routinely generate new data sources and problem-solving methods.

- Use of Intelligent Transportation Systems (ITS) resources to generate data for freight modeling.

- Development of a universal multimodal, network-based model for various geographic scales.

- Development of benefit-cost analysis tools that go beyond traditional financial measures.

- Development of funding assessments resulting from freight forecasts.

- Creation of technical guidance and support toolkits to support the infrastructure design process.

- Development of knowledge and skills among the freight planning community as a foundation for improved analysis.

This list of needs is very comprehensive and served as the basis for peer exchange discussions.

CHALLENGES AND GAPS

General

A lot of information exists on data gaps, but less in terms of how to close the gaps. Gaps include:

Data Availability Challenges

There are several challenges related to data availability including:

- Developing commonly sourced data sets (i.e., commodity flow survey, freight analysis framework, etc.) on smaller geographic scales.
- Improving the availability and visibility of data among agencies and between the public and private sectors.
- Refining supply chain management data to portray the industry practices more accurately.
- Local context incorporation–There is a general lack of local detail related to the generation of freight activity, which hinders local efforts to effectively plan for first- and last- mile freight movements. Understanding how land use and economic decisions can affect freight activity how to be more sensitive to freight needs is important for addressing goods movement in communities.
- More robust modeling tools–Freight models are typically based on population, employment, and industry-level forecasts; however, little to no consideration is given to land use and economics factors. There is also a need for a more universal open-source freight modeling tool as many users currently must piece together data or improvise with data and resources available.

Issues with QRFM

- The QRFM was developed a decade ago. It is outdated and needs updating to capture changes in the transportation and freight industries. While gaps in freight data still exist, there have been significant strides in data collection methods and sources as well as technological advances in the overall freight industry.

- The QRFM is oriented toward Federal, State, and metropolitan agency audiences, but the concepts of freight-efficient land uses and context-sensitive trip-generation are valuable to local agencies with land use planning and zoning authority. The needs of these local users are quite different due to the geographic scale and varying priorities they work with. As such, it

is important to rethink the audience of the QRFM and who uses the manual on a day-to-day basis.

- Since the last QRFM, personal behaviors have changed. The world we live in now is more connected than ever. Additionally, people have started to focus more on the user-experience of products; in other words, making products that connect to users rather than simply look good or read well. The current QRFM exists as a PDF on a website; it is straightforward and to the point. However, this is not a user-friendly format and can be quite tiresome to peruse when a user is quickly looking for a certain topic.

OPPORTUNITIES

Although there are limited identified solutions to the gaps/challenges listed above, opportunities to address the gaps abound:

Potential Development of the QRFM Update

The QRFM is updated on a roughly 10-year cycle. For the next update it is important to think about how the QRFM user base has changed or will change over the next ten years, as well as the manual's overall format and content. It can be difficult to identify ways to effectively document the state of the practice in an environment where techniques are constantly evolving. However, with the right input, particularly from a newly defined user base, the manual can affect the direction of the freight transportation industry and freight planning practices. An updated, more streamlined manual that is graphically rich will help users more quickly understand what is important to them and identify topics of highest personal relevance.

FTG Software

FTG software is now under development and will likely aid in several freight problem areas, such as:

- Infrastructure management (level of service, volume/capacity ratios, identification of freight generators)

- Truck touring models for urban goods delivery and service trips

- Parking/unloading areas management (parking analysis–needs and availability)

- Vehicle-related strategies (emissions and air quality)

- Traffic management (congestion analysis)

- Logistical management (origin-destination analysis, time-of-day analysis)

- Freight demand/land use management (FTG locational analysis, congestion, mobility)

However, the exact opportunities from the software are unclear as it is not yet available online. As such, it is difficult to determine the actual opportunities of the software and how it will play a role in addressing identified gaps related to trip generation.

Information Exchange Partnerships

The QRFM has existed as a handy, yet somewhat stand-alone resource on many practitioner bookshelves. The potential for developing a new product format can be linked with fostering information exchange between practitioners and researchers. This will support knowledge transfer to the practitioner community and solicit feedback that can help educators and researchers to manage and advance the state of the practice. These potential partnerships were explored as part of the peer exchange process of the study.

APPENDIX C-1: ANNOTATED BIBLIOGRAPHY

The following documents were reviewed for this project; details are provided in this appendix.

NCHRP Report 739/NCFRP Report 19: *Freight Trip Generation and Land Use*

NCFRP Report 24: *Smart Growth and Urban Goods Movement*

NCFRP Report 25: *Freight Data Sharing Guidebook*

NCFRP Report 26: *Guidebook for Developing Subnational Commodity Flow Data*

SHRP2 C20: Freight Demand Modeling and Data Improvement

NCHRP Report 750: *Strategic Issues Facing Transportation, Volume 1: Scenario Planning for Freight Transportation Infrastructure Investment*

Trip Generation Handbook, 3rd Edition, An ITE Proposed Recommended Practice

SHRP2 C20–*Piedmont Triad Freight Study–Winston-Salem Innovations in Local Freight Data*

SHRP2 C20–*Port Everglades Petroleum Commodity Flow Pilot Study*

SHRP2 C20–*Agricultural Freight Data Improvement Study SD2014-09*

SHRP2 C20–*Innovative Local Freight Data*

NCHRP Project 08-96 Report: *Guide for Integrating Goods and Services Movement by Commercial Vehicles in Smart Growth Environments*

NCFRP Report 37: *Using Commodity Flow Survey Microdata and Other Establishment Data to Estimate the Generation of Freight, Freight Trips, and Service Trips: Guidebook*

NCHRP REPORT 739/NCFRP REPORT 19: *FREIGHT TRIP GENERATION AND LAND USE*

NCHRP; Transportation Research Board; National Academies of Sciences, Engineering, and Medicine, 2012.

Primary Purpose of Document

This document describes relationships between land use and FTG.

Material Highlights

- Confirms superiority of economic classification over standard land use classification for FTG

- Sets up the review and release of commodity flow survey micro-data for trip generation estimates per NCFRP Report 37

New Concepts Adding to or Supplementing QRFM?

While information provided in NCHRP Report 739/NCFRP Report 19 is a landmark step forward in assessing the relative merits of several FG and FTG models, it also showed that commodity flow data was a superior data source for these models. The work in this document has been superseded by NCFRP Report 37, released in February 2017.

Materials Updating QRFM?

Superseded by NCFRP Report 37.

NCFRP REPORT 24: *SMART GROWTH AND URBAN GOODS MOVEMENT*

Puget Sound Regional Council and University of Washington, 2013.

Primary Purpose of Document

This document examines the state of the practice in defining smart growth and urban goods movement. It uses the Puget Sound region as a testbed for scenario planning of emerging urban goods movement concepts.

Material Highlights

- Chapter 7 notes the Calgary (Alberta, Canada) and Atlanta, Georgia, regional models as examples of emerging activity-based freight models

New Concepts Adding to or Supplementing QRFM?

This document is important for its holistic approach to smart growth and urban goods movement. It also recognized the degree to which the effects of smart growth on freight have not yet benefitted from research and development already underway for passenger travel. However, for the most part, the innovations considered in NCFRP Report 24 have been superseded by newer materials such as the SHRP2 C20 initiative.

Materials Updating QRFM?

No, per prior comment on concepts.

NCFRP REPORT 25: *FREIGHT DATA SHARING GUIDEBOOK*

Cambridge Systematics, Inc.; North River Consulting Group; and University of Washington, 2013.

Primary Purpose of Document

This report provides a series of guidelines for sharing freight data, primarily between public and private freight stakeholders. The report recognizes the difficulties in obtaining data from private entities and the significant costs associated with data collection.

Table 3.1–Provides guidelines categorized into different topics, including:

- Nonrestricted Data

- Privacy Concerns

- Scrubbing or Restricting Access to Freight Data

- Stakeholder Engagement

- Articulating Benefits of Sharing

- Funding for Data Sharing and Projects

Material Highlights

- Table 3.2–Public and commercial data sources

    o The table provides 18 different sources of public and commercial data. It is important to note that most of the freight data collected by government agencies or trade and industry associations can be assessed without restrictions.

- Appendix A–32 Freight Data Sharing Projects

    o The appendix provides a list of projects that were analyzed in the research of NCFRP Report 25. Projects analyzed included both those in the United States as well as internationally.

New Concepts Adding to or Supplementing QRFM?

NCFRP Report 25 applies to a range of contexts and environments; concepts and references are slightly dated.

Materials Updating QRFM?

Recommendations:

- Incorporate Table 3.1 guidelines into QRFM update as it provides best practices and will be useful to public sector freight planners, private freight data providers, freight partnership leaders, and freight data practitioners.

NCFRP REPORT 26: *GUIDEBOOK FOR DEVELOPING SUBNATIONAL COMMODITY FLOW DATA*

Cambridge Systematics, Inc., 2013.

Primary Purpose of Document

This report provides State DOTs and other subnational agencies with a comprehensive discussion of how to obtain and compile commodity flow data useful for their analysis.

Material Highlights

- Existing public and private commodity flow data

- Procedures for compiling data at different scales (State, MPO, Freight Analysis Framework [FAF] region, zip code)

- Procedures for conducting subnational commodity flow surveys and studies

- Examples of using commodity flow data

New Concepts Adding to or Supplementing QRFM?

The report supplements Chapter 5.0 (Commodity Models) in the QRFM by detailing the process of collecting and disaggregating commodity flow survey data.

Materials Updating QRFM?

Recommendations:

- Incorporate Chapter 6.0 (Playbook) guidelines into the QRFM, specifically:

    o Chapter 6.0 focuses on helping users develop a structured approach to accessing their commodity flow data needs and figuring out what method would be best applied to a certain freight planning problem. In many cases, users will want to use multiple methods to approach their situation. A sample game plan worksheet includes:
    - o Determining the circumstances generating the concerns
    - o Formulating question(s)
    - o Identifying stakeholders
    - o Laying out an action plan
    - o Reflecting on additional strategies

SHRP2 C20: *FREIGHT DEMAND MODELING AND DATA IMPROVEMENT*

Final Report and Strategic Plan, TRB, 2013.

Primary Purpose of Document

This report identifies the means for moving forward in improving freight data development and use.

Material Highlights

- Summary of Strategic Objectives (Plan p. 5-7)

- Summary of strengths/weaknesses of practices (p. 23-38)

- Economic flow models

- Land use and economic input-output models

- Commodity-based models

- Trip-based models

- Localized estimation routines

- Aggregate/trendline measures

- Quick response procedures (note: QRFM used to describe 1996 Cambridge Systematics "model" and not the 2007 document)

- Sample research plans for each of the initiatives A-M

New Concepts Adding to or Supplementing QRFM?

The report adds a discussion of current and emergent freight technologies and processes as well as innovative freight programs that could be incorporated into the QRFM.

Materials Updating QRFM?

Recommendations:

- Discussion of broad-scale issues such as global trade, technology, innovation, and competitiveness that will influence freight strategies and decisions.

NCHRP REPORT 750: *STRATEGIC ISSUES FACING TRANSPORTATION, VOLUME 1: SCENARIO PLANNING FOR FREIGHT TRANSPORTATION INFRASTRUCTURE INVESTMENT*

Chris Caplice and Shardul Phadnis, 2013.

Primary Purpose of Document

This report provides decisionmakers with a critical analysis of the driving forces behind high-impact economic and social changes, as well as sourcing patterns that may affect the U.S. freight transportation system. Additionally, the report introduces scenario planning as a tool that can be used in long-range transportation infrastructure planning.

Material Highlights

- Schwartz Eight-Step Method for Scenario Planning:

    1. Identify focal issue
    2. Identify key local factors
    3. Identify driving forces
    4. Rank driving forces by importance and uncertainty
    5. Select scenario logic
    6. Flesh out scenarios
    7. Apply the scenarios and uncover implications
    8. Identify leading indicators and signposts

- Examples of freight scenario planning initiatives (p. 8-10)

- Provides methodology of scenario planning workshops

New Concepts Adding to or Supplementing QRFM?

The current QRFM does not discuss in-depth scenario planning as a way of developing freight forecasts.

Materials Updating QRFM?

Recommendations:

- Provide freight scenario discussion into QRFM and highlight factors that should be considered when developing scenario models.

TRIP GENERATION HANDBOOK, 3RD EDITION, AN ITE PROPOSED RECOMMENDED PRACTICE

ITE, Washington DC, August 2014.

Primary Purpose of Document

This report provides practitioners with guidance for site-level trip generation with a focus on person trips and vehicle trips by land use code.

Material Highlights

The need to consider truck trip generation is reflected in:

- Chapter 11, a two-page summary of issues and concerns regarding goods movement with references to NCRFP Report 26, NCHRP Report 739/NCFRP Report 19.

- Chapter 12, a summary of trip generation survey tools includes a series of questionnaire elements for a truck data collection survey from Thompson, Yarbrouh, Anderson, Harris, and Harrison in TRR No. 2160, p. 163.

- Appendix J, which includes the following:

    o Compendium of findings from NCHRP Syntheses 298, 384, 358, 410, and 606.
    o Summary of the NCFRP Report 19 database hosted by Rensselaer Polytechnic Institute, and
    o Summary of available ITE database truck trip percentages for 18 land uses.

- Recognition that in all literature observed, all sample sizes are very low and therefore results should be used with caution.

New Concepts Adding to or Supplementing QRFM?

The handbook supplements Chapter 4.4 (Site/Facility Planning) in the QRFM.

Materials Updating QRFM?

Recommendations:

- Include the ITE Trip Generation Handbook, 3rd Edition as a listed source of potential truck trip rates in the QRFM as it includes improved guidance on the estimation of truck trips generated by development site and new guidance for the estimation of trips generated in urban settings.

- Include TRR 2160 survey process as a listed source for truck data collection survey instruments.

SHRP2 C20: *PIEDMONT TRIAD FREIGHT STUDY–WINSTON-SALEM INNOVATIONS IN LOCAL FREIGHT DATA*

Parsons Brinckerhoff, Westat, National Center for Smart Growth–University of Maryland, North Carolina Center for Global Logistics, May 2015.

Primary Purpose of Document

This report documents the first phase of an effort to develop a freight nodes database in the Piedmont Triad region and the collection of survey data to better understand the key attributes and trip-making characteristics of these facilities. Both geospatial data and descriptive data about the nodes was collected.

Material Highlights

The survey data revealed some useful findings with respect to relationships between building square footage, full-time employment, the number of truck bays and the number of truck trips (Tables 14-16). These types of metrics can easily be collected and used to inform truck trip patterns around the region. However, these types of variables should be supplemented with other forecasting tools.

Phase 2 of the project will focus on model development, while Phase 3 will focus on more intensive data collection.

Appendices B and C provide a template for truck driver interview questions and mail questionnaire.

New Concepts Adding to or Supplementing QRFM?

The handbook supplements Chapter 10.0 (Freight Data Collection) in the QRFM.

Materials Updating QRFM?

Recommendations:

- Reference Appendices B and C as sources for truck data collection survey instruments.

SHRP2 C20: *PORT EVERGLADES PETROLEUM COMMODITY FLOW PILOT STUDY*

Cambridge Systematics, Inc., February 2016.

Primary Purpose of Document

This report highlights emerging technologies that add value to the data-collection activities associated with better understanding goods movement flows into and through communities. The document focused on petroleum; however, technologies used can be applied to any types of freight commodities.

Material Highlights

- Table 4-1 highlights vehicle detection technologies and their implementation potential

- Video image processing

- Laser/Light Detection and Ranging (LiDAR)

- License Plate Recognition

- Transponders

- Inductive Loops

- Weigh-In-Motion (WIM)

- Microwave Doppler

- Microwave Radar

- Magnetometer

- Piezo/Quartz Sensor

- Passive Infrared

- Magnetic Detector

- Air Switch/Road Tube

- Ultrasonic

- Passive Acoustic Array Sensors

- Table 4-31 highlights advantages, disadvantages, and concerns of potential truck detection technologies

- The analysis provides a viable solution to resolve the issue of lacking "last mile" petroleum information in the current TRANSEARCH database widely used by FDOT and project partners to analyze commodity flows

New Concepts Adding to or Supplementing QRFM?

The handbook adds additional means of freight data collection that could be applied to Chapter 10.0 (Freight Data Collection) in the QRFM.

Materials Updating QRFM?

Recommendations:

- Follow up on methodology developed for estimating fuel consumption of trucks based on local factors such as land use, socioeconomic, roadway, and traffic inputs as this could be a source of data for fuel delivery touring models.

SHRP2 C20: *AGRICULTURAL FREIGHT DATA IMPROVEMENT STUDY SD2014-09*

Cambridge Systematics, Inc., March 2016.

Primary Purpose of Document

This report focused on ways to better explain agricultural freight demand to efficiently predict impacts on transportation systems and improve policy and transportation investment decisions. The focus was to identify alternative means of freight generation data besides historical trends.

Material Highlights

The key findings of this study include the following:

- Nine different agricultural freight-related data sources were identified that can be utilized for planning purposes over a horizon ranging from days to months, seasons, and years.

- Innovative data collection methods such as unmanned aerial vehicles and smartphones offer significant promise for cost-effective means to filling large gaps in data on local roadway traffic counts and surface condition.

- The demonstration developed a compendium of conventional and "unconventional" agricultural freight data related to major crops and livestock facilities. The demonstration included trip generation estimates for four major crop types and two types of livestock facilities, and testing of various planning scenarios, including facility siting and public roadway closures.

New Concepts Adding to or Supplementing QRFM?

In line with the goal of SHRP2, the freight modeling data and tools developed in this project will have substantial value to a wide range of agricultural and transportation stakeholders in States with agricultural interests, and the freight transportation community as a whole. This report supplements several topic areas in the QRFM, including trip generation, freight data collection, and freight forecasting.

Materials Updating QRFM?

Recommendations:

- Include spreadsheet evaluation tool into QRFM developed as part of the methodology to knit together agricultural and transportation data sources to achieve a common baseline for analysis. As the focus of this research was to craft a methodology using low- or no-cost data available in the public realm, others are easily able to recreate the demonstration from scratch, or plug and play using the existing spreadsheet tool with their own data.

SHRP2 C20: *INNOVATIVE LOCAL FREIGHT DATA*

Capital District Transportation Committee and Rensselaer Polytechnic Institute, 2016.

Primary Purpose of Document

This report focused on the production of a dynamic freight database that would aggregate data at the more local level. The report characterizes a comprehensive list of potential freight datasets, sources, the process of obtaining data, compatibility to research, level of disaggregation, advantages, and limitations.

Material Highlights

The key findings of this study include:

- Table 1: Summary of freight data sources included in the master freight database, both public and private, that includes common sources such as Commodity Flow Survey, FAF, and employment data—as well as lesser user data like overweight, oversize permitting, truck crash data, and Weigh-In-Motion (WIM) station counts.

- Table 27 summarizes the variables available in the dynamic freight database such as origin-destination trip information, cargo type/value, vehicle characteristics, levels of aggregation, and update frequencies.

New Concepts Adding to or Supplementing QRFM?

The report supplements Chapters 9 and 10 of the QRFM as it focuses on identifying various types of data sources as well as the method needed to collect them.

Materials Updating QRFM?

Recommendations:

- Include a review and discussion of freight data sets discussed in the report, but not included in the current QRFM into the updated QRFM.

NCHRP PROJECT 08-96 REPORT: *GUIDE FOR INTEGRATING GOODS AND SERVICES MOVEMENT BY COMMERCIAL VEHICLES IN SMART GROWTH ENVIRONMENTS*

Lamm, Kirk, Stewart, Fregonese, and Joyce, TRB, 2016

Primary Purpose of Document

This report summarizes a wide range of strategies for accommodating goods movement demand and operations given the context-sensitivity of particularly freight-sensitive land uses, with a focus on issues for areas transitioning from freight-intensive to mixed use.

Material Highlights

The key findings of this study include:

- Table 2.2: Development of Smart Growth land use categories and overlay with traditional land use transect, recognizing six specific types of both new development and redevelopment that affect how goods movement may be developed or retrofitted. These six classifications are industrial areas in transition, working waterfronts in transition, older commercial areas being revitalized, aging commercial corridors, greenfields, and large-scale reconstruction.

- Table 3.1 summarizes the types of strategies to best achieve goods movement objectives with minimal adverse effects, including setting the stage, creating places and streets, operating with minimal impacts, and ongoing monitoring.

New Concepts Adding to or Supplementing QRFM?

The report provides useful case studies for implementing progressive strategies. The report does not contain information on how the strategies would be expected to affect freight demand from a quantitative perspective.

Materials Updating QRFM?

- Reference as a state of the practice for considering different strategies to plan for and manage freight demand.

- Covers different types of emerging land uses that can be expected to substantially alter freight demand.

NCFRP REPORT 37: *USING COMMODITY FLOW SURVEY MICRODATA AND OTHER ESTABLISHMENT DATA TO ESTIMATE THE GENERATION OF FREIGHT, FREIGHT TRIPS, AND SERVICE TRIPS: GUIDEBOOK*

José Holguín-Veras, Catherine Lawson, Cara Wang, Miguel Jaller, Carlos González-Calderón, Shama Campbell, Lokesh Kalahashti, Jeffrey Wojtowicz, and Diana Ramirez; National Cooperative Freight Research Program; Transportation Research Board; National Academies of Sciences, Engineering, and Medicine, 2016 (pre-publication document).

Primary Purpose of Document

This report provides estimated freight generation using commodity flow data as a function of characteristics such as establishment size and economic activity. The models and data will aid practitioners in better curb management, planning for properly sized loading/unloading areas, and improved support for traffic impact analyses.

Material Highlights

- Proportionality between FTG/STG and business size happens only in a few industry segments.

- The models estimated at the establishment level are transferable, but need more testing to reach definitive conclusions.

- NCFRP Project 25 models generally outperformed the models in previous literature including the ones in the ITE Trip Generation Manual and the QRFM.

- Commodity flow surveys can be efficiently used to estimate freight production (FP).

- FP patterns statistically differ across States and vary from region to region, thus national models may lead to errors in estimation.

New Concepts Adding to or Supplementing QRFM?

This report stresses the importance of accounting for service trips as mentioned in the QRFM. Service industries represent almost 55 percent of establishments and 51 percent of employment in metropolitan and micropolitan areas of the country. As such, they create a large number of service trips and tend to control a high proportion of curb space, which can impact freight providers looking for suitable parking.

Materials Updating QRFM?

Recommendations:

- Explore the use and validity of FTG software under development: https://coe-sufs.org/wordpress/ncfrp33/appendix/ftg/.

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