The Effects of Transportation Infrastructure Investments on Freight Mobility: A Megaregion Perspective

Rydell Walthall
C Michael Walton

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Freight within megaregions comprises a large number of regional trips, but has received less attention from planners. This report shows how travel demand models that consistently handle freight throughout a megaregion can be used to plan for infrastructure investments or strategies to increase freight mobility. To do this, the Texas Triangle Megaregion is used as an example because it is mostly contained within a single state with an existing statewide travel demand model. Additionally, this report provides descriptions of freight data sources and emerging freight trends that planners without a freight expertise might not be familiar with.</td></tr>
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1. Overview

Megaregions demonstrate strong economic linkages and support extensive internal freight movements amongst their constituent metropolitan areas.[1] As megaregions continue to grow, freight movements are likely to increase, and new infrastructure or policies will be necessary to accommodate that growth.

In 2017, traffic congestion cost urban areas of the United States $166 billion with trucks accounting for a disproportionately large share.[2] Additionally, the transportation sector causes over a quarter of the United States' greenhouse gasses and substantial fractions of oxides of nitrogen, volatile organic compounds, and particulate matter.[3] [4] Improving the efficiency of freight flows within megaregions therefore has the potential to drastically reduce pollution and congestion. This research examines how planners can prepare for innovative strategies to increase the productivity of freight movements at the megaregion level. Specific strategies examined include truck-only lanes, trucking platoons, electrification, and improving rail intermodal terminals, but the focus is not on those strategies themselves. Rather, the focus is on the method by which planners in a megaregion might assess such strategies.

While all of those strategies are active areas of research, they have not been widely examined in the context of megaregions. The strong linkages within megaregions can create conditions for those strategies to work better than they otherwise would, but the lack of uniform governance throughout megaregions creates challenges for their implementation. For example, megaregions that cross state boundaries might not have unified travel demand models, and the regional travel demand models within a megaregion might be inconsistent.

Aside from specific analysis of several freight topics, the primary contribution of this research is to provide a resource for regional policy researchers who are less familiar with freight transportation topics. The framework used in this research to compare different freight technologies is widely extendable to other freight policies. This report is also a resource for policy

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[1]Harrison, Robert; Johnson, Donovan; Loftus-Otway, Lisa. "Megaregion Freight Planning: A Synopsis." Center for Transportation Research, TxDOT Technical Report number 0-6627-1. August 2011. link

[2]Schrank, David; Eisele, Bill; Lomax, Tim. "2019 Urban Mobility Report." Texas A&M Transportation Institute. August 2019. link

[3]United States Environmental Protection Agency. "Sources of Greenhouse Gas Emissions, Total U.S. Greenhouse Gas Emissions by Economic Sector in 2017." September 2019. link

[4]United States Environmental Protection Agency. "EPA's Report on the Environment (ROE)." July 2019. link

researchers on how freight planning is currently treated at the regional level and the resources available to improve freight planning.

The primary take-away from this report is that a travel demand model encompassing an entire megaregion in high resolution can be a valuable tool for megaregion planning. This is particularly true for freight strategies, as freight trips tend to be much longer distance than passenger trips.

1.1. Outline

The first section of this report provides an overview of the findings, as well as an overview of the Texas Triangle Megaregion for those that may be unfamiliar and some of the existing research into freight in megaregions. Section 5 looks at data sources for freight research that planners without freight back grounds might be unfamiliar with. Section 5 also presents a new data source that can be useful for megaregion planning developed by the Cooperative Mobility for Competitive Megaregions University Consortium (CM^2). Section 12 provides an overview of several emerging strategies for handling freight that are relevant for megaregion planning, and section 20 discusses how a megaregion-wide travel demand model might be combined with an economic model to evaluate those strategies. Finally, section 23 shows the results of applying the section 20 methodology to one of the strategies discussed in section 12, truck-only lanes. Section 27 provides conclusions and outlines areas for further research.

1.2. Texas Triangle Megaregion

This research focuses on the Texas Triangle Megaregion in order to provide concrete examples. To make the findings more accessible, this section outlines the characteristics of the Texas Triangle Megaregion for readers who may be less familiar.

The Texas Triangle Megaregion is primarily composed by the major metropolitan areas of Dallas-Fort Worth to the north, Houston to the southeast, and San Antonio to the southwest. Other major metropolitan areas within this triangle include Austin, Killeen-Temple-Belton, Waco, and Bryan-College Station. By some definitions, the megaregion might extend further northward into Oklahoma, including metropolitan areas such as Oklahoma City and Tulsa.[5] Figure 1 below shows

[5]Regional Plan Association. “Texas Triangle.” America 2050, 2016. link

the extent of the Texas Triangle Megaregion according to America 2050, which includes the areas in Oklahoma.[6] The Houston-Galveston area is also a part of the Gulf Coast Megaregion.

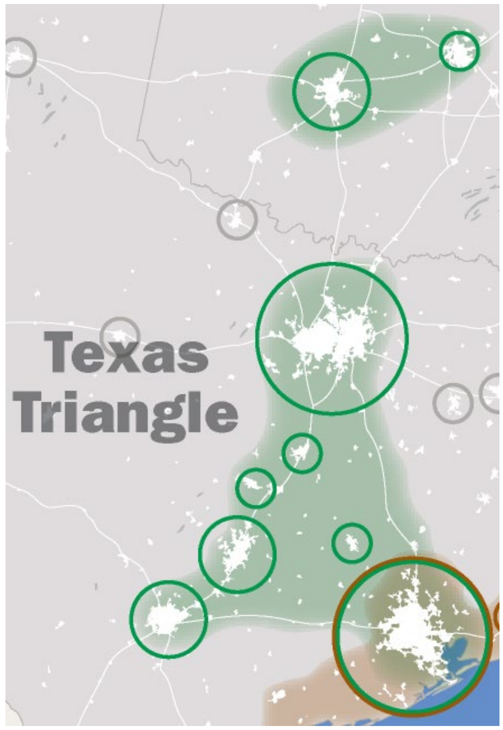

Figure 1: Texas Triangle Megaregion (green) according to America 2050. [5]

According to America 2050, the Texas Triangle contained six percent of the US population and accounted for seven percent of the US economy in 2010.[7] Much of the region's economy is related to trade, both via NAFTA trade traveling along the corridor from Laredo through San Antonio and Dallas-Fort Worth and by maritime trade through the Port of Houston.

The Texas Triangle Megaregion is heavily involved with international trade, both from the Port of Houston and from the Mexican border. Additionally, the megaregion is home to some of the world's largest oil companies and refineries in the Houston area, and several tech firms in Dallas-Fort Worth and Austin.

1.3. Freight in megaregions: existing research

While much of the research into megaregions has focused on passenger transport, freight transportation has also received some focus. A peer exchange of representatives from metropolitan

[6] *Ibid*.
[7] *Ibid*.

planning organizations (MPOs) in different megaregions identified a disconnect between how transportation networks are planned and how the economy is currently linked.[8] As economic ties have grown to encompass megaregions, transportation planning remains rooted at the regional level through MPOs. Since each MPO encompasses many local governments, and MPOs vary substantially in size and governance structure, even planning at a regional level has become a challenge.[9] Coordinating freight challenges through multiple interconnected regions can thus be daunting.

1.4. Megaregions as a test bed

Megaregions display large volumes of freight movements in concentrated areas, allowing for the testing of new policies and technologies in settings that are particularly favorable. Some technologies might be viable in a megaregion before they mature to be widely applicable. In addition to research specifically examining freight policies related to megaregions, some projects have employed the unique characteristics of megaregions for pilot studies of new technology implementation.

[8] Atlanta Regional Commission. "Megaregions Freight Movement Peer Exchange." Atlanta, GA. Hosted in partnership with the Metro Atlanta Chamber, the Center for Quality Growth and Regional Development at the Georgia Institute of Technology, FHWA, FTA, and the Volpe National Transportation Systems Center. November 2013. link

[9] There are 404 MPOs across the country. While they each MPO is designated by US DOT and ultimately answers to FTA and FHWA, there is a large amount of leeway in how each individual MPO is structured and how it meets federal planning requirements.

2. Data sources for regional freight research

Many planners and researchers who are well-versed in the topic of megaregion planning might be less familiar with freight data sources. This section is meant to provide a high-level overview of several common public and private freight data sources and will not contain new information for freight experts.

2.1. Public data sources

Two of the largest public data sources for freight movements in the United States are the Commodity Flow Survey and the Freight Analysis Framework.

2.1.1. Commodity Flow Survey

The Commodity Flow Survey, or CFS, is created by a partnership between the US Census Bureau and the Bureau of Transportation Statistics. The survey is conducted every five years, and the most recent version comes from 2017.[10] The CFS "represents the only publicly available source of data for the highway mode."[11] A Public-Use Microdata Sample (PUMS) allows for some high-resolution analysis of freight movements. The 2012 version of the PUMS contained 4.5 million records.[12]

2.1.2. Freight Analysis Framework

The Freight Analysis Framework, or FAF, is created in partnership between the Federal Highway Administration and the Bureau of Transportation Statistics.[13] The most recent version of the FAF, FAF4, is based on CFS data from 2012, and includes freight flows for 2012, 2007, 2002, and 1997, as well as flow projections for 2045.[14] Unfortunately, for some applications at the megaregion level, the data from the FAF may be "too broad in certain areas of the country and does not discriminate by precise location."[15] This is because the FAF uses large zones for its freight-

[10]Bureau of Transportation Statistics. "Commodity Flow Survey Overview." United States Department of Transportation. link

[11]*Ibid*.

[12]Bureau of Transportation Statistics. "2012 CFS Public-Use Microdata Visuals." United States Department of Transportation. link

[13]Office of Operations. "Freight Analysis Framework." Freight Management and Operations; Federal Highway Administration; U.S. Department of Transportation. 1 October 2018. link

[14]*Ibid*.

[15]Harrison et. al, 2012

movement centroids. FAF can be very useful for examining movements between states or large metropolitan regions, but it might not have adequate resolution for movements within a megaregion.

2.2. Private data sources

In addition to public data sources, several private data sources are relevant to regional freight analysis. These data sources are often based on publicly available data sources, but have the data processed and combined using economic functions. They can be very expensive for planning entities to gain access to.

2.2.1.IMPLAN

IMPLAN, which stands for Impact Analysis for Planning, can provide data down to the county level and offers up to 536 economic sectors for analysis.[16] Its datasets combine statistics from sources such as the Bureau of Economic Analysis, Bureau of Labor Statistics, and Census Bureau with economic functions to estimate outputs such as production, employment, and value added.[17]

2.2.2.Transearch

Transearch is a planning tool meant to help project US freight flows by mode, origin-destination pair, or commodity over time horizons of up to thirty years.[18] While IMPLAN is more generally applicable to economic input and output, Transearch is specifically set-up for tracking freight flows.

Transearch uses the Standard Transportation Commodity Code (STCC) to classify movements by commodity type. STCC provides categorization at up to seven digits, but the Transearch dataset goes as far as four digits covering four hundred fifty separate commodity groupings.[19]

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[16]IMPLAN Group. "United States Economic Data Sources." 2019. link

[17]Cheney, Phil. "IMPLAN Data Sources." IMPLAN Group. 2019. link

[18]IHS Markit. "Transearch: Prepare for future transportation demand." 2019. link

[19]Walton, C. Michael; Jiang, Nan; Walthall, Rydell; Savage, Kevin; Bujanovic, Pavle; Kam, Katie; Seedah, Dan; Wang, Zuocheng; Li, Jia; Murphy, Michael; Harrison, Robert. "Commodity-based Approach for Evaluating the Value of Freight Moving on Texas's Roadway Network." Center for Transportation Research. FHWA/TX-17/0-6898-1. August 2017. p. 62

The Transearch data set tracks freight flows in seven different transportation modes.[20] While Transearch is estimated annually, each year of data has to be purchased separately, meaning that a particular planning entity such as a state DOT might only have a specific year's estimates.[21]

2.3. A new data source available from CM²

As part of separate work under CM², researchers are developing a database of information on all of the MPOs across the country.[22] [23] [24] Part of that database includes variables tracking the freight modeling capabilities of each MPO, and, in particular, how freight is handled within each MPOs travel demand model.

For each MPO, researchers tracked whether freight was included in the model and whether trucks were assigned to the roadway network. In addition to the modeling variables, the database tracks how airports are handled by MPOs, and airports can be an important link for valuable commodities.[25] The database itself will be made available through the CM² consortium, but some of the preliminary freight-related findings are presented here.[26] Overall, 241 of 404 MPOs are within megaregions, and those MPOs are slightly more likely to include freight in their travel demand models than MPOs outside megaregions.

Creating a freight planning process at the megaregion level is a daunting challenge that planners are continuing to address.[27] This database allows planners to take stock and see how different

[20] *Ibid*.

[21] *Ibid*.
As of 2017, the TxDOT had access to Transearch's 2010 data as well as forecasts for 2020 and 2030.

[22] Sciara, Gian-Claudia. "Transit Operators in Metropolitan Transportation Decision Making." Cooperative Mobility for Competitive Megaregions. To be published.

[23] Sciara, Gian-Claudia; Ryerson, Megan. "Airport Governance in U.S. Metro Regions: Institutional Models and their Implications for Megaregion Transport." Cooperative Mobility for Competitive Megaregions. To be published.

[24] Walton, C. Michael. "Incorporating active transport into the regional planning process to support first and last mile travel." Cooperative Mobility for Competitive Megaregions. To be published.
[22], [23], and [24] are all ongoing projects, but the database produced from them has information which will be useful for freight planning at the megaregion level.

[25] Walton, C. Michael; Jiang, Nan; Walthall, Rydell; Savage, Kevin; Bujanovic, Pavle; Kam, Katie; Seedah, Dan; Wang, Zuocheng; Li, Jia; Murphy, Michael; Harrison, Rob. "Commodity-based Approach for Evaluating the Value of Freight Moving on Texas's Roadway Network." Center for Transportation Research, TxDOT Technical Report 0-6898-1. August 2017. link

[26] This information is based on 319 of the 404 MPOs across the country. MPOs were ordered pseudo-randomly in an effort to ensure that these 319 MPOs do not disproportionately represent large-population or small-population MPOs.

[27] Harrison et al, 2012

MPOs within a megaregion handle freight planning. One megaregional planning goal is for a megaregion transportation plan that integrates the plans of disparate MPOs in order to consider the inter-city movements of goods and people.[28]

2.3.1.MPOs within megaregions

Each of the 404 MPOs across the country can be categorized within a megaregion. The categorizations described here use the America 2050 Emerging Megaregions map first published by the Regional Plan Association in 2008, and shown in Figure 2 below.[29] Because the travel patterns and economic ties that result in a megaregion change over time, and different sources use different bounds for megaregions, this research also categorizes an additional fifty-three MPOs as adjacent to one or more megaregions. The number of MPOs for each megaregion would vary if a different source were used.

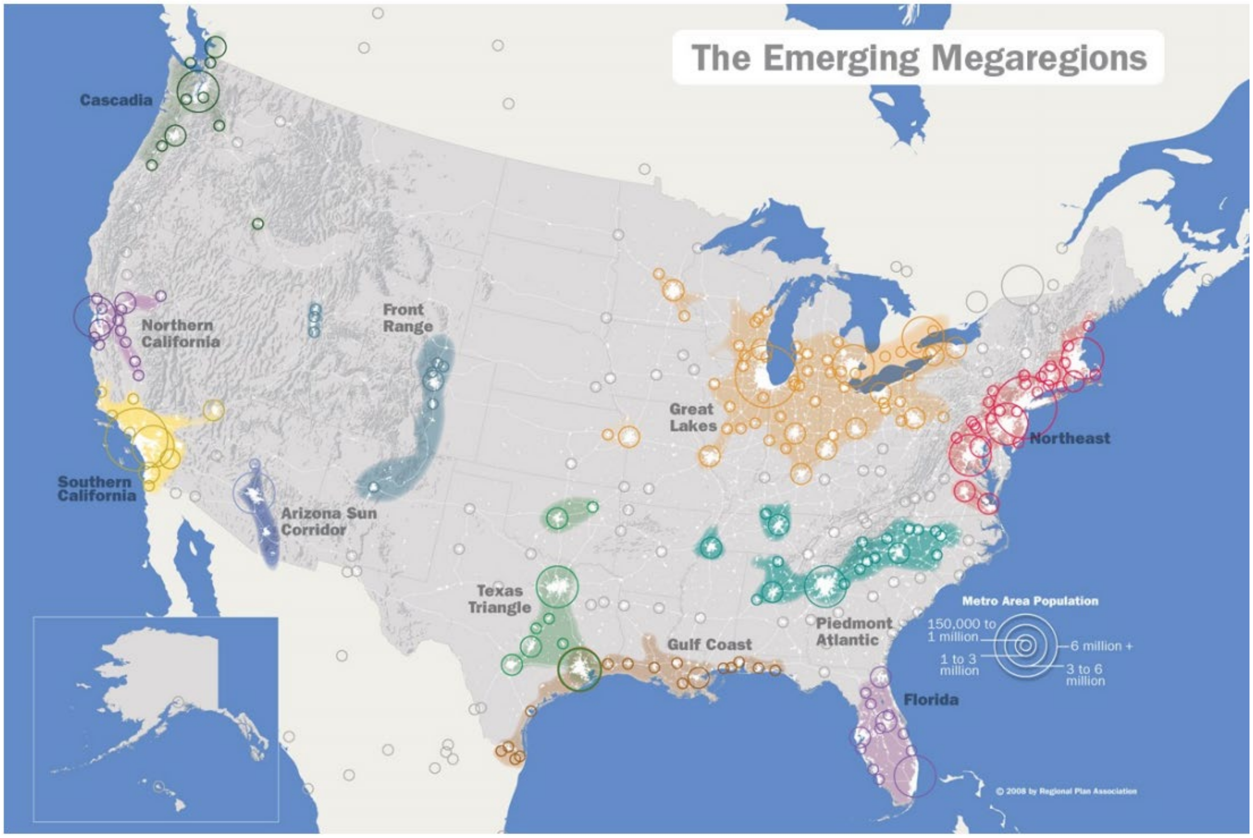

Figure 2: Megaregions defined by the America 2050 report [29]

[28]Zhang, Ming; Steiner, Frederick; Butler, Kent. "Connecting the Texas Triangle: Economic Integration and Transportation Coordination." The Healdsburg Research Seminar on Megaregions. April 2007. link

[29]Regional Plan Association. "America 2050: The Emerging Megaregions." 2008. link

In total, 241 MPOs lie within one of the eleven defined megaregions. The Great Lakes Megaregion has by far the most, with seventy-one separate MPOs within the bounds and an additional twenty adjacent MPOs. Table 1 below shows the breakdown of MPOs by megaregion. Note that some MPOs can be within or adjacent to multiple megaregions.

Table 1: MPOs by megaregion

Megaregion	Primary MPOs	Adjacent MPOs
Arizona Sun Corridor	4	1
Cascadia	11	3
Florida	23	3
Front Range	7	1
Great Lakes	71	20
Gulf Coast	19	2
Northeast	46	11
Northern California	12	3
Piedmont Atlantic	34	6
Southern California	6	3
Texas Triangle	9	7

This categorization allows the MPO database, developed by CM^2 researchers, to be applied to megaregions. This application of the data can help show whether the freight planning characteristics for MPOs vary for MPOs within megaregions.

2.3.2.Freight statistics from the MPO database

Preliminary statistics

Because the creation of this MPO database is a part of different projects within the CM2, the database is not complete as of the writing of this report, and only preliminary statistics are available. Because of the way the database is constructed, it is fairly representative of each megaregion, and Table 2 below shows the percentage of MPOs in each category that are included for these statistics.

Table 2: Representation of MPOs within the preliminary statistics used for this report

Category of MPOs	Total MPOs in category	MPOs from category included in preliminary statistics	Percentage of category included in preliminary statistics
All	404	319	79%
Within Megaregions	241	190	79%
Adjacent to Megaregions	56	46	82%
Within or adjacent to Megaregions	294	234	80%
Within Arizona Sun Corridor Megaregion	4	4	100%
Within Cascadia Megaregion	11	9	82%
Within Florida Megaregion	23	18	78%
Within Front Range Megaregion	7	6	86%
Within Great Lakes Megaregion	71	53	75%
Within Gulf Coast Megaregion	19	18	95%
Within Northeast Megaregion	46	32	70%
Within Northern California Megaregion	12	10	83%
Within Southern California Megaregion	6	6	100%
Within Piedmont Atlantic Megaregion	34	28	82%
Within Texas Triangle Megaregion	9	7	78%

Table 2 shows that, by percentage of MPOs, the Northeast Megaregion is the most under-represented category. Despite this under-representation, even the Northeast Megaregion has seventy percent of its MPOs included. Overall, the percentage of MPOs in the data coming from within megaregions is the same as the percentage of MPOs coming from outside megaregions—79%.

Findings

One way to look at whether freight is being considered in an MPOs planning practices is whether freight is included in an MPOs travel demand model. Nationwide, this MPO database identifies 31% of MPOs as directly assigning freight in their travel demand models. A slightly higher fraction of MPOs in megaregions assign freight in their travel demand models – 35% – but that fraction varies considerably between megaregions. Both the Florida and Southern California Megaregions have disproportionately high numbers of MPOs that include freight in the regional travel demand models. In the case of the former, this may be due to the fact that the entire megaregion is within the same state, and that the Florida DOT has worked to create some consistency in regional travel demand models via the Florida Standard Urban Transportation Model Structure.[30] In the case of the latter, all six MPOs cover very large urban areas.

At the other end of the spectrum, the Northeast and Great Lakes Megaregions both have lower fractions of MPOs that assign freight in their regional travel demand models than the national average (22% and 26% percent respectively). Those megaregions have the highest numbers of MPOs, including many smaller MPOs with few resources, which may help to explain the low percentages.

[30]Forecasting and Trends Office. "FSUTMS Online." Florida Department of Transportation. 2019. link

3. Trending freight policies that affect megaregion planning

One goal of this research is to explore a framework for analyzing freight policies or technologies at the megaregion level. To accomplish this, several such policies were analyzed to give a broad overview of the type of information that can be provided from different tools. This research examines the following concepts as they apply to the Texas Triangle Megaregion:

- Truck-only lanes
- Train intermodal facilities
- Electric trucking
- Electric rail
- Truck platooning

This section provides an overview of these concepts. The next section outlines how each concept might be analyzed at the megaregion level and provides some preliminary results for the Texas Triangle Megaregion.

3.1. Truck-only lanes

Truck-only lanes have the potential to reduce highway conflicts, improve freight and passenger movement efficiency, and increase reliability.[31] Trucks and passenger vehicles tend to operate at different cruising speeds, particularly if the terrain is not flat.[32] This speed differential changes driver behavior in several ways that can increase highway travel costs. In high traffic densities, mixing passenger vehicles and heavy trucks forces passenger vehicles, which have relatively better acceleration and breaking capabilities, to follow behind heavy trucks. This following behavior increases the number of breaking and acceleration maneuvers necessary, imposing emissions and congestion costs.[33] For example, the Highway Performance Monitoring System Field Manual uses

[31] Forkenbrock, David J.; March, Jim. "Issues in the Financing of Truck-Only Lanes." Public Roads, Federal Highway Administration Research and Technology. FHWA-HRT-05-007, Vol. 69 No. 2. October 2005. link

[32] Hallmark, S. L.; Isebrands, H. "Evaluating speed differences between passenger vehicles and heavy trucks for transportation related emissions modeling." October 2005. link

[33] *Ibid*.

the fraction of heavy vehicles along a roadway as a factor in reducing the roadway's overall capacity.[34]

Even in low traffic densities, mixed passenger vehicle and truck traffic can impose safety costs because there will be a higher frequency of complex passing maneuvers.[35] Such maneuvers not only increase the frequency of crashes, but they can also disproportionately increase the frequency of angle conflicts versus less severe rear-end conflicts.[36]

In order to avoid the costs associated with mixed traffic streams, a few agencies have implemented truck-only lanes, but the practice is still fairly uncommon.[37] California has trucking lanes designated at two locations along the Interstate 5 corridor: one in Los Angeles County has a length of 3.9 kilometers (2.4 miles) in both directions, and one in Kern County extends only 0.6 kilometers (0.4 miles) in the southbound direction. Both segments are in the Southern California Megaregion.[38] In both of those cases, trucks are required to use the truck lanes, but passenger vehicles are only advised to avoid using them – they are not true truck-only lanes because there is no enforceable mechanism to prevent passenger vehicles from using the truck facilities. For truck-only lanes, Caltrans recommends that, when right-of-way acquisition costs are high, it might be feasible to construct above-grade lane sections for passenger vehicles, but that trucks should always operate at-grade for safety.[39] Elsewhere in the country, there was a proposal by the Georgia Department of Transportation to add truck-only lanes to a one hundred twenty-two kilometer (seventy-six mile) stretch of Interstate 75 in the Piedmont-Atlantic Megaregion.[40] [41]

Truck-only lanes could have a substantial effect on overall roadway maintenance costs because trucks consume pavement at much higher rates than passenger vehicles.[42] Lanes used only for

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[34]Federal Highway Administration. "HPMS Field Manual; Appendix N: Procedures for Estimating Highway Capacity." US Department of Transportation. June 2017. link

[35]Zhao, Peibo. "Safety Evaluation of Car-Truck Mixed Traffic Flow on Freeways Using Surrogate Safety Measures." Electronic Theses and Dissertations, University of Windsor, record 5923. 2016. link

[36]*Ibid*.

[37]Chrysler, Susan T. "Preferential Lane Use for Heavy Trucks." Transportation Policy Research Center, Texas A&M Transportation Institute. PRC 15-39 F. July 2016. link

[38]Caltrans. "Truck-Only Lanes." 2019. link

[39]*Ibid*.

[40]Casale, Matt. "Georgia's $2 Billion Truck-only Lanes: A Lesson in Outdated Transportation Planning." United States Public Interest Research Group. February 2018. link

[41]Selin, Tracy. "Memorandum: Impact Analysis for Roadway Improvements." Cambridge Systematics. May 2016. link

[42]Federal Highway Administration. "Comprehensive Truck Size and Weight Study; Chapter 5: Pavement." Study submitted originally August 2000. Website updated September 2017. link

trucks would likely need increased maintenance, while other lanes would have reduced maintenance. Because of the scarcity of truck-only lanes in operation, the overall maintenance effect is not well studied, and it may be possible to reduce overall costs by using different materials for the different lanes.[43]

Truck-only lanes might be more useful within megaregions because megaregions tend to have long corridors with sustained high intensities of mixed-traffic where truck-only lanes can produce higher benefits. NCFRP Report 3, which studied tolled facilities for the exclusive use of commercial vehicles, identified thirteen long-haul corridors with high suitability for truck-only facilities.[44] Of those thirteen corridors, seven were entirely within megaregions, and the remaining six connected adjacent megaregions with substantial portions of the corridors within either adjacent megaregion. Based on such a ranking, it makes sense to consider truck-only lanes as one of the potential freight-related solutions to mobility within megaregion planning.

3.2. Rail intermodal facilities

Rail intermodal facilities are vital components of freight movements for megaregions.[45] They allow for relatively quick loading and unloading of long intermodal unit trains, which are among the most efficient means of moving intermodal containers over land.[46] However, unloading and loading trains still represents a bottleneck in rail transport, and is one of the reasons rail is not competitive with trucking for many of the medium-haul transport distances found within

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[43] *Ibid*.

[44] National Academies of Sciences, Engineering, and Medicine. "Separation of Vehicles CMV-Only Lanes." Washington, DC: The National Academies Press. 2010. link p.80
The selection was based on corridors with at least 10 000 trucks per day along some segments. Ranking criteria included daily truck volumes, the fraction of the corridor with truck-volumes in excess of a 10,000-vehicle threshold, corridor congestion levels, connectivity to the national network, and willingness of trucking companies to use truck-only facilities along the corridor. The report only considered corridors meeting the threshold of at least 10 000 trucks per day along some segment, but indicated that, for a tolled truckway, 2000 to 4000 trucks per day would be adequate for the corridor to be self-sufficient from truck tolls.

[45] Rodrigue, Jean-Paul. "The Geography of Transport Systems, 4th Edition." ISBN 978-1138669574. Chapter 6: Transportation Terminals. 2017. link

[46] National Academies of Sciences, Engineering, and Medicine. "Funding and Managing the U.S. Inland Waterways System; What Policy Makers Need to Know." Washington, DC. The National Academies Press. Appendix G, page 196. 2015. link
In some circumstances, river barges may be more efficient than rail – studies have found either mode to be more efficient for some O-D pairs depending on the directness of the waterway versus the directness of the railway, the grade of the tracks, and whether the barge is moving upstream or downstream.

megaregions.[47] [48] Inefficiencies in rail intermodal facilities can impose the following public or private costs:

Labor: any delays in intermodal facilities mean additional labor-hours for yard workers, additional labor-hours for rail operators who have to wait for trains to be ready to proceed, and additional risk of on-the-job injuries due to work in close-proximity with heavy machinery.[49]

Time: the time spent at intermodal facilities ties up expensive rail equipment, preventing it from being used elsewhere and causing rail companies to spend money on additional equipment. It also delays cargo, imposing logistics costs on clients. Finally, it increases the likelihood that trains will spill out of the rail terminal and create traffic delays for adjacent rail crossings.[50]

Space: related to the time costs, busy intermodal facilities require space to store rail equipment while it waits to be loaded or unloaded. For long-running historical reasons, some of these facilities are located relatively close to urban centers.[51] This might reduce costs for drayage, but it also means that land is not available for other uses. There are various opportunity costs associated with urban land used for freight rail transport[52]

Pollution: rail terminals require many short, low-speed movements of heavy equipment. Because these movements require high torques but do not require high speeds, the locomotives used in rail yards are often older and more polluting than the locomotives used for line-haul movements.[53] Because of the relative proximity to urban locations, rail yards are not only relatively more

[47] Seedah, Dan; Owens, Travis; Bhat, Chandra; Harrison, Robert. "Evaluating Truck and Rail Movements along Competitive Multimodal Corridors." FHWA/TX-13/0-6692-1. January 2014. link

[48] Arnold, Pierre; Peeters, Dominique; Thomas, Isabelle. "Modeling a rail/road intermodal transportation system." Transportation Research Part E: Logistics and Transportation Review, Volume 40, Issue 3, pages 255-70. May 2004. link

The location of intermodal rail terminals has a large effect on the competitiveness of rail with trucking, but there is also a high amount of variability in the cost of traversing the route.

[49] Kemme, Nils. "Making Automation a Success." Freight & Terminal Forum Conference Presentation, Utrecht, The Netherlands. March 2019. Abstract available at link

[50] Bryan, Joseph; Weisbrod, Glen; Martland, CarlD.; and Wilbur Smith Associates, Inc. "Assessing rail freight solutions to roadway congestion: final report." NCHRP Project 8-42. October 2006. link

[51] American Society of Planning Officials. "Rail Lines and Terminals in Urban Planning." Chicago, Illinois. January 1956. link

[52] Prozzi, Jolanda; Walthall, Rydell; Kenney, Megan; Warner, Jeff; Morgan, Curtis. "Public Use of Rail Right-of-Way in Urban Areas." Policy Research Center, Texas A&M Transportation Institute. PRC 14-12 F. December 2014. link

[53] United States Environmental Protection Agency. "Rail and Locomotives Best Practices." March 2018. link

polluting than rail corridors, but that pollution also has a higher likelihood of leading to negative health outcomes.

3.2.1. Rail terminal automation

One potential method to reduce all of the costs associated with rail terminals is automation.[54] Terminal automation has already progressed at several sea ports, but it is becoming more common for inland rail-truck intermodal terminals as well.[55] [56] Automating the rail loading and unloading process can reduce delays, decrease labor requirements, improve terminal safety, reduce the amount of space required in terminals in order to free-up urban space, and make rail more competitive with trucking for freight movements within megaregions.[57]

3.3. Electrification

Over thirty-six percent of overall US energy-related CO_2 emissions came from the transportation sector in 2018,[58] and roughly thirty-three percent of transportation energy use is for freight.[59] Reducing freight pollution within megaregions can be considered a higher priority because, in addition to reducing emissions responsible for climate change, it reduces health-degrading emissions produced in proximity to urban centers.[60] Urban trucking is among the largest sources of urban PM2.5 emissions.[61] One way to reduce the emissions from freight movements is via electrification. Electric motors tend to be more efficient, reducing the overall energy consumed,

[54]Mongelluzzo, Bill. “US intermodal rail automation faces steep challenges.” Journal of Commerce, JOC Group, Inc. September 2017. link

[55]*Ibid*.

[56]Planning and Economic Development Division, Port of Los Angeles. “Container Terminal Automation.” City of Los Angeles Harbor Department. March 2014. link

[57]Zumerchik, John; Rodrigue, Jean-Paul; Lanigan, Jack. “Automated Transfer Management Systems and the Intermodal Performance of North American Freight Distribution.” Journal of the Transportation Research Forum, Vol 48, Issue 3. ISSN: 1046-1469. 2009. link

[58]Energy Information Administration. “What are U.S. energy-related carbon dioxide emissions by source and sector?” Monthly Energy Review. May 2019. link

[59]Energy Information Administration. “Annual Energy Outlook 2019; Transportation Sector Energy Use by Mode and Type.” 2019. link
This statistic is based on 2017 energy consumption, as the 2018 energy use in the report is based on a projection.

[60]Kijewska, Kinga; Konicki, Wojiciech; Iwan, Stanisław. “Freight Transport Pollution Propagation at Urban Areas Based on Szczecin Example.” Transport Research Procedia Vol 14 pages 1543-52. June 2016. link

[61]Harikishan, Perugu; Wei, Heng; Yao, Zhuo. “Estimating the Contribution of Heavy-Duty Trucks to the Urban PM2.5 Pollution.” Transportation Research Board Standing Committee on Transportation and Air Quality. 2016.

and it is possible to produce electricity from sources cleaner than the diesel engines that currently power most freight movements, further reducing emissions.

Rail movements are already electrified in many places outside the United States via overhead contact systems (OCS),[62] but it is also possible to electrify trucking movements.[63]

3.3.1.Electric trucking

The two main methods of electrifying heavy truck movements are via batteries or an OCS.

Battery-operated

Trucks could operate electrically with on-board batteries. It is possible to run a fully electric truck in this manner, or to have hybrid trucks that operate electrically while battery power is available and then switch to diesel operations once the batter charge is depleted.[64] For short-haul and some medium-haul freight transport, it might be possible to operate trucks fully on electricity, although current technology would make the conversion of all truck operations impractical.[65] However, such a system might impose logistics costs to shippers due to the greater time it takes to charge a batter versus adding similar amounts of energy to a diesel tank.

Overhead electric trucking

It is also possible to construct highway infrastructure that charges trucks as they travel along a designated lane.[66] Such a system could use an OCS similar to electric rail systems along busy stretches of highway. Hybrid trucks along the stretch would operate from the overhead electric power while simultaneously charging their batteries. This allows the trucks to continue to operate electrically for short segments outside of the electric infrastructure. The freight patterns within

[62]International Union of Railways. "Railway Statistics – Synopsis." 2016 Report. June 2017. link
According to the statistics, fifty-two percent of European rail lines, twenty-four percent of African rail lines, and thirty-eight percent of rail lines in Asia and Oceania were electrified. Only a small fraction of rail lines in the United States are electrified.

[63]Kelly, Kenneth; Bennion, Kevin; Miller, Eric; Prohaska, Bob. "Medium- and Heavy-Duty Vehicle Duty Cycles for Electric Powertrains." National Renewable Energy Laboratory, United States Department of Energy. PR-5400-66228. March 2016. link

[64]*Ibid*.

[65]Çabukoglu, Emir; Georges, Gil. "Battery electric propulsion: An option for heavy-duty vehicles? Results from a Swiss case-study." Transportation Research Part C: Emerging Technologies, Vol 88, pages 107-23. March 2018. link

[66]Sachgau, Oliver. "Germany's First 'Electric Highway' Charges Trucks as they Drive." Bloomberg. 13 May 2019. link

megaregions might be ideal for such systems because it would be possible to electrify significant portions of the trucking present without imposing charging delays.

3.3.2. Electric rail

The first electric rail vehicle operated as early as 1842 in Scotland[67] and the Baltimore & Ohio Railroad started running electric locomotives on short segments of its mainline in Maryland in the 1890s.[68] Today, many passenger trains worldwide operate on electricity, including several regional and commuter routes in the United States. Some freight locomotives in Europe and Asia run on electricity, and there are even electric rail systems under construction in Africa.[69] Only a few freight operations in the United States are electrified, however. The characteristics of freight transport within megaregions, where rail corridors operate at high density, could make freight rail electrification within some megaregions cost effective.

3.4. Truck platooning

Connected vehicles are able to wirelessly communicate with one another in order to improve flow and safety. Applications of this technology range from simple messages to alert drivers of conditions experienced by downstream vehicles to partial automation of vehicle control in order to enable platooning. Vehicle platoons have the potential to smooth vehicle following behavior, which can in-turn stabilize the traffic stream to improve flow and safety.[70] Vehicles in a platoon use wireless communication to follow one another in single-file and maintain spacing. Because platoons are able to maintain much smaller vehicle spacings than normal driving allows, platoons have the potential to increase roadway capacity and reduce vehicle energy consumption.[71] The efficacy of trucking platoons depends in part on how platoons are formed – there are enough passenger vehicles along major corridors that platoons can form whenever two or more platooning-enabled vehicles are close enough together, but trucks might be dispatched as platoons from origin

[67] Reid, John S. "Robert Davidson – pioneer electrician." The Scientific Tourist: Aberdeen. University of Aberdeen. No date. link

[68] Smithsonian Institution. "Preliminary Guide to the Baltimore and Ohio Railroad Records." Collection ID NMAH.AC.1086. 2019. link

[69] Ollingo, Allan. "Ethiopia, Tanzania electric trains to speed up cargo movement." The East African. January 2018. link

[70] Bujanovic, Pavle. "Developing Vehicle Platoons and Predicting their Impacts." Electronic Theses and Dissertations, The University of Texas at Austin. August 2018. link

[71] *Ibid*.

to destination.[72] Additionally, allowing more trucks in a single platoon can further improve capacity and emissions reductions, but it has the potential to make other drivers uncomfortable if there are very long platoons – for example, passing maneuvers might become too complex.

Megaregions can also be used as testing grounds for new technologies. The Federal Highway Administration, Texas Department of Transportation, several research institutions, and private stakeholders are currently collaborating "to deploy connected vehicle technologies to more than 1,000 commercial vehicles to improve traveler information, asset condition management and system performance" in a project called Texas Connected Freight Corridors.[73]

[72] *Ibid*. p.146

[73] Traffic Safety Division. "Texas Connected Freight Corridors." Texas Department of Transportation. 2019. link

4. Methodology for testing technologies and policies in megaregions

4.1. Methodology for analysis

A general idea for the effects of different policies can be achieved by combining a travel demand model with economic models for benefits and costs. The travel demand model should encompass the entire megaregion in a high level of detail. In order to assess freight strategies, the model could be more accurate if it includes areas outside the megaregion that generate freight flows. External nodes could be used instead, but those might not accurately predict flows that have the choice of going through the megaregion or bypassing it.

4.2. A freight network

This section will focus on how general planning tools can be adapted to model the challenges facing freight at the megaregion level. It will take the Texas Statewide Analysis Model (SAM) as an example and show some of the benefits and shortcomings when such a planning tool is applied to megaregion freight planning.

4.2.1.SAM overview

SAM is a standard four-step model developed for the entire state of Texas. It includes nearly two hundred five thousand links. Roughly 180 000 of those are roadway links, and are for roadways and about sixty-four thousand links are within Texas. Of the links within Texas, roughly 61 500 are roadway links. Part of what makes a tool like the SAM ideal for freight analysis within the Texas Triangle Megaregion is that most of the links outside Texas are implemented as a freight network in the model. Figure 3 below shows the extent of the SAM network.[74]

[74]TxDOT. "Statewide Analysis Model." Prepared by Alliance Transportation Group. 2010.

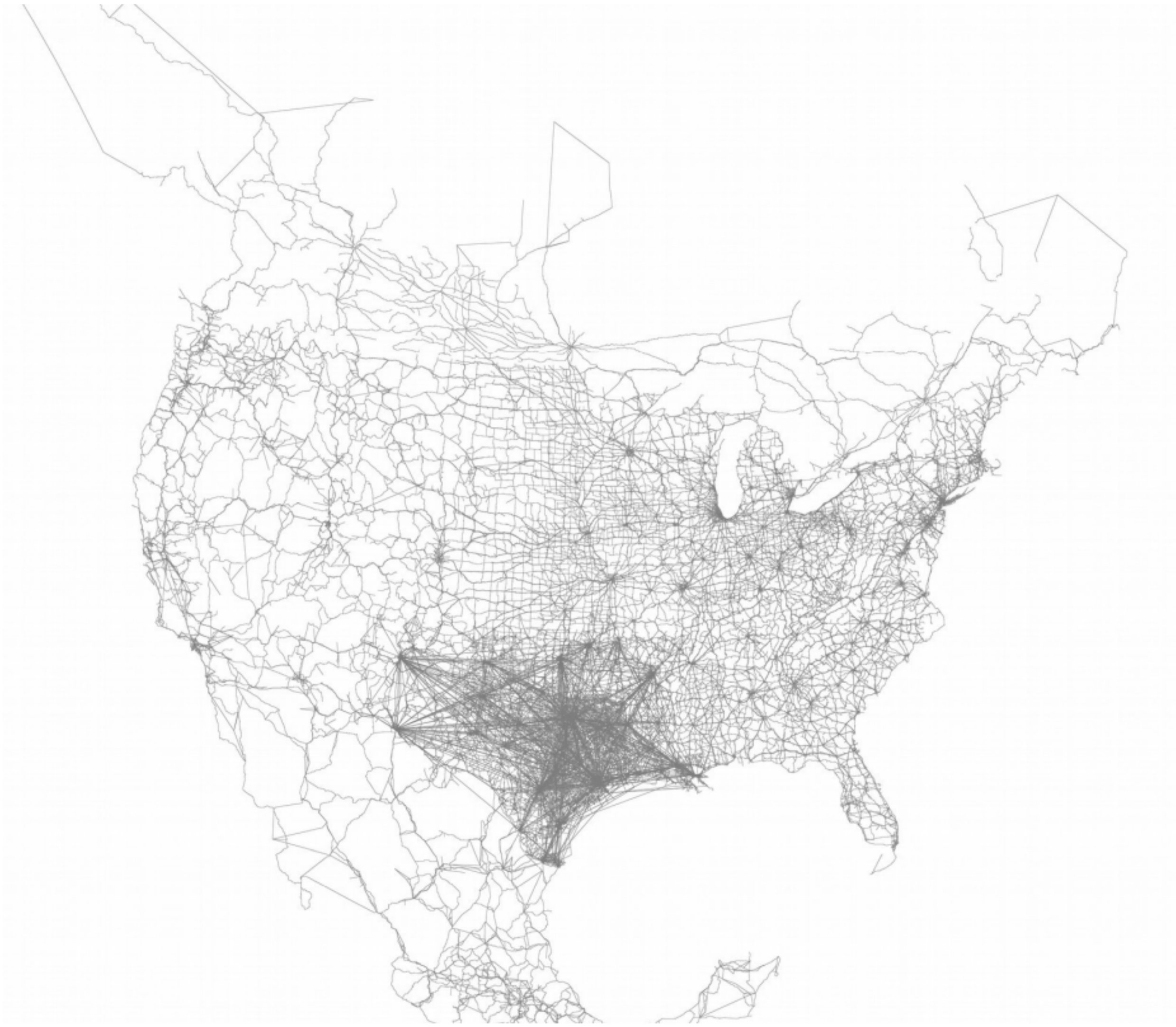

Figure 3:links within the Texas Statewide Analysis Model (SAM) [74]

4.2.2.Freight in the SAM

The SAM has three assigned modes for heavy-duty trucks, medium-duty trucks, freight rail, and cargo shipping. Other freight modes, such as cargo ships, air, or pipeline, are handled through trip generation at their terminal locations.

Freight rail has its own network using county centroids within Texas. This rail network uses tonnage flows rather than assigning rail vehicles. Both trucking modes are assigned as vehicles to the roadway network.

The SAM is ideal for analyzing the Texas Triangle Megaregion because it provides a high resolution throughout the megaregion as well as bordering areas, and still depicts the effects of other regions across the country.

It is possible to estimate the effects of a particular freight planning practice by testing a base case of the network against travel changes when the network reflects the practice.

4.3. Economic analysis

Changes in travel patterns impose economic costs and benefits. These can broadly be categorized as traveler benefits and non-traveler benefits.

Traveler benefits accrue to transportation system users. The primary traveler benefits consist of changes in vehicle operating costs, such as from changes in the distance traveled, changes travel time, either in-vehicle or out-of-vehicle, changes in travel time reliability, and changes in safety for the traveler.

Non-traveler benefits are benefits that fall on people who do not use the transportation system. These are externalities. The primary categories for non-traveler benefits are changes in emissions affecting climate change and air quality, and changes in safety for bystanders.

TREDIS is a tool suitable for converting the outputs from the SAM into economic effects. Because travel demand models vary substantially, converting travel demand model outputs into economic model inputs is a non-trivial task. This is why starting with a single travel demand model for the megaregion is so important for megaregion planning. Using models from each separate MPO would not be consistent as shown in section 9.

Work began on incorporating the SAM with TREDIS in 2013,[75] and continued through collaborative work between TxDOT and the Center for Transportation Research.[76] The methodology developed through that work, which mainly focused on the state of Texas as a whole, can readily be applied to the Texas Triangle Megaregion. With appropriate travel demand models, that methodology can also be applied to other megaregions.

[75] Higgins, Samuel. "Estimating economic impacts from transportation investments using the Texas Statewide Analysis Model and TREDIS." Electronic Theses and Dissertations, The University of Texas at Austin. August 2013. link

[76] Kam, Katie; Jiang, Nan; Zivanovic, Stasa; Walthall, Rydell; Walton, Michael. "Final Report: Evaluating Travel and Economic Impacts of Texas Freight Corridor Projects." TxDOT Inter-Agency Contract #8027 Part II. August 2015.

5. Application to the Texas Triangle Megaregion

This section presents some of the results of combining the TREDIS economic model with the SAM for truck-only lanes within the Texas Triangle Megaregion. The benefits discussed here use a seven percent discount rate unless stated otherwise.

5.1. Applying the methodology to truck-only lanes

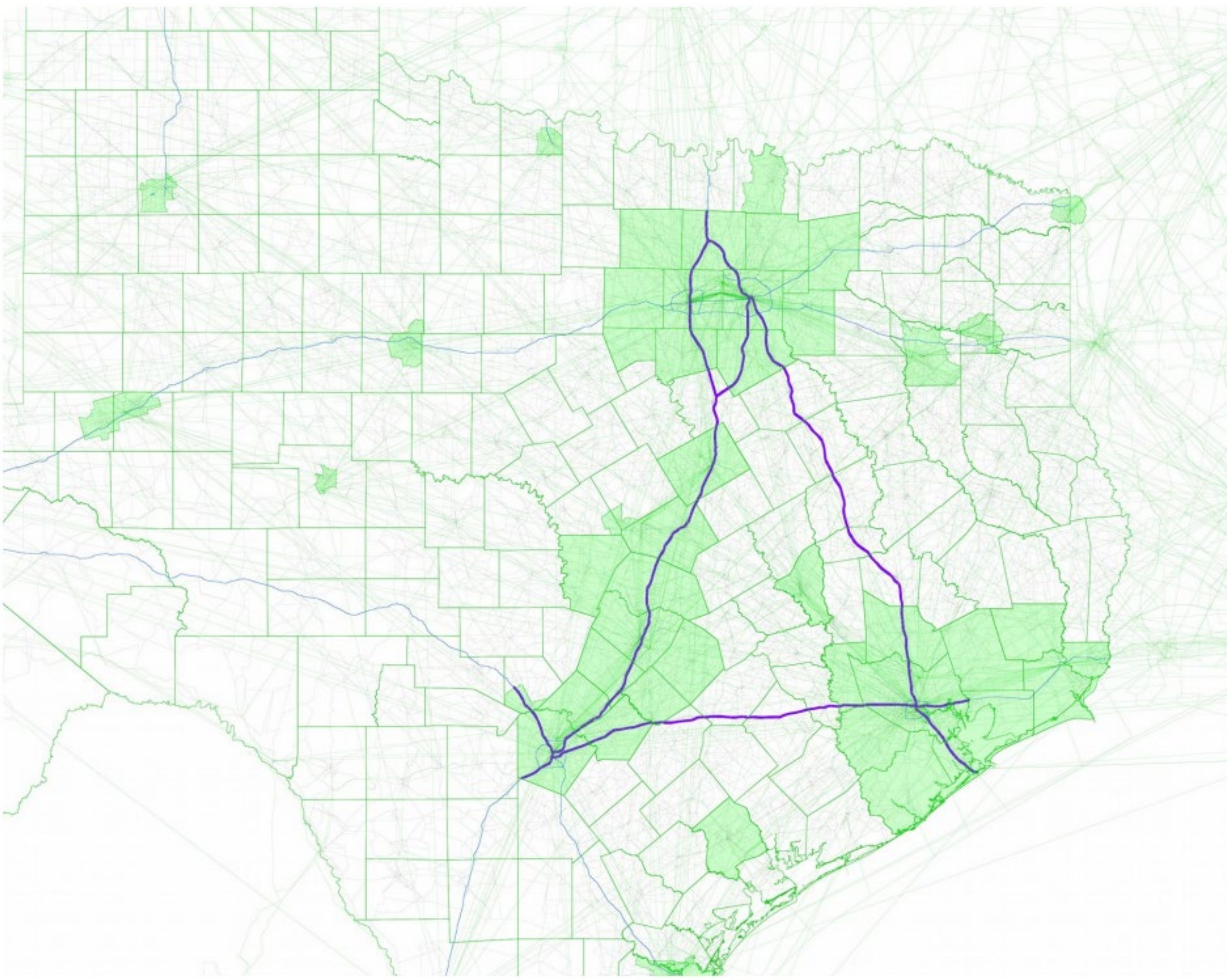

Figure 4: Extent of truck-only lanes tested for the example. The green areas show Texas MPOs, and the light blue lines show interstates. The bold lines show the extents of the interstates modified in the simulation to include truck-only facilities.

Truck-only lanes can be directly modeled within the SAM as new links. The model simulated truck-only lanes along the IH-10 corridor from San Antonio to Houston, IH-35 corridor from San Antonio to Dallas-Fort Worth, and the IH-45 corridor from Houston to Dallas-Fort Worth. Figure

4 above shows the extent of the truck-only facilities for this example. The facilities were simulated along the three interstates up to the boundaries of three significant MPOs in the Texas Triangle: the Alamo MPO (San Antonio), the North Central Texas Council of Governments (Dallas-Fort Worth), and the Houston-Galveston Area Council (Houston).

There are several different ways to implement truck-only lanes, and two were modeled. In one scenario, once the extra lanes are constructed for trucks, trucks are required to use the new facilities – in other words, the three corridors within the Triangle would have trucks and passenger vehicles fully separated. In another scenario, the trucks are still able to use the existing facilities if the truck-only lanes become too crowded. This second scenario would ensure that the truck-only lanes do not reduce overall trucking capacity, but it would reduce the benefits from traffic separation.

The model shows that truck-only lanes cause a slight mode shift from rail and have the effect of reducing congestion for both trucks and passenger vehicles along the affected corridors. The facilities appear to produce larger benefits when trucks are still allowed to use the existing facilities. This may be due to stretches of the tested corridors having truck demand higher than the capacity of the truck-only lanes modeled, so it might be necessary to build larger truck-only facilities in those locations if planners desire full traffic separation. The model indicates that the benefits of truck-only lanes in the Texas Triangle might have a net present value of nearly $11.4 billion, of which roughly $9.0 billion are traveler benefits and $2.4 billion are non-traveler benefits.[77]

Figure 5 below shows how the benefits and costs of the outlined truck-only lanes would accrue based on construction beginning in 2020 and continuing through 2030. Costs continue to accumulate after construction because of the added maintenance for the new facilities.

[77]The TREDIS economic model combines the traveler and non-traveler safety costs by using average crash rates that include crashes involving only motorists as well as crashes involving non-motorists.

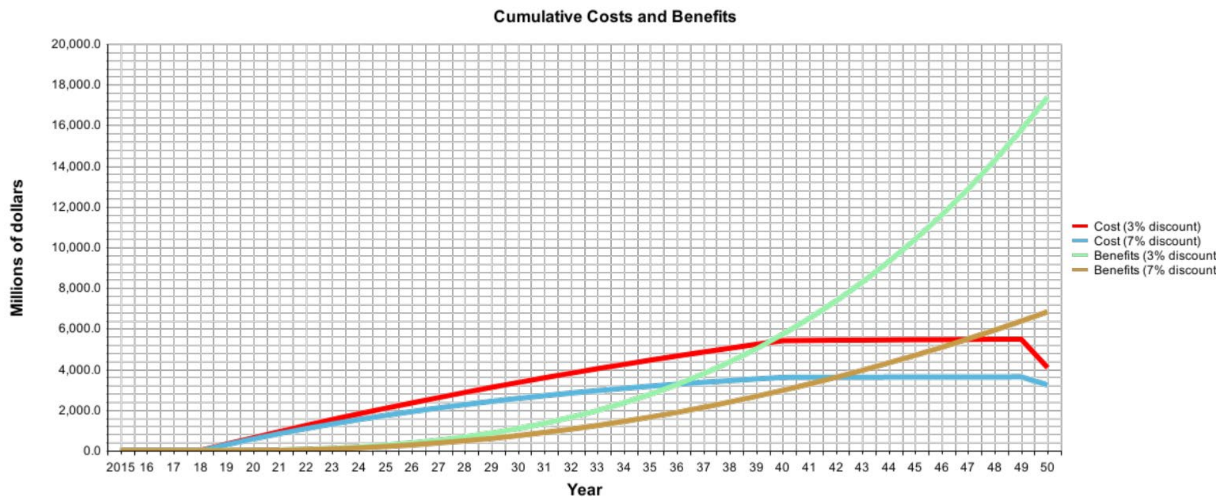

Figure 5: Projected benefits and costs of truck-only lanes implemented in the Texas Triangle with complete exclusion. At a three percent discount rate, the benefits and costs equal each other after about nineteen years, while it takes about twenty-two years at a seven percent discount rate. This method is able to account for travel pattern changes across the entire megaregion, instead of only focusing on the affected corridors.

Without a travel demand model encompassing the entire megaregion, it would be possible to approximate the effects of the truck-only lanes, but such an approximation would likely miss the mode-shift from rail or the congestion that the full travel demand model predicts along certain stretches of the corridor. Using a full travel demand model can therefore improve the effectiveness of megaregional freight planning.

The same methodology can be applied to the other strategies discussed in section 3.

5.2. Possible improvements for freight megaregion modeling

Static traffic analysis is not the best tool for analyzing some freight technologies such as platooning or coordinated logistics scheduling. Static traffic assignment assumes constant vehicle flows throughout a study period, but many of the benefits from these technologies are based around sending vehicles in bursts or during periods of otherwise low activity. Dynamic traffic assignment can more accurately capture the effects of that type of travel behavior, but it is much more computationally intensive.[78]

[78] Boyles, Stephen; Ukkusuri, Satish; Waller, Travis; Kockelman, Kara. "A Comparison of Static and Dynamic Traffic Assignment Under Tolls: A Study of the Dallas-Fort Worth Network." Transportation Research Board. January 2006. link

A larger issue might be latent demand, which a travel demand model like the SAM does not account for.[79] Improvements to the transportation network can increase the peak demand for a facility by shifting trip departure times, shifting trip paths, shifting trip modes, or generating new trips. The SAM can account for path and mode shifts, but it does not use network conditions in estimating trip generation. As a static travel demand model, it is also unable to shift trip departure times.[80]

[79] TxDOT. "Statewide Analysis Model." Prepared by Alliance Transportation Group. 2010.

[80] Static travel demand models model vehicles as flows within given time periods. With fixed demand, the overall demand for each time period is set. A static travel demand model with variable demand and a large number of time periods could approximate departure time shifts.

6. Conclusions

Current modeling capabilities vary widely across MPOs within megaregions. A travel demand models with a megaregion-wide scope is a useful planning asset to assess the efficacy of trending freight strategies. Such models can be combined with economic models in order to provide useful information about the overall effects of new strategies for handling the growth in megaregional freight movements.

6.1. Future work

The first extension of this work would be to apply this methodology to other megaregions. The Arizona Sun Corridor and Florida Megaregions are both good candidates, as they are entirely contained within their respective states. It might be possible to apply this methodology using the Arizona or Florida statewide travel demand models. For other megaregions, application would depend on unifying various regional travel demand models. The lessons learned in applying this methodology to single-state megaregions could help inform the planning process in creating megaregion travel demand models. The database of MPO planning tools developed as a part of the CM2 could also help establish what inconsistencies between models within a megaregion would need to be addressed first.

Within the CM^2, this work will be expanded-on in the project, "Freight megaregional planning and financial policy."[81] That project will expand the methodology described in this report to examine funding mechanisms for megaregion-scale projects.

[81] This is a project for Year 3 of the Cooperative Mobility for Competitive Megaregions consortium, which will be completed in August of 2020.

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