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FINAL REPORT

Improving Trip Generation Methods for Livable Communities

NITC-RR-757 ■ February 2017

NITC is the U.S. Department of Transportation's national university transportation center for livable communities.

IMPROVING TRIP GENERATION METHODS FOR LIVABLE COMMUNITIES

Final Report NITC RR-757

by

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16. Abstract Recent efforts to improve trip generation data available for transportation impact analysis of new development include the collection of multimodal trip generation data, development of models that account for the built environment, and new recommendations for practice. Building on a long line of research on transportation and built environment, many studies have identified important features of the surrounding built environment that most impact trip rates and mode shares, building on a long line of research on transportation and the built environment. Despite these improvements in data and methods, less attention is placed on identifying the conditions of the site itself and the immediate surrounding environment that influence trip generation and mode choice. To fill this gap, this study builds upon previous work (Contextual Influences on Trip Generation (Project Number: OTREC 2011-407), 2012), re-examines the information collected in that study, and includes new site-level observations. The objective of this study is to examine establishment multimodal trip generation more closely from a finer-grained scale and identify site-level attributes of the built environment that help explain multimodal trip generation. From this, we have the additional objective of developing a framework for trip generation analysis that takes findings from this study into consideration. We placed emphasis on those sites in our previous study with a discord between the expected travel patterns, based upon the larger urban context and built environment of the site, and the observed. The research approach will make use of mixed methods. In addition to using archived data from the previous study, site visits provided direct observation of the overall performance of the site, including travel patterns on and around the site as well as specific site configuration, urban design details and traffic operations. The analysis of this combination of data provided a more complete picture of site-level trip generation and our findings highlight the influence of: people living nearby and using the site; the nature of the land use on the site; the development along arterial roadways; site permeability and access; and the local culture around walking and cycling. Finally, this report ends by reflecting on the numerous concerns identified from practice, the research findings from various recent studies, and the need for a sustainable process for evaluating the transportation impacts of new land development. We present a potential framework to advance the methods for how site plans fit into neighborhood and regional planning, using locally defined standards and goals. Here, we de-emphasize the site and its immediate environs as the primary (and only) scale of analysis and lessen the reliance on the problematic methodologies for estimating site-level travel demand. Rather, we argue that transportation impact analysis would benefit by first taking a district, neighborhood or area-wide approach with attention to the urban context—the built and social environment—where a site is located. At this larger scale, there is a better ability to understand the various elements that work together to shape travel demand and allows for a better assessment of how a specific site proposal will integrate into this larger context.			
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EXECUTIVE SUMMARY

Recent efforts to improve trip generation data available for transportation impact analysis of new development include the collection of multimodal trip generation data, development of models that account for the built environment, and new recommendations for practice. Building on a long line of research on transportation and built environment, many studies have identified important features of the surrounding built environment that most impact trip rates and mode shares, building on a long line of research on transportation and the built environment. Despite these improvements in data and methods, less attention is placed on identifying the conditions of the site itself and the immediate surrounding environment that influence trip generation and mode choice. To fill this gap, this study builds upon previous work (Contextual Influences on Trip Generation (Project Number: OTREC 2011-407), 2012), re-examines the information collected in that study, and includes new site-level observations. The objective of this study is to examine establishment multimodal trip generation more closely from a finer-grained scale and identify site-level attributes of the built environment that help explain multimodal trip generation. From this, we have the additional objective of developing a framework for trip generation analysis that takes findings from this study into consideration.

We placed emphasis on those sites in our previous study with a discord between the expected travel patterns, based upon the larger urban context and built environment of the site, and the observed. The research approach will make use of mixed methods. In addition to using archived data from the previous study, site visits provided direct observation of the overall performance of the site, including travel patterns on and around the site as well as specific site configuration, urban design details and traffic operations. The analysis of this combination of data provided a more complete picture of site-level trip generation and our findings highlight the influence of: people living nearby and using the site; the nature of the land use on the site; the development along arterial roadways; site permeability and access; and the local culture around walking and cycling.

Finally, this report ends by reflecting on the numerous concerns identified from practice, the research findings from various recent studies, and the need for a sustainable process for evaluating the transportation impacts of new land development. We present a potential framework to advance the methods for how site plans fit into neighborhood and regional planning, using locally defined standards and goals. Here, we de-emphasize the site and its immediate environs as the primary (and only) scale of analysis and lessen the reliance on the problematic methodologies for estimating site-level travel demand. Rather, we argue that transportation impact analysis would benefit by first taking a district, neighborhood or area-wide approach with attention to the urban context—the built and social environment—where a site is located. At this larger scale, there is a better ability to understand the various elements that work together to shape travel demand and allows for a better assessment of how a specific site proposal will integrate into this larger context.

1.0 INTRODUCTION

Over the last decades, cities have become more invested in fostering the conditions to support multimodal transportation and increasing the sustainable transportation options in urban areas. One challenge is the land development process. Transportation planning regulations and processes often rely on historical data and methods that were originally developed to help address the impacts of the automobile in suburbanizing American cities. But this information is not useful in urban areas with more density, mixing of uses and more viable alternatives to driving than in the suburbs. Thus, cities lack information to create planning and design requirements that support non-automobile modes and to deal with the mitigation of anticipated transportation impacts in more sustainable ways.

To this end, there have been recent efforts to provide the development of alternatives to or adjustment of the vehicle trip rates provided by the Institute of Transportation Engineers (ITE) *Trip Generation Handbook* (Clifton, Currans, & Muhs, 2015; Shafizadeh, Lee, Niemeier, Parker, & Handy, 2012; Millard-Ball, 2015). To date, there have been numerous efforts devoted to the collection of multimodal trip generation data, development of models that account for the built environment, and revisions to ITE's *Trip Generation Handbook* (2014)¹ to incorporate new recommendations for practice. Many studies have identified important features of the surrounding built environment that most impact trip rates and mode shares (Clifton, Currans, & Muhs, 2015; Currans & Clifton, 2015; Schneider, Shafizadeh, & Handy, 2015), building on a long line of research on transportation and the built environment (Cervero & Kockelman, 1997; Ewing & Cervero, 2010; Handy S., 1992).

Despite these improvements in data and methods, there has been less attention placed on identifying the conditions of the immediate environment around and including a site that can influence trip generation (Schneider, 2013; Larco, 2015). Many mitigations to anticipated transportation issues attributed to growth are proposed during the development process, often during a transportation impact analysis. These proposed remedies involve attention to site design, intersection reconfiguration, changes in signal timing, or the placement of bus stops and bicycle parking with the goal of shifting demand away from the automobile or lessening its impact. Yet, there has been little assessment of the influence of site conditions and environments in close proximity on multimodal trip generation. By ignoring these elements and the potential synergies with the larger urban context, there is little evidence to support their effectiveness.

To help remedy this, this study builds upon previous work by the principle investigator (Contextual Influences on Trip Generation (Project Number: OTREC 2011-407), 2012), re-examines the information collected in that study, and conducts site-level observations. The objectives of this study are to build on those previous findings and examine establishment trip generation more closely from a finer scale to identify site-level attributes of the built environment that help explain

¹ ITE's *Trip Generation Handbook*, currently in the 3rd edition, includes a description of the data and methods used to analyze trip generation data. The corresponding 9th Edition of the ITE *Trip Generation Manual: An Informational Report* (2012), includes the descriptive and graphics of the data and rates. In this report, when we refer to the *Handbook*, we are referring to the most recent set of the ITE's *Trip Generation Handbook* (3rd Edition) and *Manual* (9th Edition).

multimodal trip generation. From this we have the additional objective of developing a framework for trip generation analysis that takes findings from this study into consideration.

Based upon the results from the previous study, we intend to start by placing emphasis on those sites with a discord between the expected travel patterns, based upon the larger urban context and built environment of the site, and the observed. For example, we have many establishments in our previous study where the non-automobile mode shares are much higher (or lower) than expected given the surrounding land use, urban form and transportation options available. We hypothesize that the missing factors here are related to the characteristics of the site and its immediate surroundings and those of the visitors traveling to those sites.

The research approach will make use of mixed methods. We will rely on our archived data about the establishments, the travel patterns of a sample of site visitors, and the built environment from our prior project. Aerial images for the immediate area around each site will be extracted from Google Earth. In addition, site visits will provide direct observation of the overall performance of the site, including travel patterns on and around the site as well as specific site configuration, urban design details and traffic operations. The analysis of this combination of data will provide a more complete picture of site-level trip generation. A map of the Portland region and our study sites is included in Appendix A. Descriptive statistics for each location mentioned in the text can be found in Appendix B.

From this analysis, a set of lessons learned will be identified. These lessons will be presented as case studies to describe qualitatively, and where appropriate quantitatively, the various factors that have some influence on the overall site performance, over and above those identified in our previous work. From our complete body of work, we will then develop an overall framework to help guide planners in creating environments that support multimodal transportation in the land development process. This framework will consider the long-term performance goals for an area and the links between the various scales of the built environment building upon the state of the knowledge in trip generation, including this study.

The remainder of the report is organized as follows: The next section provides background information that builds upon previous reviews of trip generation research and adds the urban design literature that intersects with transportation outcomes. Then, the methodology used in this study and how it relates to our previous work is presented. The findings of our study are summarized as lessons learned. This is followed by a framework that synthesizes our findings along with those from the literature. The appendices are provided to supplement this report by providing more information about the specific sites.

2.0 BACKGROUND

There have been many reviews of the current practice and research regarding trip generation in recent years (Clifton, Currans, & Muhs, 2015; Currans & Clifton, 2015; Schneider, Shafizadeh, & Handy, 2015; Ewing, et al., 2011; Bochner, Hooper, Sperry, & Dunphy, 2011; Walters, Bochner, & Ewing, 2013). This work has covered various trip generation policy and methodological issues, including: critiques of current practice, the influence of the built environment on vehicle and multimodal use, models to estimate trip generation, and data needs. This body of research significantly intersects with and draws upon findings from the land use and travel behavior literature. Rather than re-presenting the information from this work, this background section will focus on the perspectives specifically considered in this research – the impact of site design, parcel-level attributes and the characteristics of the immediate area around the establishment on trip-making characteristics. Here we are interested in the person and vehicle trip rate, as well as the non-automobile mode shares and trip distances of travel to and from various locations. This study has a particular interest in commercial establishments and destinations other than residential locations.

The scale at which we measure the built environment matters (Gehrke & Clifton, 2016). The research in non-motorized transportation has brought attention to the faults of using built environment measures taken over larger areas, such as census geographies or transportation analysis zones (TAZs), as they may be obscuring variations or configurations that have implications for travel. For example, pockets of density, mixing and connectivity at levels that support walking may exist in many suburban locations and, in turn, there is evidence of substantial levels of walking activity in suburban areas - particularly around commercial centers (Moudon, Hess, Snyder, & Stanilov, 1997; Hess, Moudon, Snyder, & Stanilov, 1999; Larco, Stockard, Steiner, & West, 2013; Boarnet, Joh, Siembab, Fulton, & Nguyen, 2011; Larco, 2009; Handy & Clifton, 2001). Similarly, urban areas that on the aggregate would be considered walkable may have areas that present major barriers to walking or be inhospitable to cycling.

Many researchers now have access to disaggregate data and are using more refined scales at quarter- to half-mile buffers around a location representing the near-term environments, for example Gehrke & Clifton (2014). This has helped to advance understanding of conditions that support walking, cycling and transit access. However, disruptions in the urban fabric can occur at even finer scales and are particularly problematic when examining the conditions to, from and around a specific location or, in this case, an establishment. The immediate environment surrounding a location comprises the “first and/or last steps” of a journey and connects the site to these near-term conditions that have been studied in greater detail.

Further, some of the critical components of the environment are not captured altogether. Take the connectivity of pedestrian networks, as one example. Informal paths, off-road trails, large parcels with internal circulation (e.g., parks, parking lots, yards), and inter-parcel connectivity are all important when evaluating pedestrian access (Larco, 2015). Yet, these dimensions are rarely captured in archived data sets (Saelens & Handy, 2008; Ewing & Cervero, 2010; Forsyth & Krizek, 2010). Rather, the street network often serves as a proxy for non-motorized networks in studies of pedestrian and cycling behaviors. These road-based networks may provide an adequate representation of non-motorized networks in some cases; however, they may be inappropriate in others. For example, in many cases the walkability or bikeability behavior in suburban areas may

be vastly underestimated with the presence of large lots, trails and informal routes (Larco, 2009; Chin, Van Niel, Giles-Corti, & Knuiman, 2008).

At these fine scales, design factors such as street widths, traffic control, bicycle parking, transit access and other urban design features play a role in the attractiveness of specific destinations and the choice of modes. These features have played prominently in the urban design literature (e.g., Alexander, Ishikawa, & Silverstein, 1977; Appleyard, Gerson, & Lintell, 1981; Jacobs, 1993; Lynch, 1960; Ewing & Bartholomew, 2013), but have only recently been incorporated into the active transportation research (e.g., Schneider, Shafizadeh, & Handy, 2015; Ewing & Bartholomew, 2013; Ewing, Handy, Brownson, Clemente, & Winston, 2006; Adkins, Dill, Luhr, & Neal, 2012). Many walkability audits have incorporated some of these design features (Clifton, Smith, & Rodriguez, 2007; Forsyth & Krizek, 2010). The costs of collection and maintenance of comprehensive, detailed datasets that include these features are prohibitive on a large scale and thus hinder progress towards our understanding of the linkages with travel choices and interactions with other conditions of the built environment.

Yet, there are likely synergies in the relationships in the built environment across these various scales that matter for transportation and other outcomes. Larco (2015) outlines a matrix of urban design elements for attaining sustainability, measured at scales from the regional, neighborhood, block, street and parcel level. While much of the transportation literature acknowledges many of the individual elements important for sustainable transportation at each of these scales (e.g., Gehrke & Clifton, 2014; Duncan et al., 2010; Handy, Boarnet, Ewing, & Killingsworth, 2002), there has been little understanding of the interactions of these features across and within each spatial level.

Statistical analysis is hampered by the correlations that exist between many of the individual measures (i.e., density tends to be correlated with land use mix and street connectivity) and thus many rely on data aggregation techniques such as the creation of indices or factors to group co-varying features (Cervero & Kockelman, 1997). Although this aids in our empirical work, the ability to understand interactions, minimum/maximum thresholds and the critical links between scales remains a challenge.

The challenges posed here impact many efforts to better coordinate land use and transportation to create more sustainable and multimodal environments. Within the context of trip generation studies, there is little to no support for the kinds of mitigations at the site and immediate area that aim to reduce automobile traffic or lessen its impact. Similarly, the broader urban context where a site is being developed is often ignored, using standards or vehicle trip rates that are insensitive to the local conditions. For example, one such form of impact mitigation is street widening, which attempts to increase available capacity and mobility. In an attempt to accommodate higher predicted rates of automobile use—which are often overpredicted in urban areas anyway—developers dedicate urban land toward additional roadway space, thereby reducing potential densities and expanding the lane widths, which has shown to induce higher vehicle speeds of travel and, consequently, higher crash rates (Marshall W. E., 2015). Additionally, areas with higher rates of connectivity and permeability have been shown to relate to lower overall crash rates and fatal crashes in particular (Marshall & Garrick, 2011a), as well as increasing rates of biking and walking (Marshall & Garrick, 2011b). And yet the connectivity and permeability of the surrounding area are rarely taken into account when estimating the transportation impacts of site-level development.

This study aims to identify these elements, their interactions with features at different scales and provide a framework to integrate them. Before describing our methodology, we discuss trip generation data in general, and how traditional methods for evaluation may not be appropriate as we move towards multimodal trip generation and traffic impact analysis approaches.

3.0 METHODOLOGY

The aim of this study is to determine the site-level and urban design characteristics that help to shape multimodal trip generation. This study builds upon a previous study conducted in 2011-2012 in Portland, OR (Clifton, Currans, & Muhs, 2015) sponsored by the Oregon Transportation Research and Education Consortium (Report Number: OTREC 2011-407), where the research question attempted to identify the built environment influences on trip generation measured at half-mile buffers around various retail and service establishments. In that study, we collected multimodal trip generation data for the PM peak period (5-7 p.m.) at 78 restaurants, drinking places, and convenience markets within the Portland metropolitan area. These data provide the basis for the initial site selection and evaluation within the current research.

Once the sites were selected from the previous sample of establishments, we visited the locations in order to qualitatively evaluate the performance of the site and identify additional influences on multimodal trip generation adding to the analysis done in the previous study. The process for site selection is documented in the following section, followed by the site investigation methodology including both in-person observations and study of archived photos. We include a discussion of how we identified potential trends, including influences in socio-demographics and the built environment.

3.1 SITE SELECTION

As mentioned previously, study locations are based on a total of 78 establishments included in an earlier study from which various transportation and built environment data were collected during the summer of 2011; for more detailed information, see (Clifton, Currans, & Muhs, Contextual Influences on Trip Generation (Project Number: OTREC 2011-407), 2012) or (Clifton, Currans, & Muhs, 2015). These data include a two-hour PM peak (5-7 p.m.) person count and intercept survey. The intercept survey was conducted using short and long forms, depending on the respondent's willingness to take the long survey. Included in the long survey was information about the trip-maker's entering and exiting mode choice and vehicle occupancy; a suite of socio-demographic questions about the individual and household; information regarding the trip-maker's home, work, previous and next destinations; as well as the amount of time and money spent at the location. The short survey included a small number of comparable questions. The total number of completed surveys varied for each location.

Figure 1 Mode Share at 78 Sites (Clifton et al., 2015)

The 78 locations from the previous study were screened for suitability for inclusion in this research. The first filter applied was to include only those sites with a minimum of 20 completed surveys (a total of both long and short surveys), which amounted to 42 of the total 78 establishments. We assessed the 42 locations in terms of the built environment in each site for supporting non-automobile modes relative to the observed multimodal mode share and the other travel behavior data collected for this site (Cervero & Kockelman, 1997; Ewing & Cervero, 2001; Ewing & Cervero, 2010). The observed travel behavior was evaluated against the expected (or average) travel choices, given the environment around each site. In a very simplistic view, each site was then placed along two axes representing how supportive the environment surrounding the site is for a variety of modes—in terms consistent with the previous literature exploring contextual influences on trip generation (e.g., Clifton, Currans, & Muhs, 2012)—and whether the observed behavior met our expectations (see Figure 2). We were most interested in those sites where the environment would seem to support more multimodal travel than we observed in the previous study (quadrant I in Figure 2) and those places where the observed mode shares were greater than we expected, given the built environment (quadrant IV in Figure 2). Quadrant I and IV represent areas where there appears to be a discord between the level of non-automobile support and the observed behavior—quadrant I and IV containing above- and below-expected performances, respectively.

Figure 2 Evaluating Built Environment and Multimodal Travel

To qualify an urban form as supportive for multimodal transportation options, we first evaluated the site and surrounding location in terms of a number of different built environment measurements (e.g., population density, land use mix, access to transit, block size). Segmenting the study sites into two categories representing the most urban area types (downtown Portland and the urban core) and less urban area types (urban residential neighborhoods, suburban area types), we evaluated sites relative to expected high and low mode shares for the respective two categories of area types. Figure 3 depicts an example of evaluating active mode shares by population density for downtown and residential/suburban neighborhood sites. A “supportive” environment was therefore contingent on whether the location was identified as distinctly urban or suburban/residential. Our expectations of the behavior observed for the dense urban establishments were different for these two categories.

Within the most urban areas, if we observed less than 60% non-automobile mode share, we considered that site to have a below-expected non-automobile mode share for the given supportive urban form (Quadrant IV, 36% of sites). For the urban residential neighborhoods and suburban area types, if we observed more than a 15% non-automobile mode share at sites without a supportive multimodal urban form, we considered the site to have above-expected non-automobile mode shares and placed the site in quadrant I (38% of sites). Meanwhile, if the site had a supportive environment, but did not have more than 30% non-automobile mode share, we placed the site in quadrant IV (24% of sites). By classifying sites into quadrants in this initial evaluation, we were then able to prioritize our site investigations at one of two types of locations: (Quadrant I) locations where the non-automobile mode shares were high despite a less supportive environment, and

(Quadrant IV) locations where the non-automobile mode shares were low even though the surrounding environment was supportive of non-automobile travel.

Figure 3 Population Density and Active Mode Shares for Downtown (top) and Urban Residential and Suburban Area Types (bottom)

After the initial review of the sites and the rough categorization, these locations and their environments were inspected more closely using archived resources (satellite images from Google Maps, Google StreetView, and images taken during the 2011 survey), more detailed analysis of

our survey results and in-person site visits. We frequently iterated between our quantitative data collected previously, the archived images and site visits to try and understand why sites were under- or over-performing in attracting non-automobile trips to and from the site relative to our expectations.

In addition to site and surrounding area photos that were collected the day of our intercept survey and data collection, Google Maps provides current and archived satellite images, maps, and street-view perspectives that allow the user to step into the environment as one may have seen it during the time of the original data collection (Google, Inc., 2011-2014). Although this tool did not provide us a comprehensive review of the surrounding area and facilities adjacent to the sites, it allowed us to perform an initial investigation to explore the availability and condition of the multimodal facilities on and surrounding the study sites. We explored the proximity to nearby generators, such as residential, commercial, recreational and office land uses, and began to list the potential influences on each location prior to site visits. This list provided us with a topical outline for how we investigated the sites in person, ensuring that we cover the same questions and themes for every site visit. Some of the questions include:

- “How does this site connect with land uses in every direction from the site?”;
- “How comfortable is it to walk along these facilities in terms of noise, exposure, lighting?”; and
- “How are the majority of people interacting with this establishment (e.g., work destination, family sit-down restaurant, to-go orders, etc.)?”

Using the evaluation of sites relative to measured multimodal facilities and observed multimodal behavior (see Section 3.1), and following the list of questions and topics to review at each study location, we visited urban and rural sites over several days during the morning and evening. We began our visit with a review of the site itself, assessing the immediate environment, the orientation of the building and site access, setbacks, quality of the nearby facilities and appearance of the structures. We then began walking to the surrounding land uses and back, evaluating the ways in which the study site connected with nearby land uses and allowed for connections with other transportation facilities, including transit stops and lines, pedestrian crossings and paths (including informal, non-mapped paths), bicycle facilities, other automobile access points, traffic intersections and signalization. We tracked the larger generators that were not visible or obvious from the Google maps interface (e.g., mobile home or multifamily units, other commercial land uses, institutions or schools). The research team discussed how these elements worked together (or against each other) for each study area, resulting in the relative measured built environment as well as the observed multimodal behavior. These online investigations and site visits laid the groundwork for how we identified and outlined trends observed at the study sites, ultimately informing the lessons learned and framework discussed later in this report.

Based upon the qualitative assessment of archived photos and the site visits, combined with the quantitative information collected previously, the team discussed the issues identified with each site. From this, we acknowledged trends in the built environment, traffic operations, transportation movements and site visitors that are influential to trip generation, which are outlined in the next section.

4.0 LESSONS LEARNED

Through the insights learned from this largely qualitative study, we are able to add to the knowledge gained from our previous study about the macro-level built environment (as measured at a half-mile buffer). Here, our site observations, analysis of archived imagery and re-examination of the quantitative data collected previously have given rise to several lessons learned. These are articulated below with specific examples from our study and reinforce the need to go further in our work, examining the environment and travel behavior in closer detail, and constructing a framework for dealing with a number of these aspects we have not historically considered or those which may be difficult to predict.

4.1 PEOPLE MATTER

The sociodemographics have a key role in shaping travel behavior. Income, race, ethnicity, gender, social class, education, marital and family status, and so on are commonly accepted within the travel behavior community to influence transportation choices, with varying effects and degrees of importance. Within the four-step travel demand modeling framework, trip generation productions are directly estimated as a function of these individual and household characteristics. Yet, at the site level, the characteristics of travelers are overlooked as explanatory factors in favor of measures of establishment or land use size (square footage of the space or number of tables, rooms, beds, employees, etc.). The failure to account for the characteristics of site visitors or the potential market for businesses can lead to large errors in the estimation of the numbers of trips, the mode shares and the trip length distribution.

Areas with more low-income households tend to own fewer cars and travel more by non-automobile modes. In an examination of the 2001 National Household Travel Survey (NHTS), one study found lower-income households to have lower rates of car ownership, indicating that approximately 26% of households with less than \$20,000 in annual income do not have a car accessible to them, while 5% of households with incomes between \$20,000 and \$39,999 do not own a vehicle and between 0.9% and 2.3% of households with greater than \$40,000 in annual incomes do not have a vehicle (Pucher & Renne, 2003). It stands to reason that these extremely low-income households (less than \$20,000 per year) tend to walk and take transit more (walking: 16.2% versus 8.8-9.5%; transit: 4.6% versus 0.9-1.5%) for all trips (Pucher & Renne, 2003), including travel to non-work destinations (Murakami & Young, 1997).

Moreover, households with low incomes come from all racial and ethnic backgrounds but tend to have disproportionately higher representation (compared with the regional population) among immigrants and non-whites (Simms, Fortuny, & Henderson, 2009). The 2001 NHTS allowed researchers to show that households whose race or ethnicity were black, Asian, or Hispanic had substantially higher non-automobile modes shares than white households, traveling more often using transit (Black: 5.3%; Asian: 3.2%; White: 0.9%; Hispanic: 2.4%) and walking (Black: 12.6%; Asian: 11.7%; White: 8.6%; Hispanic: 11.8%). Black and Asian households were also shown to travel slightly less by bicycle than white households (Black: 0.6%; Asian: 0.5%; White: 0.9%; Hispanic: 0.9%) (Pucher & Renne, 2003). Additionally, areas with higher rates of low-income or non-white households also have disproportionately high rates of injury and death as transportation system users (Cottrill & Thakuriah, 2010).

Conversely, more affluent persons often choose to drive even when conditions are ideal for using other modes, and most of the research on the built environment and travel behavior support this. The convenience of the automobile, either real or perceived, often outweighs local accessibility and supports for alternative modes.

Our site observations support these previous findings. We saw that many transport-disadvantaged people will walk, bike or take transit even when the built environment does not provide support for those modes and at times taking great risks. There was physical evidence of these trips, in the form of informal trails, breaks in fence lines, and bicycles chained to signs or left unsecured. Walking (or running) against the pedestrian signal or jaywalking midblock was a common occurrence even during our relatively short visits. We saw several cases of cyclists riding on sidewalks where there was no bicycle infrastructure or where automobile traffic speeds and volumes were high.

Of the sites, we chose to examine more closely, we highlight three establishments that show some notable differences in mode shares, the local built environment, and the people living in the area. In Table 1 below, we can see that Convenience Stores 1 and 2, which are both located along major arterials in suburban Portland, have a significantly non-automobile mode share than expected (31% and 46%, respectively), particularly given the characteristics of the built environment. Contrast these stores with urban Convenience Store 3, which has a higher automobile mode share (77%) despite its location in the central eastside of Portland which has a more supportive built environment for active travel. The table also shows some clear differences in the socioeconomics of the residents who live near each of these establishments. Convenience Store #3—compared with 1 and 2—is located in a block group that has nearly two times the median household income (despite having a similar average household size), 30-40% more white or Caucasian households, and a third the proportion of foreign born residents. While the percent of zero-car households is similar for the neighborhood around Convenience Store 1 and 3 (4-5%), Convenience Store 2 has half the proportion of households that do not own a car (2.1%) and still maintained the lowest automobile mode share of the three stores (54%). Additionally, Convenience Store 1 is located in a neighborhood with the greatest proportion of households at or below the poverty line (25%), while Convenience Stores 2 and 3 are located in areas with 6% of households living in poverty.

Convenience Stores 1 and 2—located in areas with lower median incomes, higher rates of non-white households as well as foreign-born households—had considerably higher person-trip rates (a proxy of overall activity on the site) compared with Convenience Store 3 (approximately 45, 48, and 20 person trips per PM peak hour per 1,000 square feet of gross floor area, respectively). While the three-count sample does not provide enough information to examine the relative levels of competition with alternative land uses, Convenience Store 1 is located directly across from several food retail and restaurant establishments (discount, market-rate, and luxury), suggesting that higher overall rates of use may not always be associated with lack of competition for alternative uses. And although Convenience Store 3 has a greater rate of automobile use despite being located in a more urban environment, the overall vehicle trip rate for this store was still a quarter of the rate estimated using ITE's *Trip Generation Handbook* (13.0 versus 52.4 vehicle trips per PM peak hour per 1,000 square feet of gross floor area)—an artifact of both the higher non-automobile mode share and the lower overall activity at the site. Understanding the variation in person-trip rates and overall activity use across the region becomes essential in interpreting what mode shares mean, in terms of trips by mode, in different neighborhoods. With similar mode

shares, two establishments may have drastically different mode-specific counts if the overall peak-hour activity (in terms of person-trip counts) varies substantially.

Not all visitors to a site live in the areas directly surrounding it. Better data on trip length distribution and trip origins and subsequent destinations can help understand the relationships between the market area of an establishment, the distances traveled by visitors, and their modes, all of which have a strong relationship with socioeconomics. As the calls for more and better establishment-level data increase (Clifton, Currans, & Muhs, 2013; Schneider, 2013; Dock et al., 2015), including socioeconomic and -demographic information about the transportation system users, it is critical to include these data to increase our understanding of trip generation.

Table 1 Travel Characteristics of Three Convenience Markets

Convenience Market:	1	2	3
Gross Leasable Area <i>square feet</i>	2,500	3,000	3,334
Mode Share (observed)			
Automobile	69%	54%	77%
Walk	15%	23%	13%
Bicycle	4%	8%	6%
Transit (e.g., streetcar, MAX, bus)	12%	10%	3%
Trip Rates (PM Peak Hour of Adjacent Facility, 5-6PM) <i>Trips per 1,000 square feet</i>			
Person-Trip Rate (observed)	44.8	48.3	19.5
Vehicle-Trip Rate (observed)	26.7	22.5	13.0
ITE Vehicle-Trip Rate (estimated)		52.4	
Trip Length from Origin to Establishment ¹ (observed) <i>Average miles (standard deviation, surveys sampled)</i>	6.5	2.9	2.4
Built Environment <i>Half-mile Euclidean Buffer</i>			
Activity Density <i>(residents and jobs per acre (Metro RLIS, 2010))</i>	14.5	12.4	17.2
Employment Density <i>(jobs per acre (Metro RLIS, 2010))</i>	6.2	1.6	6.8
Lot Coverage <i>(percent of land covered by building (Metro RLIS, 2010))</i>	20%	13%	28%
Bike Facilities <i>(lane miles (Metro RLIS, 2010))</i>	4.2	3.7	4.1
Access to MAX Light-rail <i>(yes/no)</i>	Yes	No	Yes
Intersection Density <i>(intersections per acre (TIGER, 2011))</i>	<0.1	<0.1	0.2
Demographics of Neighborhood <i>Census block group of establishment</i>			
Median Household Income (US dollars) ¹	\$41,771	\$56,336	\$99,879
Race (percent of total population) ²			
White or Caucasian	45%	56%	87%
Hispanic or Latino	49%	30%	4%
African American	2%	2%	1%
Asian	3%	4%	8%
Percent Households at or Below Poverty Line ³	25%	6%	6%
Average Household Size ⁴	3.0	3.0	2.7
Percent Foreign Born ⁵	27%	29%	8%
Percent Zero-Car Households ⁶	4.6%	2.1%	4.2%

NOTES:

¹ 2013 American Community Survey (ACS), 5-year summary, Table B19013; ² 2010 Census, Summary File 1 (SF1), Table P2; ³ 2013 ACS, 5-year summary, Table B17010; ⁴ 2010 Census, SF1, Table H13; ⁵ 2013 ACS, 5-year summary, Table B99051; ⁶ 2010 ACS, 5-year summary, Table B25044

4.2 FOCUSING ON THE “USE” IN LAND USE

The role and function of land use have an influence on the various dimensions of trip generation, including—but not limited to—the number of trips, mode shares, duration of activities, group size, and peak hour of the generator. The activities performed at a site are often multifaceted and are correlated with the characteristics of site visitors and the surrounding community (people and place). The field of travel behavior attempts to cover these complex relationships. In terms of the site visitors and the neighborhood population, we know that the income, attitudes, employment, ages, ethnicities, family status and size, education level and many other characteristics shape activity and travel behavior. We discussed the importance of these traveler aspects more in Section 4.1. Here, we will focus on the impacts that the function of the site itself and the surrounding land uses has on travel patterns to and from the site.

ITE’s *Trip Generation Handbook* defines more than 150 land use categories, and trip information is provided for each use. In many cases, there is a fine delineation of uses; in others, there are categories that cover a broad number of uses, and some are missing altogether. For example, in the *Handbook* (Institute of Transportation Engineers, 2012) a separate category is given for “fast-food restaurant with drive-through windows” and “bread/donut/bagel shops with drive-through windows,” even though their function and perhaps their travel patterns are statistically similar. There was no significant difference between the means of vehicle trips for fast food restaurants (average: 50; standard deviation: 28; sample size: 65) and bread/bagel/donut shops (mean 37; standard deviation: 6; sample size: 4) per 1,000 square feet gross floor area per AM peak hour of the adjacent facilities (t-test with a p-value of 0.7). The distinction between restaurants and drinking places is whether customers come for the food and stay for the beer, or come for the beer and might have some food (Institute of Transportation Engineers, 2014). Mixed-use developments, such as buildings with primarily residential and/or office uses with retail on the ground floor, pose challenges for assessing trip generation due to the interaction between uses and internal capture of the site and surrounding area. The sum of the individual uses often does not equal its parts (Bochner, Sperry, & Dunphy, 2011). Many housing products – such as affordable multifamily housing, micro apartments (or any measurement of dwelling unit size), co-housing, and short-term rentals (e.g., AirBnB) are not included as separate categories or variables under residential uses even though the travel patterns of residents may fundamentally differ from residents of conventional housing. Further, the ways that we interact with certain land uses has changed dramatically, impacting the travel patterns of customers. For example, our use of bank facilities has changed over time with the addition of drive-thru facilities, then automated teller machines, the rise of debit and credit card use, and now online banking. These changes are not limited to passenger activities and travel. On the freight side, the supply-chain and logistics of goods movement, distribution and retailing has had pronounced impacts on warehousing. Several types of warehousing facilities have emerged, each with different trip generation categories depending upon the good, its position within the supply chain, and its proximity to markets.

These designations and definitions used by ITE are often defined in an ad hoc process of adding new information to *Trip Generation*. Trip generation data for land uses are compiled by ITE, submitted by consultants and municipalities, and subject to ITE’s standards and formats. So the availability of data for various uses depends upon the willingness of others to collect and submit it. New categories of land uses can be created upon request, usually when the practitioner-submitted data verify the distinction is necessary. Further, there is no publicly documented

empirical examination of the travel characteristics between the different land use categories; thus the land use types are supported by weak theoretical and empirical rationale.

From our previous studies (Clifton, Currans, & Muhs, 2012; Clifton K. J. et al., 2013), establishments within the same land use classifications—sometimes within the same chain or franchise with the same products/services, price points and marketing—often have different person-trip rates, access/egress mode, group sizes, consumer spending rates and peak hours. The results contributed to understanding how the urban context influenced trip rates (Clifton, Currans, & Muhs, 2015) and mode share (Currans & Clifton, 2015); however, the built environment was not able to explain all of the variation we observed in these travel patterns. When examining differences between ITE’s suburban estimates and urban sites (Clifton, Currans, & Muhs, 2015), activity density, although significant, explained only 3% of variation in vehicle trips (adjusted R^2 , linear regression, 78 establishments). When estimating automobile mode shares in Currans & Clifton (2015), we found the built environment (including activity density, distance to the CBD, and presence of a transit-oriented development) to account for approximately 20-23% of the variation observed in automobile mode shares for restaurant and retail establishments (Nagelkerke R^2 , binary logistic regression of household travel survey trip ends).

These differences were confirmed during our site visits. We observed many variations within one land use type in how visitors interacted with each site, including the duration of time spent at the location, the number of people in each group, and the transportation access/egress mode. From this analysis, we have come to understand that it is very important to understand how a land use is functioning in the community and the nature of that community itself.

Below, we present two specific cases in which the environment influences the function of the land use. While there are limitations as to the predictability of the land use’s function, there are some indicators that might suggest the development might be less of what it is defined as, and more of something else.

The Curious Case of the Pizza Shop in the CBD

In this case study, we hypothesize the reasons why three establishments that fall within the same land use category and are located in the same area have very different trip generation characteristics. In our previous study, we included three restaurants located in the downtown area, all of similar size and land use code (ITE Code #932, “high-turnover (sit-down) restaurants”). Two were located next door to each other within the same building in the Pearl District, a revitalized mixed-use neighborhood near the city center, and the third site was approximately a mile away, within the Portland State University campus near the central business district (CBD). Although all three restaurants are located within the same area with similar employment and residential densities, transit accessibilities and pedestrian accommodations, the three establishments reveal different mode shares, vehicle-trip rates and person-trip rates (all modes) (see Table 2 below).

Table 2 Travel Characteristics of Three High-Turnover (Sit-Down) Restaurants in the Same Urban Context

Restaurant Number:	1	2	3
Location Number:	1	1	2
Food Type:	Pizza	Mixed	Pizza
Gross Leasable Area <i>square feet</i>	1,850	2,300	1,500
Mode Share (observed)			
Automobile	63%	14%	5%
Walk	22%	64%	47%
Bicycle	7%	14%	5%
Transit (e.g., streetcar, MAX, bus)	7%	9%	41%
Trip Rates (PM Peak Hour of Adjacent Facility, 5-6PM) <i>Trips per 1,000 square feet</i>			
Person-Trip Rate (observed)	60.0	38.7	18.7
Vehicle-Trip Rate (observed)	23.1	2.6	0.6
ITE Vehicle-Trip Rate (estimated)		11.15 (9.13)	
Built Environment <i>Half-mile Euclidean Buffer</i>			
Activity Density <i>(residents and jobs per acre (Metro RLIS, 2010))</i>	85.8	85.8	110.0
Employment Density <i>(jobs per acre (Metro RLIS, 2010))</i>	64.5	64.4	87.3
Lot Coverage <i>(percent of land covered by building (Metro RLIS, 2010))</i>	57%	56%	45%
Bike Facilities <i>(lane miles (Metro RLIS, 2010))</i>	12.0	12.0	12.2
Access to MAX light-rail <i>(yes/no)</i>	Yes	Yes	Yes
Intersection Density <i>(intersections per acre (TIGER, 2011))</i>	0.4	0.4	0.3

The first restaurant (Restaurant 1, Location 1), a pizza shop, had a 63% automobile mode share during the PM peak period (5-6 p.m.) and a 22% pedestrian mode share. Across the hallway within the same building, the neighboring restaurant (Restaurant 2, Location 1), offering a variety of types of food, had a 14% automobile mode share, while pedestrian trips accounted for 64%. The third downtown restaurant located a mile away from the other two establishments (Restaurant 3, Location 2)—a similar style of pizza restaurant—had a 5% automobile mode share, with the majority of trips taken by pedestrians (47%) and transit (41%). These are marked differences in establishments that fall within the same land use code and are located in similar built environments (see the comparisons in Figures 4 and 5). Particularly interesting is the relatively high automobile mode share of Restaurant 1, given the supportive environment for non-automobile modes and the stark contrast with Restaurant 2 across the hallway in the same building.

Figure 4 Satellite Images² at a Half-mile Euclidean Buffer for (left) Location 1 and (right) Location 2

Figure 5 Close Up Satellite Images for (left) Location 1 and (right) Location 2

A lunchtime visit to the site that housed both Restaurant 1 and Restaurant 2 revealed little difference in how people were interacting with the site and taking advantage of the outdoor seating. The bike rack in the front was nearly full of bicycles (see Figure 6); people appeared to be walking and cycling to the restaurants; and the small parking lot was half full with some movement of vehicles (see Figure 7). People arrived alone and in groups. Customers appeared to be “the

² All satellite imagery included in this report was provided using the following sources: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

lunchtime crowd” coming from local employment or residential locations and there were not many families. There was not a noticeable difference in mode shares between the two establishments; however, we were not collecting specific counts. There was nothing obvious during lunchtime that might explain the differences we observed in our data for the evening peak hour.

Figure 6 Bike Parking at Location 1

Figure 7 Location 1 Automobile Parking

However, in the evening, customers appear to interact differently with these two establishments based upon our observations and discussions with those who frequent the site. Customers

frequenting Restaurant 1 (pizza shop) in the evening peak may be picking up a whole pie (rather than buying a slice) and driving home to eat it there. These customers may not work or live in the immediate area and thus drive to work. From our previous data collection efforts at other pizza restaurants, customers who drove were more likely to purchase a whole pizza “to go” than people using other modes.

Restaurant 3 has a customer base comprised of college students, faculty and staff and the travel behavior of customers does not appear to be significantly different from the afternoon to evening. However, the peak hour of the generator (as opposed to the adjacent facilities) is likely later in the day than the evening peak hour (5-6 p.m.) when our data were collected previously, and there are more likely more person trips concentrated around lunchtime than at other times of the day. The market area is limited to campus and the nearby CBD area and, thus, trip distance distributions are within a reasonable walking and bicycling distance.

While these may be intuitive findings, this case study highlights the need to make more careful distinctions between how customers, employees and suppliers may interact with a business, the characteristics of those using the site, the market area, the presence of nearby generators (such as a university or dense office area), and the products or services sold. All of these have an impact on the trip generation characteristics of a site, even for establishments that would otherwise fall within the same land use category. The next case study reinforces these points and brings attention to additional considerations.

When a Supermarket is not “Convenient”

In this second case study, we examine a site with a convenience store that had a much higher rate of walking than expected given the exurban environment. Here, the establishment falls into the ITE convenience market land use type (ITE Code #851). It is part of a local chain and all of their stores are a similar size and design with little variation in products and/or price points. The store is located along a state highway with a low-density strip development oriented towards the automobile. Thus we were surprised to find the establishment had a 20% walk mode share in our previous study and decided to investigate further.

Compared with the restaurants described in the previous sub-section located in the city center, this study site (a convenience market) does not have built environment conditions that one would expect to support pedestrian travel. It has low activity and employment densities. Other destinations in the area tend to be far apart with generous setbacks, with an average lot coverage over a half-mile radius buffer of only 16%. The intersection density of this suburban area is low, with bike facilities on the adjacent highway—although the high speeds and vehicle volumes do not make this facility an attractive place to ride a bicycle. Table 3 highlights the travel and environmental conditions of this market compared with the averages for all the convenience markets in our previous study.

Table 3 Travel Characteristics of a Convenience Market

	Convenience Market	Average for All Convenience Markets (N: 26)
Gross Leasable Area <i>square feet</i>	2,500	2,530
Mode Share (observed)		
Survey Responses (Sample Size)	34	987
Automobile	76%	59%
Walk	21%	26%
Bicycle	0%	7%
Transit (e.g., streetcar, MAX, bus)	3%	6%
Trip Rates (PM Peak Hour of Adjacent Facility, 5-6PM) <i>Trips per 1,000 square feet</i>		
Person-Trip Rate (observed)	75.6	43.2
Vehicle-Trip Rate (observed)	50.0	20.8
ITE Vehicle-Trip Rate (estimated)	52.4	52.4
Trip Length from Origin to Establishment ¹ (observed) <i>Average miles (standard deviation, surveys sampled)</i>		
Overall	4.4 (6.4, 6) ²	2.8 (4.4, 264)
Automobile	---	4.3 (5.3, 122)
Walk	---	0.7 (1.1, 98)
Bicycle	---	1.4 (1.4, 19)
Transit (e.g., streetcar, MAX, bus)	---	5.5 (5.1, 19)
Built Environment <i>Half-mile Euclidean Buffer</i>		
Activity Density <i>(residents and jobs per acre (Metro RLIS, 2010))</i>	85.8	27.9
Employment Density <i>(jobs per acre (Metro RLIS, 2010))</i>	64.5	16.0
Lot Coverage <i>(percent of land covered by building (Metro RLIS, 2010))</i>	57%	25%
Bike Facilities <i>(lane miles (Metro RLIS, 2010))</i>	12.0	5.9
Access to MAX light-rail <i>(yes/no)</i>	Yes	54% Yes
Intersection Density <i>(intersections per acre (TIGER, 2011))</i>	0.4	0.2

¹ Only long survey responses were able to obtain trip origin information.

² Only six long surveys were collected at the convenience market, five of which were automobile.

The PM peak-hour vehicle trip rate observed at this convenience market (50 trip ends per 1,000 square feet) is similar to that given in the ITE *Handbook* (52.41 trip ends per 1,000 square feet). The *Handbook* excludes trips made by non-automobile modes and thus we cannot compare our observed mode share (21% and 40 person trips by walking) and the person-trip rate (76 person trips per 1,000 square feet). We can, however, compare this to the other trip generation data from convenience stores in our sample (see Table 3, under “All Convenience Markets”).

Despite the exurban location, we observed a person-trip rate that was 75% greater than the regional average (75.6 versus 43.2 person trips per PM peak hour per 1,000 square feet of gross floor area), suggesting this location to be very active during the PM peak-hour time period. Combined with a high exurban non-automobile mode share (21% walking and 3% transit), this suggests this establishment has a high level of pedestrian activity (approximately 16 walking trips per PM peak hour per 1,000 square feet gross floor area).

Our site visit revealed that the store, despite its location on a state highway, had good pedestrian connectivity to the multifamily housing and trailer park, as well as the nearby high school located behind the site (see Figure 8). These local generators are the likely source of much of the pedestrian traffic to the site. In addition, there are five grocery stores within 1.5 miles (the nearest being 0.7 miles) so residents do not live in a food desert, per se. But the convenience store is more accessible by foot than the grocery locations and may substitute for, rather than complement, the larger food retailers, particularly for those with low incomes (see Figure 9). Only six visitors to this location opted to respond to our questions regarding the origin or destination of this location (five of them automobile users) and, therefore, comparisons of trip length distribution overall or by mode with the regional average are difficult. However, the average trip length of walking trips to convenience markets in the region was 0.7 miles (26 stores, 98 responses)—the equivalent to the distance of the closest grocery store. We will need more data from these customers to understand this relationship with any certainty.

Figure 8 Surrounding Area of Convenience Market

Figure 9 Convenience Market with Neighboring Land Uses (Distance in Miles from Convenience Market)

This case study highlights several issues. First is the exclusive focus on automobile trips within trip generation studies, which ignores the opportunity to address pedestrian planning issues during the land development process. If we were to rely on ITE’s vehicle trip rates alone, the estimates of automobile trips would closely mirror those observed. Yet, many suburban locations have more pedestrian traffic than conventional planning wisdom would lead us to believe, as shown here (in our case 20% of the demand) and reinforced by others (Larco, 2015). We rarely observe these “hidden” trips in our studies, masked as an artifact of the data collection process (Clifton, Singleton, Muhs, Schneider, & Lagerwey, Improving the Representation of the Pedestrian Environment in Travel Demand Models, Phase I (Report: OTREC-ED-510), 2013), and thus our expectations fall short of reality and our plans and mitigations fail to consider them.

The second, but related, issue arises from ignoring the social context of a site. The traveler's characteristics are commonly recognized as a fundamental influence on transportation choices within travel demand models, travel behavior studies, and other realms of transport policy. But they are ignored in trip generation studies and omitted entirely from the data collection process. Given that the area surrounding a potential site is low- to moderate-income residential, the occurrence of significant numbers of trips being made by foot (or transit or bicycle) would seem likely. In this case, the residents of multifamily and low-cost housing nearby generate many of the pedestrian trips.

Finally, the ways that these customers use and frequent the site may be different than one might expect from a convenience market. At this site, in particular, we observed nearly 10% more visitors (compared to our regional average) that said they make a trip to this establishment either “daily” or “a few times a week” (see Figure 10). These trips may be substitutes for food shopping at supermarkets and grocery stores for some of the non-automobile traffic to the site. Similar to the previous case study, this establishment may be functioning slightly differently than other convenience store land uses. Of course, this speaks to larger public policy issues than merely transportation but it underlines the importance of considering and perhaps anticipating these “hidden” trips.

Figure 10 Frequency of Visits to the Establishment (Percent of Sample)

Moving Forward with How We Define Land Uses

In this section, we question the land use categories used to describe establishments for trip generation purposes. This current approach lacks any theoretical basis that relates the nature of the activity at the land use with travel behavior of visitors to and from the site. In order to better capture the impacts on the transportation system, we need to consider the people using the site and put the “use-r” in land use. Here, we have shown that seemingly similar land uses can have very different travel outcomes, even within the same area type, because the users interact with the site activity in different ways. Further, the second case study suggests that one establishment may fill different needs for different people and that the social context matters as much as the built environment.

However, addressing these issues within the land development process is no easy task. At that development stage, the land use is proposed and it is difficult to know how people will engage with it. Further, this is likely to evolve over time, given the urban dynamics of technological, social, economic, cultural and built environment change. To this end, we are challenged to define land use in a way that: (a) considers the nature of human activities and interactions on the site; (b) has a strong theoretical link to travel behavior; (c) places the end-user at the center; (d) does not over-prescribe, and; (e) allows for flexibility and re-classification over time. This is a tall order and more research will be needed to frame and develop such a methodology.

As we examine the influences of the environment on the traffic impacts of establishments, specifically as we focus on the way in which land uses function within a larger environment, we begin to see that classification itself should be a function of the surrounding environment. Perhaps then, when we estimate transportation impacts for a given land use, we should relax the boundaries of transportation impact analyses to include the surrounding neighborhoods or districts so that we might better understand how the new development might function within the larger context of the surrounding area. By expanding the scope of these analyses, we allow ourselves to consider the people who live, shop, or work there, the alternative land use options available (or missing), and the larger system connecting these users and destinations.

Considering Proximity to Nearby Land Uses/Other Generators

Sometimes the proximity to other destinations—the relative accessibility—may lead the land use to function different than expected (as we saw in the previous section). Many times the proximity to other land uses creates unplanned pedestrian or bicycle districts. Of the locations studied in this analysis, we found that restaurants and convenience markets within a close distance to other commercial, institutional, or residential land uses derived a significantly higher amount of walking (10-15%) and occasionally biking (on the sidewalks), many of the trips leading to or from nearby land uses.

The “micro-density” provided by these adjacent sites may be overlooked in walkability studies. Measures of the built environment in these studies may mask these nodes of density, particularly when measured at quarter-mile buffers or larger geographies. Also, measures of density used in research and practice tend to use population and employment as a proxy for level of activity in an area. But some land uses, such as libraries, parks or some retail uses, may attract concentrations of people, more than the employment numbers would indicate. The interactions between these various land uses in close proximity may support more walking and cycling than the larger built environment would seem to suggest.

It is worth noting that locations with great proximity to other land uses may not have excellent connectivity. In our site evaluations, we found that several suburban locations with adjacent or nearby multifamily housing developments, shopping districts, and recreational land uses (e.g., community centers, swimming pools, libraries, parks) did not always have high levels of connectivity, thus requiring pedestrians and cyclists to incur significant burden or risk. For example, we observed pedestrians or cyclists undertake the following in the process of reaching destinations nearby:

- walk more than 10 times the distance through curvilinear sidewalk paths instead of through a chain linked fence
- cross at least one five-lane arterial with intersections typically 1,000 feet apart
- experience significant delay at intersection crossings before obtaining priority to cross
- jaywalking or crossing mid-block across large arterials in order to avoid delay in walking to and/or waiting at intersections
- walk, bike, and wait (for transit) next to high-speed (greater than 40 miles per hour) traffic volumes with little or no protection
- wait to cross site access for cars to turn first rather than walk or bike through before them

Despite all these barriers, delays and discomforts, the proximity of other land uses results in significant numbers of people walking and biking. Discussed further in Section 5.0, one potential solution to resolve the lack of considerations provided for non-motorized modes and the relationships between new development and the surrounding environment may be a relaxed scoping of the study area similar to a district-based approach to assessing the transportation impacts of new development.

Internal Capture in Existing Neighborhoods

In trip generation analysis, “internal capture” is defined as “a person trip made between two distinct on-site land-uses at a mixed-use site without using an off-site road system” (Institute of Transportation Engineers, 2014). This trip can be made by any type of transportation mode. Developers argue that trips captured internally within development, without touching off-site roadway facilities, should not be considered within the transportation impact estimates of new development. Generally speaking, literature discussing mixed-use developments, trip generation, and internal capture tends to reflect the data analysis of large planned communities.

A mixed-use development is defined as “an integrated development (usually master planned) consisting of at least two complementary and interactive land uses designed to foster synergy among activities generated by the land uses” (Institute of Transportation Engineers, 2014). By ITE’s definition, however, the scale of these developments tends to include mostly single developments (planned simultaneously, but built out in stages), ranging from 7 to 300 acres in scale (Bochner, Hooper, Sperry, & Dunphy, 2011), but other comparable studies have even focused on developments anywhere between 5 to over 2,000 acres (San Diego Association of Governments, 2010; Ewing et al., 2011).

The term “mixed-use development,” however, includes a broader definition than considered in ITE-related studies. Mixed-use development includes any area where the mix of land uses results in trip chaining between the land uses. For larger mixed-use developments—planned through a singular process, but potentially built out in several stages—the internal capture of trips includes

all modes of travel. Trips “captured” within the development, no matter the mode, are not placed on existing facilities and, therefore, not suspect to a development review of impacts on public facilities. For urban mixed-use corridors and centers, the internal capture derived from the close proximity of land uses may result in reductions in vehicle traffic in the study area overall due to non-automobile trip chaining that occurs within these districts. Additionally, as users of the *ITE Handbook* expand their applications and needs beyond investigating site-level transportation impacts of new development—such as evaluating metrics and proxies for greenhouse gases or estimating the impacts of operating and maintaining roadways facilities, like a transportation user fee—there is an increasing need to understand, estimate, and evaluate the ability for neighborhoods or districts to “capture” a portion of the transportation impacts of infill.

While there is a growing literature on the overall transportation impacts of mixed-use planned developments, we understand less about how infill developments function within an existing mixed-use community—like historic downtowns, urban commercial corridors, or the central business district. In a 2013 study, Schneider (2013) surveyed visitors to shopping districts in suburban and urban areas and found that 65% of trips between land uses in all shopping districts were walking trips, but in urban centers, approximately 96% of trips between land uses were walking trips. Furthermore, we have only begun to understand the ways in which trips are captured within mixed-use buildings (e.g., Walters, Bochner, & Ewing, 2013), but the available methods have not been adequately tested with a range of contexts.

The trips captured by infill development in existing urban, mixed-use contexts, however, reflect the proximity of a mix of destinations within districts, neighborhoods, and communities—particularly as they reduce vehicle travel by providing a walkable area usable even to the vehicle trip-makers arriving at the sites. The reductions in vehicle trips in these locations, therefore, do not result in “internally capturing” trips by any mode, but rather through changing the primary mode to an alternative access mode—walking, biking, or taking transit.

4.3 DEVELOPMENT ALONG ARTERIAL ROADWAYS

Mode choice and the overall feel of an area are largely affected by land use and site permeability. What connects these two factors is the roadways that provide access and move traffic. Of all the roadways that connect neighborhoods and other key locations, a special role is reserved for arterials. Arterials are generally high-capacity roadways that collect traffic from smaller routes and deposit them onto freeways or expressways. These roadways are usually arranged in a grid fashion so as to provide equal access from multiple areas, and often result in creating barriers for non-motorized movement between neighborhoods. On a neighborhood scale, arterials move traffic away from local streets and land uses (e.g., residential areas, schools, community centers) creating internal neighborhoods (see Figure 17 for Clarence Perry’s “Neighbourhood Unit” (1929)), but as a result, these fast-moving, high-volume arterials can act as barriers to inter-neighborhood connections. When businesses along arterials also have problems with permeability to the neighborhood behind them, the non-automobile, site-level access suffers, creating higher automobile use, even in areas where the built environment, statistically speaking, suggests otherwise.

Figure 11 Clarence Perry's Neighbourhood Unit (Perry, 1929)

Roadways need to be designed to promote accessibility rather than mobility (Schlossberg, Rowell, Amos, & Sanford, 2013). To do this, the quality of features incorporated in arterial design need to be increased to effectively connect destinations and origins without ignoring active and transit modes. However, not all arterials are created equal. Even along the same roadway, the streetscape and feel of the facility can change from one block to the next creating pockets of livability mixed with stretches of desolate bike and pedestrian behavior—even in higher-density, urban areas where the adjacent residential neighborhoods are supportive of bicycling and walking. There are a few elements of the design of arterials (and the connecting areas) that—based on our qualitative and quantitative analyses—may help provide a more contiguous urban fabric to support active and transit mode use at businesses suffering from low connectivity due to barriers such as arterials.

4.4 SITE PERMEABILITY

Walking, biking, and transit use are sensitive to smaller-scale changes in trip length (Krizek & Johnson, 2006; Ewing & Cervero, 2010). For this reason, maximizing the connectivity—or the directness of routes—of a site can affect the potential mode choice of users. While district- or

neighborhood-scaled connectivity is often considered in terms of street and block configuration and size (Handy, Butler, & Paterson, 2003), the site itself and the degree of connection it has to surrounding areas—also known as the site’s permeability—can play an important role in overall connectivity. This is especially true of sites that are located within large blocks and/or blocks that front on high-traffic or otherwise inhospitable roadways. Being located within a longer, inhospitable arterial block, for instance, can be a deterrent for users who are walking or biking from neighboring streets.

Site-scaled connectivity or permeability relates to the degree and distribution of its access points. Sites that have a large “access shadow” (Larco, Kelsey, & West, 2014) have limited access points and can hence require longer trip lengths to get to areas that may be directly adjacent to them, but only accessible through a poorly connected street network (see Figure 11). These types of sites—especially around commercial areas—often have informal paths such as “goat trails” and knocked down fences at their perimeter as users find ways around the limited connectivity of the site (Larco, 2015).

Figure 12 Access Shadow, Site Permeability, and Maximizing Distribution of Access Points, graphic from (Larco, Kelsey, & West, 2014, p. 24)

In this study, we found various informal paths within or near sites that had limited site permeability. While these paths do allow more direct connections and point towards the pent up demand for direct routes, they are often uneven, poorly lit, and with restricted visibility, limiting the users who would feel comfortable in these areas—especially at different times of day.

Further, buildings tend to be oriented toward the “front,” usually facing an arterial, with access points for the public there. The rear of the building is often reserved for deliveries, employee parking and access, garbage and refuse, and other utilitarian functions of the establishment. These

areas tend to be separated from other uses with fences, walls, ditches, and landscaping that buffer neighbors' views of these utilitarian areas and intentionally inhibit access.

These spaces in the rear of buildings are often missed opportunities to increase non-automobile access, particularly in the suburbs where the retail and service locations within strip development along arterials is backed by multifamily housing. Increasing access to these small nodes of density may be key to increasing walking and cycling in the suburbs. Taking a “360-degree” view of the opportunities to increase site permeability of a development can reduce the access shadow and increase connectivity. This could be achieved through designated easements at the backside of sites, the legitimizing of existing informal paths, or by creating sites that span an entire block depth, allowing access from both sides.

We present, as one example, a local brewery and restaurant that is known for its embrace of bike culture. The design and orientation of this site embodied many of the permeability issues observed at other sites. Their site at Powell Boulevard, shown in an aerial view in Figure 13, has much of the basic infrastructure to encourage people for walking and biking. It has generous bicycle parking and sidewalks. The site has attractive landscaping and is adjacent to highly walkable and bikable southeast Portland neighborhoods (see Figure 12). But we observed a low non-automobile mode share at this location in our previous study, despite the fact that brewpubs in Portland tend to attract walking and cycling and this one in particular supports a number of cycling events.

Figure 13 (top) Brewery Entrance, Landscaping and Bike Parking and (bottom, same location but view facing arterial) People Wishing to Visit Bike-Themed Brewery Must Bike Along Sidewalk Next to 40-mph Traffic

However, there are some significant barriers to non-motorized access to the brewery. The site is located along Powell Boulevard, which is a highway (U.S. Route 26) with five lanes (including a two-way left-turn lane) that experiences high traffic volumes and speeds throughout the day. There are limited pedestrian and bicycle crossing aids and the nearest signalized intersections are a quarter-mile away from the site. These conditions make it difficult for site visitors to cross the arterial and walk or bike to the establishment. Recommendations for sites located on major arterials are discussed in detail in the next section; however, the access issues with the arterial do not explain all of the barriers to reaching the site. The aerial view reveals that the site backs up to a residential area, with a mix of single-family and multifamily housing, good street connectivity, sidewalks and bicycle-friendly streets (see Figure 13 and Figure 14). Residents in the area behind this site wishing to visit this restaurant on foot or by bicycle have to traverse Powell Boulevard. Site permeability is a major barrier to access from this neighborhood (see Figure 12, bottom image and Figure 13).

Figure 14 Aerial View of Satellite Imagery, Bike Route and Bus Stops

Figure 15 Aerial View of Land Use (Metro RLIS 2011) around Brewpub

Behind the building that houses the brewpub, there is another large building associated with the brewery's function and a rectangular parking lot. The back of the lot is surrounded by a chain-link fence and a steep embankment on the east side. Residents who are familiar with this area may know of the informal path from the neighborhood to the establishment (see Figure 15) that can be clearly seen from satellite imagery (Figure 16). This indicates that residents are making their own routes to access the destinations and transit on Powell Boulevard. However, this "goat trail" passes through a site with an adult entertainment establishment located next to the brew pub. The nature of this business may prohibit some, including families, from using this shorter path to access local destinations. Further, the lack of site permeability means that pedestrians must walk longer distances and time on exposed sidewalks along the noisy and fast-moving arterial, which is not a comfortable or pleasant experience. The combined effect results in a large access shadow.

Retrofitting this site to amend the lack of permeability is not easy after the development is in place. The lack of public easements, the embankment, building configurations, fences and the development of other properties create a situation that can be costly in terms of time and money. However, if the development review process considered non-motorized access as much as automobile traffic impacts, these issues would be much more worthwhile to address.

Figure 16 Informal Path from Multifamily and Single-family Housing towards Brewery, through Strip Club

Figure 17 Close-up of the Brewery and Informal Path to Residential Area

Speed of Traffic

One of the key aspects of designing a street that is safe is design speed. For arterials this is a major factor because the main purpose of an arterial is to move a high volume of automobile traffic at a high speed. However, as a consequence, speed plays a major role in the severity of traffic collisions. In 2013 alone, 4,735 pedestrians were killed in motor vehicle crashes; of the fatalities that year, 73% occurred in urban areas and 69% occurred at non-intersection locations, like crosswalks or mid-block access points (NHTSA, 2015). The design speed of a street is not solely the posted speed of a street but rather the speed that drivers are restricted to within the environment. Factors that contribute to design speed are the design of the roadway itself, road space allocation, lane width, street-scaping, building setback, and lighting (NACTO, 2013). These factors act in the physical realm to reduce speeds and calm traffic. While these features are rarely considered when examining transportation impacts in the site development process, they often shape mode shares to the site through indirect encouragement or discouragement of travel along and across these corridors.

Enclosure

Beyond reducing posted speeds, another way of creating safer streets is to force drivers to be more aware. By enclosing streets in a dense environment with no significant setbacks, drivers are forced to slow down and be aware. This element of street design focuses on how tight a roadway feels. Factors that contribute to this overall goal are buildings along the street, width of sidewalks, street and sidewalk lighting, sitting area, signage, and buffer strips. In addition to these factors, street trees are also extremely valuable in narrowing the visual field of drivers to promote awareness. Trees provide enclosure both horizontally and vertically and add a degree of protection in inclement weather. Street parking can act as a valuable buffer between a street and pedestrians.

Enclosing the surrounding street is vital in establishing safe streets. However, when considering businesses, setbacks can be both a positive and negative feature. Setbacks establish how a site relates to an arterial by directly affecting the contact a site has with a roadway. Because of this, setbacks are often criticized for diluting the relationship of a building to the street. If the setback is also used to accommodate site parking, it has the additional impact of inhibiting non-automobile site access. However, setbacks may offer a positive benefit by distancing site activities from the negative externalities of the arterial such as noise, light, and pollution. Additionally, the negative effects of setbacks may not be too severe if the site has good permeability and non-auto patrons have access through other entrances. All things considered, setbacks can be positive for an arterial if site connections to multimodal facilities are well established.

Crossings and Connections

Comfortable, safe, and connected crossing are vital in encouraging pedestrian activity, and large, high-speed vehicle corridors tend to lack connections for pedestrians that make non-motorized activity plausible. For the brewery discussed earlier in Section 4.3 (see Figure 12), the adjacent arterial includes two traveling lanes in each direction—the outer lanes are 14 feet and the inner lanes 12 feet—with an 11-foot, two-way turn lane making up a 63-foot traveling distance for pedestrians wishing to cross the 45-mile per hour speed limit (if they can get traffic to stop for them). From this brewery, the pedestrian crossings are about 500 feet away in either direction just to get across the street. Assuming an average walking speed of 3.5 feet per second, customers who wish to cross this arterial will have to walk 2.4 minutes out of their way. This is comparable to asking the drivers on this facility to travel between 1.6 and 2.0 miles out of their way, for speeds between 40-50 miles per hour. If traffic will not stop for the pedestrian, the user has to travel between 1,000 and 1,220 feet out of their way to reach a signalized intersection—which is the equivalent of asking drivers to travel between 3.6 and 4.6 miles out of their way at 45 miles per hour (see Figure 18 for more information³).

³ Walking distances are converted to driving equivalents using an average walking speed of 3.5 feet per second and variable driving speeds (e.g., 25, 35, 45, 55) using the following formula:

$$\frac{Distance_{walking}}{(Speed_{walking})/((3600\text{ seconds})/hour)} * Speed_{driving} = Distance_{driving}$$

Figure 18 Driving Equivalent to Walking "Out of the Way"

On these high-speed and wide vehicle corridors, the ability for pedestrians to cross is dependent on getting drivers (in all five lanes) to see the people waiting to cross, recognize a legal crosswalk, and do all of this in time to stop for the pedestrian. Anecdotally speaking, our observations and knowledge of wide-lane facilities suggest this to be much more difficult for drivers than it sounds.

Limiting speed and enclosing streets is important for creating an environment in which pedestrians are comfortable. However, if pedestrians cannot cross a road and access locations of interest then the problem has not been solved. Crossings and connections are vital in establishing how walkable an area is. They shape and respond to pedestrian demand and guide pedestrians to the safest route through an area. Factors that influence effective crossings and connections are bulb outs, crosswalks, transit connections, multimodal facilities, and curb cuts. Facility cross-sections are not the only means for reducing (or at least equalizing) pedestrian burden. For newer facilities, reducing the block size can play a major role in increasing the opportunities for pedestrians (including transit users) and bicyclists to cross. Added intersections and access from local streets and minor corridors can also help decrease speed, especially alongside narrowing the feel of the facility by reducing lane widths and adding bulb outs. Added access from minor corridors can also help reduce access to commercial driveways mid-block, decreasing the safety and comfortability of pedestrian and bike travel mid-block.

Prioritizing Movement

For businesses suffering from inhibiting arterial barriers, the treatments discussed here are only a small sample of the potential considerations that should be taken. In our example, we consider the brewery located along major arterials, suffering also from a lack of permeability to the adjacent neighborhood. Not all areas of this facility are as bad. One mile down the arterials both ways and the intersection density nearly doubles, allowing for quicker access to businesses from the adjacent

neighborhoods as well as more opportunities to cross. Although the speed of this facility and the correspondingly wide cross-section of automobile travel remain problematic, this characteristic of good spots and bad spots along the same roadway was consistent in many of the urban arterials we evaluated. As an artifact of incremental development and site design, limiting the scope of the planning process to a site level—especially for large-scale developments—increases the inconsistency of the non-automobile use of these facilities. It is not only the arterial that sets the mode for how the businesses perform in terms of active travel; the development itself has a way of changing the arterial. By examining the transportation impacts of new development at a broader scale, incremental improvements in adjacent facilities can feel less like patchwork, which create surprises for all users when the connectivity expected on a facility fails on one block but not the next. A higher-level approach to evaluating impacts can also aid in improving connections upstream from the site, at the least by encouraging users from further and further away to not avoid certain facilities.

4.5 COMMUNITY & BUSINESS CULTURE

Travel choices are complex and there is increasing recognition that perceptions, attitudes, motivations, social norms and other psychosocial characteristics play an important role in shaping behaviors (e.g., Van Acker, Van Wee, & Witlox, 2010). Motivation and support from family, friends and co-workers can provide encouragement to try new things and make different choices. People's travel choices are also shaped by the social norms and motivations projected by the community at large (e.g., Bamberg, Hunecke, & Blöbaum, 2007; Páez & Scott, 2007). As such, business owners can exert influence in the culture of the community, including the use of active transport (Heinen, van Wee, & Maat, 2010; Clifton, Morrissey, & Ritter, 2012). Since transportation impact studies typically happen very early in the development review process, understanding the business or community culture of new development is extremely difficult to predict. However, many agencies are now considering evaluating the ongoing impacts of development in terms of a user fee or through mitigation monitoring programs. By considering the expanded use of trip generation studies, it will become more important to understand how business, marketing, or community culture persuades changes in behavior. In this section, we discuss bicycle culture and how we have seen it take hold in Portland's restaurant industry. But business culture may extend to how "creative" office culture or residential development marketing or transportation demand strategies encourage workers and residents to travel. While we focus on bike-related culture, "car culture" also persists in many communities, potentially overriding strategies to encourage or promote biking, walking, or taking transit.

Many of our study sites were in the city of Portland, which is renowned for its public investments in cycling infrastructure, bike friendliness and overall use of the mode. In 2015, the League of American Bicyclists named Portland as one of four communities given a "platinum"-level ranking, the highest rating (League of American Bicyclists, 2015). There is a strong sense of bicycle culture and the attitudes of many residents reflect their desire to travel by bike. From the survey data collected in our previous study, the percentage of biking is almost double (10% of trips observed, 64 locations) for Portland sites than those located in surrounding cities within the same region (5%, 14 locations). This social support and culture extends to the business community as well. Many businesses support and reinforce this bicycle culture not only in terms of site accommodations, but in subtle ways, such as their décor, specials offered to cyclists, sponsorship of cycling events, and other visible expressions of their attitudes about cycling.

In our study we had several sites which provide cycling infrastructure and have a strong cultural desire to promote more biking. For example, one brew pub in our study is playing an active role in promoting a broad-suite of environmental values, including encouraging cycling through marketing and promotional activities, which has earned this business a “gold”-level rating as a bike-friendly business by the League of American Bicyclists (2015). Both of their locations have attractive covered and uncovered bike parking, but even their interiors are decorated with both rare and salvaged bike parts—using art to integrate cycling interests into the track lighting, tables, bar, and chairs. Beyond their prevalent sponsoring of cycling events throughout the region, in one establishment customers can receive a discount for every 15-minute interval they pedal on an electricity-producing stationary bike. On their menus, alongside symbols for vegan, vegetarian, and gluten-free foods, they include symbols that denote good “bike to go” options that fit well in water-bottle cages on bikes.

Another “bike” bar in our study provided only bicycle parking, including spots for carrier bikes, and storage for helmets and messenger bags (see Figure 19). Bicycles and art representative of bike culture throughout the century are once again integrated into the interior décor. Their website encourages cycling by stating: “Always tons of bike parking” and “Drink, DON'T DRIVE.” Forget your bike lock? This bar has spare locks for loan for free to cyclists. In the summertime, the bar attracts many cyclists and often the bike parking is at or over capacity. This bar is on a busy neighborhood arterial and passing motorists can see that it is popular for cyclists. It is also located on a busy bicycle commuting corridor and, recently, major cycling infrastructure investments have resulted in greater numbers of cyclists. The specific role that these businesses play in contributing to culture, reinforcing norms, and rewarding desired behavior is important. At this establishment, they do not offer food, but encourage purchasing from the neighboring restaurants on site and across the street. These restaurants will deliver food, which the bike bar allows them to eat from there, encouraging economic benefits to their greater neighborhood through a neighborhood-level internal capture, and providing substantial seating which the other businesses would not be able to handle (small shops, limited seating). And the available restaurant options have since grown, further encouraging staying to eat locally without actually providing food on site. But more studies are needed to identify the mechanisms of bike culture and how they shape behavior and vice versa.

Figure 19 "Bike" Bar

5.0 A SUSTAINABLE MULTIMODAL PLANNING FRAMEWORK FOR TRANSPORTATION IMPACT ANALYSIS

The findings from numerous studies have identified numerous issues with trip generation studies for site development that hamper the ability to better coordinate land use and multimodal transportation planning. Prime among the issues with trip generation studies is the reliance on data and methods that consider vehicle trips only; are not sensitive to the urban environmental, economic and social context; and focus predominantly upon the peak hour of vehicle trips on the adjacent facilities (Clifton, Currans, & Muhs, 2015; Currans & Clifton, 2015; Schneider, Shafizadeh, & Handy, 2015; Ewing, et al., 2011; Bochner, Hooper, Sperry, & Dunphy, 2011; Walters, Bochner, & Ewing, 2013). Further, the complexity added by mixed-use sites or structures requires a better understanding of internal capture (or additional trips made on site) and the interrelationships between land uses (Ewing, et al., 2011; Bochner, Hooper, Sperry, & Dunphy, 2011). Yet another problem is the piecemeal process by which each site is developed and planned independently, and where the only constraint is the vehicle capacity of the adjacent roadway facility or intersection (Millard-Ball, 2015). This site-by-site assessment, planning and mitigation process can create problems for planning and developing areas that support more sustainable transportation.

There are already efforts underway to address some of these concerns and improve upon the trip generation data and methods available to practitioners and researchers. The latest version of the Institute of Transportation Engineers (ITE) *Trip Generation Handbook* (Institute of Transportation Engineers, 2014) and the corresponding *Informational Report* (Institute of Transportation Engineers, 2012) has incorporated a set of recommendations from the state of the research intended

to offer further guidance on how to address some of these long-standing shortcomings. Among researchers and practitioners, there is a charge to collect person-counts and multimodal data, trip origins and next destination location, attach more detailed information on the temporal and spatial location of data collection in order to augment with archived built, and social and economic environmental information. Greater attention has been paid to the unique issues in evaluating trip generation for mixed-use, infill and smart growth sites (Schneider, Shafizadeh, & Handy, 2015; Bochner, Hooper, Sperry, & Dunphy, 2011; Daisa, et al., 2013). There is convergence on the methods used to collect this information in order to have more standardization, allowing pooling of information across locations (Clifton, Currans, & Muhs, 2013; Schneider, Shafizadeh, Sperry, & Handy, 2013). Finally, nascent efforts are underway to consider the basis for the land use types for which data are collated and used for analysis (Currans K. M., 2013).

Even with these advances, the process for transportation impact analysis remains largely a “predict and provide” approach focused on accommodating automobile traffic—driven by individual site development reviews, predominantly divorced of larger neighborhood and regional planning efforts, and considering impacts on a near-term planning horizon (2-3 years). With a few exceptions, most cities still rely on national methodologies, standards and data for their local site plans. For the moment, new methods using person-trip and multimodal data tend to be motivated by the desire for more precise and accurate estimates of vehicle traffic in different urban contexts rather than as a mechanism for planning for all modes. This approach tends to be a reactive rather than a proactive one that employs a coordinated area-wide planning process consistent with regional-, urban- and neighborhood-scale plans. A proactive approach creates the conditions to support the character and modal mix that are desired, rather than accepting a forecast based upon current conditions as a given.

This chapter brings together our reflections on the numerous concerns identified from practice, the research findings from various recent studies, and the need for a sustainable process for evaluating the transportation impacts of new land development. Below we present one potential framework to advance the methods for how site plans fit into neighborhood and regional planning, using locally defined standards and goals.

5.1 FRAMEWORK

In this section, we provide a comprehensive framework to better coordinate land use and transportation planning at the local level, as shown in Figure 20. The approach attempts to balance the transportation demand generated by the land uses planned for an area with the necessary transportation investments. To do this, we propose moving away from the idea that we need to mitigate the transportation impacts of new development solely at a site level, and instead facilitate a process that helps cities realize neighborhoods with the character and transportation options that they want. This requires an intermediate step that links between urban transportation and land use planning and transportation impact analysis done during development review.

Figure 20 Proposed Framework for Evaluating Transportation Impacts of New Development

Area-wide analysis

In this proposed framework, we want to de-emphasize the site and its immediate environs as the primary (and only) scale of analysis and lessen the reliance on the problematic methodologies for estimating site-level travel demand. Rather, we argue that transportation impact analysis would benefit by first taking a district, neighborhood or area-wide approach with attention to the urban context—the built and social environment—where a site is located. At this larger scale, there is a better ability to understand the various elements that work together to shape travel demand, including but not limited to: multimodal transportation infrastructure and services; land use densities and mix; parking supply and policies; public and private resources; and, most importantly, the people living, working and visiting the various sites in the area. Further, this allows for a better assessment of how a specific site proposal will integrate into this larger context.

This scale can be the system-wide, region, quadrant, neighborhood, district, transportation analysis zone, census geography or some other areal unit for which data are available to support planning and analysis. A greater benefit may be had from splitting the area-wide analysis into two or more parts at different spatial scales: a neighborhood-based approach that is nested within a system-wide plan—accounting for the impacts of new development at the system level (perhaps focusing on motorized modes) and fine-grained, multimodal analysis that considers the local transportation impacts at some sub-regional geography. Linking the site development to the larger neighborhood and regional context can better coordinate and leverage short- and long-term planning goals.

1. Future travel demand

The first step shown in Figure 20 is the task of estimating the area-wide demand for a future time horizon based upon land use and transportation plans. Land use plans are developed for cities to

provide a consistent set of goals to guide decision making. The plans provide specifics on the location, character, level and intensity of development that are allowed, supported, and encouraged in a community, which are described in the text and shown on a land use map. Here, a typical time horizon for these plans is 10 to 20 years, but they tend to be updated on a more frequent cycle. Plans are implemented using the regulatory instrument of zoning ordinances and other local legislation. The intensity of residential uses tends to be designated in terms of the number of dwelling units per unit area. Non-residential uses tend to indicate intensity by a floor-to-area ratio (FAR). This information, combined with existing methods and data, can be used as the basis to estimate anticipated travel demand in terms of person trips generated.

Transportation demand estimates at this scale should include person trips by mode and, ideally, consider variations over the day (or other temporal unit) at a commensurate time horizon with the build-out time horizon of land use plans. As shown in Figure 21, these estimates of area-wide person-trips by mode could come from “top-down” or “bottom-up” methods, both relying on the land use scenario(s) articulated in the plans.

In the top-down approach, trip generation estimates could be obtained from urban travel models – the first step in the “four step” modeling approach (San Francisco Planning Department, 2002). These models tend to be sensitive to the characteristics of the traveler, trip purposes, and modes available. These models tend to estimate person-trip production-ends and attraction-ends by purpose. Many models are now replacing attraction-end models with agent-based destination choice models, which provide more refined estimates using distributions instead of averages. Either way, estimates of the total number of person trips for an area for a specific time horizon can be obtained from these approaches.

Alternately, a bottom-up method would rely on the summation of the trip generation data for each individual land use within an area to obtain the person-trip estimates. If available, locally obtained trip generation data should be used. These counts are often regressed upon a variable of size, such as the number of dwelling units, employees, and square feet of gross or leasable floor area. Thus, there are consistencies with the information provided in trip generation data with that information that can be gleaned from land use plans. To supplement nationally (8) or locally developed person-trip rate (e.g., San Francisco Planning Department, 2002; New York City, 2014), there are now several models to estimate vehicle-trip rates for developments in specific urban contexts and convert vehicle trips to person trips (e.g., Clifton, Currans, & Muhs, 2015; Currans & Clifton, 2015; Schneider, Shafizadeh, & Handy, 2015; Ewing, et al., 2011; Daisa, et al., 2013). All of these methods currently adjust the vehicle trip rate data (from largely suburban locations) provided in ITE’s *Trip Generation Handbook* (Institute of Transportation Engineers, 2014) and convert vehicle trips to person trips using a set of assumptions about the baseline locations (e.g., baseline mode shares and vehicle occupancy rates). This baseline adjustment approach was adopted by ITE in the 3rd edition handbook.

Figure 21 Area-wide Person-trip Generation Estimates

One challenge here is derived from the inconsistency between the land use and/or zoning categories used in these plans and the more specific categories of land use types available for trip generation analysis. Land use planning tends to have rather aggregate categories that vary from agency to agency (e.g., residential, institutional and public buildings, open space, and recreational land, industrial and commercial). In contrast, ITE's *Trip Generation Handbook* (9th ed.) has data for 172 different land uses. Currently, there are some questions about whether this large number of distinct categories is necessary and improves analysis (e.g., Currans K. M., 2013) and this report. If there are no significant differences in trip rates between these various land uses and the functions of the land use are similar in terms of how visitors to the site interact, then a strong argument can be made for aggregating the land uses into a smaller number of categories. It is likely that using a taxonomy corresponding to planning or zoning may be too coarse, potentially leading to a lot of variation in person-trip rates within one category (e.g., commercial or retail).

One possible solution is to consider in the analysis the potential ranges of trip rates that may be realized in any given land use category and developing several demand scenarios for a neighborhood. There is uncertainty in any demand estimation and opportunity for error, whether from demand models (Zhao & Kockelman, 2002) or trip generation data (Millard-Ball, 2015). Similarly, there is a great deal of uncertainty about how plans may be realized, what and when development will occur, and even the specific uses that will ultimately occupy a site in the near term and over a longer time span (McRae, Bloomberg, & Muldoon, 2003). Thus, efforts that focus on obtaining detailed, precise and singular estimates of demand to inform decision making may ultimately lead to failure. A more robust planning approach may involve accepting the uncertainty and error involved in any planning and forecasting endeavor and incorporating that into investment decisions. Examining the range of possible outcomes for an area and a site and weighing them against overall planning goals may yield better results.

One advantage of conducting both a “top down” analysis using travel demand models, and a “bottom up” approach using trip generation data, is that this provides the ability to observe, understand and potentially reconcile any differences between the two methods that operate at two

different scales. This would lead to greater links and consistencies with the information used in regional travel demand modeling, local transportation and land use plans, and ultimately site design.

After the future person-trips are estimated for the area, the next step in the demand analysis is to distribute those person trips across available and future modes. Mode share analysis can be done at the area-wide level based upon the local characteristics of the built environment that support various trip types and modes and consideration of the economic and social context. From the top-down perspective, regional travel models estimate mode shares, although their abilities vary widely across the United States (Singleton & Clifton, 2013). However, the factors that impact mode choices are relatively well-developed and documented in the literature (e.g., Cervero & Kockelman, 1997; Ewing & Cervero, 2010) compared to some aspects of transportation and the ability to consider non-motorized modes has been advancing (Broach, Dill, & Gliebe, 2012; Clifton, Singleton, Muhs, & Schneider, 2016).

Alternately, from the bottom up perspective, one could analyze differences in potential mode shares for different land use types at the site level and aggregate them to the area. As with trip generation, some of the same issues apply when considering mode split for a site in terms of the variations or range of probable modes within coarse land use categories. For example, the automobile mode share may be very different for a furniture store and a bookshop even though both are located in a downtown district and are both categorized as commercial or retail. Again, producing a range of mode share outcomes, say with the most auto-oriented land use scenario and one with a set of land uses more likely to attract users from walking, cycling and transit, may offer more insight into how best to plan for an area.

The time of day that demand occurs becomes an important element in coordinating the transportation needs for new investments. Since not all activities occur on the same temporal schedule, there may be opportunities to capitalize on different temporal distribution of demand by mode for uses in an area. Most vehicle trip generation data are only available for limited time frames, usually the peak hours of the facility. There are currently calls to expand the time frames for data collection, particularly because there may be different demands on the system at different times of day (Clifton, Currans, & Muhs, 2013; Puget Sound Regional Council (PSRC), 2009). At the moment, data are insufficient to consider variations over time; however, household travel and activities surveys may offer some intermediate ability to understand the temporal dimensions of trip purposes and mode use.

2. Assess area-wide transportation performance

Once area-wide demand estimates are obtained, in terms of person trips and trips by mode, the framework then focuses on assessing the suitability of existing and planned performance in the system and area for meeting the projected demand. In this step, analysis attempts to answer the question “can current infrastructure and services adequately handle future trips?” Traditionally, performance would be evaluated using some volume-to-capacity measure – such as facility level of service (LOS). Multimodal LOS was developed for the *Highway Capacity Manual* (United States National Research Council, 2010), but there are still challenges to implementing these measures (Carter et al., 2013).

Alternatively, cities could adopt multiple evaluation metrics, of varying or equal importance, to measure the multimodal or person-based capacity and quality of service the system provides. Some

agencies are exploring alternative performance measures for multimodal travel (e.g., City of Portland, 2014; Kittleson and Associates, 2014). The City of Bellevue and the Puget Sound Regional Council, for example, have conducted a pilot project to develop and implement a method for evaluating multimodal concurrency (Puget Sound Regional Council (PSRC), 2009). In addition, alternative performance measures are being developed by communities around the country that consider specific modal aspirations as well as a broader range of goals such as health, safety, economy, and air quality (Singleton & Clifton, 2014). Many of these communities face data and methodological challenges to implementation in future scenarios. The City of Portland is working to adopt a policy of making transportation system decisions based on a hierarchy of modes—prioritizing walking, biking and transit over taxi/shared vehicles, zero emissions vehicles and, lastly, personal vehicles (City of Portland, 2014, pp. GP9-7). Adopting multi-objective policies allows (and sometimes forces) planners and analysts to more actively consider all travelers at the various scales of sustainable multiple planning (see Table 4 or (Kittleson and Associates, 2014)).

3. Plan for infrastructure and services to meet demand

The next step of the framework is to focus on the investments needed to meet future demand, if the current capacity or performance is deemed insufficient. New infrastructure, services and policies can be added (or removed) to accommodate future demand across all modes. There is an opportunity to re-evaluate land use plans and the assessment of future demand in light of new planned investments and policies, as shown by the dotted arrow between Step 3.b. to Step 1. Unlike “predict and provide methods,” this iterative approach allows for adjustments between area plans in order to achieve the desired character and performance over the long term.

For example, if a city has a long-term goal to curb automobile demand, encourage trips by walking, cycling, or transit or substitute telecommunications for travel, a suite of policies may be necessary to ensure this change. These transport policies may include allocating more street right-of-way to desired modes, reducing parking supply, pricing, supporting vehicle sharing programs, and increasing transit service. Further, it may include a suite of incentives for residents, employers and businesses to utilize desired modes more often. However, achieving the end goals may also require changes to land use plans or adjusting the density, mix, development regulations and/or design of an area. Thus, this proposed process supports compromise and balance between plans, investments and desired ends.

Table 4 Example Performance Metrics by Planning Goals and Scale of Evaluation

Potential Planning Goals				
Safety	Mobility	Multimodal	Greenhouse Gases	Equity
System-wide				
Crash or fatality frequency	Accessibility of freight network	Mode-specific system completeness	Vehicle miles traveled	Housing or transportation affordability
	Work accessibility		Air quality	
Area-wide				
Crash frequency by crash type	Speed suitability	Mode choice availability	Vehicle miles traveled per capita	Jobs-Housing Accessibility
Crime statistics by type	Person miles/hours traveled	Mode share	Land use mix	
	Person throughput	Pedestrian crossing frequency		
Site-Level				
Linear miles of connected walking paths	Person delay at driveways or intersections	Person trips by mode	Vehicle trip length distribution	Transit accessibility
Driveway Frequency (access management)		Street design or layout	Vehicle trips	Pedestrian connectedness

NOTES:

For more resources about potential performance metrics at varying scales of analysis, see the appendix of the memo by Kittleson and Associates (2014).

4. Estimating the costs of future improvements

Once a suite of transportation investments and policies that meet future needs has been determined, then the effort is focused on estimating the total costs of implementation, operations and maintenance of the planning horizon. New development should be asked to contribute to only the proportion of costs relative to the growth in demand attributed to them. Some fair mechanism for apportioning the transportation costs relative to the overall system-wide burden imposed by the planned future development should be in place, thus incorporating a second tier of area-wide scales (e.g., system-wide and some smaller nested geography). Agencies that wish to explore a transportation utility fee, supporting the costs of operation and maintenance of existing facilities,

could also use this framework, substituting capital costs with operations and maintenance in this calculation.

5. Transportation system development charges (impact fees)

The rate for transportation system development charges/impact fees (or utility fees) can then be calculated by dividing the costs of improvements (or operations and maintenance) by the total demand in person trips estimated for the area. Then as new land is developed or redeveloped in the area and according to the plans, the appropriate fees can be assessed.

One potentially controversial issue here is that in this framework, all trips are subject to the same rate regardless of the mode of travel. Impact fees or system development charges consider the whole system. Investments for an area are planned in proportion to desired ends for the area. So a firm that aims to build in the area should be basing their location decision on these future attributes along with other considerations. Some businesses may attract very different mode shares and the costs for supplying each of these modes may be different. Despite these inequities, each bears some responsibility for contributing to the overall transportation system in the larger region or neighborhood where they reside.

The inequities caused by differences in mode shares and the burden that they place on the transportation system are addressed or ameliorated in two ways. The first is by incenting or encouraging the types of development with lesser or more desired burden on the transportation system with some sort of reductions in fees. The process with which reductions are provided are in accordance with the area-wide capacity-based performance metrics, where development that satisfies additional specified planning objectives (e.g., safety, mobility, equity) are rewarded for identifying the ways in which they can or will contribute to the area-wide planning goals. The second opportunity comes with the transportation impact analysis done at the site level, which is presented in the next section.

Site-level Analysis

The framework shown in Figure 20 also provides guidance for evaluating the impacts of individual land development sites that are located within the larger area. This is the more traditional scale for most transportation impact analyses performed during the land development process. However, much of the process is similar to the area-wide analysis and draws upon similar methods, data and resources, albeit at a different scale. However, there are some important distinctions to be considered the site level.

As discussed in the previous section, there have been many calls to expand modes considered in this assessment and to promote this, a need to collect person trips, see (Clifton, Currans, & Muhs, 2013; Schneider, Shafizadeh, Sperry, & Handy, 2013; ENVIRON International Corporation, 2013) for a discussion. These new requirements have implications for the type and amount of data collected to support the creation of robust methods to estimate site-level multimodal transportation demand. These methods are still largely under development; nevertheless, we present this large framework in support of a more comprehensive and equitable analysis of impacts and assessment of fees.

1. Site-level multimodal travel demand

If a “bottom up” approach is used to estimate travel demand for the area-wide analysis, then those estimates for individual sites could be used here. However, the area-wide analysis is based upon

land use plans, and there may be more site-specific information available at the time of development review to bring to bear on the demand estimation. Yet, the assessment of site-level transportation impacts tends to occur early in the development process when some details of the proposed use of space remain vague or even unknown. Over confidence in the land use and site characteristics proposed at the time of the review can result in larger errors in the site-level travel demand estimates. For example, in a post-development review of 12 traffic impact analyses, McRae et al. (2003) found four developments were not built as planned (three were retail, the fourth was underdeveloped). Further, the specific uses for a site can change over time and are not required to undergo an additional transportation impact analysis if no change in zoning is needed. As in the area-wide analysis, a range of possible estimates could be estimated based on the likely scenarios for the site.

As mentioned above, trip generation analysis for a site would historically rely on vehicle trip rates from over 170 different land use types provided in ITE's *Trip Generation Handbook* (2014) and corresponding *Informational Report* (2012). The total vehicular demand for a site would be estimated for a time period—such as morning or evening peak hour or 24 hours for a weekday or weekend—based upon the given trips rates per an appropriate size metric for the land use (acres, building square footage, number of rooms or beds, employees, etc.). As yet, there are currently limited sources of person-trip or multimodal counts, thus hampering the ability to predict those rates, but as mentioned earlier, there are efforts to change the data collection protocols to inform these new requirements. As discussed in the “bottom up” approach of the Area-wide Analysis (Step 1), an alternative method of estimating person trips has been used in several alternative approaches (e.g., Currans & Clifton, 2015; Ewing, et al., 2011; Daisa, et al., 2013) —and is recommend by ITE (Institute of Transportation Engineers, 2014).

The local site-level modal demand (used to allocate baseline person trips) can be estimated using a variety of methods and techniques. Mode choice is arguably one of the more studied aspects of travel behavior, and as such, there exists a variety of methods to estimate mode shares or mode-specific trips or trip length (Ewing & Cervero, 2010). Several methods have already been developed to estimate mode shares focusing on site-level analysis specific to mixed-use developments (Ewing & Cervero, 2010) and infill (Currans & Clifton, 2015; Daisa, et al., 2013). Alternative models are also used more broadly for evaluation changes in behavior of development and policies based on synthesized travel behavior studies (Ewing & Cervero, 2010; ENVIRON International Corporation, 2013; Nelson/Nygaard, 2005).

Figure 22 displays the relationship between a set of eight dimensions (people, costs, built environment at the macro- and meso-scale, site design, land use function, culture and technology) that have been identified in the literature as influential to travel choices. This figure goes beyond these site-level evaluations and asks that the unit of analysis be the neighborhood. While meant to address the challenge of accommodating the travel demand from land development, this figure can serve as a more general guide to planning for sustainable transportation at a neighborhood or district scale. Grounded in travel behavior theory, each of the eight dimensions included here is defined by a number of characteristics or features shown to have important correlations with travel outcomes.

Conceptually, we have stacked these eight dimensions on top of a fulcrum, loosely ordered by their history of consideration in travel behavior research. The application of different levels and combinations of policies (conceptualized by the point where the fulcrum is on the scale of each

dimension) results in the lever pivoting on the fulcrum. The consequence of this combination of policies is shown on the spectrum of sustainable transportation outcomes (such as non-automobile mode share, amount of walking, etc.). Not all of these dimensions and their underlying features have the same magnitude of importance in shaping transportation, but they are all important policy levers to consider. Below we will briefly review each of these policies and their relative impact on transportation choices.

Figure 22 Sustainable Multimodal Planning

2. Calculate Transportation System Development Charges for the New Development

Based upon the costs per person trip in the Area-wide Analysis Step 5 and the total number of person trips from the Site Analysis Step 1, the responsibility for the costs for supplying future infrastructure (or operations and maintenance) can be assigned to a development in proportion to the burden imposed. These system costs are not mode specific. Rather, this process recognizes that any neighborhood requires investment in a variety of modes to be vibrant, economically successful, resilient, adaptable and sustainable. Using person trips permits a fair assessment of the overall impacts and allows flexibility for the area and the site to invest in a variety of modal options over time. It also reduces the need to deal with pass-by traffic and internal capture, as all of these trips will have an area-wide impact on one or more modes. However, the process recognizes that different land uses can distribute those person trips across a variety of modes and trip lengths, based upon the nature and function of the land use on the site, the design features of the site and immediate environs, public policy and private initiatives. These site-level modal differences will be assessed and mitigated in the following steps.

3. Assess the current transportation capacity at and near the site

Using multiple performance metrics for each mode informed by local planning objectives and goals, a capacity analysis can be performed for the area directly surrounding the site. Using multiple performance metrics allows agencies to examine the balance of support for each mode in terms of multiple locally relevant dimensions, continuing to support regional planning goals but with a focus on site-level contributions (see Table 4). Instead of relying on a single, nationally defined automobile-based measure, using agency-defined metrics that are easily measured,

monitored, and evaluated provides a resilient approach to assessing the multimodal capacity and provisions from new development.

4. Mitigations for transportation impacts

Typically, in a more conventional vehicle impact analysis, the capacity would be compared to the demand using performance metrics such as intersection LOS and reparations would be made to either increase capacity to accommodate new demand or to reduce vehicle demand. In the approach presented here, all modes will be considered and the impacts can be evaluated using the desired performance measures. Similar to the Area-Wide Step 3 above, there is the opportunity to invest in those mitigations that support the desired mode shares in the future, rather than those that replicate the current patterns.

5. Estimate cost of investments needed to address impacts

Similar to the cost estimation in Step 4 of the Area-wide Analysis above, the costs for these capital investments, qualifying public improvements, programs and policies related to site-level impacts will be estimated.

6. Evaluate total costs, mitigations, policies and other measures

The responsibility for the various mitigations (including payment, construction, public improvements, management, monitoring) will be assigned to the developer, the city and other agencies involved in transportation infrastructure, service and program provision. The proposed framework would benefit most from the scenario-planning based approach, providing a range of potential multimodal impacts. Final costs will be a result of policy priorities, incentives, subsidies and negotiations between the developer and the agency. By providing a range of potential outcomes, the developer has more transparency and autonomy to make the best decisions for their project in selecting mitigations—available and determined from the area-wide planning process—based on the relative costs to the system.

5.2 CONCLUSIONS

In this paper, we provide a framework for sustainable multimodal planning, which includes an approach for site-level and area-wide analysis, assessment, and mitigation. The basis for this framework stems from a background in research investigating site-level transportation impact analysis and attempting to reconcile some of the longstanding issues hampering advancement of sustainable transport. The addition of an area-wide scale addresses the issue of piecemeal site development disconnected from the larger neighborhood context where it resides.

What does this mean for transportation impact analysis? Both the area-wide analysis and the site-specific analysis, which includes both an assessment of travel demand as well as an evaluation of multimodal capacity, will require more thoughtful and careful examination about the potential impacts of a range of development outcomes and transportation investments on person-trip generation, trip length, and mode shares. While this adds some complexity, it relaxes the need to make detailed adjustments, justify ad-hoc reductions in rates, or fit new or unusual land uses into a specific category. However, this manuscript presents a proposed framework; it does not remove the need to continue to collect new data to understand the trip generation and mode share impacts of specific land uses.

This framework postulates that to accurately and robustly assess multimodal transportation impacts for land use development, one has to consider the role the larger context plays in shaping the success of a single site, while at the same time understanding how each site contributes to city or regional goals. The framework proposed here incorporates the lessons we have learned in estimating the overall demand for activities (person-trip rates) and the corresponding influences of mode share estimation and accommodation. While the larger, multiscale context of the site influences behavior in terms of activity (person trips), mode use and trip length, the developer continues to have flexibility in accommodating the site to adjust for multimodal provisions as they see fit for the land use relative to the area and the broader planning objectives.

Our findings also suggest a more dynamic framework is needed, accommodating the changing transportation and urban landscape by using ongoing monitoring of sites to evaluate current approaches and expanding our ability to develop more effective strategies. By expanding our methods to include considering either more stochastic estimates or a range of potential impact scenarios—or at least to place less weight on a deterministic, single-answer forecast derived from nationally aggregated data—we make room for a discussion about the full spectrum of potential outcomes of new development, and how they fit into multiple, multimodal goals. The main objective here is to shift the transportation impact analysis from a “predict and provide” attitude, toward a more flexible and locally sensitive approach.

In order to establish change in the transportation impact analysis process, the initial burden falls primarily on agencies. Defining what the scale and scope of what local area boundaries might be depends heavily on how agencies think about neighborhoods and areas within their own area. There is no quick and easy rule for how neighborhoods function and interact. However, there are several cities that have begun thinking in these area-specific terms before (San Francisco Planning Department, 2002; Puget Sound Regional Council (PSRC), 2009), and the guidance and experience of these agencies will be valuable as a result.

This framework is not without limitations. Most notably, the existing lack of data and methods for estimating site-level person-trip demand. There are many ongoing efforts to address and begin filling these gaps, including improving data for specific land uses and area types as well as more general data collection efforts by agencies to build a more locally relevant repository of multimodal data. As data and methods are improving, other agencies are working to build an understanding of how these approaches can be incorporated into practice, through identifying relevance of methods, increasing understanding and creating opportunity for applications.

As cities work towards more multimodal, sustainable, livable transportation systems and continue to struggle to work within the existing state-of-practice for transportation impact analysis, the proposed framework provides responses to many of the issues identified in the current system. Primarily, this framework creates a higher level of integration of transportation and land use planning—linking site-level, micro-system assessment to an area-wide approach to planning the transportation network for growth in land use development. By creating a system where land use planning and transportation impacts analysis are developed in parallel and inextricably linked—and allowing developers a more transparent and flexible system to make decisions about mitigations based on the estimated range of costs to the transportation system—we empower agencies to have more autonomy to decide what the character of place should be based on the needs of the people who live there.

6.0 BIBLIOGRAPHY

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APPENDIX A MAP SHOWING LOCATIONS OF STUDY SITES

APPENDIX B DESCRIPTION OF SITES

For each location on the following pages, the following three figures are provided:

- **Figure 1:** Street View of the Establishment (Google Street View, 2011 or image taken by the authors, as noted)
- **Figure 2:** PM Peak Mode Share (OTREC, 2012, data collection)
- **Figure 3:** Aerial View (Google Aerial View, 2015, scale 1:2,000)

Table 1: Variables (Built Environment and Socio Demographic)

Variable	Unit	Source
Type of establishment	Description	Additional Information
Parking condition	Description	Additional Information
Gross floor area	Square footage	Provided by location manager or calculated from GIS Building Layer (RLIS, 2010)
Lot coverage	Percent of parcel	Tax lot and Building Layers (RLIS, 2010)
Length of bike facilities	Miles	Bike Route layer (RLIS, 2010)
Bus lines	Count of bus corridors/lines within the ½ mile buffer	Bus Lines layer (RLIS, 2010)
Bus stops	Count of bus stops within ½ mile buffer	Bus Stop layer (RLIS, 2010)
Employment density	Jobs per acre	ESRI Business Analyst (2010)
People density	Jobs and residents per acre	ESRI Business Analyst (2010) Multifamily/Household layers (RLIS, 2010)
Retail and service employment index	Index of 0 to 4	Index based on the number of retail & service establishments within ½ mile, (Metro Context Tool, 2010)
Intersection density	Intersections per acre	Lines file (TIGER 2009)
Average vehicle ownership	Cars owned per	2013, ACS 5-year
Median household income	US 2013 dollars	2013, ACS 5-year
Average households size	People per household	2013, ACS 5-year
Non-white households	Percent	2010 Census SF 1
NOTES: RLIS: Regional Land Information System from http://rlisdiscovery.oregonmetro.gov/ ; ACS: American Community Survey; SF: Summary File 1.		

#1: High-Turnover (Sit-Down) Restaurant

Figure 1: Street View of the Establishment (Google Street View, July 2011)

Figure 2: PM Peak Mode Share

Figure 3: Aerial View (Google, 2015, scale 1:2,000)

Table 1: Variables (Built Environment and Socio Demographic)

Type of establishment	Mexican
Parking condition	Bike Corrals
Gross floor area	2,250
Lot coverage	33
Length of bike facilities	5.8
Bus lines	10
Bus stops	51
Employment density	4
People density	18
Retail and service employment index	1.89
Intersection density	0.21
Average vehicle ownership	1
Median household income	81,797
Average households size	2
Non-white households	13%

#2: High-Turnover (Sit-Down) Restaurant

Figure 1: Street View of the Establishment (Google Street View, 2011)

Figure 2: PM Peak Mode Share

Table 1: Variables (Built Environment and Socio Demographic)

Type of establishment	
Parking condition	Bike Staples
Gross floor area	1,440
Lot coverage	20
Length of bike facilities	6.7
Bus lines	12
Bus stops	26
Employment density	20
People density	29
Retail and service employment index	1.72
Intersection density	0.22
Average vehicle ownership	1
Median household income	62,031
Average households size	2
Non-white households	28%

Figure 3: Aerial View (Google, 2015, scale 1:2,000)

#3: Convenience Store (24-Hour)

Figure 1: Street View of the Establishment (Google Street View, September 2011)

Figure 2: PM Peak Mode Share

Table 1: Variables (Built Environment and Socio Demographic)

Type of establishment	
Parking condition	20 Auto
Gross floor area	2,500
Lot coverage	20%
Length of bike facilities	4.2
Bus lines	10
Bus stops	26
Employment density	6
People density	14
Retail and service employment index	2.09
Intersection density	0.01
Average vehicle ownership	2
Median household income	41,771
Average households size	3
Non-white households	57%

Figure 3: Aerial View (Google, 2015, scale 1:2,000)

#4: Convenience Store (24-Hour)

Figure 1: Street View of the Establishment (Google Street View, September 2011)

Figure 2: PM Peak Mode Share

Table 1: Variables (Built Environment and Socio Demographic)

Type of establishment	
Parking condition	11 Auto
Gross floor area	2,400
Lot coverage	12%
Length of bike facilities	5.6
Bus lines	8
Bus stops	15
Employment density	4
People density	23
Retail and service employment index	1.55
Intersection density	0.08
Average vehicle ownership	1
Median household income	25,625
Average households size	3
Non-white households	86%

Figure 3: Aerial View (Google, 2015, scale 1:2,000)

#5: Convenience Store (24-Hour)

Figure 1: Street View of the Establishment (Image from Authors, 2011)

Figure 2: PM Peak Mode Share

Table 1: Variables (Built Environment and Socio Demographic)

Type of establishment	
Parking condition	Auto
Gross floor area	2,400
Lot coverage	18%
Length of bike facilities	3.9
Bus lines	2
Bus stops	12
Employment density	5
People density	16
Retail and service employment index	1.52
Intersection density	0.11
Average vehicle ownership	2
Median household income	46,853
Average households size	3
Non-white households	18%

Figure 3: Aerial View (Google, 2015, scale 1:2,000)

#6: High-Turnover (Sit-Down) Restaurant

Figure 1: Street View of the Establishment (Image from Authors, 2011)

Figure 2: PM Peak Mode Share

Table 1: Variables (Built Environment and Socio Demographic)

Type of establishment	
Parking condition	Auto & Bike
Gross floor area	1,850
Lot coverage	57
Length of bike facilities	12.1
Bus lines	57
Bus stops	54
Employment density	65
People density	86
Retail and service employment index	3.40
Intersection density	0.45
Average vehicle ownership	1
Median household income	74,000
Average households size	1
Non-white households	18%

Figure 3: Aerial View (Google, 2015, scale 1:2,000)

#7: Convenience Store (24-Hour)

Figure 1: Street View of the Establishment (Google Street View, October 2011)

Figure 2: PM Peak Mode Share

Table 1: Variables (Built Environment and Socio Demographic)

Type of establishment	
Parking condition	7 Auto
Gross floor area	3,000
Lot coverage	13
Length of bike facilities	12.1
Bus lines	2
Bus stops	8
Employment density	2
People density	12
Retail and service employment index	1.10
Intersection density	0.03
Average vehicle ownership	2
Median household income	56,336
Average households size	3
Non-white households	42%

Figure 3: Aerial View (Google, 2015, scale 1:2,000)

#8: Convenience Store (24-Hour)

Figure 1: Street View of the Establishment (Google Street View, July 2011)

Figure 2: PM Peak Mode Share

Table 1: Variables (Built Environment and Socio Demographic)

Type of establishment	
Parking condition	24 Auto
Gross floor area	2,585
Lot coverage	20
Length of bike facilities	4.1
Bus lines	20
Bus stops	37
Employment density	5
People density	15
Retail and service employment index	1.72
Intersection density	0.06
Average vehicle ownership	1
Median household income	34,667
Average households size	2
Non-white households	32%

Figure 3: Aerial View (Google, 2015, scale 1:2,000)

#9: Convenience Store (24-Hour)

Figure 1: Street View of the Establishment (Google Street View, September 2011)

Figure 2: PM Peak Mode Share

Table 1: Variables (Built Environment and Socio Demographic)

Type of establishment	
Parking condition	9 Auto
Gross floor area	3,334
Lot coverage	28
Length of bike facilities	4.1
Bus lines	16
Bus stops	51
Employment density	7
People density	17
Retail and service employment index	1.9
Intersection density	0.22
Average vehicle ownership	2
Median household income	99,879
Average households size	3
Non-white households	10%

Figure 3: Aerial View (Google, 2015, scale 1:2,000)

#10: Convenience Store (24-Hour)

Figure 1: Street View of the Establishment (Google Street View, July 2011)

Figure 2: PM Peak Mode Share

Table 1: Variables (Built Environment and Socio Demographic)

Type of establishment	
Parking condition	11 Auto
Gross floor area	2,400
Lot coverage	21
Length of bike facilities	4.6
Bus lines	6
Bus stops	38
Employment density	2
People density	13
Retail and service employment index	1.51
Intersection density	0.17
Average vehicle ownership	2
Median household income	51,765
Average households size	2
Non-white households	30%

Figure 3: Aerial View (Google, 2015, scale 1:2,000)

#11: High-Turnover (Sit-Down) Restaurant

Figure 1: Street View of the Establishment (Google Street View, 2011)

Figure 2: PM Peak Mode Share

Table 1: Variables (Built Environment and Socio Demographic)

Type of establishment	Pizza
Parking condition	20 auto, bike rack
Gross floor area	1,300
Lot coverage	19
Length of bike facilities	4.6
Bus lines	6
Bus stops	27
Employment density	1
People density	13
Retail and service employment index	1.02
Intersection density	0.11
Average vehicle ownership	2
Median household income	77,063
Average households size	2
Non-white households	17%

Figure 3: Aerial View (Google, 2015, scale 1:2,000)

PM Peak Mode Share

Mode	Share (%)
Auto	75
Walk	10
Bike	12
Transit	3

Table 1: Variables (Built Environment and Socio Demographic)

An aerial photograph of a city intersection. A large, rectangular building with a white roof is situated in the upper left quadrant, adjacent to a large parking lot filled with cars. The intersection features multiple lanes with visible traffic lights and crosswalks. Surrounding the central area are various other buildings, including smaller commercial structures and residential houses, along with green spaces and trees. The image is a high-resolution satellite view.

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#13: High-Turnover (Sit-Down) Restaurant

Figure 1: Street View of the Establishment (Google Street View, 2011)

Figure 2: PM Peak Mode Share

Table 1: Variables (Built Environment and Socio Demographic)

Type of establishment	Mexican
Parking condition	Bike Staple
Gross floor area	3,750
Lot coverage	27
Length of bike facilities	
Bus lines	5.
Bus stops	14
Employment density	41
People density	7
Retail and service employment index	20
Intersection density	1.83
Average vehicle ownership	0.24
Median household income	2
Average households size	127,386
Non-white households	3
Type of establishment	7%

Figure 3: Aerial View (Google, 2015, scale 1:2,000)

#14: Convenience Store (24-Hour)

Figure 1: Street View of the Establishment (Google Street View, 2011)

Figure 2: PM Peak Mode Share

Table 1: Variables (Built Environment and Socio Demographic)

Type of establishment	
Parking condition	32 Auto
Gross floor area	2,475
Lot coverage	10
Length of bike facilities	4.4
Bus lines	22
Bus stops	13
Employment density	15
People density	20
Retail and service employment index	1.40
Intersection density	0.01
Average vehicle ownership	2
Median household income	96,719
Average households size	2
Non-white households	23%

Figure 3: Aerial View (Google, 2015, scale 1:2,000)

#15: Convenience Store (24-Hour)

Figure 1: Street View of the Establishment (Image from Authors, 2011)

Figure 2: PM Peak Mode Share

Table 1: Variables (Built Environment and Socio Demographic)

Type of establishment	
Parking condition	9 Auto
Gross floor area	2,400
Lot coverage	22
Length of bike facilities	7.3
Bus lines	10
Bus stops	15
Employment density	4
People density	14
Retail and service employment index	1.64
Intersection density	0.23
Average vehicle ownership	2
Median household income	65,673
Average households size	3
Non-white households	17%

Figure 3: Aerial View (Google, 2015, scale 1:2,000)

#16: Convenience Store (24-Hour)

Figure 1: Street View of the Establishment (Google Street View, 2011)

Figure 2: PM Peak Mode Share

Table 1: Variables (Built Environment and Socio Demographic)

Type of establishment	
Parking condition	14 Auto
Gross floor area	2,500
Lot coverage	16
Length of bike facilities	3.9
Bus lines	8
Bus stops	15
Employment density	4
People density	12
Retail and service employment index	1.37
Intersection density	0.02
Average vehicle ownership	1
Median household income	45,118
Average households size	2
Non-white households	19%

Figure 3: Aerial View (Google, 2015, scale 1:2,000)

#17: Convenience Store (24-Hour)

Figure 1: Street View of the Establishment (Google Street View, 2011)

Figure 2: PM Peak Mode Share

Table 1: Variables (Built Environment and Socio Demographic)

Type of establishment	
Parking condition	9 Auto
Gross floor area	2,600
Lot coverage	51
Length of bike facilities	9.4
Bus lines	25
Bus stops	37
Employment density	38
People density	41
Retail and service employment index	2.43
Intersection density	0.45
Average vehicle ownership	1
Median household income	25,326
Average households size	1
Non-white households	17%

Figure 3: Aerial View (Google, 2015, scale 1:2,000)

#18: High-Turnover (Sit-Down) Restaurant

Figure 1: Street View of the Establishment (Google Street View, 2011)

Figure 2: PM Peak Mode Share

Table 1: Variables (Built Environment and Socio Demographic)

Type of establishment	
Parking condition	Auto & Bike
Gross floor area	8,900
Lot coverage	27
Length of bike facilities	5.0
Bus lines	8
Bus stops	34
Employment density	9
People density	22
Retail and service employment index	1.62
Intersection density	0.17
Average vehicle ownership	1
Median household income	55,455
Average households size	2
Non-white households	19%

Figure 3: Aerial View (Google, 2015, scale 1:2,000)

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