Making Freight-Centric Communities More Livable

CFIRE

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16. Abstract

Communities that attract or retain industrial viability are considered less livable, but reducing, limiting, or mitigating freight operations direct, measurable economic impacts. Thus, the focus of this research was to further the understanding of livability, and particularly the freight (specifically truck traffic) plays on livability in communities. A multi-method analysis involving development of perception surv livability and freight's impact, a detailed review of the literature regarding strategies to reconcile freight and livability, an in-depth mod exercise for several of these strategies, and a visualization exercise were conducted. The methodology was applied to a case study locat Memphis, TN for the neighborhoods bordering the Lamar Avenue Corridor, a high-volume truck corridor that is the most congested nor Interstate freight corridor in Tennessee. The survey instruments developed through this research can be replicated and adapted for use other regions to improve the generalizability of findings in future studies beyond the Memphis, TN area. Furthermore, simulation resul contribute to the understanding for both research and practice on how technology, strategies and practices affect livability. The findings to the importance of developing a common understanding of livability among residents, planning, and transportation agency officials ar means for measuring this in a quantifiable and translatable way may be a first step in developing a means for increasing collaborative approaches to improving livability.

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Table of Contents

Table of Figures

List of Tables

Executive Summary

Freight and livability are conflicting concepts that have been of interest to multiple disciplines from planning, to transportation, to logistics and public health. Only recently have researchers begun examining the intersection of these concepts and the impact of freight movements on livability in communities. Community attempts to try to attract or retain industrial viability are often seen as decreasing livability.

It should be considered that reducing, limiting, or mitigating freight operational impacts could have direct and measurable positive economic and social impacts. Research has begun to identify advanced technologies and practices that safely blend freight movements with passenger, transit, bicycle, and pedestrian traffic. These ideas can mitigate a community's safety, noise, congestion and environmental concerns, and accelerate implementation of improved practices.

This report documents a multi-method analysis involving development of perception surveys on livability and freight's impact, quantitative measurements of livability, a detailed review of the literature regarding strategies to reconcile freight and livability, and an in-depth modeling exercise for several of these strategies. The methodology was applied to a case study location in Memphis, TN for the neighborhoods bordering the Lamar Avenue Corridor, as this area is a freight-centric community. The focus of this case study was on the impact of truck traffic in the community, as the Lamar Corridor is a high volume truck corridor.

The survey instruments developed through this research can be replicated and adapted for use in other regions to improve the generalizability of findings in future studies beyond the Memphis, TN area. For the Memphis case study, findings from survey efforts suggest that various stakeholder groups have similar perceptions regarding the factors influencing livability; however, there are noted differences in perceptions of livability in communities with a significant presence of freight. These findings contribute to the body of knowledge for both livability and freight research. Findings also suggest there may be potential benefits to practitioners and decision-makers by considering different freight policies in the two types of communities in order to enhance livability.

Furthermore, simulation results contribute to the understanding for both research and practice on how technology, strategies and practices affect livability. Results from gate scheduling technology and strategy simulations did not garner expected results, instead indicating that a shift of truck traffic similar to that achieved in other communities would not be effective for improving air quality for the corridor in this case study. Simulations based on alternative fuels for trucks did show clear improvements to livability based on improved air quality; however, the practicality of adoption at a strategic level is an important consideration given the limited infrastructure supporting alternative fuels.

This research contributes to the understanding of livability, and particularly the role freight (specifically truck traffic) plays on livability in communities. It is important for planning and

other municipal officials to investigate options for improving quality of life for all residents. Developing a common understanding of livability among residents, planning, and transportation agency officials and a means for measuring this in a quantifiable and translatable way may be a first step in developing a means for increasing collaborative approaches to improving livability.

Problem Statement
Livability of communities is a topic of much interest to a variety of stakeholders, including public officials, community organizations, and community residents themselves. In areas where significant freight traffic is present, the assessment of livability becomes increasingly complex. While a few limited studies examine this intersection, further research is needed to quantify the positive and negative impacts of truck freight on neighborhood livability (Lowe, et. al, 2013). This research focuses specifically on advancing the state of knowledge and contributing to the state of practice related to livability of freight-centric communities. While numerous types of freight traffic may impact livability of a community, this study focuses specifically on the impact of truck traffic. The following sections outline literature pertaining to livability and transportation and freight-centric communities, followed by a description of the case study investigated as part of this research.

Livability and Transportation
Defining livability would be straightforward if one considered only basic services such as food, security, and shelter. When higher amenities are introduced, livability becomes more complex. Definitions of livability vary by perspective, lifestyle, and geographic scope - urban or rural. Some livability definitions reference health and wellbeing of individuals and communities while others focus on satisfying the human requirement for social amenity (Pacione, 2003; Newman, 1999; Veenhoven, 1995).

According to the Federal Highway Administration, "livability in transportation is about leveraging the quality, location, and type of transportation facilities and services available to help achieve broader community goals such as… enhancing the natural environment through… enhanced air quality, and decreased greenhouse [sic] gasses" (Rue, et al., 2011).

A set of guiding principles or objectives has been identified as the framework for livability policy and strategy. The US Department of Transportation (USDOT), the US Environmental Protection Agency (EPA), and the US Department of Housing and Urban Development (HUD) at the direction of President Barack Obama established the Interagency Partnership for Sustainable Communities in 2009. The six principles endorsed by the partnership are listed in Table 1 along with the more detailed explanations that the Partnership provided.

Table 1 Principles and Clarifications of Meaning Provided by the Partnership

Principle	Clarification
1. Provide more transportation mode choices	Develop safe, reliable, and economical transportation choices to decrease household transportation costs, reduce our nation's dependence on foreign oil, improve air quality, reduce greenhouse gas emissions, and promote public health.
2. Promote equitable, affordable housing	Expand location- and energy-efficient housing choices for people of all ages, incomes, races, and ethnicities to increase mobility and lower the combined cost of housing and transportation.
3. Enhance economic competitiveness	Improve economic competitiveness through reliable and timely access to employment centers, educational opportunities, services and other basic needs by workers, as well as expanded business access to markets.
4. Support existing communities	Target federal funding toward existing communities—through strategies like transit-oriented, mixed-use development and land recycling—to increase community revitalization and the efficiency of public works investments and safeguard rural landscapes.
5. Coordinate and leverage federal policies and investment	Align federal policies and funding to remove barriers to collaboration, leverage funding, and increase the accountability and effectiveness of all levels of government to plan for future growth, including making smart energy choices such as locally generated renewable energy.
6. Value communities and neighborhoods	Enhance the unique characteristics of all communities by investing in healthy, safe, and walkable neighborhoods—rural, urban, or suburban.

An extensive body of research in livability measures and tools is being developed as result of the Partnership (Miller, 2013, Marshall, 2013).

This framework essentially organizes livability around a transportation perspective, but some other dimensions of livability, and even some transportation related issues, are not highlighted. Freight and its impacts received very little explicit attention within this framework, which serves as one impetus for exploring a different framework for communities living with freight.

Freight-Centric Communities

The research team crafted the definition of a freight-centric community after observing a number of neighborhoods adjacent to areas of high-freight activity. Freight-centric communities are residential areas that bear spillover effects from freight movements through or bordering their neighborhoods. Freight-centric communities can be located in urban, suburban, and rural locations.

Freight-centric communities may:

- Lack an adequate buffer zone between a freight-generating land use and an adjoining residential area.
- Be in proximity to freight hubs; a port, an inland port, intermodal terminal, airport, logistics center, or an agglomeration of these types of freight generators.

- Be located away from freight generators as is the case of communities located along border crossings. Trucks en queue for customs processing will generate high levels of emissions that impact air quality.
- Experience truck traffic comprising 25 percent of all traffic on arterials and the presence of truck on local roads may indicate the lack of designated truck routes through the community.
- Have a problem with congestion, which could hamper commuting.
- Have a high frequency of trains, a rail yard in proximity, or long delays at grade crossings.
- Experience a high frequency of air traffic or truck traffic generated by air cargo operations.

The development of freight-centric communities is often due to inadequate planning and zoning protections at the onset of new or growth of freight activity. New inland ports are developing in rural areas of the country, and creating freight-centric communities. These small towns are at higher risk for livability issues associated with freight movement (Hricko, 2014).

Some communities are economically vibrant and have a large freight presence. Many freight-centric communities however may suffer from a lack of investment, loss of property values, transient population, and business vacancies. These neighborhoods become unsustainable and cannot support the consumption needs of the community. Without places for neighbors and nonresidents to visit, shop, or congregate, there is a precipitated degradation of services in some freight-centric communities. Poverty and crime complicate issues of livability.

Many freight-centric communities experience a loss of community identity. There may be a lack of "voice" that represents the interests of the community. In such cases, local government serves as the voice (Holden and Scerri, 2012).

While goods movement in the urban core has been researched, there has been little research on suburban livability. Strategies to improve freight operations are being implemented namely due to congestion concerns in the inner core (Browne, et. al, 2012; Lindholm, 2010; Long & Grasman, 2012).

Livability in Freight-Centric Communities

The negative impacts shown in Figure 1 decrease livability. Air quality and noise pollution are common externalities of freight but are not typically incorporated in strategies to change private sector freight operations (urban deliveries, freight movement through a city, etc.). In general, for freight moving through US cities, the focus has been on infrastructure expansion in order to address mobility or safety.

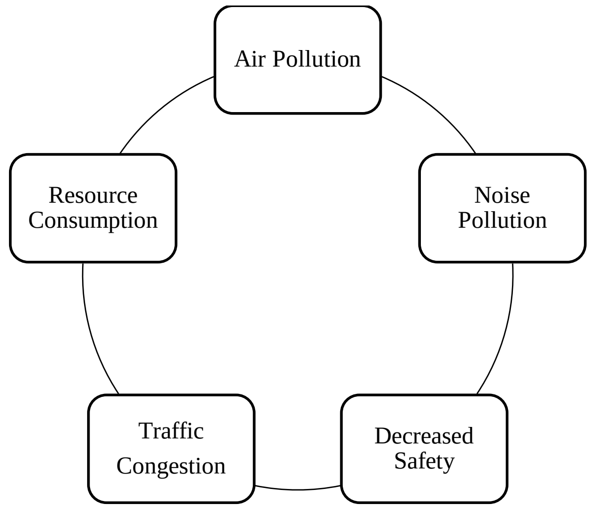


Figure 1 Externalities of Urban Freight Transportation (adopted from Browne et al., 2012)

There is a growing awareness of the relationship between health and transportation. Many actors are also looking to measure all costs and benefits to society in a much broader manner than several decades ago. This approach is compelling researchers and practitioners to begin to advance holistic approaches to urban freight movement. The ever-changing, intangible mixture of conflicting and overlapping needs of all the urban transportation constituents (freight carriers, passenger cars, transit participants, local business owners, urban residents, etc.) requires adequate planning and consideration when trying to achieve increased livability (Munuzuri, Larraneta, Onieva, & Cortes, 2005).

Consequently, there are many reasons why freight systems and livability principles need to be integrated. Freight is expected to increase globally and nationally (Long and Grasman 2012; Chandler and Gwin 2008; Browne et al. 2012). Both industry and the public sector continue to approach this problem by improving efficiency or through infrastructure expansion. In the US, freight is projected to increase 70 percent over 2008 truck freight volumes by 2020 (FHWA, 2008). The projected increase is spurring investments within the freight industry to solve the most congested bottlenecks and is forcing policymakers to examine the costs and benefits of increased freight volumes.

Study Area Description

This project develops and tests surveys and metrics for assessing livability of communities and strategies for addressing freight externalities. We collect data in Memphis, TN with special emphasis on a highly freight-centric community along the Lamar Avenue Corridor.

Memphis, Tennessee is considered to be a national freight hub. Memphis contains three interstates, five Class I railroads, and one of the largest freight airport hubs in the world (Memphis MPO, 2014). Memphis was designated by the US Government as an area to be targeted for livability improvements (Daniels & Meeks, 2010). We define the Lamar Avenue

Corridor as a 6.5-mile long corridor in southeast Memphis, which runs from I-240 South to E. Holmes Road. Lamar Avenue is a crucial component of Memphis' freight and passenger transportation infrastructure. The corridor is shown in Figure 1 with the surrounding five neighborhoods, which make up the study area: Fox Meadows, Hickory Hill, Oakhaven, Oakville, and Parkway Village. Figure 2 shows census tracts within the boundaries of the study area. For the 20 census tracts in Figure 3, the total population is 83,712 as of 2010 (US Census Bureau, 2010).

The area surrounding Lamar Avenue (or US 78) has a heavy industrial presence. Some significant freight generators within this study area include the Burlington Northern Santa Fe (BNSF) intermodal terminal and the FedEx Hub located at the Memphis International Airport. A significant volume of truck traffic is present along the corridor, which connects traffic from I-40 to the intermodal, warehouse, and commercial facilities. The heavy industrial and commercial presence, results in this region being considered a trade node with associated freight problems (Giuliano, O'Brien, Dablanc, & Holliday, 2013).

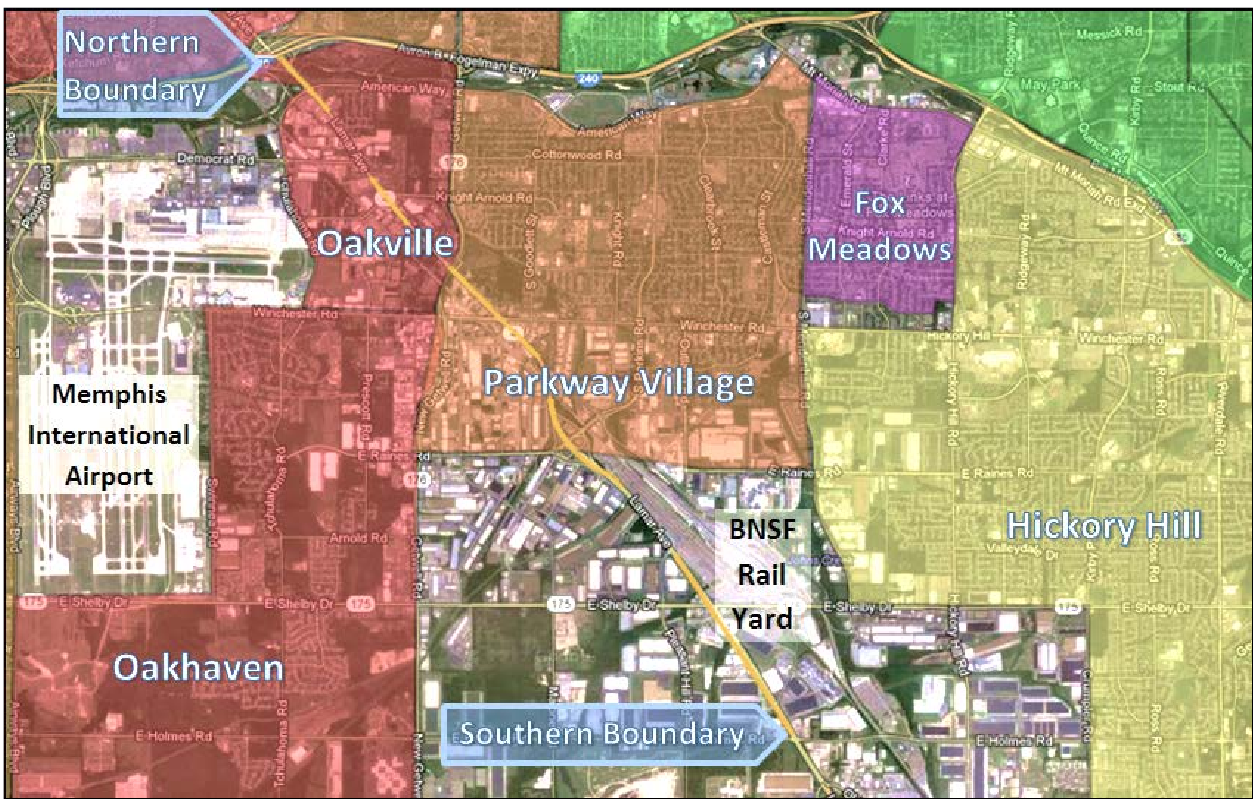


Figure 2 Neighborhoods of the freight-centric Lamar Avenue Corridor.

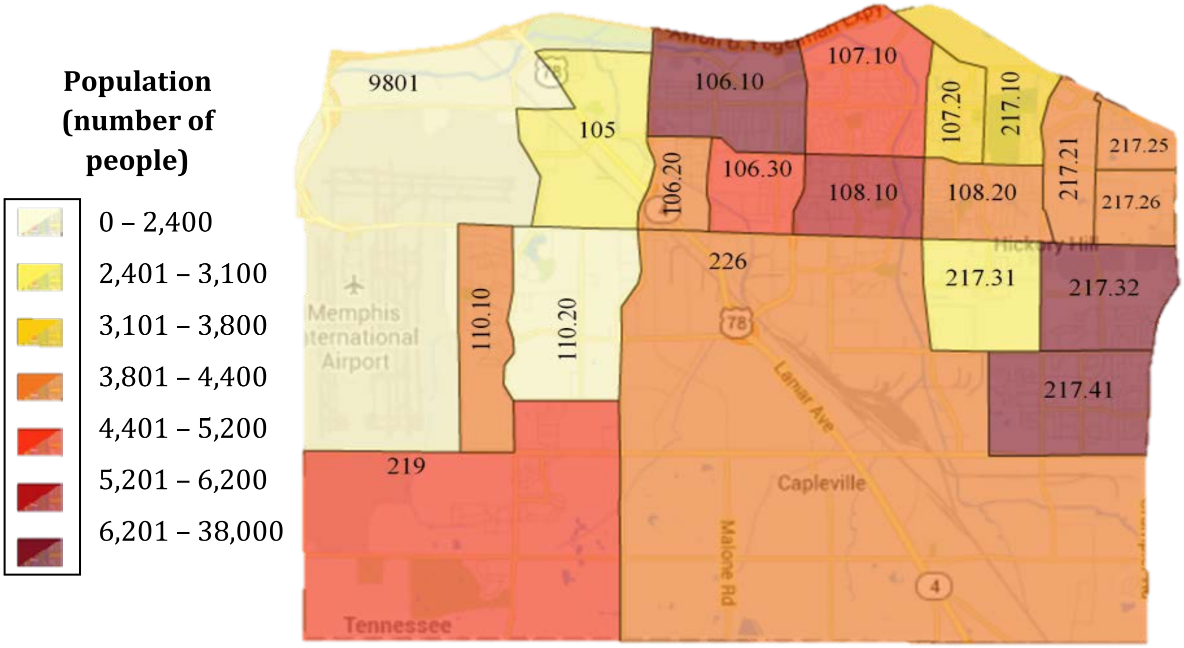


Figure 3 Study Area Census Tracts with Population Counts

Table 2 provides information on the inflow and outflow of workers across the study area boundary. Only a fraction of the study area's residents work within the study area. The workers that live and work within the study area yield an "In-Area Employment Efficiency" of 10.8 percent. A significant amount of traffic is attracted to this community for work, contributing to congestion of the transportation network.

Table 2 Employment and Commuting Statistics for Jobs and Workers in the Study Area

Jobs within study area (live inside or outside)	80,724
Workers residing within study area (work inside or outside)	35,009
Residents who exit study area for work elsewhere	26,320
Non-residents who enter study area for work within	72,035
Workers living and working within the study area	8,689
Net inflow of workers	45,715
Total commutes across study area boundary	98,355

The highest percentage of jobs by industry sector was found in Transportation and Warehousing (14.2 percent).

Truck volume on Lamar Avenue is 8,000 average annual daily trucks (AADTT) constituting approximately 27 percent of the annual average daily traffic (AADT) (Cambridge Systematics, 2011). Two of the major facilities within this study area are the Burlington Northern Santa Fe (BNSF) intermodal terminal with a capacity to lift 1 million containers per year and parking that can accommodate 6,000 trucks and the Memphis International Airport, the second busiest air-cargo hub in the world due to FedEx. Figure 4 shows the density of buildings associated with freight movement or possessing a freight dock in the study area.

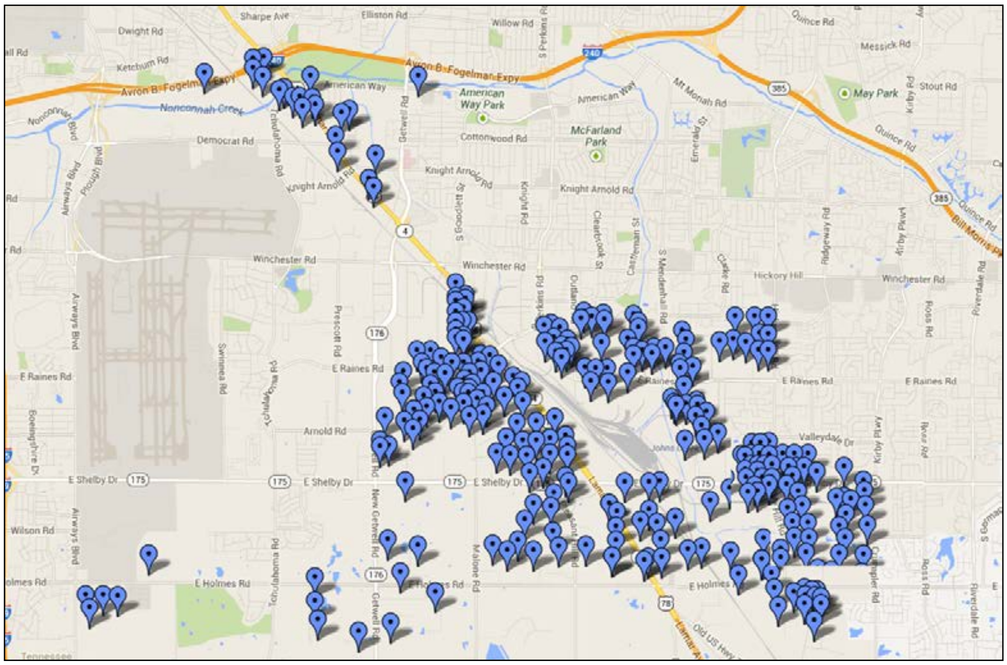


Figure 4 Freight-Handling Facilities in the Lamar Avenue Corridor

The Lamar Corridor is primarily industrial with pockets of closed businesses and vacant rundown lots. The neighborhoods surrounding Lamar Avenue are impacted by significant freight activity, can be defined as freight-centric communities, and serve as the basis for the analysis in this research.

The City of Memphis in collaboration with the Greater Memphis Chamber and the Department of Housing and Urban Development is exploring the Aerotropolis concept (Airport City) to re-develop the area to attract businesses that rely on air freight transportation and to improve the first impression of visitors as they travel from the airport to the central city (Memphis Aerotropolis, 2014).

Recent engineering studies have evaluated a number of infrastructure alternatives for Lamar Avenue to improve congestion and reduce delay. Converting Lamar Avenue to an interstate would be the most effective strategy in terms of improving travel delay but was also the costliest. The alternative with the highest benefit/cost ratio was the conversion of Lamar

Avenue to a six and eight-lane road. Despite all the scenarios, findings also showed that by 2030 Lamar would again be congested (Cambridge Systematics, 2011). In 2015, a widening project designed to improve safety and reduce congestion was delayed due to lack of funding.

Research Questions and Objectives

The following questions shaped this research on freight and its impact on the communities around Memphis.

1. What factors are important for community livability?
2. Are the priorities and barriers to livability different between freight-centric communities and non-freight-centric communities?
3. Does freight have a significant impact on livability perceptions?
4. Does freight have a significant impact on quantitative measures of livability?
5. What is the current state of operations and functionality of the freight transportation system?
6. Can we measure livability?
7. How do freight movements impact livability within the region from the industrial perspective?
8. Do industries surrounding the Lamar Corridor currently employ strategies or technologies that promote the livable priorities of the community?
9. What are some options for reducing the impacts of freight operations on livability?

Research Objectives

1. Design surveys and conduct interviews with the residential, industrial, and political stakeholders of a freight-centric community and identify priorities for livability from each perspective. Furthermore, compare the perceptions of livability and freight's impact on livability from residential samples from both the freight-centric community and the non-freight-centric community.
2. Investigate the potential for quantifying livability assessment through multi-criteria analysis.
3. Determine methodology for baseline and scenario analyses for examining potential strategies for reducing externalities of freight.
4. Perform a global review of literature regarding advanced technologies and transportation-related policies that can be implemented to mitigate major externalities of freight in a community.
5. Use simulation models to test the potential impact of some of those technologies or strategies.
6. Draw conclusions regarding the impact of freight on livability and identify a set of best practices that promotes livability and can be utilized in freight-centric areas across the United States.
7. Develop a visualization that shows baseline conditions of freight, livability and environmental justice in Memphis and the study area neighborhoods.

Perceptions of Livability

The goal of the three surveys developed through this reserach, administered to residents, industry, and policy-makers, was to more thoroughly understand each stakeholder groups' perspective on livability, the barriers to livability, and the impact of freight on livability. The literature review and collective experience of the research team informed development of the survey instruments. This research explored these concepts through statistical comparisons between freight-centric and non-freight-centric samples. This section highlights the analysis and results for the residential, industrial, and political/decision maker surveys. We discuss the implications of how freight affects livability of the region from all stakeholders' perceptions.

Residential Survey

The survey instrument was first administered in a focus-group setting to identify any confusion or misunderstandings related to the questions themselves. The survey was revised based upon this feedback, and was then distributed in both online and paper formats. Those who received the paper copies were introduced to the subject and some discussion occurred. The online survey (administered via an email invitation) and the paper survey sessions were facilitated through a partnership with Livable Memphis, a nonprofit organization that maintains relationships with neighborhood associations throughout Memphis, TN. Through this partnership, neighborhood leaders assisted with the online dissemination of the survey to residents both within and outside of the study area. Results were collected from October 2013 through June 2014. The survey was issued both printed and in-person to community groups in Parkway Village (October 9, 2013 and March 4, 2014) and in Hickory Hill (March 11, 2014).

Responses from the survey were used to (1) identify factors affecting livability of freight-centric and non-freight-centric communities, (2) establish relative importance of these factors, and (3) solicit perceptions regarding the impact of high freight volumes in a neighborhood. The survey included a number of open-ended, ranking, and rating questions that captured the residential opinions regarding how freight traffic affects the livability of their neighborhood. Participants were asked about their perceptions of how their neighborhood has changed over time, what livability means, what the contributors and barriers to livability are, and what factors need improvement in their neighborhood.

Table 3, Table 4, and Table 5 summarize the content of this residential survey instrument.

Table 3 Residential Survey: Definitions of Livability and Barriers to Livability

Survey Question	***Type***
Please tell us the closest intersection to where you live:	Short Answer
How has your neighborhood changed since you have lived here?	Open-ended
How do you define livability for your community?	Open-ended
In your opinion, what things are important for making a community livable?	Open-ended
In your opinion, what things are barriers to livability?	Open-ended
How do you rate your neighborhood for livability? 10 being very livable.	Rank 1-10
What are the most important contributors to livability? **(Please pick your top 5 most important.)** • Having a park in my neighborhood • Living close to school/work • Living near a hospital • Having a community center • Knowing my neighbors • Feeling safe in my neighborhood • Having alternative transportation options (walk, bike, public transit) • Good bus service • Living in an economically thriving neighborhood • Having a sense of community • Having a say in what happens in my neighborhood • Quality affordable housing • Minimal road congestion • Clean air and water • Good quality roads • Public art/ landscaping	Choose 5
In terms of transportation (walking, biking, driving, and public transportation), what are areas that need improvement in your neighborhood?	Open-ended
How does freight traffic (rail, trucks, air) affect your neighborhood?	Open-ended
Have you experienced any negative environmental effects in your neighborhood (smog, pollution, or otherwise)?	Yes or No (explain)
Do you attribute these environmental factors to the freight traffic in or around your neighborhood? Please explain.	Open-ended

The first meeting of neighborhood residents served as a test run of the survey. The survey was then calibrated to address questions that were difficult to interpret in the original instrument. The question, “How do you define livability for your community?” was changed to, “In your opinion, what does livability mean for a neighborhood?” The original version prompted a numerical response, where the later version prompted an open-ended response. The question, “What do you think is the impact of the freight presence in your neighborhood?” was simplified to “How does freight traffic (rail, trucks, air) affect your neighborhood?”

Table 4 Residential Survey: Commuting, Transportation, and Public Policy Relationships

Survey Question	*Type*
Please tell us about your traffic experiences in the Lamar Corridor: **How often do you notice the presence of freight or heavy trucks?** **How often are you stuck in traffic due to this freight presence?** **How often are you stuck in traffic not caused by freight?**	Rating: 0 – Never 1 2 – Just as often as elsewhere in Memphis 3 4 – Extremely Often
Do you find yourself taking alternative routes to avoid the Lamar Corridor? Yes No Sometimes Other	Choose 1
What is your primary mode of travel? Walks/public transit Bike Carpool Car/personal vehicle Taxi	Ranking
Do you feel safe/ secure using these modes of transportation? Please explain.	Open-ended
What do you consider most important in terms of transportation options? • Sidewalks and/or paths to shopping, work, or school • Bike lanes or paths to shopping, work, or school • Reliable bus or rail transportation • Reliable long-distance bus or train transportation to and from surrounding cities • Major roads or highways that access and serve the community • Easy access to the airport • Pedestrian-friendly streets • Adequate parking • Minimal road congestion/delay	Ranking: 1 is most important and 9 is least important
How much importance do you think you hold to industry leaders/ municipal decision makers?	Open-ended
How much involvement do you have with industry leaders/ municipal decision makers?	Open-ended
Would you be willing to become more involved in the decisions made by industry and policy decision makers in or around your neighborhood?	Open-ended

Transportation-related questions included questions about residents' personal commuting patterns (including whether or not a heavy freight presence alters these patterns) and a question asking participants to rank the importance of different elements of a transportation network. Participants were asked to describe current involvement with public/municipal leaders and to indicate whether or not they would be willing to be more involved in decisions pertaining to their neighborhood. These questions, along with a demographic section, provided insight on the residential perceptions about freight and livability characteristics.

Table 5 Residential Survey: Demographics

Survey Question
Are you currently renting or do you own your home/apartment?
Do you work at a business on or near Lamar Avenue?
How old are you?
Which of the following race/ethnicity do you best identify with?
Including yourself, how many people currently live in your household?
How many children live in your household?
Are you married, separated, divorced, widowed, or have you never been married?
How many vehicles are owned, leased, or available for regular use by the people who currently live in your household?
What is the highest level of education you have completed?
Are you employed full-time, part-time, not employed for pay at the moment, retired, or a student?
How many years have you lived in this neighborhood?
Would you say your neighborhood is very safe, somewhat safe, or unsafe?
During the last calendar year, about how much was your total family income before taxes?

Two statistical tests were used for comparing the freight-centric (FC) and non-freight-centric (NFC) data obtained from the residential survey. To analyze the statistical differences between the samples, the Chi-squared (χ^2) test was used for survey items that yielded categorizable frequencies of non-ordinal data. Because many of the survey items were open-ended, responses were coded and frequencies were recorded for each unique response. Many of the respondents provided answers that spanned multiple categories, so the total frequency of responses is often higher than the total number in the sample. Contingency tables like the one shown in Table 6 were set up for each question.

The Wilcoxon's Rank Sum (WRS) test was used for questions that yielded a set of ordinal frequencies. This test compares the entire distribution rather than the median or mean of the distributions. The WRS test is also known as the Mann-Whitney U test. The null hypothesis is that the two sample populations are identical, and an alternative hypothesis is that the two sample populations are different.

Table 6 An Example of a Contingency Table Used in Testing for the Categorical Frequency Analysis of Open-Ended Questions

	$Category_1$	$Category_2$	$Category_3$	…	
FC Frequencies					Total FC
NFC Frequencies					Total NFC
	$Total_1$	$Total_2$	$Total_3$	…	

The results from the three neighborhood meetings held within the study area combined with multiple online campaigns yielded a set of 421 complete residential survey responses. Figure 5 displays the location of the closest intersection for each respondent. The orange diamonds represent a resident of a non-freight-centric portion of Memphis (n = 346) while the blue shapes represent a resident of the freight-centric community within the study area (n = 75). The freight-centric community lacked natural or man-made barriers to freight traffic and saw significant freight volume intersecting residential areas, while the responses deemed non-freight centric were from areas having some type of barrier or boundary that resulted in separation of high volumes of freight traffic from the community. The samples for each of question are smaller than the total number of survey participants due to nonresponse to some items.

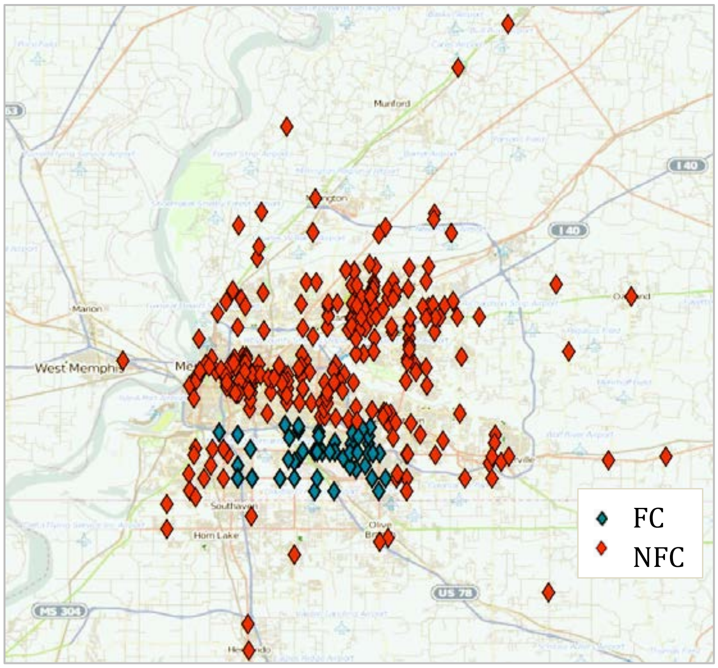
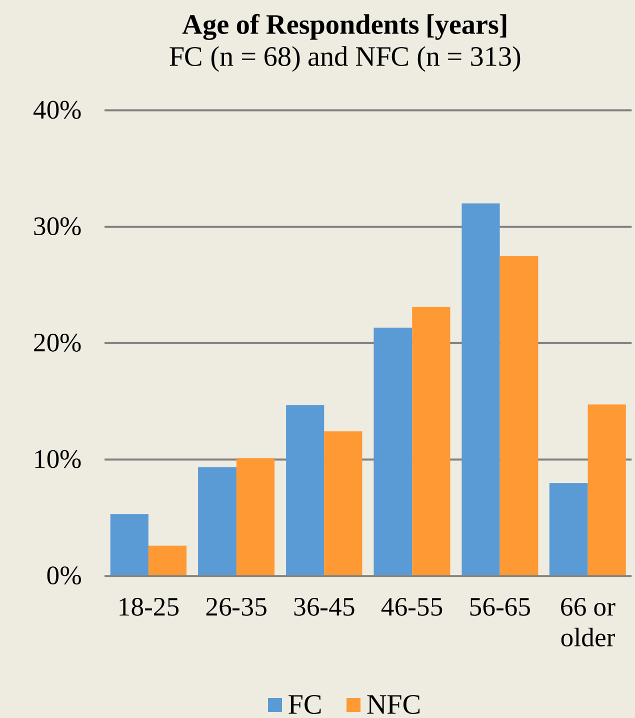
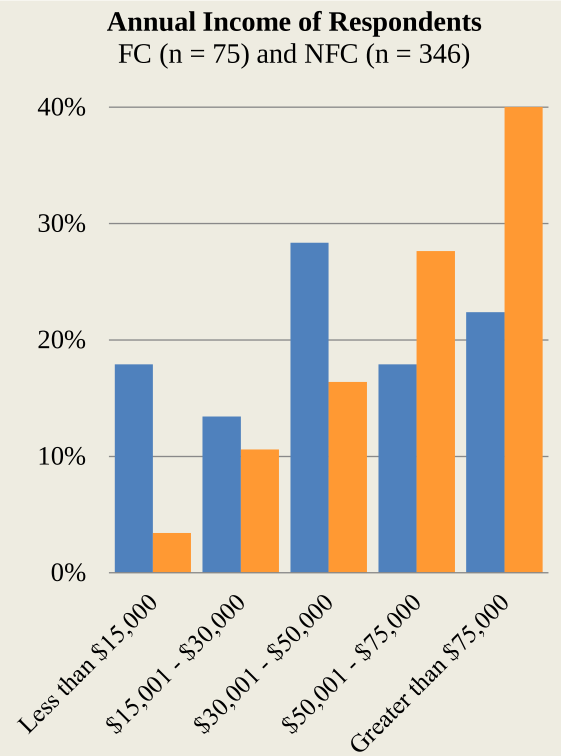


Figure 5 Nearest Intersection Location for Survey Respondent (75 in freight-centric study area, 346 in greater Memphis).

Demographics
Of all respondents, 67 percent of freight-centric and 70 percent of non-freight-centric members are employed full- or part-time; while 9 percent freight-centric and 2 percent of non-freight-centric are not employed for pay. The rest of the population is either retired or in school (21 percent of freight-centric and 17 percent of non-freight-centric). The large majority of freight-centric respondents, or 80 percent, are Black or African American, while for the non-freight-centric sample 54.3 percent are Caucasian and 25.1 percent are Black or African American. Figure 6 shows the age and income distributions of freight-centric and non freight-centric groups. The demographics of the freight-centric respondents closely match that of the study area, indicating a representative sample was obtained.





Age (yrs.)	FC	NFC
18-25	4	9
26-35	7	35
36-45	11	43
46-55	16	80
56-65	24	95
66 or older	6	51
No response	7	33
Total	*75*	*346*

Income	FC	NFC
Less than $15,000	12	10
$15,001 - $30,000	9	31
$30,001 - $50,000	19	48
$50,001 - $75,000	12	81
Greater than $75,000	15	123
No Response	8	53
Total	*75*	*346*

Figure 6 Age Distribution and Income Distribution of FC and NFC Respondent Population

Figure 7 displays information regarding the total number of people per household, total number of children per household, and total number of vehicles (leased or owned) per household.

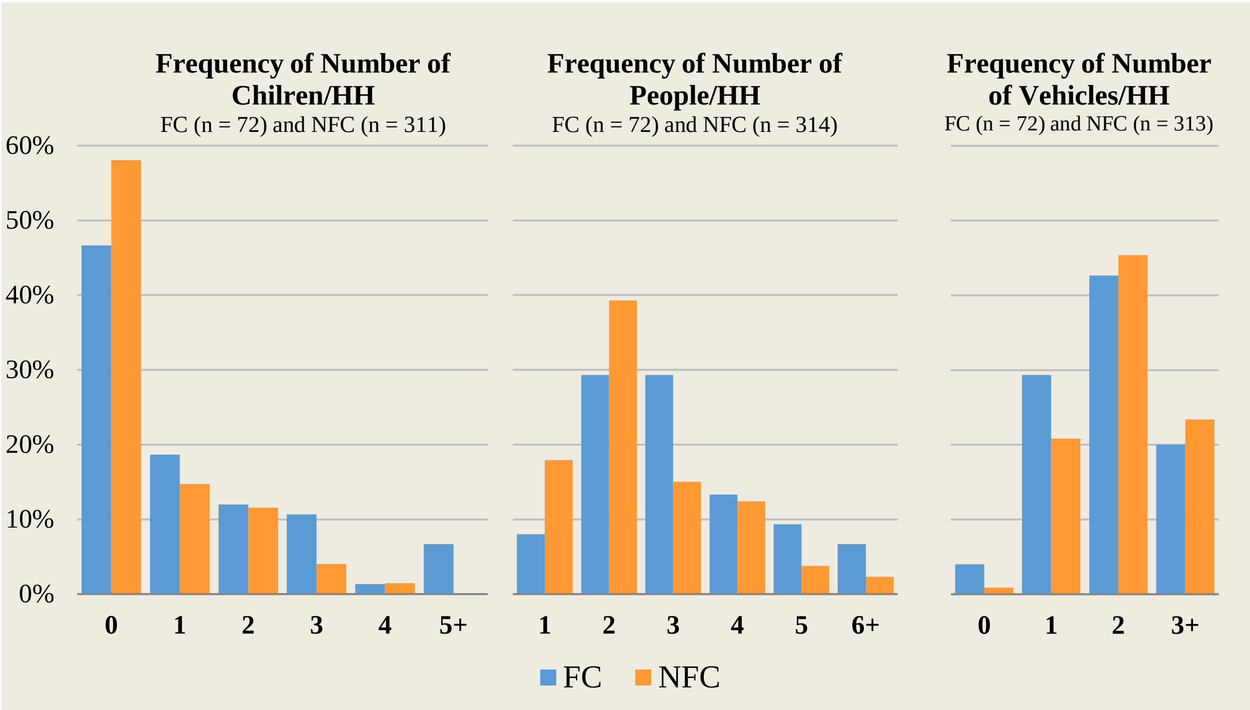


Figure 7 Number of People per Household, Number of Children, and the Number of Vehicles per Household for the FC and NFC Respondents.

Livability Priorities and Barriers

We initially focused analysis on answering whether or not the priorities and barriers to livability are statistically different between freight-centric communities and non-freight-centric communities. This analysis illustrates the differences between the community types and indicates that heavy freight volumes impact livability in a community. As commonalities emerged in the open-ended data responses, it became clearer what priorities and barriers exist for both types of communities.

Question: ***What are the most important contributors to livability?***

The results seen in Figure 8 yielded a χ^2 value of 51.379 which is greater than, $\chi^2(0.05; 15)$, the value of χ^2 with 15 degrees of freedom and a 95 percent confidence interval, which has a value of 24.996. The null hypothesis that there is no difference between the freight-centric and non-freight-centric distributionss was rejected, and therefore, a significant difference does exist in this case.

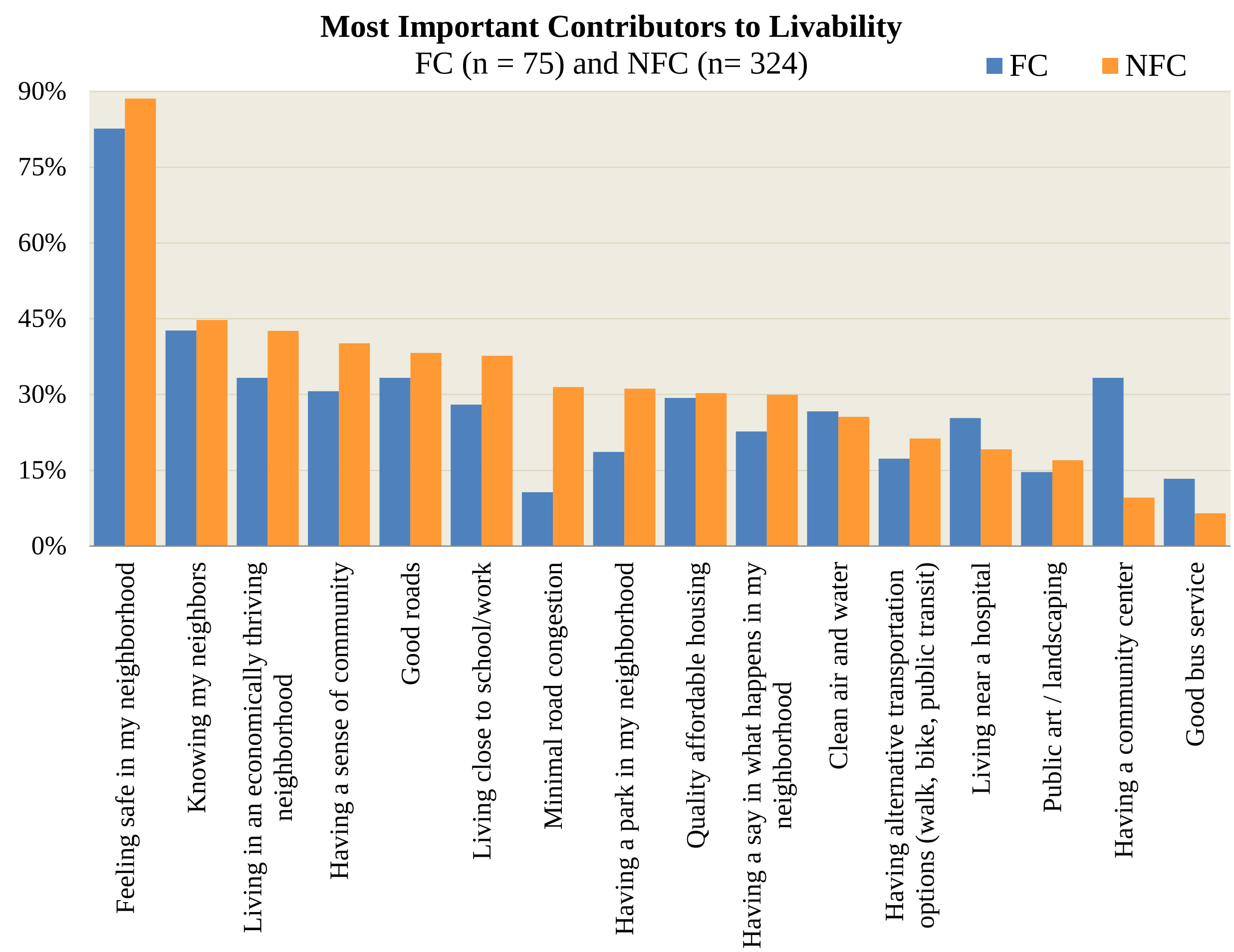


Figure 8 Results of "What are the most important contributors to livability?" Respondents were asked to choose 5 from a list of 16 contributors.

The freight-centric group identified the top five most important contributors as:

1st	Feeling safe in my neighborhood
2nd	Knowing my neighbors
3rd – 5th	Living in an economically thriving neighborhood
	Good roads
	Having a community center

The non-freight-centric groups identified some different contributors:

1st	Feeling safe in my neighborhood
2nd	Knowing my neighbors
3rd	Living in an economically thriving neighborhood
4th	Having a sense of community
5th	Good roads

Despite a statistically significant difference of overall opinions regarding the most important contributors to livability, it is also true that each group named the same four out of five of the most important contributors. The differing responses in the top contributors were both community oriented. Because respondents from the freight-centric study area placed more than three times as great of an emphasis on the importance of a community center, their responses for several other factors were reduced. This indicates that the freight-centric and non-freight-centric residents have similar perceptions of contributors to livability.

Question: ***In your opinion, what things are barriers for livability?***

Statistical analysis of the data regarding barriers to livability yielded a χ^2 value of 18.218. Because this is less than $\chi^2(0.05; 14)$, which equals 23.685, the null hypotheis of no difference between the freight-centric and non-freight-centric variables cannot be rejected. Figure 9 shows response rates for the two study groups.

Open-ended response questions pertaining to the topics of barriers for livability did not elicit significant differences between the groups. The most prevalent barriers to livability in both the freight-centric and non-freight-centric communities were crime, blight/poor upkeep of property, poverty/ unemployment, apathetic attitudes within the community, and poor transportation infrastructure (i.e. potholes, lack of sidewalks, too few lanes, etc.).

Results of neighborhood discussions further identified a perception of freight-centric residents that community leaders and officials address transportation infrastructure and general attention to needs of the community more for non-freight-centric neighborhoods than for freight-centric neighborhoods. Aside from implementing measures that could mitigate air pollution or manage harmful emissions, it may be beneficial to increase efforts to engage freight-centric residents in community planning activities and communication between residents and policy makers.

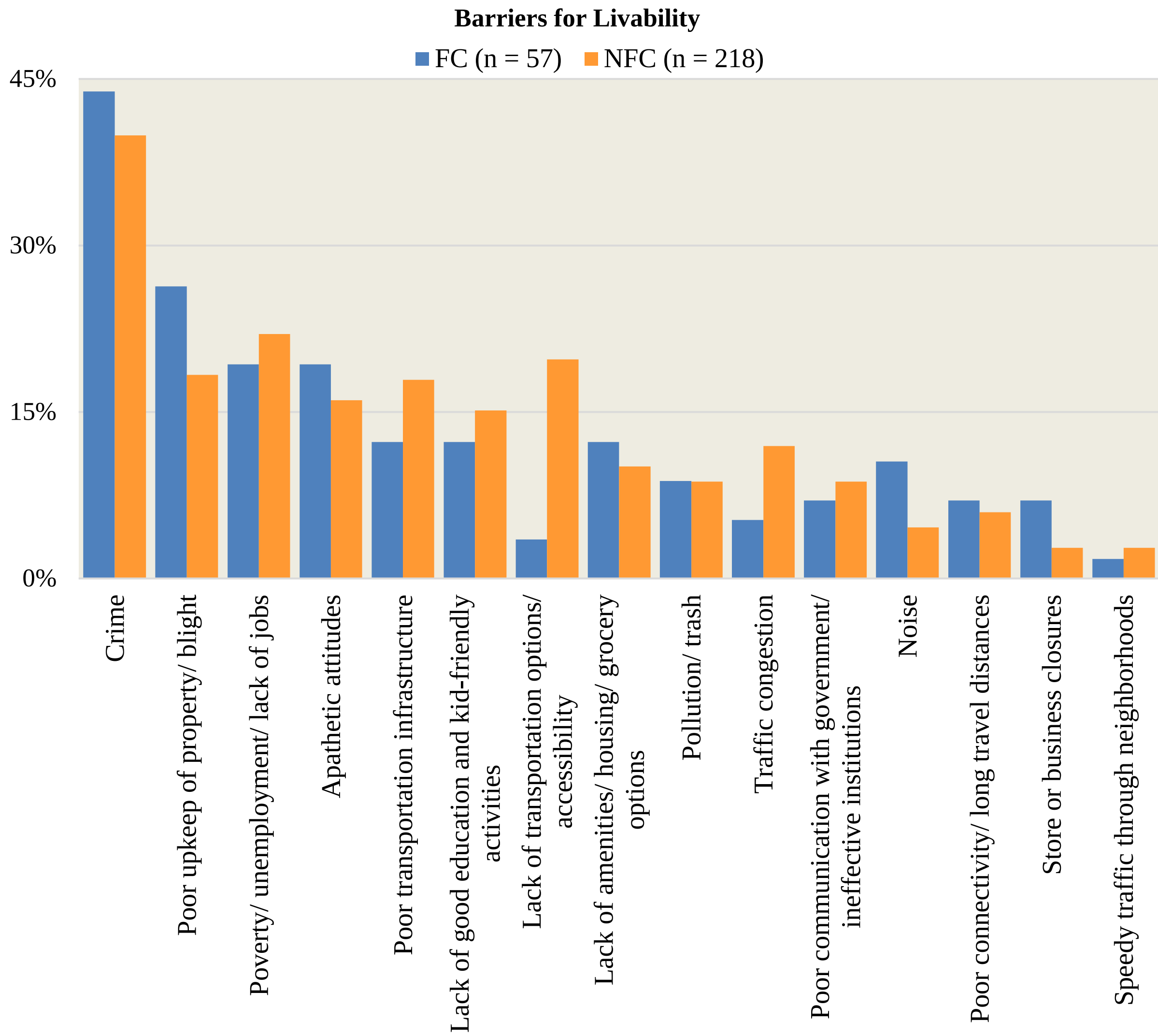


Figure 9 Perceived Barriers to Livability (Categorized open-ended responses)

Question: ***How often do you notice the presence of freight in your community?***

The WRS test for this set of ordinal data resutled in a Z-statistic of 2.43 which is greater than Z_α = 1.6, the level required to reject the null hypothesis. The distributions for the freight-centric and non-freight-centric responses are significantly different (Figure 10). It is to be expected that the freight-centric respondents notice freight more often than the non-freight-centric respondents, as they live in an area with an increased volume of freight traffic according to the definition of a freight-centric community.

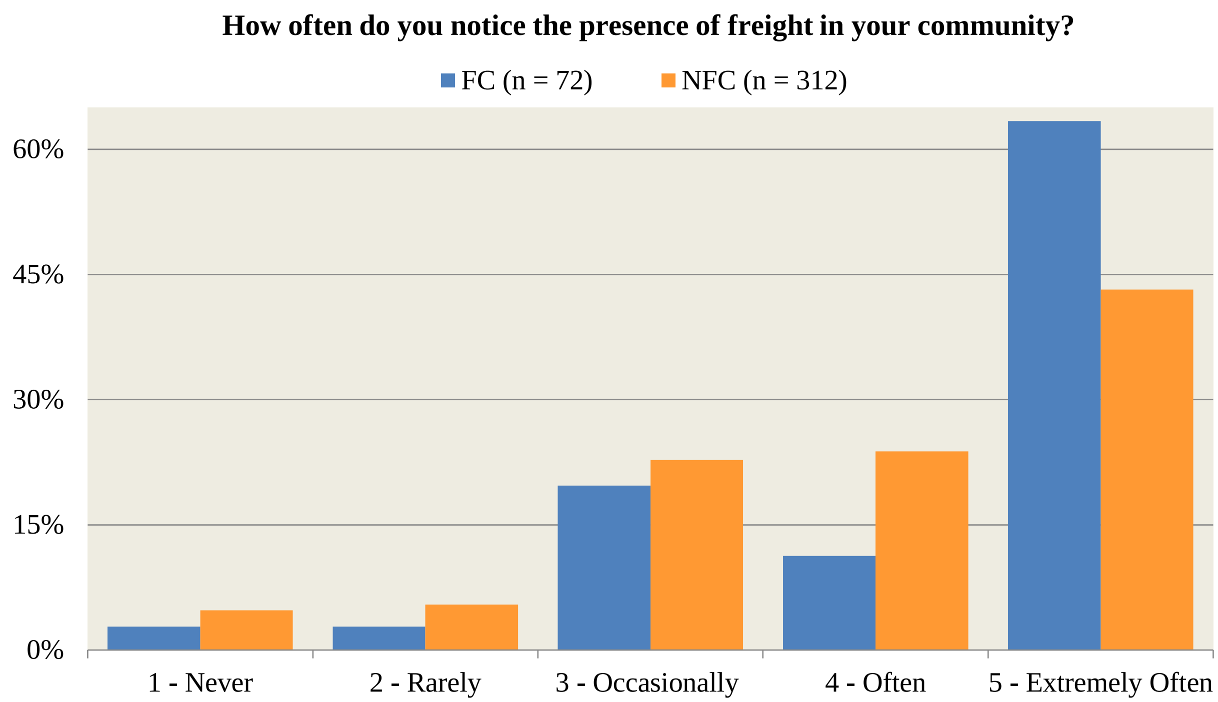


Figure 10 Perceived Presence of Freight in the Community.

Question: ***How has your neighborhood changed over time?***

Common categories were formed and considered to be either negative, positive, or neutral or unknown (Figure 11). The Chi-squared test for the entire data set yielded a score of 78.367. A score greater than 40.113 = χ^2 (0.05; 27) rejects the null hypothesis that there is no difference between the freight-centric and non-freight-centric communities.

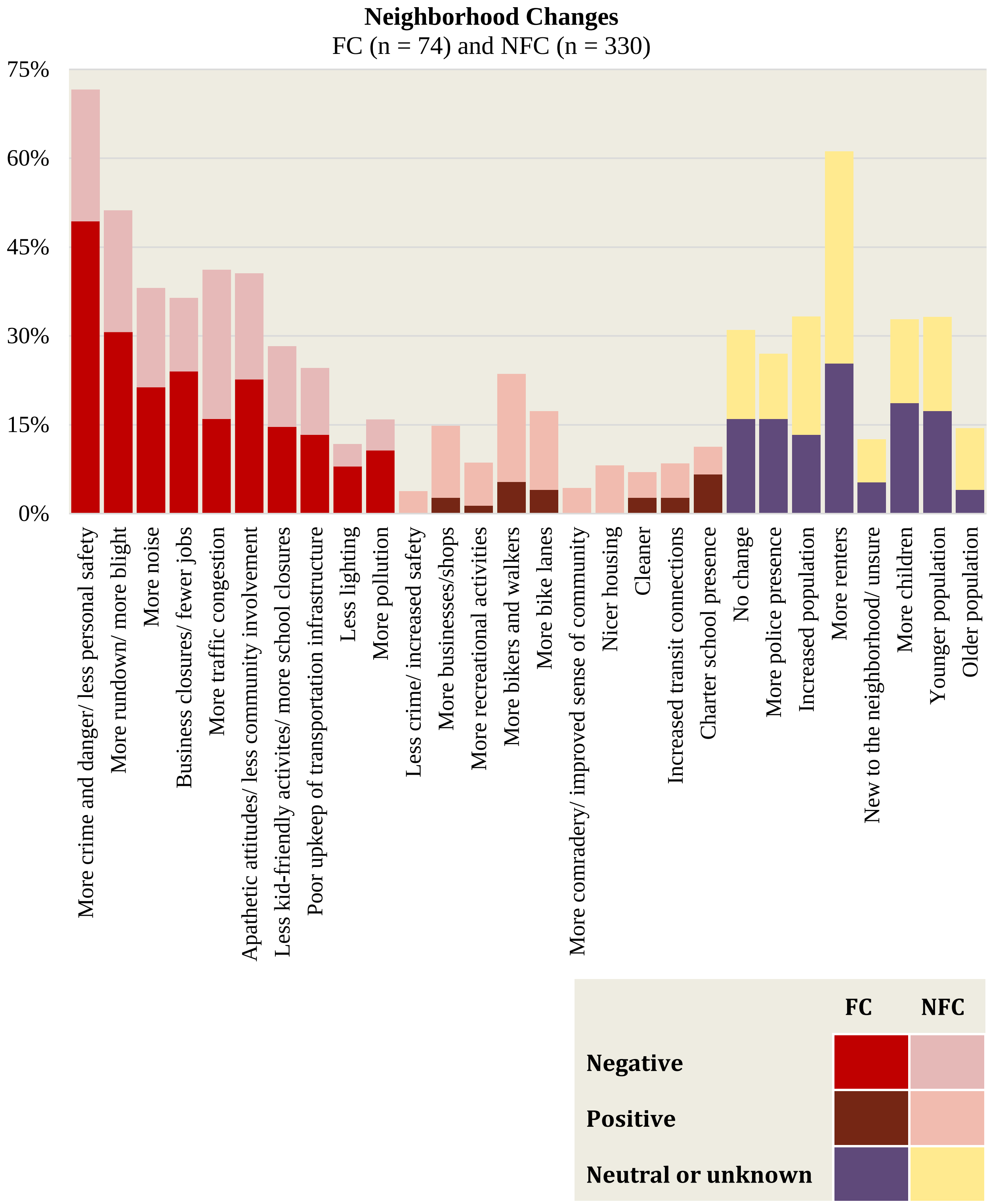


Figure 11 Results for "How has your neighborhood changed over time?" with positive, negative, and neutral or unknown changes indicated.

Figure 11 shows that the freight-centric community responded with mostly negative changes while more of the positive changes came from the non-freight-centric community. Statistical analysis shows that the overall distributions of the two groups are different. These results further the idea that, while people in both the freight-centric and non-freight-centric groups possess similar perceptions of what is important for livability, the reality in their communities is very different.

Question: How do you rate your neighborhood for livability? 10 being very livable.

Using the WRS test, a Z-statistic of *|-4.50|, which is greater than* Z_α *= 1.65, leads us to reject* the null hypothesis. The difference in the distribution of the freight-centric and non-freight-centric responses are statistically significant. Figure 12 shows that the distribution of the non-freight-centric community was higher than the distribution of the freight-centric community.

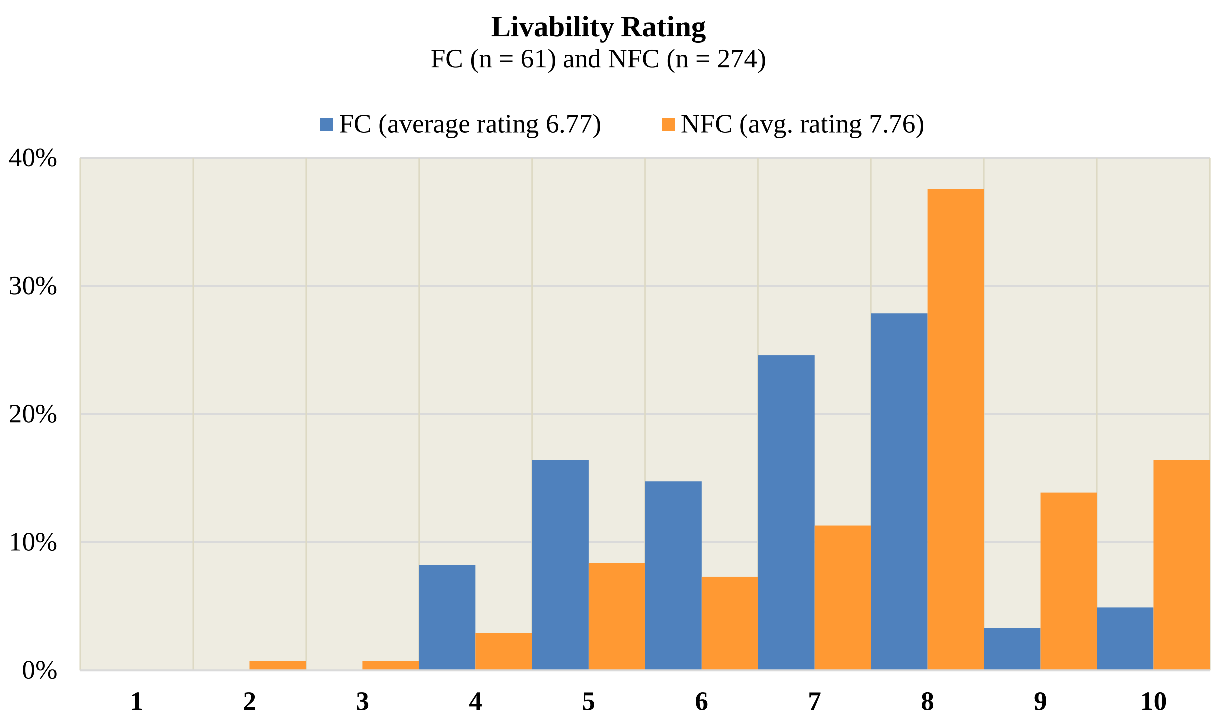


Figure 12 Response rates for "How do you rate your neighborhood for livability? 10 being very livable."

Industry Stakeholder Survey

This survey was designed to explore the impact of freight on livability from an industry perspective and to understand how livability priorities affect freight operations within individual industry enterprises. The survey was administered online to a 495-member industry contact list via email invitation on behalf of the Intermodal Freight Transportation Institute at the University of Memphis. The survey was disseminated on April 21, 2014, and 114 respondents completed the survey before May 6, 2014 (23 percent response rate). Of the 114 respondents, 66 were within the Lamar Avenue Corridor study area.

Responses from the industry survey were used to identify the makeup and background of some the industries/freight-generating sites surrounding the Lamar Corridor, as well as to explore transportation-related perspectives regarding infrastructure and the efficiency of freight flows. Industry respondents were also questioned about the possible use of some of the alleviation methods identified in the literature review. This survey included a number of open-ended and rating questions, shown in Table 7.

Table 7 Industrial Survey Questions Regarding Background Information

Survey Question	***Type***
Please indicate the number of employees at your company: 1-25 / 51-100 26-50 / 100+	Choose 1
What type of industry is your business related to? Shipper/receiver / Freight forwarder Common carrier / Retail/wholesale Private carrier / Real estate Terminal facility / Public sector	Select all that apply
Is your office or primary business location within Shelby County, TN physically located in one of the following zip codes? 38111 38115 38118 38130 38132 38114 38116 38125 38131 38141	Yes or No
How long has your business been in operation at this location? Less than 1 year / 5-10 years 1-2 years / 10-20 years 2-5 years / More than 20 years	Choose 1
If you were involved in the decision to locate your business, why was your current location chosen? Cost of land / Markets that can be reached in one day / Workforce Public/private cooperation / Availability of rail/runway/river/road infrastructure Customer base / Supplier proximity / Other (please specify)	Select all that apply

Taxes		
How would you rate the transportation infrastructure in the Memphis region:		Rating:
Roadway connectivity Pavement conditions Roadway capacity Interstate/highway accessibility Signage and markings Traffic signals/timing Street lighting	Curbs/road geometrics Intermodal facilities Rail Air Safety/Security Port Other (please specify)	1 – Inadequate/ poorly maintained 2 3 – Average 4 5 – Extremely adequate/ well-maintained
To move freight more efficiently to support the regional economy, how important are the following transportation factors?		Rating:
Infrastructure condition Transportation cost Reliability/On-time delivery Access to needed modes Direct/indirect cost of congestion Capacity bottlenecks	Institutional bottlenecks Safety and security Regulatory cost and increase in regulations Cooperation of public/private sector	Critical Important Neutral Not Important
Do you encounter the following barriers to freight-related productivity? If you do not consider an option as one that impedes productivity, please choose N/A.		Rating:
Peak-period traffic congestion (AM and PM rush hours) Off-peak traffic congestion Congestion due to incidents on the roadway Congestion due to presence of freight Bridge/tunnel restrictions for freight	Emissions regulations Noise regulations/limits Incoming scheduling difficulties Load/unload zone restrictions Access to intermodal facilities Other (please specify)	1 – I never encounter this 2 – I rarely encounter this 3 – I sometimes encounter this 4 – I often encounter this 5 – I always encounter this Not Applicable
What is the most significant cost to your business associated with congestion?		Choose 1
Delayed departures/deliveries due to congestion Additional fuel expended due to congestion Increased labor costs		

Does your company use any of the following? Electronic credentialing for commercial vehicle operations Transponders for electronic tolling Computer aided dispatch systems Automatic vehicle location systems Cargo tracking Driver monitoring Intelligent speed adaptation Floating car data (vehicle location information through the use of Bluetooth and mobile phones)	Select all that apply
What are some of the results you've obtained by using any of the above technologies?	Open-ended
Do you use any operational strategies to reduce negative impacts of freight traffic on nearby communities and improve operations for freight carriers? (For example: off-peak operations, load/unload restrictions, consolidation efforts, or appointment systems).	Open-ended
Are there any other recommendations that you have regarding freight policy, infrastructure improvements, or other freight-related concerns?	Open-ended

Figure 13 shows the composition of the businesses that responded. Most respondents (62 percent) represent companies with more than 100 employees, and 53 percent have been in their current locations for more than 20 years. The majority of respondents are either shipper/receivers, common carriers, or private carriers. Table 8 summarizes a company's reasons for picking their current location for business operations. A large portion indicated that availability of intermodal infrastructure and close proximity of markets contributed to the decision to operate close to the Lamar Avenue Corridor.

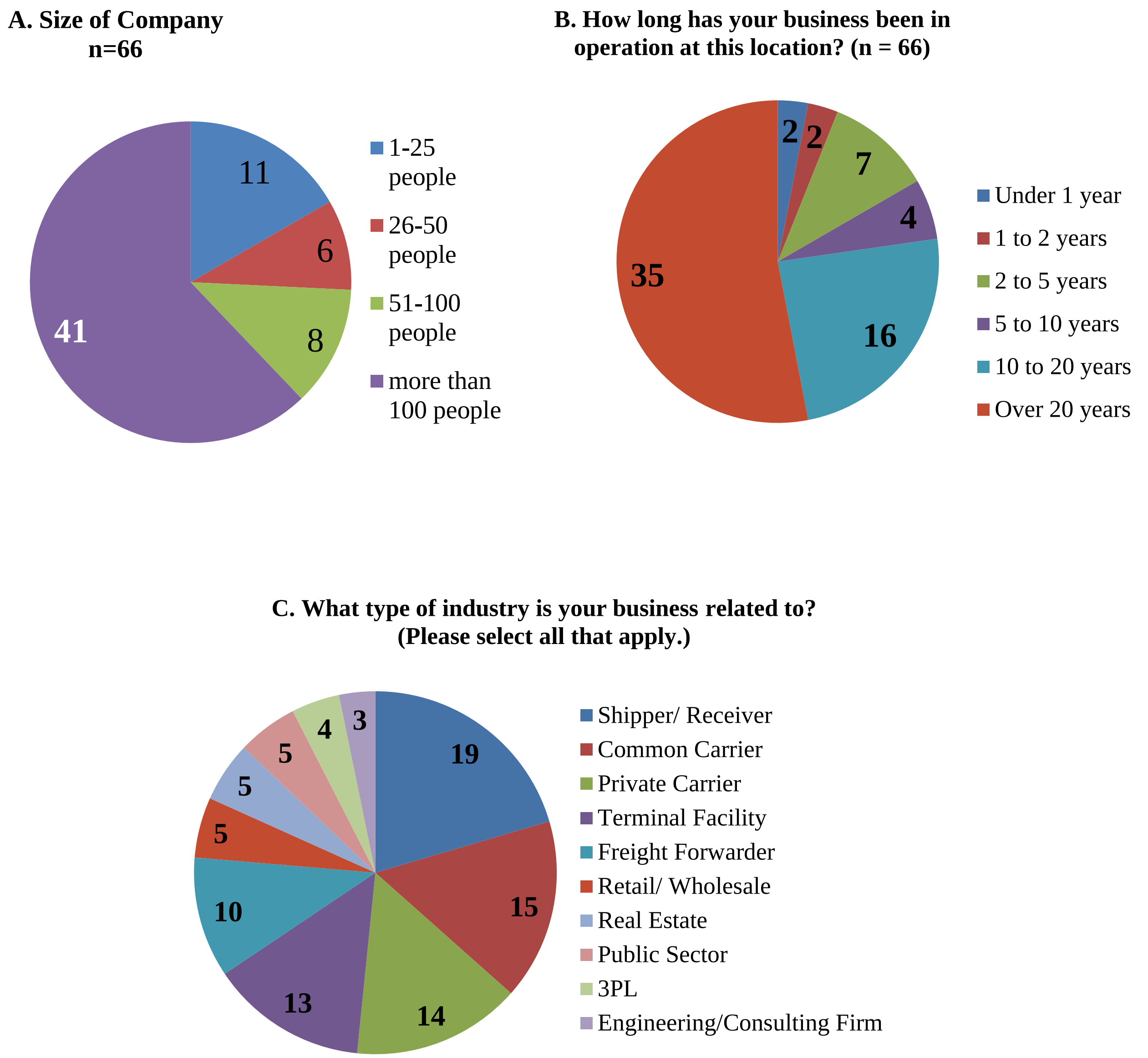


Figure 13 Industry survey respondents profile (A) company size (number of employees), (B) duration of company residence, and (C) industry type.

Table 8 Reason for choosing the company's current location

If you were involved in the decision to locate your business, why was your current location chosen? (Select all that apply.)

Availability of rail/runway/river/road infrastructure	25	46.30%
Markets that can be reached in one day	23	42.59%
Customer base	16	29.63%
Cost of land	6	11.11%
Supplier proximity	5	9.26%
Taxes	3	5.56%
Public/private cooperation	3	5.56%
Workforce	2	3.70%
Market availability	2	3.70%
Not Applicable	10	18.52%

Figure 14 shows that those features bringing business to the area surrounding the Lamar Corridor remain in good condition -- intermodal facilities, rail, and air are the best-maintained and adequate transportation system features within the area. Among the worse reviewed transportation features are pavement conditions and safety/security, mirroring the findings from the residential stakeholder group.

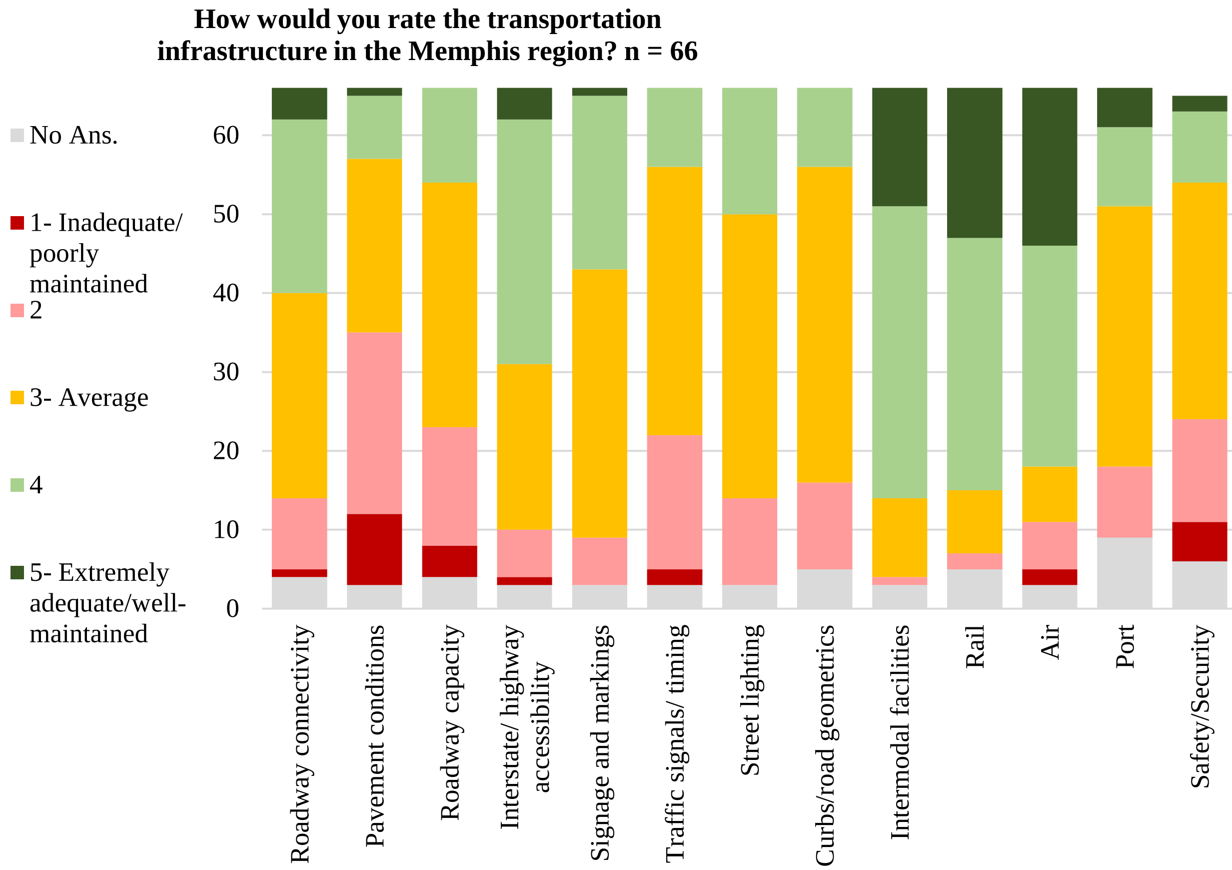


Figure 14 Industry or business perceptions opinion of the quality of local transportation infrastructure.

We asked if methods or policy-related restrictions put in place to enhance livability for residents might hinder the productivity of freight movement along the Lamar corridor (Figure 15).

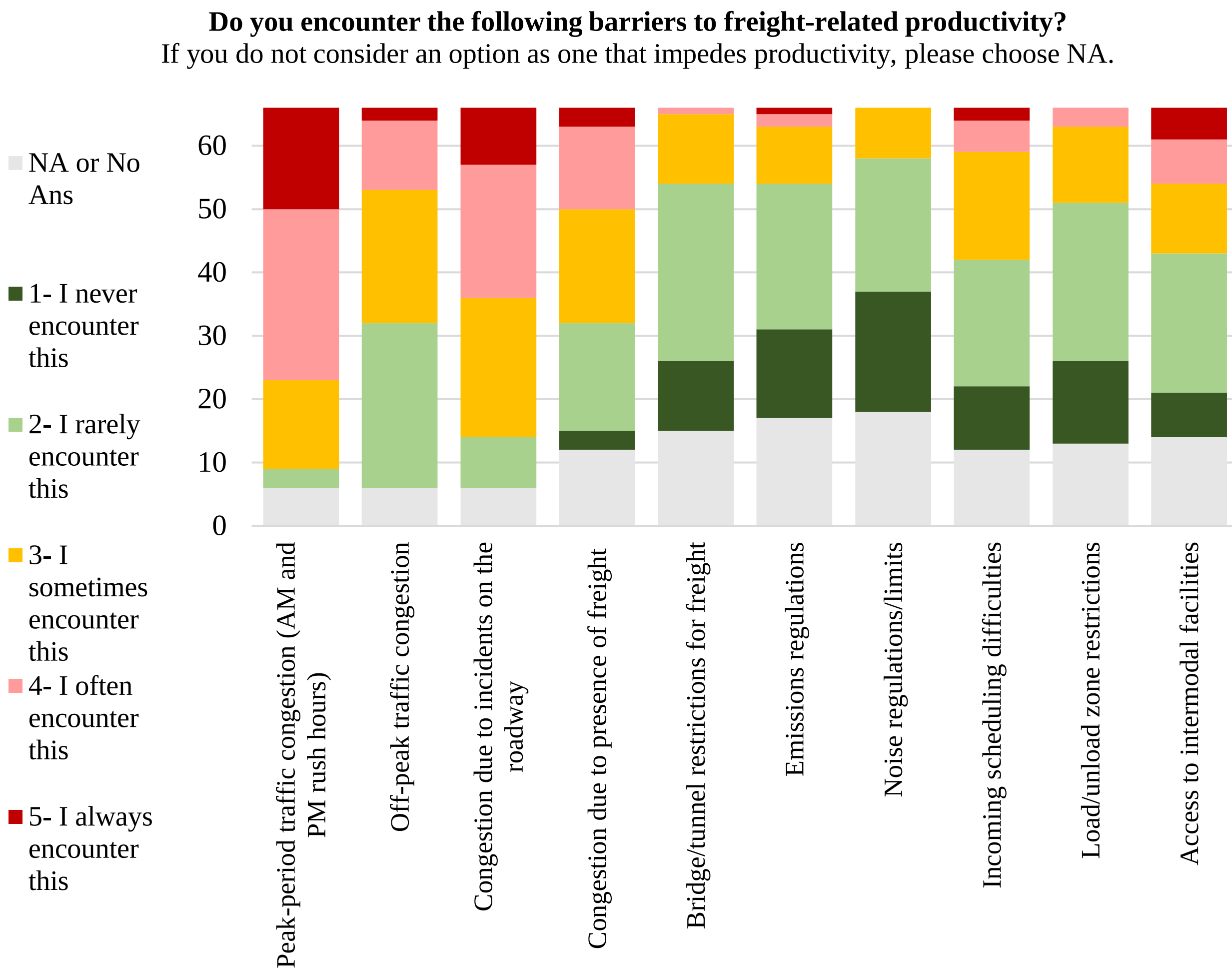


Figure 15 Frequency of encountering certain barriers of freight-related productivity.

By far, the most significant barrier was found to be peak-period traffic congestion. Table 9 identifies how this cost is incurred within a business.

Table 9 Cost imposed by increased congestion along the Lamar Corridor

What is the most significant cost to your business associated with congestion?	
Delayed departures/deliveries due to congestion	57.14%
Increased labor costs	30.16%
Additional fuel expended due to congestion	12.70%
	100.00%

The industry survey also served as a way to discover if any of the methods for improving livability in freight-centric areas identified in the literature review are currently in use by local businesses. In some cases, businesses are implementing the strategies outlined in Table 10. Part A includes the ITS/technological solutions, while Part B pertains to operational strategies.

Table 10 Company usage of ITS solutions or operational stratagies that might improve livability from the residential perspective or operations productivity from the industry perspective

A. ***Does your company use any of the following? (n = 56)***	
Cargo tracking	26
Computer aided dispatch systems	24
Driver monitoring	24
Automatic vehicle location systems	22
Electronic credentialing for commercial vehicle operation authorizations	14
Transponders for electronic tolling	12
Intelligent speed adaptation	10
Floating car data (vehicle location information through the use of Bluetooth and mobile phones)	7

B. ***Do you use any operational strategies to reduce negative impacts of freight traffic on nearby communities and improve operations for freight carriers? (For example: off-peak operations, load/unload restrictions, consolidation efforts, or appointment systems).***	
No	9
Off-peak operations	7
24 Hour drop offs allowed	2
Appointment scheduling systems	2
N/A	2
Consolidation	1
Direct loading	1
Nonintrusive routing	1
No response	43

In an open-ended question, respondents commented on the results of using such strategies or technologies. Responses were analyzed by grouping commonalities and trends. The results are shown in Table 11. It should be noted that some answers included multiple categories.

Table 11 Perceived results of using above technologies/strategies

What are some of the results you've obtained by using any of the above technologies? (n = 20)	
Delivery time estimates for customers	9
Driver accountability	4
Enhanced revenue	1
Facilitate communications	1
Greater efficiency (reduction in idle times, late arrivals/departures, and load/unload times)	5
Improved safety	4
Total	24

Policy Maker Survey

Professionals involved in planning, design, and policy decisions related to freight transportation and livability were engaged in this research as the final stakeholder group. The purpose of this component was to determine how well the perspectives of those involved in the decision-making process for infrastructure and community planning align with the residential and industry stakeholder perspectives. Members of survey group were classified as engineers, planners, or municipal leaders with input in regard to infrastructure and planning decisions. The survey was sent to 21 officials of local municipalities, planning organizations, and key engineering consultants leading transportation projects on the behalf of these groups. The survey was administered via an email request on behalf of the Intermodal Freight Transportation Institute on Friday, June 20, 2014. Five of these recipients responded to the questions. The survey was limited to four open-ended questions to reduce the time required for participants to respond. Table 12 contains the five responses to the first question.

Table 12 Policy maker responses for livability priorities within a community

What do you think is important for livability within a community? (n = 5)
Accessibility to the things that make life enjoyable. This could be a mass transit system or good road system with limited congestion.
Contributing factors - choice. Choice in housing types. Choice in business or home locations. Choice in transportation. There is no one answer that is good for everyone. Some people like to live in closely spaced housing, like on Harbor Town, and others like to live in traditional subdivisions or on large tracts of land. Some people like to walk or bike to work and others like to drive, or need to drive for work purposes. So, livability is NOT one size fits all. It is offering people choices to live how they want to live.
(1) Easy and safe accessibility to major roads from neighborhoods. (2) Easy, safe accessibility to amenities such as parks by bike/peds.
Livability Factors: (1) Infrastructure (2) Medical Services (3) Entertainment Industry (4) Culinary Offerings (5) Faith Based Community (6) Civic Pride Livability Barriers: (1) Crime or the perception/belief that crime is out of control (2) Poverty (3) Education
I think of "livability" issues as civic amenities that improve quality of life, so that these considerations come after basics such as employment, security and affordable housing have been addressed. Then the early matters are related to community size, so that livability is improved if the local population is adequate to support competition among retailers and service providers. Beyond the basics, livability is enhanced with good transportation, efficient government services, good schools, parks, playgrounds, other recreational opportunities, and a range of entertainment venues.

In question two, participants were asked to identify local practices or initiatives that impact livability. Examples of programs, policies, or other initiatives currently in place in Memphis ranged from programs focusing on healthy living, flexible work hours and options for working remotely, to smart growth zoning districts and infrastructure maintenance and improvements.

The policy-maker stakeholders were also asked to recommend potential strategies to alleviate barriers to livability, specifically for the Lamar Avenue Corridor. Table 13 displays the responses to this third question.

Table 13 Policy maker suggestions for improving livability along the Lamar Corridor

Please briefly describe any potential strategies that could alleviate barriers to livability, with specific emphasis on the Lamar Avenue Corridor. (n = 5)
As we all know, the Lamar Ave. corridor is past due on controlled access coming from the southeast to I-240. As this area is improved, we need to ensure there are sufficient alternate routes so that this key, congested corridor doesn't completely gridlock.
Providing improved transit service. Providing housing choices. Encouragement or incentives for businesses/ employers to locate in the area to provide jobs for those that live in the area. Improved police presence and security.
Shared-use driveways in an effort to reduce number of drives. Use medians to provide access management strategies.
Roadway improvements to meet capacity
The entire corridor is in need of economic revitalization. Lamar Avenue is notably divided into the "inside the I-240 loop" and "outside the loop." Inside the loop the roadway itself could stand to have sidewalk repairs and bottleneck relief (railroad underpasses). The corridor could benefit from senior centers, training opportunities and improvements to area schools. Outside the loop, Lamar Ave is a notorious traffic jam, principally due to the growth of warehousing in the area. Traffic capacity improvements would be very helpful. Also, there seems to be a need for a full-service truck stop, considering the very high volume of trucks and the lack of such a facility. Truckers have livability issues also.

Key themes evident from these responses include a significant barrier to livability related to the high level of congestion and need for revitalization and safety improvements. Several strategies related to access control were recommended to improve corridor operations. It is interesting to note one of the respondents recognized barriers to livability for truck drivers along this corridor, and suggested a truck stop facility is needed.

Finally, four respondents identified innovative technologies or new practices that could be used to improve livability. One respondent suggested that practices do not necessarily have to be new to be effective, and that any strategies to improve choices in terms of transportation or housing would be helpful. Another recommended fiber optic interconnected signals to improve the progression of traffic along the corridor. The final two respondents focused on the need for economic development in the area. One recommended formation of a group focusing on revitalization of the area, while the other pointed out a planning policy failure that has resulted in significant underutilized space within urban areas in Memphis because commercial expansion is allowed to occur at will without a land use plan in place.

Survey Analysis Summary
The goal of the survey was to investigate factors that are important for an individual's perception of livability in both the freight-centric and non-freight-centric community, industry and policy-maker perspectives on livability, and whether or not each of these stakeholder groups' perspectives align. It appears that while both freight-centric and non-freight-centric residents recognize similar important factors and barriers for livability of a community, freight-centric residents are impacted significantly by freight externalities, and this alters their perceptions of livability in their respective neighborhoods. Freight-centric residents perceive a difference in how government and community leaders address transportation infrastructure and community improvements between freight-centric and non-freight-centric communities.

The primary factors affecting perceptions of livability include: feeling safe in one's neighborhood, a sense of community and knowing one's neighbors, having an economically thriving neighborhood, and good roads. Both groups identified crime, blight, and high unemployment as barriers to livability. While the results show that no significant difference exists between the two groups in terms of perceived barriers for livability when regarding the response distributions as a whole (although the freight-centric group did respond much more frequently that lack of transportation options is a barrier to livable communities), a significant difference does exist among the livability conditions within each type of community. While people from both groups have similar opinions about what makes a community livable or unlivable, the two groups are reporting very different realities within their communities.

Measuring Livability

Livable communities are often defined by various aspects: affordable housing choices; multiple transportation options, including pedestrian and bike trails; accessible services; a vibrant economy; arts and cultural attractions; access to fresh food sources; safe routes to schools and places to play for children and youth; access to open space and recreation; and a healthy, sustainable environment (Dolesh, 2010; Oberlink, 2006).

Several research efforts have performed literature reviews of indicators and systematically assessed them for suitability to their respective scopes. The Place, Health, and Livability Research Program in Melbourne, Australia was interested in health and livability and indicators that could be shown to compare disparities within cities. This research reviewed and evaluated over 200 indicators distinguishing whether the indicator was an objective or subjective measure, required further development and whether the measure was suitable at the individual, social/built environment or policy levels, as well as suitability to project goals (health and livability). This research showed that a great majority of measures need further development to measure disparity within cities and that there was a strong overlap between health and livability. Under the transport policy area, it was acknowledged that … *the contribution of car and road freight infrastructure to liveability has not been clearly articulated in the literature, and indeed appears to be contestable.*

It is important to consider the macroscopic system in which a given urban network is found. It is argued that the incorporation of the external effects of surrounding transportation systems, as well as the extent of human and economic variability, when planning for local, urban networks is crucial for successful policy making (Goldman & Gorham, 2006). Both the concepts of livability and sustainability are vague and multifaceted; therefore their ability to be measured is complicated. The process should be done carefully in order to apply the results in policy making (Miller, Witlox, & Trippy, 2012).

Factors already exist for measuring the livability in a general area. Miller et al. (2012) maintain: "quality of life, and sustainability measures and rankings [that] include scientifically-based policy measures such as the ecological footprint and the human development index and measures of inequality such as the Gini coefficient." They dictate that further measures of livability should ensure consistency in assumptions, possess ability to be interpreted with ease, and be comprehensive in scope. It follows, that any process of measuring the livability of an urban area should consider the variability of the local conditions (whether based in local perceptions or policy standards) in order to attain validity (Miller et al., 2012).

It is important to note that there is a distinction between successes in sustainability of transportation systems; it may be achieved in the form of a final goal, or maintained as a continuous and constant track. Goldman and Gorham (2006) deem this concept as policy pathway vs. policy end-state. Both perspectives, however, include the use of "indicators" to quantify effectiveness: whether environmental (carbon dioxide, nitrogen oxides, ozone, particulates, and noise emission regulations), social (safety measures and statistics), or economical (delivery, fuel consumption, or capacity rates related to efficiency). Indicators such as measure of fuel emissions, load quotas and capacities, traffic flow measurements, etc. may be compared across multiple projects, as long as a common base and evaluation method exists. When deciding what measures to operate with, it is important to keep in mind the current state of the problem for the specific location, and to keep multiple invested parties involved and educated. Additionally, it should be acknowledged that any decision may weigh differently among these stakeholders.

In this section a multi-criteria analysis method to model livability factors is tested.

The Use of the Analytical Hierarchy Process to Quantify Livability

There are a number of multi-criteria decision analysis tools (MCDA) that allow for theoretical approaches to solving complex problems involving many stakeholders, decision makers or multiple criteria. In this research, the Analytical Hierarchy Process (AHP) is applied to the concept of livability.

The AHP, developed in the 1970s by Saaty, has roots in the psychology and mathematics fields. Analytical hierarchies according to Saaty mimic how humans make decisions by pairwise comparison and clustering to deal with complexity (Saaty, 2007).

The hierarchy is essentially a model of the problem. Criteria can be tangible, or intangible such as the concepts of livability. The hierarchy usually has four levels: a decision or goal level (livability), a general criteria level, a sub-criteria level, and an alternatives or scenario level. At the criteria levels, the criteria are paired and compared to each other in a relative format on a scale of 1/9 to 9. These comparisons are called judgments, or trade-offs. The sets of paired comparisons are organized into square reciprocal matrices. The normalized principle eigenvector of the matrix is the set of quantitative relative priority weights for each criterion being compared. The priority weights add to 1.0. The priority weights enable one to scale qualitative social values and make tradeoffs between criteria. (Saaty, 2007). The numeric results help us to understand how much more important one criterion is over another. For example, having a good school may be twice as important than crime for one individual but three times more important for another.

The Analytical Hierarchy Process was used to test whether livability could be quantified in Memphis. Components for this approach included:

1. Developing the hierarchy of criteria,
2. Designing and conducting a pairwise comparison survey, and
3. Testing the comparison survey by evaluating the consistency of individual responses and combined group response.

Developing the Hierarchy of Criteria

The hierarchy encompasses three levels: a top (problem) level, a criteria (goal) level, and a sub-criteria (factors) level. Ideally, stakeholders come together through a focus group to build a hierarchy. For this study, researchers built the hierarchy indirectly, based on the results of the residential survey and comments gathered during focus groups. The survey asked specifically, in an open-ended format, to list livability barriers. Barriers were re-formulated to be expressed as a livability factor. For example, *crime* became *living free of crime*.

The sustainability spheres of community, environment, and economy, sometimes referred to as the triple bottom line, motivated the grouping of barriers. A final hierarchy, the Livability Tree (Figure 16) includes four criteria/goals for livability: sense of community, environment, local neighborhood economy, and community investment. There are thirteen sub-criteria in the livability tree.

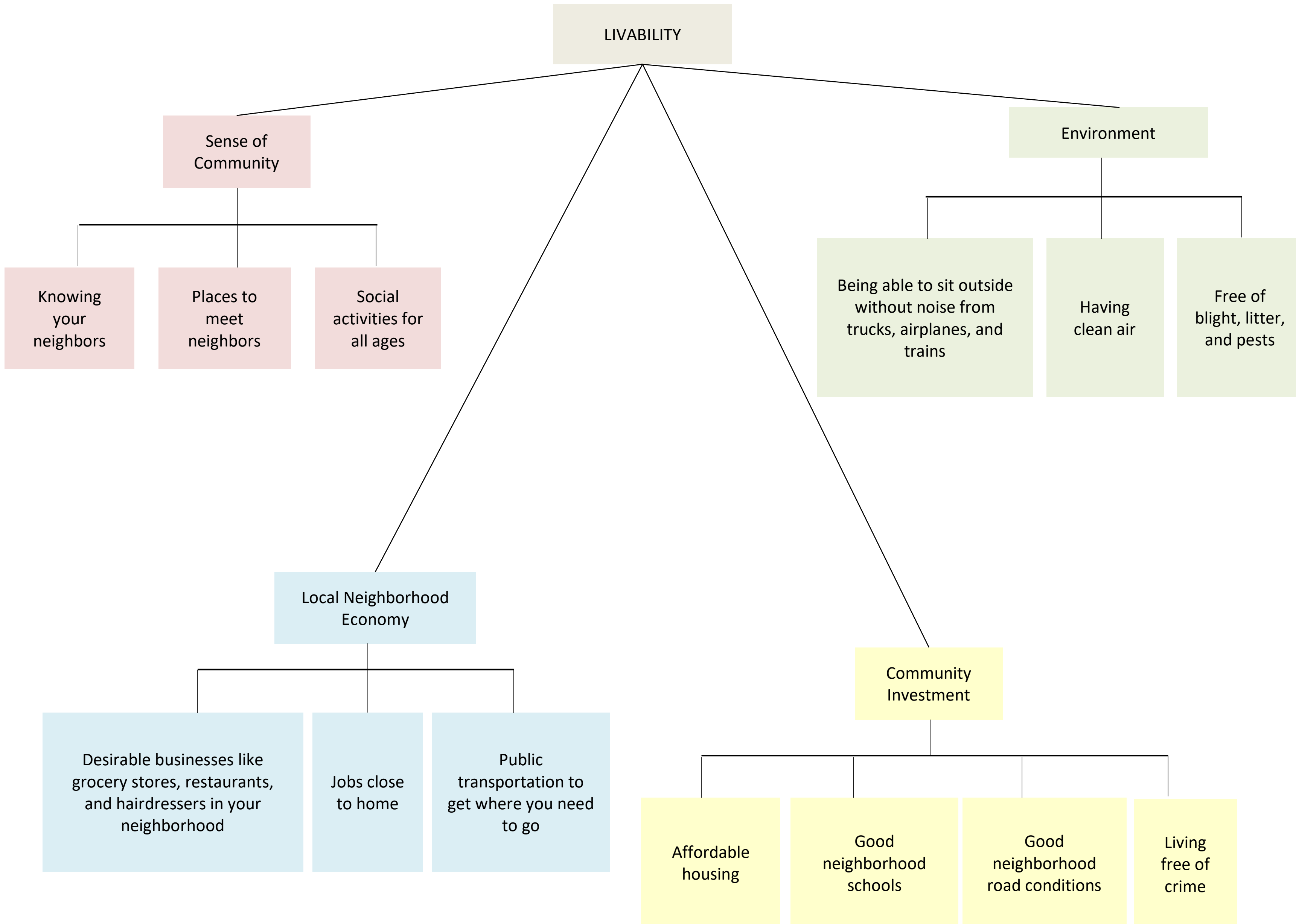


Figure 16 Livability Tree

Designing and Conducting the Pairwise Comparison Survey

In this step, each criteria and sub-criteria was compared against each other. For example, at the criteria level, *sense of community* was compared against *environment*, *local neighborhood, and community investment*. At the sub-criteria level, *knowing your neighbors* was compared to *places to meet neighbors*. The AHP requires that for each matrix,

$\frac{n(n-1)}{2}$

comparisons be made. In our case, a total of 21 criteria are compared. The two survey questions for each pair were formulated as:

Which is more important to you?

Having good neighborhood schools, or having good neighborhood road conditions?

How much more important is it?

The scale "Equal, Moderately, Strong, Very Strong, Extreme" came from Table 14. A total of forty-two questions were dedicated to the pairwise comparisons in the survey.

Table 14 The Fundamental Scale for Pair-wise Comparisons in the AHP method (Saaty, 2009)

Intensity of importance	***Definition***	***Explanation***
1	Equal importance	Two factors contribute equally to the objective.
2	Weak or slight	
3	Moderate importance	Experience and judgment slightly favor one activity over another.
4	Moderate plus	
5	Strong importance	Experience and judgment strongly favor one activity over another.
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favored very strongly over another; its dominance demonstrated in practice.
8	Very, very strong	
9	Extreme importance	The evidence favoring on activity over another is of highest possible order of affirmation.
Reciprocals of above	If activity *i* have one of the above non-zero numbers assigned to it when compared with activity *j*, then *j* has the reciprocal value when compared with *i*.	A reasonable assumption

The sets of paired comparisons are organized into square reciprocal matrices. The normalized principle eigenvector of the matrix is the set of quantitative relative priority weights for each criterion being compared. The priority weights add to 1.0. The priority weights enable one to scale qualitative social values and make tradeoffs between criteria.

Testing the Comparison Survey by Evaluating the Consistency of Individual Responses and Combined Group Response

In AHP, two tests developed by Saaty, are applied to determine whether individual responses are consistent. The Consistency Index (CI), which measures the degree of consistency, is compared to a Random Index. For 3 x 3 and 4 x 4 matrices, the Random Index (RI) is .58 and .90 respectively.

The second test is the Consistency Ratio, which is calculated by dividing CI/RI. Values over 0.1 indicate that some adjustments need to be made to the survey. Individual responses with high CR may be removed from the analysis. However, it is prudent to understand the impact of inconsistent individual responses on the CR of a combined group response.

To arrive at priority vectors for a group, the geometric mean of the individual priority vectors is calculated. Likewise the CI and CR are calculated.

Application to Case Study Area in Memphis, TN

To test this technique, researchers contracted with Survey Monkey Audience for 50 responses. Respondents were also asked to provide the closest road intersection to their residence so that spatial representation could be obtained. The survey yielded 53 complete responses within the Memphis Metropolitan Statistical Area (MSA). Figure 17 shows the locations of the respondents in relation to the study area.

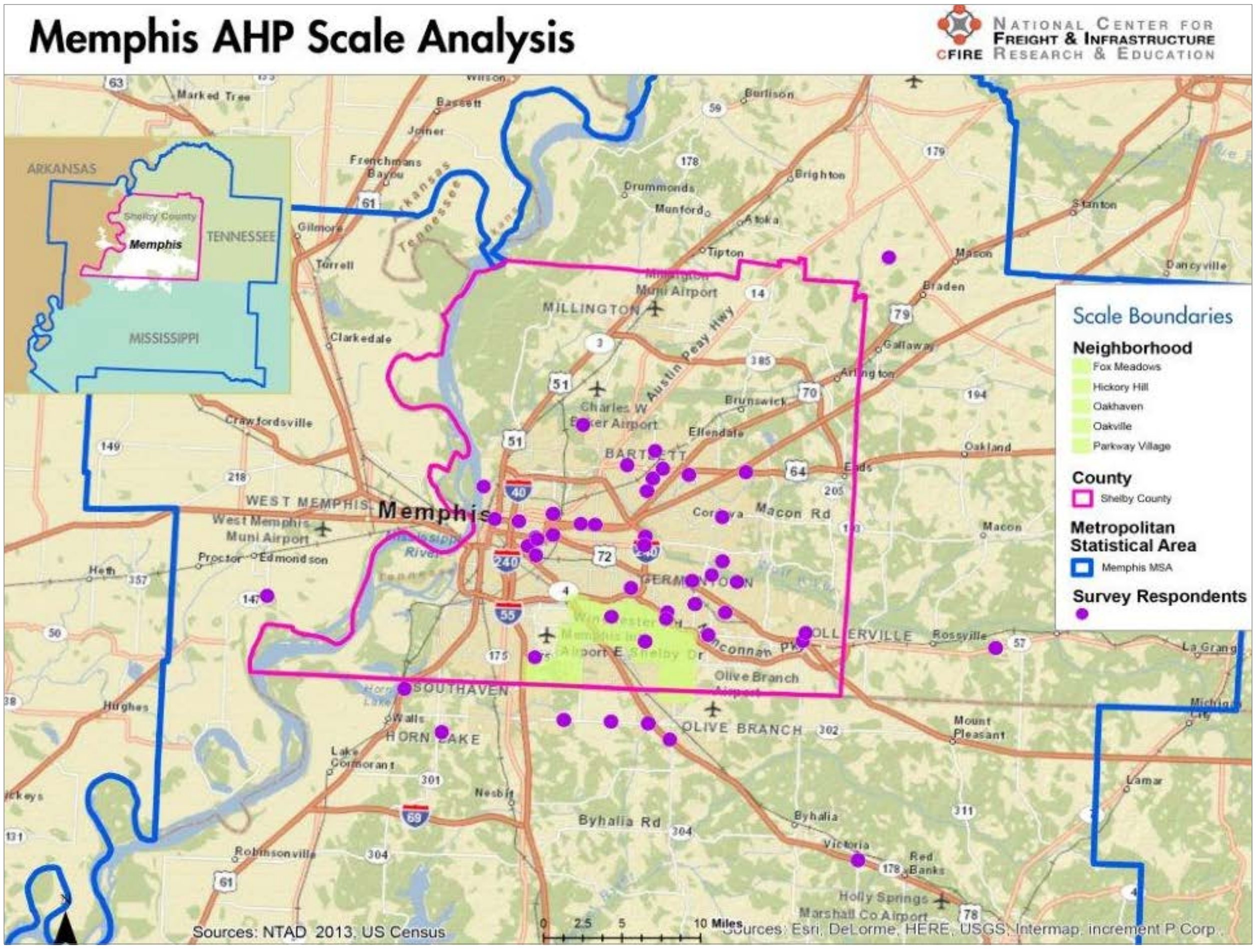


Figure 17 Memphis AHP Scale Analysis

Note: Four respondents provided partial intersection location and could not be geocoded.

Consistency of Responses

In this analysis, the CR ratios for the combined group were well under the 0.1 standard. However, some individual responses were inconsistent. Further analysis would be required to understand any trends of inconsistency. The individually inconsistent matrices were not removed from the analysis.

Priorities of Respondents

Table 15 summarizes the priority weights at three different scales: Memphis MSA, Shelby County, and the study area.

Table 15 Priority Weights for Livability Goals and Factors – Memphis, TN

Livability							
Sense of Community	**.2009** .1991 .1711	Local, Neighborhood Economy	**.1938** .1806 .2115	Environment	**.2962** .2983 .2490	Community Investment	**.3091** .3220 .3683
Knowing your neighbors	**.5105** .4900 .6152	Desirable businesses	**.5475** .5733 .2956	Sit outside without noise from trains, trucks, airplanes	**.1349** .1265 .1107	Affordable housing	**.1370** .1213 .3746
Places to meet neighbors	**.1929** .2080 .1883	Job close to home	**.2910** .2749 .5655	Clean air	**.3939** .3900 .3445	Good neighborhood schools	**.2049** .2121 .1280
Social activities for all ages	**.2965** .3020 .1965	Public transportation	**.1615** .1518 .1389	Free of blight, litter, pests	**.4712** .4836 .5448	Good neighborhood road conditions	**.0871** .0817 .0857
						Living free of crime	**.5710** .5850 .4117

KEY: **Memphis MSA**, **Shelby County**, **Study Area**

Goals

Across the four goal areas, *sense of community*, *local neighborhood economy*, *environment*, and *community investment*, the priority weights were similar at the MSA and Shelby scales. The priority weight of study area respondents was highest for the *community investment* goal (0.368) with *environment* second at 0.259. Overall, the AHP results show that the *community investment* goal comprising the livability factors of affordable housing, good neighborhood schools, good neighborhood road conditions, and living free of crime are top livability priorities for this region.

Factors

The livability factors were derived from the residential survey and were organized under the goal areas to create the AHP hierarchy. Salient observations include:

- When trading off between the livability factors of *knowing your neighbors*, *places to meet neighbors*, and *social activities for all ages*, *knowing your neighbors* is key to livability at the three scales. *Knowing your neighbor*s was three times more important for the study area residents than places and activities.

- Under *local, neighborhood economy*, *having public transportation to get where you need to go,* had lower weights at all three scales**.** This probably reflects transit availability and level of service in Memphis. According to the Census, only two percent of the population uses public transportation in Memphis (McKenzie & Rapino, 2011).

- *Desirable businesses* were more important at the MSA and County scales than the study area scales despite a preponderance of undesirable businesses in the study area. *Job close to hom*e (.5655) was more important for those from the study area suggesting that they are not employed in the freight transportation sector bordering their neighborhoods.

- These two livability factors of noise and clean air represent freight externalities. At all scales, when trading off against other environmental factors, noise is not as important as having clean air. And *living free of blight, litter and pests* was almost five times more important than *being able to sit outside without noise from trains, planes, and trucks* and 1.5 times more important than *clean air*.

- Education is considered a social determinant of health and livability (Badland et al., 2014). Yet, *having good neighborhood schools* when measured relative to the other livability factors, ranked lower than *living free of crime* and *affordable housing* and above *having good neighborhood road conditions*.

- At the MSA scale, Memphis places value on knowing your neighbors; living free of crime; living free of blight, litter, and pests; and, having desirable businesses.

The AHP technique shows promise in measuring disparity within cities when respondents are geo-located. There were some inconsistent responses primarily at the goal matrix for some individuals, which means that respondents, for example, ranked all goals as extremely important, or all equally important. It may be that truly, livability is a difficult subject to rank. Further testing with the complete 1-9 intensity ranking (Table 14) could be tried, which helps to tease out preferences.

It should be noted that the residential survey's open-ended question responses were instrumental in constructing a hierarchy that reflects Memphis' problems.

In summary, the Analytical Hierarchy Process is a valuable tool as it can analyze multi-criteria for many stakeholders allowing results to reflect each community's characteristics and circumstances *(Hai-Yan & Xun-Gang, 2012)*. While the freight-centric community targeted here was well established, this technique can be used in emerging freight communities such as those where inland ports are being sited. This technique would be helpful in looking at livability disparities within cities and help planners formulate holistic approaches that address barriers so that all neighborhoods can be vibrant places to live and work.

Strategies to Improve Livability

Several transportation and logistics practices and strategies are discussed in the literature that can be valuable in mitigating some of the livability issues due to excess freight traffic. Of the numerous suggested ways to organize alleviation techniques and practices, the following divisions are used here: (1) distribution network, (2) logistics management, (3) land use, (4) access conditions, and (5) trade nodes. Each of the initiatives for mitigating the inherent problems of increased freight volumes will be presented under these divisions. Methods dealing with infrastructure, consolidation, and access restriction may be handled by local authorities and policy makers, while specific vehicle enhancements (like efficient engines or aerodynamic vehicles) or technological solutions could by implemented in industry (Browne et al., 2012; Lindholm, 2012; Munuzuri et al., 2005). Discussion in the literature highlights the following practices in transportation and logistics for improved livability in freight-centric communities.

Distribution Network

Optimization of network transfer points both within a city center and on the outskirts will drastically improve the efficiency of the overall goods movement system. Properly located terminals stimulate efficiency by allowing the consolidation of trips and goods for one company or collaboration. The resulting improved organization may allow for the incorporation of better modal options, such as transitioning to rail, shuttle, waterway canals, or an underground system (Lindholm, 2012; Munuzuri et al., 2005). Transitioning to rail or boats from trucks often increases costs and requires subsidization (Giuliano et al., 2013). Well-located hubs that allow for direct transition from trains to delivery vans are preferable (Lindholm, 2012; Munuzuri et al., 2005).

The creation and utilization of centrally located urban distribution hubs (that also potentially incorporate clean-energy delivery vehicles) is known to reduce the frequency of inner-city truck trips (Goldman & Gorham, 2006). These Urban Consolidation Centers (UCCs), also known as urban distribution centers, are typically set up in parking lots or other empty or shared spaces where freight vehicles may unload cargo to smaller delivery vehicles. The presence of an inner-city terminal or hub may help alleviate congestion by decreasing trip frequency and minimizing total vehicle miles travelled, as well as encouraging consolidation of trips and improving the efficiency of loads (Browne et al., 2012; Munuzuri et al., 2005, 2012).

This methodology is considered by some as one of the most encompassing and successful techniques (Lindholm, 2010). Others, however, have reported this method to be “economically unfeasible” after a test period and the conclusion of external funding (Munuzuri, Cortes, Grosso, & Guadix, 2012). Even in densely populated cities, however, transport hubs are known to provide economic benefits (Lindholm & Behrends, 2012).

Another strategy would be to incorporate the use of “Alternative Fuel Vehicles” or AFVs. This strategy could be applied to transit busses or industry constituents that have large fleets (e.g., Fedex or UPS); such companies are exploring the use of AFVs in both the US and Europe, though hindrances of AFV use do exist. AFV usage includes the necessity of capital and higher operational costs, as well as limited infrastructure for their re-fueling. In fact, diesel engines may still prove to be advantageous over AFVs, especially for larger trucks (Giuliano et al., 2013).

It may be appropriate to adapt a current transit (tram or underground) system to incorporate the movement of freight, despite potential for costly or timely modifications. The advantages of improving an already-existing infrastructure as well as the potential to decrease above ground congestion may validate the process (Munuzuri et al., 2005).

Logistics Management

Logistics management is an important aspect of managing livability in freight-centric communities. Several areas in particular are important for the vitality and well-being of the surrounding community. City logistics management, neighborhood logistics management, and construction logistics management practices should be recognized for their role in alleviating the effects of freight movements on livability.

City logistics management is defined by Muñuzuri et al. (2005) as “the specific logistic concepts and practices involved in deliveries in congested urban areas, the ‘last mile’ transport, with specific problems such as delays caused by congestion, lack of parking spaces, close interaction with other road users, etc.” (2005). In response, it is suggested that where possible parking lots left unused for time periods be temporarily converted to loading/unloading zones as a means to take heavy vehicles off streets, thereby reducing delay and congestion. Furthermore, the creation of designated parking spots for heavy vehicles, where a driver may park for a longer period to deliver his goods on foot or dolly, would serve to decrease noise, air, pollution and congestion.

Neighborhood logistics management is used in an effort to minimize the necessity for under-capacity loaded trucks, it is suggested that neighborhoods/local regions designate one uniform package pick-up location (Goldman & Gorham, 2006). This concept would remove time restrictions, as the receivers would not need to be present; nighttime deliveries would also become appropriate. Such a method is especially applicable in dense areas that receive a high number of packages (Munuzuri et al., 2005).

Construction logistics management was used in Berlin with considerable success during the redevelopment of Potsdamer Platz. For example, policy mandated that concrete be mixed on-site, as well as requiring a majority of materials be moved by rail. The resulting efficiency encouraged the establishment of a national policy requiring major construction jobs to include logistics management (Goldman & Gorham, 2006).

Land Use for Urban Goods Movement

Even though the delineation of specific loading/unloading zones per destination is common practice in many cities worldwide, demand for them is increasing, and it is recommended that building regulations be updated to include accommodation for off street loading. In extreme cases such as on narrow or one way roads where loading is still necessary, proper consideration, such as signalization and/or premeditated regulations, should be used when blocking traffic, and only for short periods of time.

Although the idea may be met with opposition by certain stakeholders, it is known that in some cases traffic congestion could be lessened by removing on-street parking altogether. This method would be supplemented well by adding alternative parking lots or transit options, but is still controversial. Success exists for carriers who have learned to share land, space, and technologies. It is suggested that carriers collaborate in shipping hubs in order to jointly benefit from the space or technology. Furthermore, while the specification for reserved space (like private, handicap, motorcycle parking, and taxi and bus lanes) is crucial for the functionality of urban systems, they are often left empty for periods of time. When these empty slots align with peak freight delivery periods, sharing would induce beneficial results (Munuzuri et al., 2005).

Many of the methods for enhancing livability for urban residents and other local stakeholders outlined in this section hamper the abilities and flexibly of the freight distributors themselves, while increasing their costs. The location of logistics hubs is important, and properly locating inner-city freight or "mini-hubs" can combat these effects for industrial stakeholders as they must maintain their mobility and effectiveness in the end. Mini-hubs differ from Urban Consolidation Centers in that they do not require substantial funding (Munuzuri et al., 2005, 2012). There exists a discrepancy in the literature on specific results of many of the methods mentioned here and practiced in various European cities (Lindholm, 2010). This practice is appropriate for urban areas, but is not as applicable for suburban cases.

Access Conditions

Access conditions are some of the first measures to be implemented in most European cities, these kinds of methods are already heavily used in Europe. The specifics vary, but benefits have been reported in many cities (Lindholm, 2012). Access may be controlled through a variety of measures, whether based on weight, volume, size or other load capacity factors (Munuzuri et al., 2005). Disallowing the entrance of highly emitting vehicles in certain "zones" should have a positive impact on the environment (Lindholm, 2010). Known as LEZs (Low Emission Zones), these restrictions are claimed by some to inspire the complete reorganization of freight operations with more effective results (Giuliano et al., 2013). In the Netherlands results were less than anticipated. This outcome could be due to an excess of permits allowing access of poorly rated vehicles (Browne et al., 2012). Numerous European cities have previously experienced diminishing harmful emissions by restricting admittance of old/out of standard heavy vehicles into inner-city areas (Goldman & Gorham, 2006). It is important to note, that while benefits of LEZs are apparent, the transferability of these to the US is limited (Giuliano et al., 2013).

Another type of access condition is based on time of day. It is easy to see how restricting delivery/pick-up within congested urban areas to off-peak time periods could help minimize freight's externalities. Furthermore, as trucks are present during off-peak periods, more parking or loading/unloading areas should be available (Munuzuri et al., 2005). Delivery zone characteristics are also vital. Symptomatically based solutions will vary depending on the delivery region (tourist, residential, commercial, or a combination of these). Depending on the nature of delivery destination, night time delivery may not be appropriate (Munuzuri et al., 2005). Access to certain areas may be granted for trucks achieving a specific label or status. For example, cleaner emissions or minimal noise outputs may earn a truck access to a particular area (at a particular time). Such strategies are typically voluntary and would serve as useful ways to incentivize livable results for residents (Giuliano et al., 2013).

Due to variability among freight vehicles and companies, as well as urban regions, distinctions should be made to accommodate varying needs in an urban transportation system. Freight vehicle characteristics are based on the percentage of full capacity in a given vehicle, thus a proportionate amount of time should be allowed for loading/unloading. Vehicles making multiple deliveries on a route should be allowed less time in any one zone, as opposed to vehicles making one stop and emptying a majority of their load. Access will vary based on content of load—depending on weight or size of goods to be delivered (Munuzuri et al., 2005).

One of the most effective measures, strict emissions standards for fuel efficiency of trucks, proves to have a significant influence on freight's impact. For example, "The Los Angeles/Long Beach Ports Clean Truck Program is by far the most ambitious emissions reduction program in the United States and, in 4 years, led to large reductions in diesel truck emissions." A sustainable option as well, fuel efficiency of freight and emissions standards will continue to negate air pollution and carbon dioxide emissions in urban areas (Giuliano et al., 2013).

Finally, street characteristics that specifically relate to freight operations are also important. These categories consider aspects such as land use availability, a potential for shared space in proximity, the width and number of lanes, and the proximity to non-residential areas to classify urban streets as either: Access Streets, Restricted Access Streets, Load/unload streets, Non-freight streets, or Pedestrian streets. Consequently, it may assist freight distributing agents already facing numerous restrictions to consolidate basic strategies, where appropriate, across urban districts.

Trade Node Solutions

Trade nodes are defined as including significant freight producing facilities such as ports, airports, or intermodal yards, trade nodes not only see the freight problems associated with urban last mile/first mile transactions, but they also see the additional problems associated with an increased concentration of freight traffic (Giuliano et al., 2013).

Appointments and pricing strategies can be used in an attempt to better organize freight arrivals at ports or intermodal facilities. Gate appointment strategies have been implemented in limited locations in the US. A successful example of pricing strategies in California shifted 40 percent of its freight cargo to the evening. This spacing of concentrated freight traffic should reduce congestion in nearby corridors. While the necessity of fees for peak-hour interactions is not yet prevalent at many trade nodes in the US, the implementation of such could also serve to spread concentrated freight arrivals in congested corridors.

Road pricing and dedicated truck lanes to manage hub-related truck traffic can be used. Such strategies are sparsely found in practice, and more research is needed on their effectiveness. These strategies include tolls for freight traffic and/or the designation of certain lanes or roads for freight traffic only. Increased tolls for freight trucks would reduce truck competiveness compared to rail, and thus would benefit the personal vehicle user, as well as the environment. The increased cost to the freight carrier, however, may prevent the rapid acceptance of freight tolling in the US. Furthermore, freight-only lanes are rarely found in the US, and the cost and land requirements are high and normally unjustified by the volume of freight traffic.

Accelerated truck emissions reduction programs can also be used to promote faster upgrades to meet EPA emissions standards for new vehicles. These programs aim to reduce the average age of freight vehicles travelling through certain zones or trade node sites by incentivize the replacement of older, poorer emitting vehicles with newer, cleaner ones.

Equipment management strategies are used to incorporate the increased management of chassis and cargo containers to improve their use and movement within freight transfer operations. With an overall goal to reduce VMT, such strategies would also reduce congestion and emissions.

Trade node solutions have been executed in US locations more frequently than other freight impact mitigation strategies. Of the above solutions, the road pricing and accelerated emissions programs are expected to be the most useful in promoting livability by reducing emissions and congestion (Giuliano et al., 2013).

Cargo Oriented Development

South of Chicago, a method of Cargo Oriented Development (COD) is being explored as the South Suburban Mayors and Managers Association (SSMMA), Chicago Southland Economic Development Corporation (CSEDC), and the Center for Neighborhood Technology (CNT) collaborate in an effort to utilize empty, previously industrialized “brownfields” for locating freight distributing companies in an effort to catalyze economic development. This region is especially favorable because of the availability of this type of developable land, as well as the fact that vehicle, rail, and barge traffic all come together here (a quality preferable when executing COD practices). Quantitative and thorough analysis was conducted, along with regimented comparisons of 598 sites incorporating variables of land use and characteristics, transportation amenities, current presences of businesses, and local demographics (Dock et al., 2008).

A study conducted in 2014 by the Center for Neighborhood Technology categorized benefits of COD into system performance, cost effectiveness, regional economic development, and livability (Center for Neighborhood Technology, 2014). The study pointed out that much of the focus of previous research has been on performance and cost effectiveness, and that the practice of COD requires that all of these potential impacts be evaluated holistically. Three case studies were used to demonstrate how results from COD applications can vary, including a case study in Memphis, TN. The results indicated the importance of carefully considering the location of freight terminals and implications for surrounding communities as well as giving higher weight to freight planning from a regional perspective. The study further identified new technologies for reducing negative externalities of freight terminals to improve community livability.

A specific approach for the evaluation of the efficiency of inland hubs (not necessarily urban) was developed by Long and Grasman (2012), and is possibly applicable to other urban-related situations. To develop their evaluation techniques, they interviewed eighteen professionals in the intermodal transportation field, and the following criteria were established (Table 16):

Table 16 Summary of Criteria for Evaluating Inland Hubs (Long & Grasman, 2012)

Criteria	Description	Measurement Method	Data sources
Infrastructure	Capacity to move freight access to transport modes	Identify highways, railroads, waterways, airports, and multimodal terminals	Infrastructure maps, US Dept. of Transportation
Proximity to market	Market reach, one-day market reach	Find population within 600 mile radius of alternative region	US Census Bureau
Land availability	Land available for transportation logistics development	Identify vacant land, buildings/land available for re-development, etc.	Region-specific real estate data
Government and industry support	Government support of transportation developments and size of regional transportation/ distribution industry	Identify regional economic development councils, especially those with transportation emphasis. Find the number and size (by revenue or employment) of local industry.	Region-specific data on government organizations and industries
Labor supply	Industrial labor supply able to meet expanding transportation developments	Identify the proportion of a region's workers that have the skills for transportation jobs	Bureau of Labor Statistics
Origin/ destination distances	Distance between freight flows to and from a region	Use freight flow data to compare the near optimal location with the region's actual location	Freight Analysis Framework, FHWA
Congestion	Delays in freight movement cause by congested traffic	Use congestion indices to measure congestion levels of freight significant corridors. Other corridors will require primary data collection from local experts.	American Transportation Research Institute

These specifications could indicate the sustainability and overall effectiveness of freight hubs.

Global Case Studies

While exploring various remedies to the negative impacts of freight in communities, the European Union developed and encouraged the use of a systematic planning process called the Sustainable Urban Transport Plan (SUTP). This program relies on and encourages continuous collaboration between the various stakeholders in a community through its comprehensive and ongoing process (see Figure 18) (Lindholm, 2010; Lindholm & Behrends, 2012).

London

Beginning in 2000, a wide range of the previously mentioned solutions were carried out and analyzed in London, with a focus on reducing harmful emissions. The Mayor's directive, Transport for London (TFL), and its Freight Plan, worked toward specific goals aligned with improving livability. First of all, the Freight Operator Recognition Scheme (FORS) provided education by means of free training workshops and informative guides that would encourage environmental and operational efficiency. Delivery and Servicing Plans (DSPs) and Construction Logistics Plans (CLPs) also existed to help optimize freight flows and encourage the proper use of loading zones, thereby reducing pollution and congestion, as well as improving safety conditions. These plans reported a 20 percent reduction in the number of deliveries to a test site (over an unspecified period of time).

Furthermore, the London Construction Consolidation Centre (LCCC) was launched as a two-year pilot program. Serving four different locations with direct, just-in-time delivery from suppliers (while limiting storage time), this project was able to report a 60-70 percent decrease in the number of vehicles delivering to major construction sites. Finally, the City of London Urban Consolidation Centre, created by a local office supply corporation, employed the use of electrically powered vans and tricycles to report a complete reduction in fossil fuel consumption and a 20 percent decrease in total distance to delivery sites (Browne et al., 2012). Both Lindholm (2010) and Browne et al. (2012) attribute the success in London to the willingness and proactiveness of city policy makers, as well as other stakeholders.

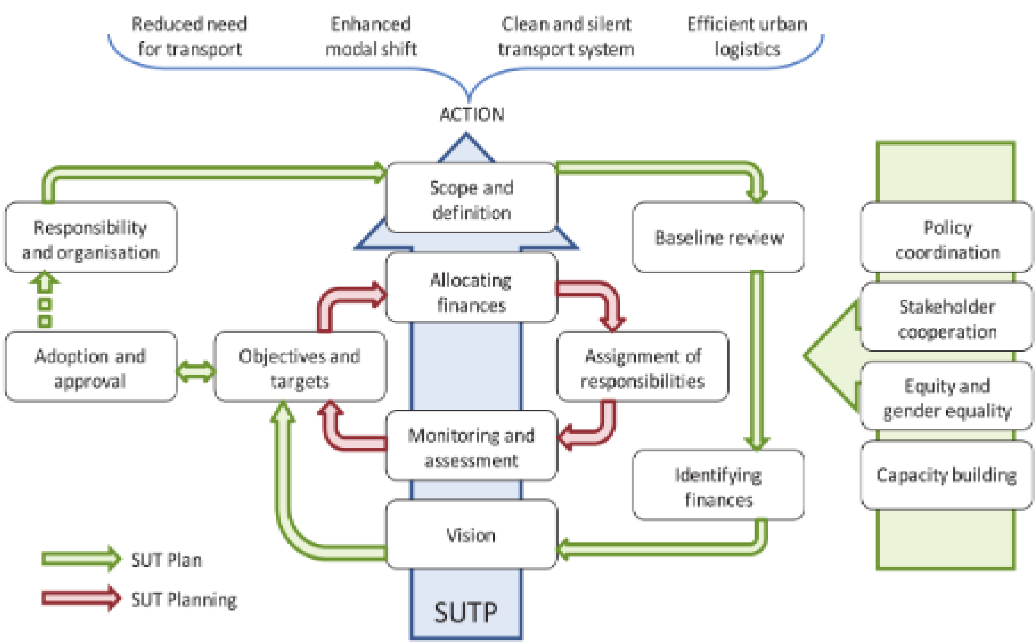


Figure 18 The SUTP Map (Lindholm, 2010; Lindholm & Behrends, 2012)Japan

As a collaborative effort instigated by approximately 300 local shop owners on Motomachi Street in Yokohama, and partnering with the city's government and police forces and the Kanagawa Trucking Association, this consolidation center (depicted in Figure 3) is the first of its kind in Japan. With a focus on air and noise pollution reduction, this effort aimed to reduce heavy congestion on its busy main street. After thorough research and planning, the center was constructed in 2004 and operates as shown in Figure 19 (Browne et al., 2012).

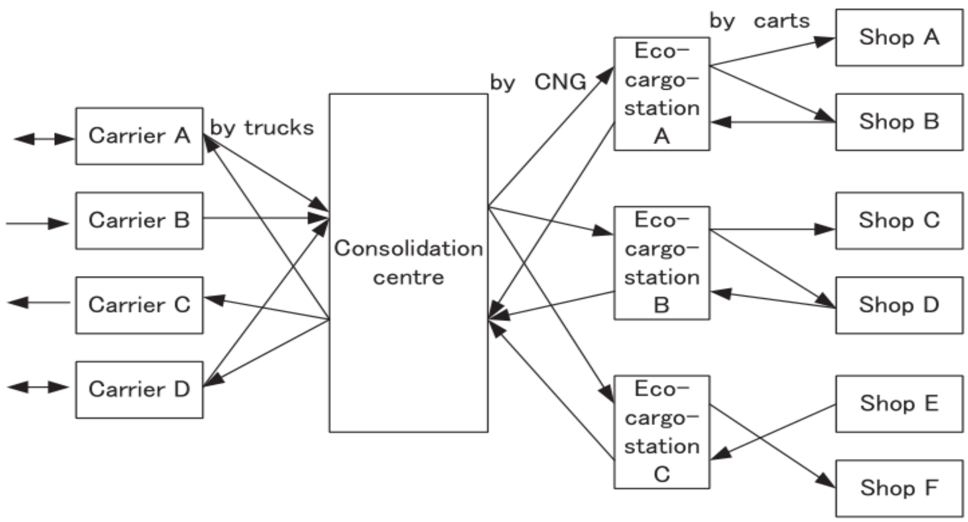


Figure 19 UCC Layout and Delivery System in Japan (CNGs are compressed natural gas vehicles) (Browne et al., 2012)

Two Emissions-Reduction Strategies to Improve Livability in Freight-Centric Communities

To examine the benefits of some of the strategies discussed in this section, we carried out model simulations to assess use of gate appointment and fleet renewal strategies along the Lamar Avenue Corridor in Memphis Tennessee. The goal of these two models was to predict the impact of these strategies on vehicle emissions as a component of livability along the Lamar Corridor.. The results of this study indicate that a common method to reduce emissions at freight terminals may actually increase emissions along the corridor itself. Instead, specific emphasis on the use of alternative fuels to reduce emissions may be warranted.

Transportation accounts for 71 percent of petroleum consumption in the United States, with non-light-duty vehicles accounting for half of this (U.S. Department of Energy, 2013n). Expected growth in freight demand by 2050 would effectively double the fuel consumption at current vehicle efficiency levels (U.S. Department of Energy, 2013n). Diesel and gasoline are the most common fuels in internal combustion engines (Piecyk, Cullinane, & Edwards, 2012). In each case, perfect combustion would result in:

$$X_a C_{X_b} H_{X_c} + X_d O_2 \xrightarrow{\text{yields}} X_e CO_2 + X_f H_2 O$$

where *X* represents the appropriate coefficients and subscripts to balance the equation and a through f denoting potentially different values of *X*. Diesel contains hydrocarbons with a carbon content from C_8 to C_{25} and gasoline contains hydrocarbons with a carbon content from C_4 to C_{12} (U.S. Department of Energy, 2013f). Due to incomplete combustion and other chemicals in the fuels, other products exist, including particulate matter (PM), heavy metals (HM), ammonia (NH_3), sulfur dioxide (SO_2), oxides of nitrogen (NOx), volatile organic compounds (VOC), carbon monoxide (CO), methane (CH_4), carbon dioxide (CO_2), and nitrous oxide (N_2O) (Piecyk, Cullinane, & Edwards, 2012).

These pollutants can affect the environment on three levels: global, regional, and local. Globally, NOx, VOC, CO, CH_4, CO_2, and N_2O are greenhouse gasses (GHGs) that retain energy within the atmosphere, contributing to global warming (Piecyk, Cullinane, & Edwards, 2012). Regionally, NH_3, SO_2, and NOx all contribute to the formation of acid rain, while NOx, VOC, and CO cause smog (Piecyk, Cullinane, & Edwards, 2012). On a local level, a variety of effects can occur from the pollution, as shown in Table 17.

Table 17 Local effects from diesel and gasoline combustion

Cause	Effect
NOx	Emphysema
Uncombusted Hydrocarbons, VOC	Cancer
NOx and VOC forming Ozone (O3)	Respiratory problems and nausea
PM	Respiratory and cardiovascular problems, asthma, cancer
CO	Cardiovascular problems
SO_2	Eye, ear, nose, and throat irritation; respiratory problems

Note. Adapted from "Assessing the external impacts of freight transport," by M. Piecyk, S. Cullinane, & J. Edwards in A. McKinnon, M. Brown, & A. Whiteing (Eds.), *Green Logistics: Improving the Environmental Sustainability of Logistics*, 2012, London: Kogan Page.

With the significant contribution of freight transportation to air emissions, it is important to consider strategies to reduce these negative externalities on community livability. One strategy is to tackle emissions through environmental public policy. Another is to address the issue through the typical freight industry planning schedule. Freight planning occurs at three levels: short-term or operational planning, medium-term or tactical planning, and long-term or strategic planning. Short-term planning relates to day-to-day operations decisions, medium-term planning relates to basic resource strategy, and long-term planning relates to decisions about the services offered (Böse, 2011).

According to literature, emissions-reduction strategies at the operational level, are aimed at modifying driver behavior. At the tactical level, strategies focus on the optimization of existing resources. At the strategic level, fleet renewal is the principal strategy. Fleet renewal does not refer to incremental improvement to vehicles (an optimization of existing equipment – tactical level planning), but replacement of vehicles.

Fleet renewal would be considered strategic level planning due to barriers that can limit a business' services offered, especially if alternative fueled vehicles are considered. Due to the variety of players involved in the typical supply chain, the low number of fueling stations available for alternatively fueled vehicles, variation of tax incentives across the country, and the limited number of heavy-duty vehicles available, adoption of alternatively fueled heavy-duty vehicles has not been widespread outside of short-haul use in transit, garbage removal, and last-mile delivery (Cardwell & Krauss, 2013).

Despite these limitations, the current low-cost of natural gas due to hydraulic fracturing within the United States is pushing an expansion of the use of the fuel in the transportation sector (Cardwell & Krauss, 2013). The United States Energy Information Administration expects under ideal market conditions, natural gas vehicles could potentially account for 32 percent of heavy-duty vehicles by 2035, up from 0.2 percent in 2010 (U.S. Department of Energy, 2012a). Citigroup more aggressively forecasts that 30 percent of heavy-duty vehicles would run on natural gas by 2020. The comparative low-cost of alternative fuels has not only lead to customers pressuring transportation providers to investigate its usage, notably by Wal-Mart and Nike, but providers have begun to recognize the benefits as well (Cardwell & Krauss, 2013). United Parcel Service of America, Inc. (UPS), after extensive study, has announced plans to shift one billion vehicle miles to alternatively fueled vehicles by 2017, and to do so, it is purchasing natural gas long-haul vehicles, partnering with fuel providers to help build-out the natural gas infrastructure, and purchasing electric short-haul vehicles. UPS' chief sustainability officer indicated that the company expects to achieve a 40 percent cost reduction within its trucking fleet through these changes (Goossens, 2013).

Although natural gas has received much press due to hydraulic fracturing, a variety of alternatively fueled medium- and heavy-duty vehicles are currently in use in the United States. According to the United States Energy Information Administration, the following breakdown shown in Figure 20 below of alternatively fueled medium- and heavy-duty vehicles existed nationally in 2011, the year for which the most current data is available.

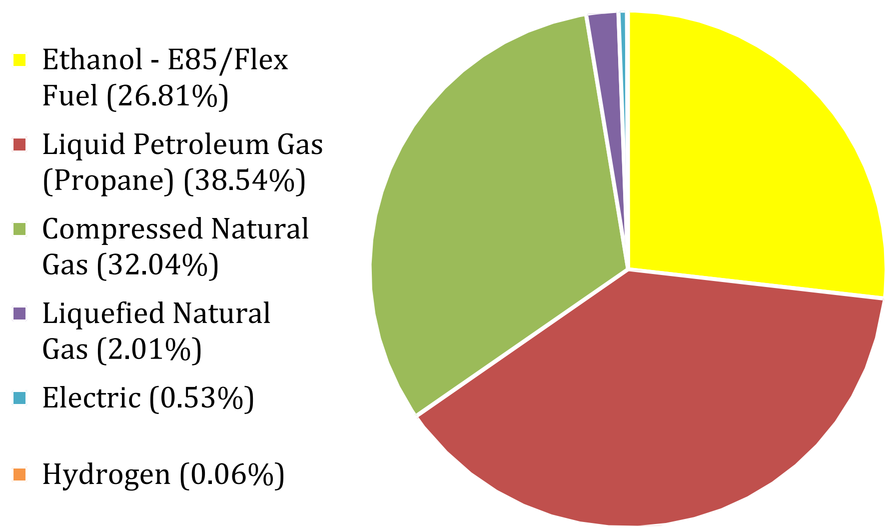


Figure 20 Alternatively Fueled Medium- and Heavy-Duty Vehicles by Fuel Type. Data adapted from How many alternative fuel and hybrid vehicles are there in the U.S.? by the US Energy Information Administration, May 16, 2013.

With growth in the usage of alternative fuels projected among medium- and heavy-duty vehicles, strategic level fleet replacement must be considered a practical possibility.

Concerning the tactical level, the optimization of existing resources, significant savings can be made. Tactical level decisions typically focus on two areas, dispatch and maintenance, and aim to eliminate unnecessary fuel consumption. Proper regular maintenance, such as proper tire inflation, using the recommended oil, and engine tune-ups can affect a vehicle's fuel economy up to 40 percent (U.S. Department of Energy, 2012b). Providing incremental retrofits to vehicles during regular maintenance can also result in improvements. For example, many long-haul truck drivers resting due to legal requirements idle their engines overnight to provide electricity, heating, and cooling at a cost of 685 million gallons per year. Equipping these vehicles with idle-reduction technologies like shore power connections during regular maintenance periods can reduce this consumption. Work-day idling, which typically occurs when drivers attempt to process paperwork, eat lunch, obtain loading dock assignments, wait for access to terminal facilities, wait for inspections, and during loading and unloading accounts for a cost of 2.49 billion gallons per year. To eliminate work-day idling, dispatch techniques can be employed. Wal-Mart utilizes drop-and-hook to eliminate delays associated with loading and unloading at its facilities, while gate scheduling and take-a-number systems allow for vehicles to be turned off while waiting for access to terminals due to the elimination of uncertainty of facility availability (Gaines, Vyas, & Anderson, 2006). Additional dispatch techniques such as route optimization have resulted in significant savings: UPS eliminated 63.5 miles of superfluous driving through route optimization techniques (U.S. Department of Energy, 2013m).

In order to examine the impact at both the tactical level and strategic level of techniques to reduce air pollution due to freight activity, traffic microsimulations were conducted of the Lamar Avenue Freight Corridor (U.S. Highway 78) utilizing Quadstone Paramics. Strategically, fleet renewal can be simulated as the vehicle types in the model can be changed. Tactically, dispatch decisions can be modeled through smoothing the medium- and heavy-duty demand on the network in order to simulate a constant arrival pattern at terminal facilities, thus avoiding congestion at the gate. Due to uncertainty regarding driver behavior, simulations at the operational level were not conducted. Subsequently, the travel data outputs were imported into the U.S. Environmental Protection Agency's Motor Vehicle Emission Simulator (MOVES) for evaluation. Modeled scenarios included the base scenario (no gate strategies, complete reliance on gasoline/diesel), adoption of gate strategies, and adoption of various alternative fueled vehicles (hydrogen, LNG, CNG, biodiesel, propane, E85 "Flex Fuel", and electric). Based upon the currently available alternative fuel stations in the Mid-South region and available medium- and heavy-duty vehicles, an attempt was made to simulate a typical mixed alternative fueled fleet serving the Memphis–area. Finally, a cost analysis was performed to assess the impact of each scenario, utilizing the methodology derived by Piecyk, McKinnon, and Allen with the Chartered Institute of Logistics and Transport (UK) (2012). In this way, the effectiveness of the implementation of strategic and tactical changes to improve air quality along the Lamar Corridor could be evaluated.

Methodology: Microsimulation of the Lamar Corridor

Traffic microsimulation allows the creation of a computer model of a selected element of transportation infrastructure and the simulation of roadway traffic at the microscopic level of detail, revealing the interactions of individual vehicles with one another and how they respond to the roadway network instead of an aggregated simulation of vehicle flows (PitneyBowes Software, 2014). Several types of traffic microscopic simulation software suites are available, including Quadstone Paramics, AIMSUN, INTEGRATION, VISSIM, TRANSIMS, CORSIM, and Synchro, many of which are able to integrate with some form of emissions modeling

(Chamberlin & Talbot, 2013). Ratrout and Rahman (2009) conducted an extensive comparison of various traffic microsimulation models in different applications and concluded that despite their differences, their variability did not prove substantial (as cited in Karafa, 2012). An existing Quadstone Paramics model of the Lamar Corridor area was selected for use as the

Figure 21 Aerial Views of the Quadstone Paramics Lamar Avenue Corridor Model.

basis for this research. This model, developed by, and used with permission from Dr. Mihalis M. Golais and Alireza Naimi from the University of Memphis, developed the model between 2010 and 2012 utilizing 2010 data from the Memphis Urban Area Metropolitan Planning Organization. The model utilizes three Origin-Destination (O-D) matrices derived from the Memphis Travel Demand Model for each vehicle class (cars, light-duty trucks, heavy-duty trucks) for the morning peak period (6:00 AM to 9:00 AM), the midday period (9:00 AM to 2:00 PM), the evening period (2:00 PM to 6:00 PM), and the overnight period (6:00 PM to 6:00 AM). These demands represent a typical weekday and there is no demand heterogeneity by income class, value of time, or trip purpose. It should be noted that two types of heavy-duty vehicles utilize the heavy-duty O-D matrix: Single Unit Long-Haul Trucks (OGV1 in Paramics), and

Combination Long-Haul Trucks (OGV2 in Paramics). Roadway geometry elements, traffic analysis zones corresponding to the O-D matrices, and traffic control elements (speed limits, traffic signals and their timings) all were entered into Quadstone Paramics and calibrated to ensure smooth operation. An aerial comparison of the model and the Lamar Corridor, showing the model's roadway network and the traffic analysis zones, is shown in Figure 21 with the Lamar Corridor highlighted in red.

It should be noted that while the location, geometry, and data of the Traffic Analysis Zones in the model do correspond with those of the US Census Bureau, they are numbered sequentially instead of utilizing the US Census Bureau numbering scheme.

Several changes were incorporated into the model prior to running the simulations for this project. First, as the data used in the generation of the model was from 2010, a growth factor was applied to ensure a valid representation of 2014 conditions. The growth factor was obtained from the Memphis Travel Demand Model documentation, which indicates expected growth in travel along the Lamar Corridor to occur at a rate of 2.2 percent per year (Memphis Urban Area Metropolitan Planning Organization, 2012). However, as data was unavailable to validate the model for future years, only the 2010 scenario was completed, as the O-D matrices were known to be correct. Second, the initial model did not incorporate any elevation changes.

Elevation can have a significant impact on emissions: Boriboonsomsin and Barth (2009) found that passenger car fuel consumption can increase by 15 percent to 20 percent over level travel rates when subjected to rolling terrain while Zhang and Frey (2006) found that emissions can increase by over 40 percent on roads with a fractional grade greater than +5 percent (as cited in Wyatt, Li, & Tate, 2014). Wyatt, Li, and Tate (2014) utilized Light Detection And Ranging (LiDAR) with a Geographic Information System (GIS) to incorporate road grade into their traffic microsimulation and found that the Technical University of Graz's Passenger car and Heavy duty Emissions Model (PHEM) estimates of carbon dioxide emissions were improved to be between 80 percent and 110 percent of actual recorded emissions over the same roadway segment, leading them to stress the importance of including elevations in the microsimulation process (Wyatt, Li, & Tate, 2014). Elevations for the Quadstone Paramics model of the Lamar Avenue Corridor were obtained through Google Earth, which utilizes the NASA Shuttle Radar Topography Mission dataset, obtained through the utilization of high-resolution radar scanning of the earth during NASA Space Shuttle mission STS-99 (Ramirez, 2009). Finally, the Mean Target Headway and Generalized Cost Coefficients were modified in accordance with Quadstone Paramics guidelines developed by the University of Wisconsin Traffic Operations and Safety Laboratory for the Wisconsin Department of Transportation. The default Mean Target Headway is calibrated to British drivers and was adjusted to 0.90 seconds; the default Generalized Cost Coefficients only include a time coefficient of 1 and were set to 0.667 for time and 0.333 for distance (Wisconsin Department of Transportation, 2014). With these changes incorporated, the simulations were run for each period, and a separate Vehicle Trajectory File was generated for every second of simulation time, revealing each vehicle's position, grade, instantaneous velocity, and instantaneous acceleration on the network. As only the Lamar Avenue Corridor is being studied, the Vehicle Trajectory Files were filtered to only include data from the links along the corridor.

Model: U.S. Environmental Protection Agency MOVES

There has been a recent trend to couple emissions models with microscopic transportation models due to the much more detailed level of analysis allowed by examining dynamic vehicle operations over a given series of timestamps (Malone & Chamberlin, 2011). While Quadstone Paramics does include an emissions modeling plugin and can easily interface with several other emissions models, the decision was made to utilize the U.S. Environmental Protection Agency's Motor Vehicle Emissions Simulator (MOVES) despite a lack of interoperability or support by either software development group.

MOVES analyses can be conducted at three different scales: the national-level; the county- level, used for emission inventory analysis for transportation conformity under the Clean Air Act; and the project-level, used for detailed carbon monoxide (CO) and particulate matter (PM) analysis of specific segments of a roadway network. Each level of analysis requires increasingly detailed inputs regarding vehicle activity. The use of MOVES has been mandated for CO and PM analysis at the project-level since December 2012 for any project that receives federal funding, any project that impacts or increases the travel of a significant number of diesel vehicles, any project that affects intersections operating at Level-of-Service (LOS) D or worse, any project that includes a bus or rail terminal due to the congregation of diesel vehicles, or any project that includes a previously identified problematic area (Malone & Chamberlin, 2011; U.S. Environmental Protection Agency, 2012b).

There are several elements regarding the Lamar Avenue Corridor that would indicate that the utilization of MOVES is appropriate. A study of the Lamar Avenue Corridor by the University of Memphis in 2009 found that many of the intersections were already operating at Level-of-Service D or worse at various times of day, as shown by Figure 22 below (Cambridge Systematics, Inc., 2011).

Intersection	a.m. (7:30-8:30)	Lunch (11:30-12:30)	Midday (2:30-3:30)	p.m. (4:30-5:30)	Average
Lamar at American Way	C	C	D	F	D
Lamar at Pearson	B	D	B	B	C
Lamar at Democrat	C	E	B	B	C
Lamar at Knight Arnold	B	C	B	C	C
Lamar at Winchester	F	F	F	F	F
Lamar at Concorde	E	B	A	B	C
Lamar at Shelby	F	F	F	F	F
Lamar at Tuggle	E	F	A	B	D
Lamar at Holmes	F	E	E	F	F
Average	**D**	**D**	**C**	**D**	**D**

Figure 22 Average Level-of-Service at Lamar Avenue Corridor Intersections in 2009. Adapted from Lamar Avenue Corridor Study, by Cambridge Systematics, Inc., 2011. Copyright 2011 Tennessee Department of Transportation. Public domain.

Additionally, the BNSF Railway Memphis Intermodal Facility is located near the intersection of Lamar Avenue and Shelby Drive. The presence of this facility and many other smaller freight and logistics facilities in the area attract a high level of diesel truck traffic along the Lamar Avenue Corridor. Finally, the Lamar Avenue Corridor was previously identified as a problematic area regarding livability with the U.S. Housing and Urban Development and the U.S. Department of Transportation funding the Aerotropolis/Lamar Corridor Initiative in 2010, though not specifically due to emissions (Daniels & Meeks, 2010). Despite conducting a study for the Tennessee Department of Transportation regarding capacity along Lamar Avenue, Cambridge Systematics, Inc. (2011) did not utilize MOVES for an emissions estimate, but applied the Federal Highway Administration's Highway Economic Requirement System's pollution impact estimates, which are based upon data from the U.S. Environmental Protection Agency's superseded MOBILE6 model (Cambridge Systematics, Inc., 2011; Federal Highway Administration, 2005). Additionally, no project-level analysis of the Lamar Avenue Corridor has been completed, but such an analysis would provide valuable information related to construction of any of the Tennessee Department of Transportation's proposed capacity improvements on Lamar (Christopher Boyd, personal communication, October 23, 2014). These factors indicate that the utilization of MOVES is an appropriate choice for modeling the Lamar Avenue Corridor. In order to ensure compliance with the future conformity targets, the recently released MOVES2014 was selected over MOVES2010b.

On the project-level, a MOVES analysis can only be conducted for a single hour of activity. As four time periods are being modeled in Quadstone Paramics, a single hour was selected for modeling in MOVES in the middle of each period. This allowed traffic flows to be fully formed and as the O-D matrices were the same for each hour within the period, the data collected would be consistent. There are three methods whereby the Vehicle Trajectory Files could be incorporated into MOVES for analysis: Average Speed, Link Drive Schedule, and Operating Mode Distribution (Chamberlin & Talbot, 2013). The Average Speed method aggregates the calculated average speed of each vehicle over a given roadway link and MOVES utilizes assumptions regarding vehicle activity (deceleration, acceleration, etc.) to generate an emissions output (Chamberlin & Talbot, 2013). However, this methodology would not provide accurate emissions estimates as vehicle activity can vary greatly from vehicle to vehicle over the same link, yet the vehicles can still have the same average speed (Barth, et al., 2000).

Additionally, idling is underrepresented, as the average speed will never equal zero unless all vehicles on the same link are idling (Zhao & Sadek, 2013). The Link Drive Schedule method utilizes a k-means clustering algorithm to cluster similar vehicle trajectories together (Chamberlin & Talbot, 2013). The generated aggregation of similar trajectories is then simulated in MOVES across each link for each cluster, a potentially computationally intensive process if a large number of vehicle clusters are obtained (Zhao & Sadek, 2013). With both the Average Speed and Link Drive Schedule methods, MOVES internally determines an Operating Mode Distribution, or percentage of time that each vehicle is operating in various modes (idling, accelerating, etc.) (Chamberlin & Talbot, 2013). However, the Operating Mode Distribution method allows a user-defined Operating Mode Distribution to be entered. Through the utilization of second-by-second vehicle trajectories, this may be done accurately. When comparing the three methods, Chamberlin and Talbot (2013) found that the Operating Mode Distribution method to be similar to direct measurements, while the Link Drive Schedule method underestimated emissions by 5 percent and the Average Speed method over estimated emissions by 10 percent to 20 percent.

Data pre-processing was necessary to incorporate MOVES into this methodology. For an in-depth description of the pre-processing methodology, please see Mersereau, 2014. In order to validate the modeling process, model results should be compared with data obtained from the Memphis and Shelby County Health Department's Pollution Control Section as it is the responsible party for emissions modeling and monitoring within the Memphis Urban Area

Metropolitan Planning Organization jurisdiction. However, the Memphis and Shelby County Health Department's Pollution Control Section has neither completed a project-level analysis of the Lamar Avenue Corridor nor obtained any field data by which such a model could be validated (Christopher Boyd, personal communication, October 23, 2014).

Scenarios

In addition to the existing conditions scenario, two other scenarios were modeled for comparison: the adoption of extended hours and the adoption of alternative-fueled vehicles. Multiple estimates peg the adoption of alternative fuels between 15 percent and 30 percent by 2035 (BP p.l.c., 2014; Cardwell & Krauss, 2013; U.S. Department of Energy, 2012a; U.S. Department of Energy, 2014f). The variation is due to uncertainty regarding fuel pricing and future public policy incentives to encourage adoption, and many of the higher adoption rates are resultant of models that see aggressive adoption rates while the lower adoption rates result from oil-industry projections (Plumer, 2013). As a result, a 20 percent market adoption of alternative fueled vehicles was selected, with the composition of the fleet being derived from the 2011 alternative-fueled vehicle population, eliminating hydrogen vehicles as there is no hydrogen infrastructure in the Memphis region (U.S. Department of Energy, 2014a; U.S. Energy Information Administration, 2013). The fuel usage by vehicle type for the alternative-fueled vehicle scenario is presented below in Table 18. Biodiesel was not included as there is insufficient data regarding the number of diesel vehicles that exclusively utilize biodiesel as a fuel.

Table 18 Alternative Fuel Scenario

Fuel	Passenger Car	Light Commercial Truck	Single Unit Long-Haul Truck	Combination Long-Haul Truck
E85 (%)	15.931	15.931	9.251	0.092
Propane (%)	1.491	1.491	5.726	10.412
CNG (%)	1.283	1.283	4.977	8.362
LNG (%)	0.003	0.003	0.028	0.909
Electricity (%)	1.292	1.292	0.019	0.225

Note. Adapted from *How many alternative fuel and hybrid vehicles are there in the U.S.?* by the U.S. Energy Information Agency, 2013. Copyright 2013 by the U.S. Energy Information Agency. Public domain.

Unfortunately, MOVES does not incorporate many of these vehicle/fuel combinations due to insufficient data. In order to address this, instead of running a single MOVES simulation with 20 percent of the vehicles running on alternative fuels, two separate simulations were run: one composing of 80 percent of the vehicles being run on gasoline and diesel in their normal conditions, and another composing of 20 percent being run on either gasoline or diesel, where each vehicle type is only run on one type of fuel. This allows for shares of the resultant emissions by vehicle type, corresponding to the alternative fuel fleet shares by vehicle type, to be converted to alternative fuel emissions utilizing the conversion rates contained within the Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) Tool developed by the Argonne National Laboratory and the U.S. Department of Energy. AFLEET is intended for fleet managers and stakeholders in the U.S. Department of Energy's Clean Cities program to compare lifetime costs, well-to-wheel and on-road emissions, and fuel use by light-, medium-, and heavy-duty vehicles powered by both traditional and alternative fuels. To estimate on-road emissions, AFLEET incorporates MOVES data for traditionally fueled vehicles and U.S. Environmental Protection Agency engine certification data for alternatively-fueled vehicles (Argonne National Laboratory, 2013).

The implementation of extended gate hours was based upon expectations of the Ports of Los Angeles and Long Beach's PierPASS extended hours program. Though exceeded, the initial measurement for success of the PierPASS program was a 15 percent to 20 percent of truck traffic shifted to night or weekend hours during the first year of the program's implementation (Federal Highway Administrations, 2013). Based upon this level of acceptable first-year usage, 17.5 percent of truck traffic was shifted to the daytime periods by manipulating the truck O-D matrices. It should be noted that the types of trucks shifted were the Single Unit Long-Haul Trucks and Combination Long-Haul Trucks, as Light Commercial Trucks are smaller and utilized for last-mile services that typically occur during the daytime.

Results and Discussion

The simulations of the existing conditions and extended hours scenarios in Quadstone Paramics generated a cumulative 28,800 separate vehicle trajectory files that had to be filtered to separate out Lamar Avenue Corridor data. These vehicle trajectory files included information about each vehicle traveling on the network at each second, including instantaneous speed, acceleration, and grade. Based upon the simulation outputs, the statistics about each representative hour from each simulated period presented in Table 19 were obtained.

Table 19 Quadstone Paramics Lamar Corridor Representative Hour Simulation Statistics

Period	Scenario	Number of Vehicles	Average Speed (mph)	Data Points
AM Peak	Existing Condition	14,082	21.16	**2,617,334**
Midday	Existing Condition	10,929	30.62	**1,269,259**
PM Peak	Existing Condition	14,104	15.66	**2,617,056**
Overnight	Existing Condition	3,990	34.86	**425,363**
AM Peak	Extended Gates	13,766	25.79	**2,150,995**
Midday	Extended Gates	11,284	30.50	**1,364,141**
PM Peak	Extended Gates	13,975	15.90	**2,266,514**
Overnight	**Extended Gates**	**4,068**	**35.23**	**439,783**

Despite modifying the O-D matrices to reduce the number of trucks on the network during the daytime periods in the extended gates scenario, the number of vehicles traveling the Lamar

Avenue Corridor increased during the midday period. This possibly occurred due to vehicles being routed over the Lamar Avenue Corridor that had not been during the existing condition scenario. Despite the increase of 335 vehicles, the average speed only dropped 0.39 percent - representing the largest change in number of vehicles traveling the Lamar Avenue Corridor and the smallest change in average speed. When examining the change in types of vehicles utilizing the corridor during this period, the new vehicles traveling the corridor are all either Passenger Cars or Light Commercial Trucks, vehicles types that retained their original O-D matrices in the Extended Gates scenario, indicating the increase is due to new routings.

The MOVES analysis of the Existing Condition scenario could be utilized to validate the modeling process. For the Existing Condition Scenario, the results for emissions of carbon monoxide (CO), particulate matter smaller than 10 μm in diameter (PM_{10}), and particulate matter smaller than 2.5 μm in diameter ($PM_{2.5}$) are given in Figure 23 and Figure 24.

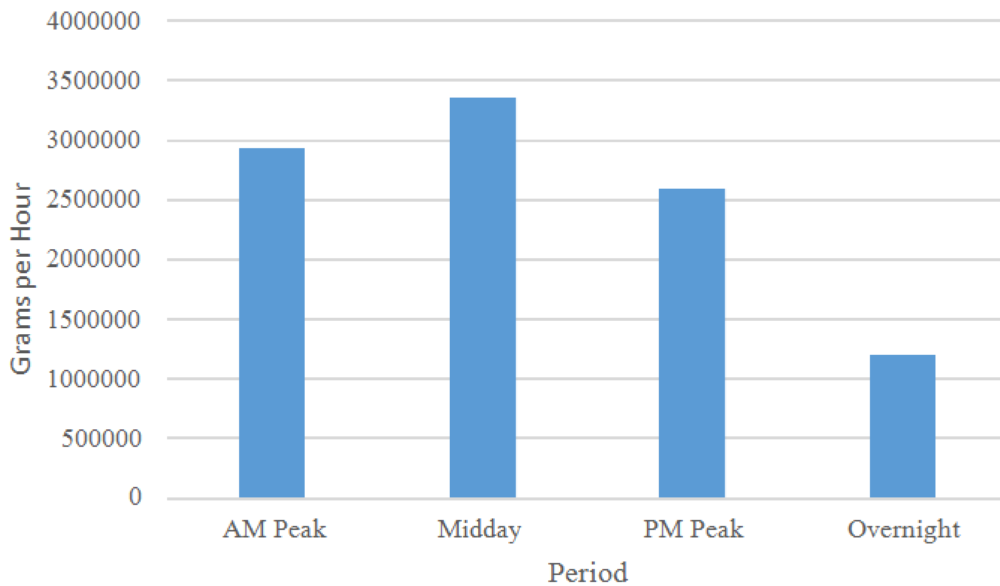


Figure 23 Carbon Monoxide Emissions Produced during the Existing Condition Scenario.

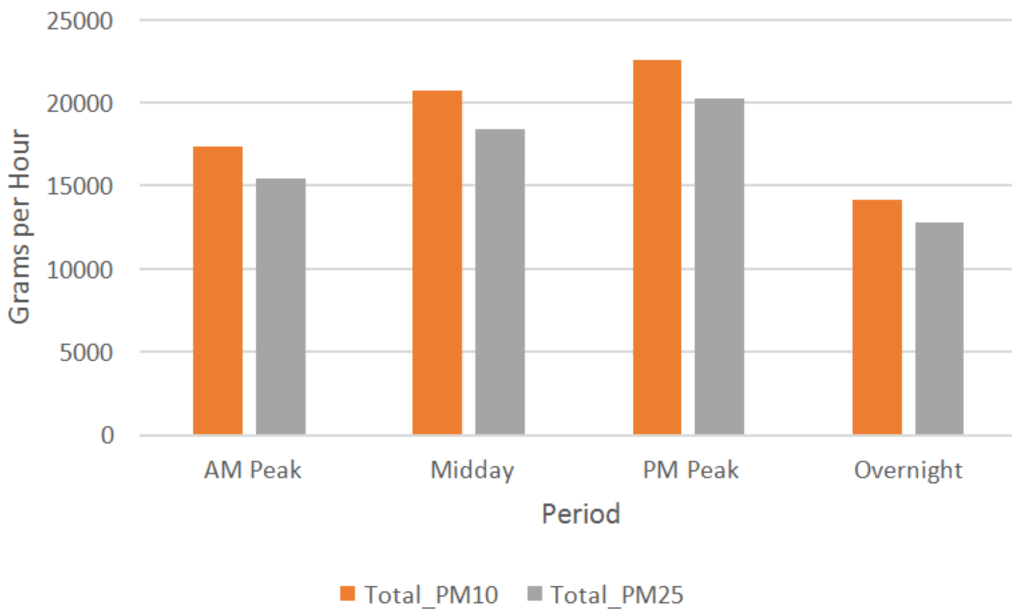


Figure 24 Particulate Matter Emissions Produced during the Existing Condition Scenario.

Unfortunately, the Memphis and Shelby County Health Department's Pollution Control Section, responsible for emissions monitoring and modeling for the Memphis Urban Area Metropolitan Planning Organization, has neither conducted emissions monitoring along the Lamar Corridor, nor conducted a MOVES analysis of the Lamar Corridor in order to compare the results to for validation (Christopher Boyd, personal communication, October 23, 2014). However, 2010 emissions data exists for heavy-duty trucks serving the Ports of Los Angeles and Long Beach, and by comparing the Existing Condition scenario truck traffic to that data, the order of magnitude of the Lamar Corridor emissions may be validated. A comparison of the 2010 Ports of Los Angeles and Long Beach and Lamar Corridor heavy-duty truck traffic is presented below in Table 20.

Table 20 Comparison of Heavy-Duty Truck Emissions at the Ports of Los Angeles and Long Beach with the Lamar Avenue Corridor

Pollutant	Ports of Los Angeles and Long Beach	Lamar Corridor
CO	352 short tons/year	219 short tons/year
PM_{10}	30 short tons/year	19 short tons/year
$PM_{2.5}$	27 short tons/year	18 short tons/year

Note. Adapted from "Reducing truck emissions at container terminals in a low carbon economy: Proposal of a queueing-based bi-objective model for optimizing truck arrival pattern," by G. Chen, K. Govindan, and M. M. Golias, August 2013, in *Transportation Research Part E: Logistics and Transportation Review*, *55*. Copyright 2013 by Elsevier Ltd. Adapted with permission.

Table 20 indicates that the Lamar Corridor emissions are on the correct magnitude, and as expected due to the comparative volumes, less than those produced at the Ports of Los Angeles and Long Beach.

Through comparing the MOVES outputs from the Existing Condition and Extended Gates scenarios, the effect on emissions along the Lamar Avenue Corridor of implementing extended hours at the gates may be determined. The results are presented below in Figure 25, Figure 26 Figure 27, and Table 21 comparing CO emissions, PM10 emissions, and PM2.5 emissions.

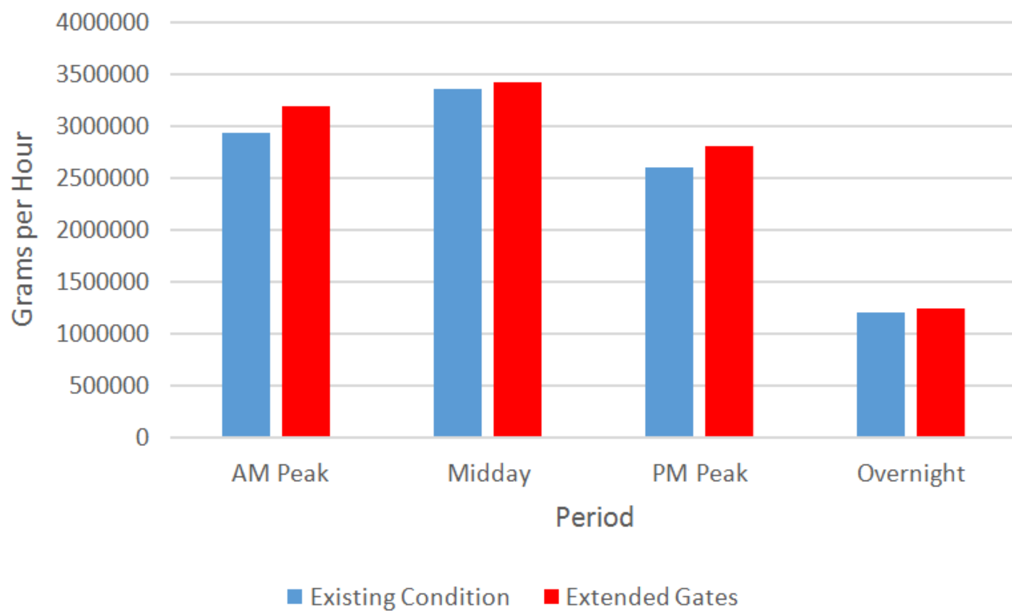


Figure 25 Carbon Monoxide Emissions along the Lamar Avenue Corridor in the Existing Condition and Extended Gates Scenarios.

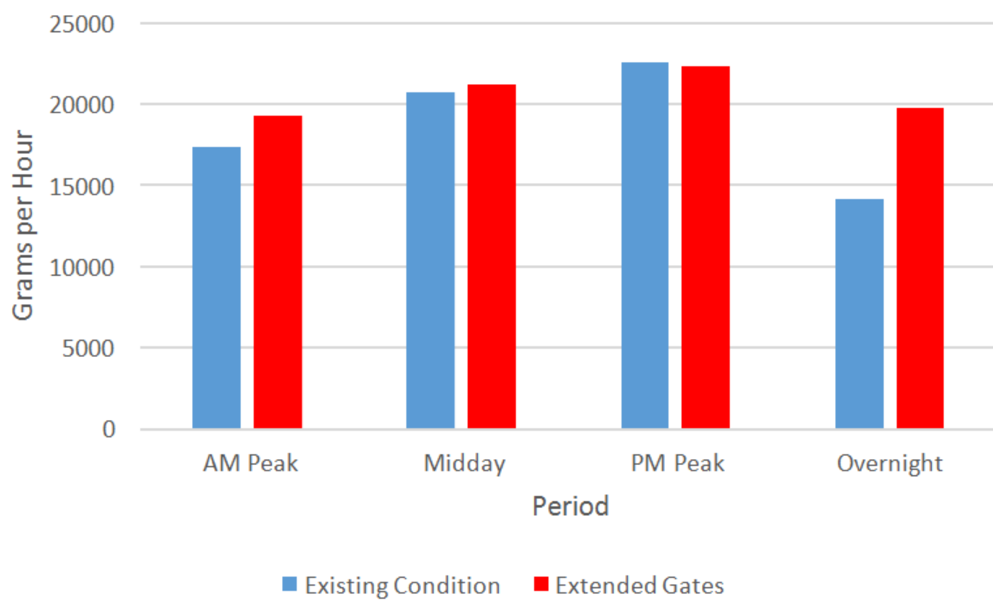


Figure 26 PM10 Emissions along the Lamar Avenue Corridor in the Existing Condition and Extended Gates Scenarios.

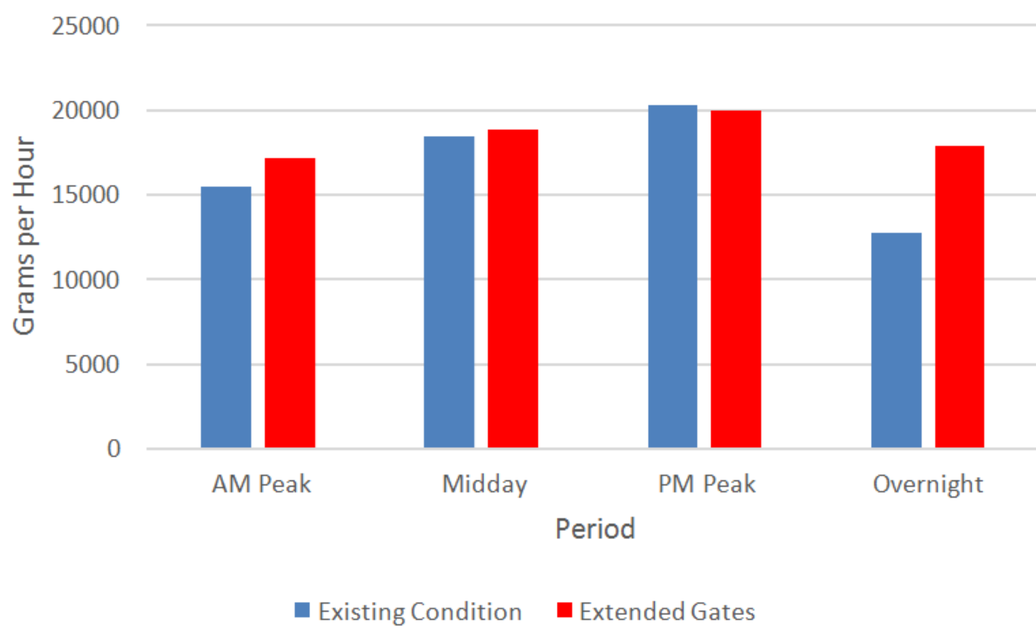


Figure 27 PM2.5 Emissions along the Lamar Avenue Corridor in the Existing Condition and Extended Gates Scenarios.

Table 21 Percent Change per Period between the Existing Condition and Extended Gates Scenarios

Period	CO	PM_{10}	$PM_{2.5}$
AM Peak	8.59%	10.93%	10.92%
Midday	1.99%	2.09%	2.12%
PM Peak	7.90%	-1.16%	-1.42%
Overnight	2.18%	39.12%	39.94%

PM emissions increased during every period except during the PM peak period. As the number of trucks on the network increases during each daytime period and given that diesel truck traffic is the greatest contributor to PM emissions, shifting trucks to the overnight period would have the greatest effect on the PM peak period. CO emissions increased during every period as well. This can be explained by comparing the Operating Mode Distributions. In 57 percent of the bins where the engine is applying power, activity increased in the Extended Gates scenario. Reexamining the equation for Vehicle Specific Power, VSP, where

$$VSP = \left(\frac{A}{M}\right)v + \left(\frac{B}{M}\right)v^2 + \left(\frac{C}{M}\right)v^3 + (a + g \times \sin\theta)v$$

the first term accounts for rolling resistance and increases linearly with speed, the second term accounts for rotating resistance and increases exponentially with speed, the third term accounts for aerodynamic resistance and increases exponentially with speed, and the fourth term accounts for acceleration and road grade and increases linearly with speed. As such, it is intuitive that as speeds increase on the network, the power being applied by each vehicle would also increase, thereby producing more emissions. This indicates that shifting 17.5 percent of truck traffic to the overnight period does not reduce traffic enough on the Lamar Corridor to offset corresponding emissions increases. While the target established by the Ports of Los Angeles and Long Beach for shifting 15 percent to 20 percent of daytime truck traffic during the first year of the PierPASS program was used as a basis for this study, it appears that in the case of the Lamar Avenue Corridor, a shift of this amount of truck traffic is too low to reduce emissions (Federal Highway Administrations, 2013). While Karafa (2012) showed that emissions at freight terminals themselves can be reduced through gate strategies that reduce the number of vehicles waiting for service at the facilities, it appears that implementing such strategies may have an adverse effect on emissions along the corridor serving said facilities, especially if the corridor serves a mix of traffic types. It is important to note that the Quadstone Paramics model did not incorporate the facilities themselves, so any emissions benefit or drawback at the facility gates are not included.

While the implementation of extended gate hours and shifting 17.5 percent of truck traffic to overnight operations was unsuccessful at reducing emission along the Lamar Avenue Corridor, the utilization of alternative fuels by 20 percent of the vehicle fleet was able to lower emissions. These reductions are shown in Figure 28 Figure 29, Figure 30, and Table 22 for CO emissions, PM_{10} emissions, and $PM_{2.5}$ emissions.

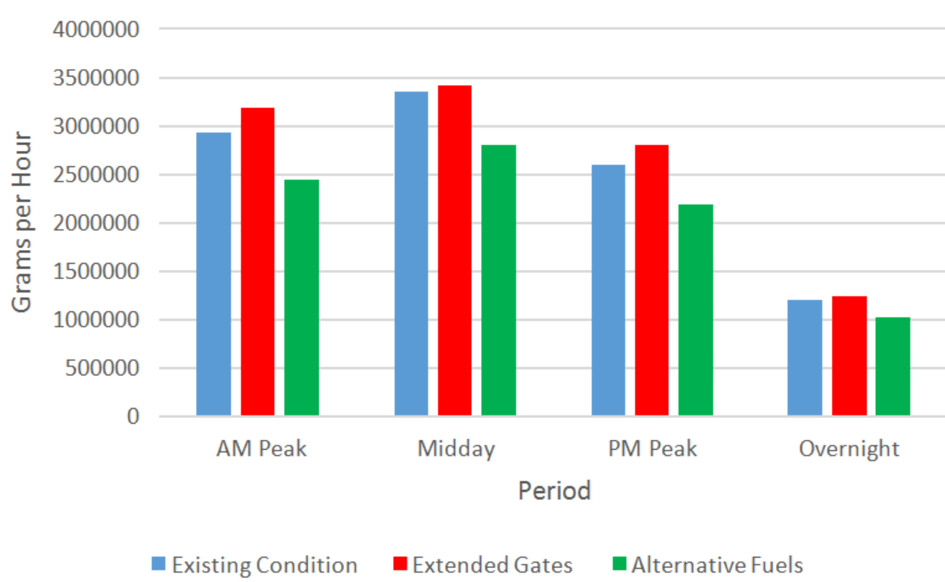


Figure 28 Carbon Monoxide Emissions along the Lamar Avenue Corridor in All Scenarios.

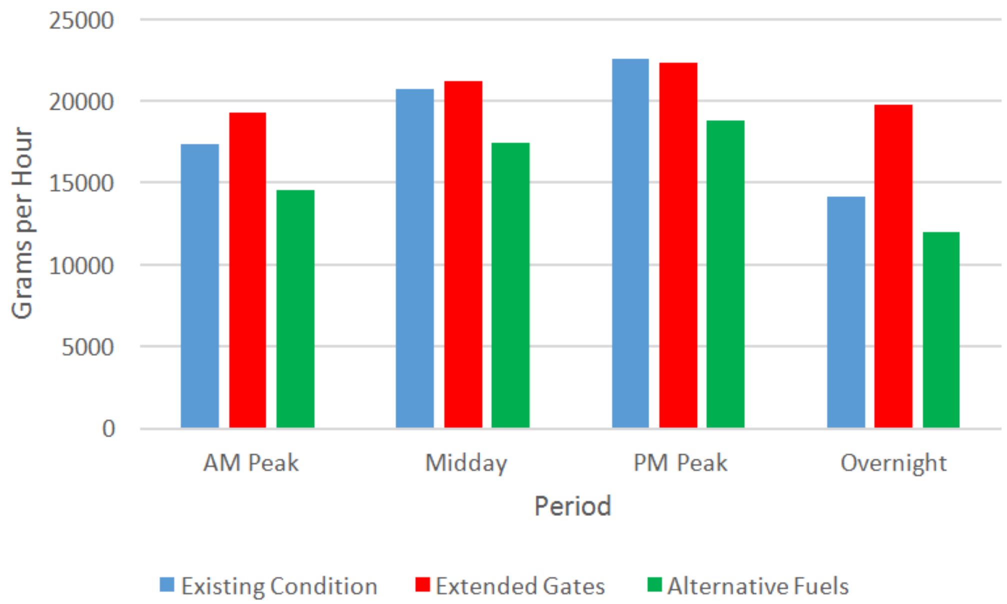


Figure 29 PM10 Emissions along the Lamar Avenue Corridor in All Scenarios.

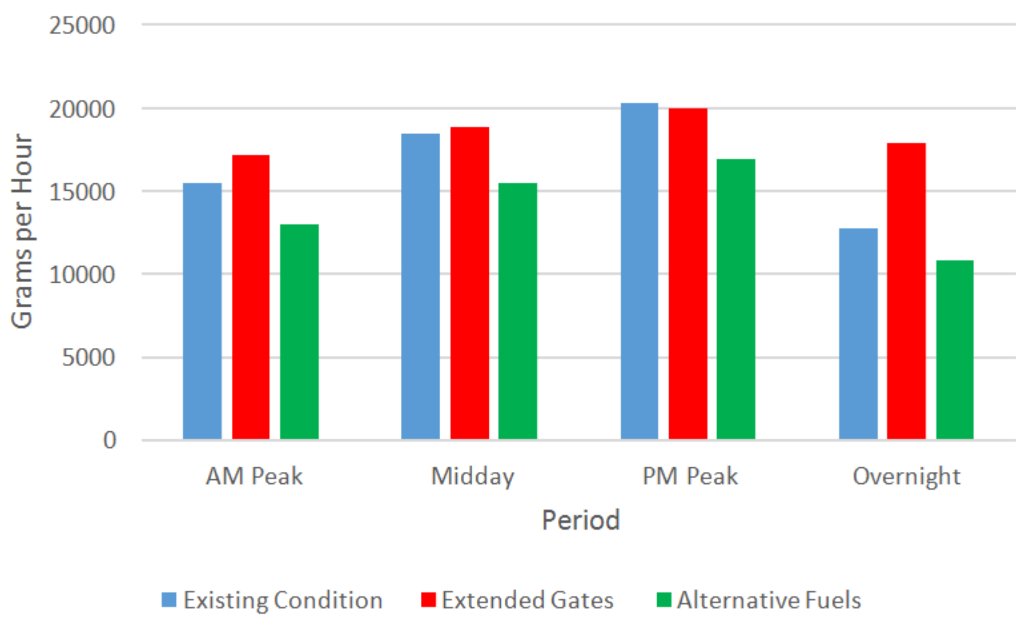


Figure 30 PM2.5 Emissions along the Lamar Avenue Corridor in All Scenarios.

Table 22 Percent Change per Period between the Existing Condition and Alternative Fuels Scenarios

Period	CO	PM_{10}	$PM_{2.5}$
AM Peak	-16.57%	-16.20%	-16.17%
Midday	-16.56%	-16.11%	-16.07%
PM Peak	-15.89%	-16.55%	-16.54%
Overnight	-15.57%	-16.56%	-15.62%

When strictly comparing heavy-duty truck emissions, heavy-duty trucks produce 9.90 percent more CO emissions, but 17.17 percent fewer PM_{10} emissions and 17.18 percent fewer $PM_{2.5}$ emissions. The increases in CO emissions result primarily from E85, Propane, and CNG applications. In the case of E85, the entire well-to-wheel process must be considered in order for an emissions reduction to be evident, as the carbon emission is balanced by the carbon absorption during photosynthesis when the feedstock crops are grown (U.S. Department of Energy, 2014f). Propane primarily also only offers benefits when considering life-cycle emissions, typically on the magnitude of 10 percent (U.S. Department of Energy, 2013l). In the case of CNG, CO is indicated by the U.S. Department of Energy to be an emission of primary concern (2013j).

Although benefits are observed when alternative fuels are utilized, as a strategic-level freight planning decision, the practicality for these fuels to be utilized must also be considered. Future work should include a market penetration analysis of alternative fuels must also be considered. For this study, the lack of hydrogen infrastructure in the Memphis region excluded it as a viable alternative fuel, thus not included in the modeling process. While a limited refueling infrastructure does exist for other alternative fuels, not all trips are possible. Assuming a maximum one-way vehicle range of 150 miles to allow for a return trip on a single tank, similar to Melania, Bremson, and Solo (2013), the range of trips possible with one refueling stop were plotted in Esri ArcGIS utilizing known station locations and the buffer tool, and propane was found to allow for the greatest range of trips and have the greatest station density. It should be noted that E85 capable vehicles can typically also run on gasoline and biodiesel and traditional diesel may also be interchanged. Major metropolitan areas that are accessible in a propane-fueled vehicle with one refueling stop include Jackson, Mississippi, Monroe, Louisiana, Little Rock, Arkansas, Nashville, Tennessee, Chattanooga, Tennessee, Huntsville, Alabama, and Birmingham, Alabama.

The modeling process accomplished three major tasks: completing the first project-level MOVES analysis of the Lamar Avenue Corridor; examining the effect of implementing extended gate hours on corridor emissions where previous studies had focused on the effects at the terminals served by the corridor; and studying the effect of the use of alternative fuels at a level of adoption probable by 2030 (BP p.l.c., 2014; Cardwell & Krauss, 2013; U.S. Department of Energy, 2012a; U.S. Department of Energy, 2014f).

Generally, emissions along the Lamar Corridor were found to increase under the implementation of extended gate hours and decrease with the utilization of alternative fuels. In order to quantify each scenario's impact on livability in the area, the externalized healthcare costs of the emissions studied are presented in Table 23 utilizing costs developed by Piecyk, McKinnon, and Allen with the Chartered Institute of Logistics and Transport (UK) (2012).

Table 23 External Healthcare Costs of Emissions Modeled Along the Lamar Avenue Corridor

Pollutant	Existing Condition Scenario ($/year)	Extended Hours Scenario ($/year)	Alternative Fuel Scenario ($/year)
CO	$722,136.31	$753,991.66	$605,604.94
PM_{10}	$21,959,413.35	$25,830,312.74	$18,447,353.17
$PM_{2.5}$	$19,673,180.19	$23,212,798.74	$16,525,507.30
Total	$42,354,729.85	$49,797,103.15	$35,578,465.41

The costs to the healthcare system in every scenario are significant, and equate to roughly the costs associated with 12 to 17 deaths from respiratory disease per year. Despite these costs being developed in the United Kingdom, the impact of particulate matter is significant and it is clear why the U.S. Environmental Protection Agency considers particulate matter to be one of the two most harmful pollutants to human health (2011).

Future use of the data produced must take into account the assumptions that were made in the methodology, namely: no projections for fluctuation in demand on the network were made beyond shifting 17.5 percent of truck activity to the overnight period; it is assumed that facilities in the area would be able to operate extended hours; and national datasets from the U.S. Environmental Protection Agency were utilized for fuel chemistry, ratio of diesel to gasoline usage for each vehicle type, and vehicle age where local data would be desirable for more accurate results. However, given these assumptions, it is possible that refinement of the results is possible by incorporating more data.

Conclusions

In an effort to better understand the contributing factors for livability, the barriers to livability, and the impact freight traffic has on livability for a community, this multifaceted project was designed to establish a framework for investigating these concepts. The following research questions were considered to examine issues related to livability for communities, and in particular to understand the impact of freight:

- What factors are important for community livability?
- Are the priorities and barriers to livability different between freight-centric (FC) communities and non-freight-centric (NFC) communities?
- Does freight have a significant impact on livability perceptions?

Furthermore, this research focused on addressing barriers to livability in freight-centric communities through the identification of alleviating technology and strategy-based methods that can mitigate barriers and enhance livability. Specifically, researchers examine the use of gate scheduling strategies and the use of alternative fuels and other practices to assess their effects on livability. To this end, the following research questions were considered for the case study area in Memphis, TN:

- What is the current state of operations and functionality of the freight transportation system?
- How do freight movements impact livability within the region from the industrial perspective?
- Do industries surrounding the Lamar Corridor currently employ strategies or technologies that promote the livable priorities of the community?

Project Introduction and Literature Review

Key aspects of the literature review include means of measuring livability and how to identify success in achieving it. Any process of measuring the livability of an urban area should consider the variability of the local conditions (whether based in local perceptions or policy standards) in order to achieve validity (Miller et al., 2012). It is also important to note that there is a distinction between successes in sustainability of transportation systems and livability of communities; this may be achieved in the form of a final goal, or maintained as a continuous and constant track. Both pathway and policy perspectives, however, include the use of "indicators" to quantify effectiveness: whether environmental (carbon dioxide, nitrogen oxides, ozone, particulates, and noise emission regulations), social (safety measures and statistics), or economical (delivery, fuel consumption, or capacity rates related to efficiency). Indicators such as measure of fuel emissions, load quotas and capacities, traffic flow measurements, etc. may be compared across multiple communities, as long as a common base and evaluation method exists. When deciding on operational measures, it is important to keep in mind the current state of the problem for the specific location, and to keep multiple invested parties involved and educated. Additionally, it should be acknowledged that any decision may weigh differently among stakeholders.

The inherent problems (and related solutions) of high freight volumes within a community can be organized into three overlapping categories of last-mile/first-mile urban goods movement, environmental impact, and trade node (the most relevant category to this particular research).

The inherent problems (and related solutions) of high freight volumes within a community can be organized into three overlapping categories of last-mile/first-mile urban goods movement, environmental impact, and trade node (the most relevant category to this particular research). Table 24 summarizes techniques that may serve to improve hindrances to livability, specifically ones caused by an increased presence of freight traffic in a community (Giuliano et al., 2013). We use the Memphis MPO's Freight Infrastructure Plan to include a Memphis MPO Plan Score in our ranking of solutions. Methods currently recognized in the MPO Plan received a score of 1.

Following the results of the stakeholder surveys, a "Relevance to Lamar Freight-Centric Community" score was added to the "Success Rating" and "US Applicability Rating" proposed by Giuliano et al. The relevance factor applied was either a 0 or 1 based on whether or not the solution addresses an issue discussed in this study.

Based on the total score in the last column, the following table could help identify strategies that may be most appropriate to consider in further research on improving livability for the freight-centric community in Memphis based upon possibility of success, applicability, and policies currently in place. Two related strategies, gate appointments and fleet renewal, are specifically analyzed in this study.

Table 24 Mitigating Strategies with Effectiveness Rating and Applicability to Problem Type and the US - A Summary of Technology-Based or Strategy-Based Solutions to Treat Last Mile, Environmental Impact, and Trade Node Problems (Giuliano et al., 2013; Memphis M

Type of Freight Problem	Description of Solution	Success Rating	US Applicability Rating	Memphis MPO Plan Score	Relevance to this FC Community	Total Score
Last-mile	Labeling or other certification programs	3	3	0	1	7
	Traffic and parking regulations	2	3	1	1	7
	Land use planning policies	3	3	1	1	8
	City logistics and consolidation schemes	1	1	1	0	3
	Off-hours deliveries	3	2	0	0	5
	Intelligent transport systems	2	2	1	1	6

Environment	Truck fuel efficiency and emissions standards	3	3	0	1	7
	Alternative fuels and vehicles	1	2	0	1	4
	Low emission zones	3	1	0	1	5
	Alternative modes	1	1	1	1	4
Trade node	Appointments and pricing strategies at ports	2	3	0	0	5
	Road pricing to manage hub-related truck traffic	3	1	1	1	6
	Accelerated truck emissions reduction programs	3	2	0	1	6
	Equipment management	2	2	0	0	4
	Rail strategies	2	2	0	1	5
	Border crossings	2	3	1	0	6

Surveys: Residential, Industrial, and Policy Maker Perspectives
The impact of freight on livability was explored from the residential, industrial, and policy maker perspectives through the dissemination and analysis of four survey instruments. The difference between freight-centric (FC) and non-freight-centric (NFC) communities was also examined. While both FC and NFC residents recognize similar factors important for, and barriers to, livability of a community, FC residents are impacted significantly by freight externalities, and this alters their perceptions of livability in their respective neighborhoods. In terms of livability, the analytic hierarchy process (AHP) is a valuable tool as it can analyze multi-criteria for many stakeholders allowing results to reflect each community's characteristics and circumstances (Hai-Yan & Xun-Gang, 2012). While the FC community targeted here was well established, this technique can be used in emerging freight communities such as those where inland ports are being sited. This technique would be helpful in looking at livability disparities within cities and help planners formulate holistic approaches that address barriers so that all neighborhoods can be vibrant places to live and work.

Industry stakeholders indicate the freight-centric aspect (multimodal infrastructure and access to key markets in 24 hours) of the community as the key reason for site selection. Industry respondents rated the Lamar Avenue Corridor facilities as being in generally good condition, and echoed perspectives of residential stakeholders related to safety/security issues and pavement conditions. Traffic congestion was cited as the most significant barrier to both livability and productivity, and nearly 50 percent of industry respondents indicate they use ITS systems to try to alleviate this barrier. Fewer (approximately 20 percent) indicated they use operational strategies to try to reduce the negative effects of traffic congestion. More than 35 percent of industry participants believe they have achieved positive results from the use of these technologies or strategic approaches in terms of productivity.

Policy makers also highlighted congestion as a significant barrier to livability for the Lamar Avenue study area. Policy respondents also recognized the potential for technologic or strategic approaches to reduce barriers and improve livability.

Thus, responses demonstrate a range of perspectives, but generally indicate that the policy, residential, and industrial stakeholders recognize similar factors that influence livability in the Memphis/Lamar Avenue case study and recognize the potential that strategies to alleviate congestion may have on the community experience.

The Analytical Hierarchy Process is a valuable tool as it can analyze multi-criteria for many stakeholders allowing results to reflect each community's characteristics and circumstances *(Hai-Yan & Xun-Gang, 2012)*. While the freight-centric community targeted here was well established, this technique can be used in emerging freight communities such as those where inland ports are being sited. This technique would be helpful in looking at livability disparities within cities and help planners formulate holistic approaches that address barriers so that all neighborhoods can be vibrant places to live and work.

Improving Livability

A Comparison of Emissions-Reduction Strategies to Improve Livability in Freight-Centric Communities

The modeling process accomplished three major tasks: completing the first project-level MOVES analysis of the Lamar Avenue Corridor; examining the effect of implementing extended gate hours on corridor emissions where previous studies had focused on the effects at the terminals served by the corridor; and studying the effect of the use of alternative fuels at a level of adoption probable by 2030 (BP p.l.c., 2014; Cardwell & Krauss, 2013; U.S. Department of Energy, 2012a; U.S. Department of Energy, 2014f). Generally, emissions along the Lamar Corridor were found to increase under the implementation of extended gate hours and decrease with the utilization of alternative fuels. The Ports of Los Angeles and Long Beach sought to shift 15 percent to 20 percent of daytime truck traffic during the first year of the PierPASS program, and in the case of the Lamar Avenue Corridor, it appears that the shift of this amount of truck traffic may have been too low to reduce emissions (Federal Highway Administrations, 2013). While Karafa (2012) showed that emissions at freight terminals themselves can be reduced through gate strategies that reduce the number of vehicles waiting for service at the facilities, it appears that implementing such strategies may have an adverse effect on emissions along the corridor especially if the corridor serves a mix of traffic types. However, the Quadstone Paramics model utilized does not incorporate activity occurring at any terminals, so the increase in emissions along the Lamar Avenue Corridor may be balanced by the reduction of trucks idling in queue. Completing the same modeling process with the terminals included could be insightful. Additionally, shifting more trucks to overnight arrivals may reduce emissions along the corridor as the average speed along the corridor approaches the speed limit.

In order to quantify each scenario's impact on livability in the area, the externalized healthcare costs of the emissions studied are presented below (Table 25) utilizing costs developed by Piecyk, McKinnon, and Allen with the Chartered Institute of Logistics and Transport (UK) (2012).

Table 25 External Healthcare Costs of Emissions Modeled Along the Lamar Corridor

Pollutant	Existing Condition Scenario ($/year)	Extended Hours Scenario ($/year)	Alternative Fuel Scenario ($/year)
CO	$ 722,136.31	$ 753,991.66	$ 605,604.94
PM_{10}	$ 21,959,413.35	$ 25,830,312.74	$ 18,447,353.17
$PM_{2.5}$	$ 19,673,180.19	$ 23,212,798.74	$ 16,525,507.30
Total	$ 42,354,729.85	$ 49,797,103.15	$ 35,578,465.41

The costs to the healthcare system in every scenario are significant, and equate to roughly the costs associated with 12 to 17 deaths from respiratory disease per year. Despite these costs being developed in the United Kingdom, the impact of particulate matter is significant and it is clear why the U.S. Environmental Protection Agency considers particulate matter to be one of the two most harmful pollutants to human health (2011).

Future use of the data produced must take into account the assumptions that were made in the methodology, namely: no projections for fluctuation in demand on the network were made beyond shifting 17.5 percent of truck activity to the overnight period; it is assumed that facilities in the area would be able to operate extended hours; and national datasets from the U.S. Environmental Protection Agency were utilized for fuel chemistry, ratio of diesel to gasoline usage for each vehicle type, and vehicle age where local data would be desirable for more accurate results. Future studies should evaluate potential for market penetration of various fuels.

Recommendations for Future Research

While the results of this study provided valuable insight regarding factors important for and barriers to livability of communities as well as strategies with the potential to alleviate negative externalities of freight, the work was largely a pilot scale project and several limitations exist that reveal opportunities for future research.

More research is necessary to determine if the findings related to the Lamar Avenue Corridor in Memphis, TN can be applied to other FC communities. A major limitation exists in the limited number of responses received for the survey efforts for this study. The research related to livability quantification was conducted at the neighborhood-level however; exploration of a block-level approach may reveal heterogeneity that impacts metric scores. As the Memphis and Shelby County Health Department's Pollution Control Section, responsible for emissions monitoring and modeling for the Memphis Urban Area Metropolitan Planning Organization, has neither conducted emissions monitoring along the Lamar Avenue Corridor, nor conducted a MOVES analysis of the Lamar Corridor in order to compare the results for validation, no real-world emissions data for comparing the model outputs was available.

Future research recommendations are:

1. It is essential to identify better methods for community engagement that work for diverse members of a community. The key obstacle faced in this research was in obtaining participants in the project. Only 75 responses from people living within the freight-centric study are were obtained over the course of an entire year. Planning organizations and other government agencies (particularly Departments of Transportation) are constantly challenged with obtaining input on plans and projects from a representative sample of community stakeholders.
2. It is important to obtain a larger dataset to determine if differences (or not) identified through this project are representative of the larger Memphis and Lamar Avenue community. With a larger dataset, additional methodologies can be used to analyze the data and identify relationships between factors and perceptions of livability.
3. If a large enough sample size is obtained, there is value in investigating differences in responses and perceptions of community residents based upon gender, age, race, and other demographic data. Any differences may lead to recommendations regarding strategies for engagement, education, and approaches for addressing livability in ways that consider needs of all stakeholders.
4. Future research should also investigate freight-centric communities in other cities and states in order to determine if a common definition of and approach to measuring livability and community priorities is possible, or if these are community dependent. A national-level project should be conducted using both the residential stakeholder surveys and livability metric to determine whether or not the approach is transferrable. A formally defined framework for delineating freight-centric community boundaries should also be established.
5. Additional research should be conducted to determine if there should be development of different livability principles (or revised definitions of the existing) based on the environment being studied: urban, sub-urban, and rural. If consistent principles are to be used across settings, consideration should be given to establishing different measures, weights or thresholds for comparison for each principle based upon community setting.
6. Additional research is needed to determine if there are proxies for stakeholder perceptions (such as community crime data, transportation facility access, etc.) that can be used to establish a quantitative approach to assessing community livability.
7. Establishing a target for the quantity of trucks that needs to be shifted to achieve livability impact is a much-needed area of future research, as is identifying a means for obtaining emissions data for model validation. Additionally, better mechanisms for enforcing truck routes should also be explored.

8. Techniques for measuring disparity are needed.
9. Finally, though Chamberlin and Talbot (2013) showed that the Operating Mode Distribution method produces the most accuracy out of the three methods of conducing a project-level MOVES analysis, the method is computationally intensive at the corridor level. While Chamberlain and Talbot (2013) only focused on a single intersection in their study and Alam and Hatzopoulou (2014) focused only on bus traffic in their corridor study, neither incorporated the volume of data utilized here. The vehicle trajectory files output by Quadstone Paramics measured 11.9 GB of data that needed to be processed prior to entry into MOVES. The development of a more efficient method for study at the corridor level would also be desirable.
10. Indicators for freight–centric communities need to be developed. Recent advancement such as the EPA's EJSCREEN easily integrates air pollution indicators with environmental justice data to create indexes that help identify problem areas. Recently announced efforts by the Obama Administration target reducing C02 emissions by 26 percent by 2030 will mean improvements in air quality for last-mile residents. New rules will target trucks and planes.
11. The connection between health and freight is obvious as air pollution, noise, are the major externalities of freight. Indicators that reflect health outcomes would make a more compelling framework.

While this has been a pilot-scale study, the ultimate goal is to incorporate all recommendations above into a larger-scale study and then to integrate within this a measurement methodology that will provide a quantitative assessment of freight-centric communities using existing data related to influential factors affecting livability.

Contributions to research and practice

This research contributes to the understanding of livability, and particularly the role truck traffic plays on livability in communities. No known empirical studies have been completed that test livability in freight-centric and non-freight centric communities from a variety of stakeholder perspectives. Not only does the developed survey instrument contribute to research, but results from collected data contribute to both research and practice. The instrument can be replicated and adapted for use in other regions to improve the generalizability of findings in future studies beyond the Memphis, TN area.

In general, findings from survey data collection suggest that various stakeholder groups have similar perceptions regarding what factors influence livability, however, there are noted differences in perceptions of livability in communities with a significant presence of freight. These findings contribute to the body of knowledge for both livability and freight research. Findings also suggest there may be potential benefits to practitioners and decision-makers by considering different freight policies in the two types of communities in order to enhance livability.

Furthermore, a variety of alleviating technology and strategies were also examined and contribute to practitioner and researcher understanding of alleviating technology and strategy options in freight-centric areas. Simulation results contribute to the understanding for both research and practice on how technology, strategies and practices affect livability. Results from simulation of alternative fuel shifts for trucks alone show clear improvements to livability based on improved air quality. Simulations based on gate scheduling technology and strategy simulations did not garner expected results; however, these results still provide valuable implications for research and practice.

The presence of freight traffic in urban areas may yield significant regional economic benefits, but can also play a significant role in deteriorating livability of a local community. It is important for planning and other municipal officials to investigate options for improving quality of life for all residents. This is of particular importance in communities where externalities of freight lead to diminished experiences, and engagement of community stakeholders, while challenging, is critical for addressing these issues and improving livability. Developing a common understanding of livability among residents, planning, and transportation agency officials and a means for measuring this in a quantifiable and translatable way may be a first step in developing a means for increasing collaborative approaches to improving livability. As one means for developing a tool for exploring impact of freight on a community, a visualization was developed for the Lamar Corridor as part of this work, and is presented in Appendix A.

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Appendix A: Interactive Visualization – Living with Freight Project: Memphis

The research team wanted to explore the use of an interactive visualization to tell the story about freight-centric communities. A website was designed called Living with Freight Project: Memphis which consists of an ESRI Story Map Journal with embedded interactive maps. Users can explore objective indicators—indicators of the current conditions of Memphis and the neighborhoods bordering Lamar Avenue, as well as understand the freight landscape. The narrative talks about the interaction of Freight (Goods Movement), Livability, and Environmental Justice in Memphis.

Perceptions of the barriers to livability from the residential survey responses serve as the voice from the community.

While data is available at the census block for some type of data, neighborhood-level data to show disparity within a city is still unavailable. Crime data, a major barrier to livability, also is not readily available for Memphis.

The visualization as well as findings from this report helps the user wonder many questions from a freight, environmental justice, and livability perspective.

- Why is there only one EPA monitor near Lamar Avenue?
- What difference would it make to establish strategies – like low emissions zones—investigated in this report, unless crime is abated?
- Should schools be re-sited in light of freight?
- Should the city incentivize fleet renewal or adoption of natural gas in certain corridors?
- Why do we allow people to live near areas of high freight activity?

A copy of this report can be found on this website http://uw-mad.maps.arcgis.com/apps/MapJournal/?appid=090c0247e1384fcf8092e664670cb0f5

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