A SUSTAINABLE MULTIMODAL PLANNING FRAMEWORK FOR TRANSPORTATION IMPACT ANALYSIS

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ABSTRACT

There is desire to move away from a paradigm of "predict and provide" to a process that fosters the conditions that support the desired multimodal transportation options and character of place. This paper presents a sustainable multimodal framework to advance the methods for how site plans fit into neighborhood and regional planning, using locally defined standards and goals. 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. Among the contributions of this approach is better coordination land use and transportation planning at the local level across a variety of scales. The addition of an area-wide scale addresses the issue of piecemeal site development disconnected from the larger neighborhood context where it resides.

INTRODUCTION

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 *(1, 2, 3, 3, 4, 5, 6)*. 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 *(4, 5)*. 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 *(7)*. 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 (8)* and the corresponding *Informational Report (9)* 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 multi-use, infill and smart growth sites *(3, 5, 10)*. There is convergence on the methods used to collect this information in order to have more standardization, allowing pooling of information across locations *(11, 12)*. Finally, nascent efforts are underway to consider the basis for the land use types for which data are collated and used for analysis *(13)*.

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 paper 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.

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 1. 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.

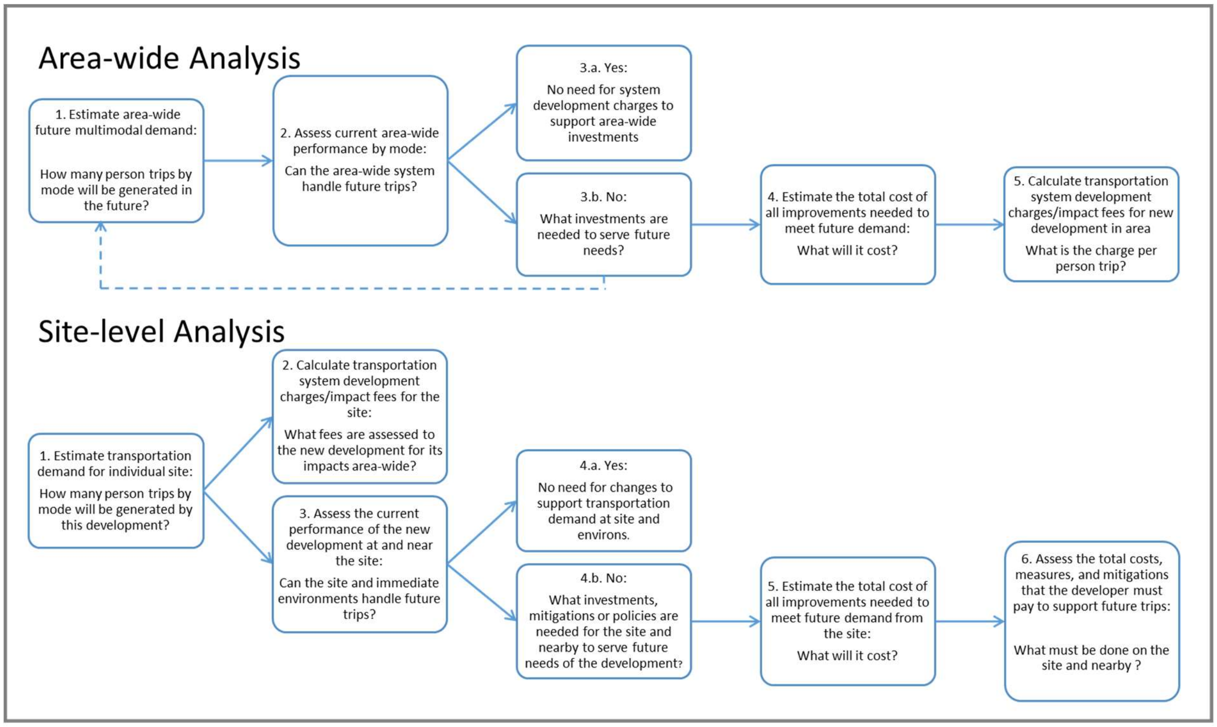

FIGURE 1 Proposed framework for evaluating transportation impacts of new development

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 1 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 2, 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 *(14)*. 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, 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 rates *(e.g., 14, 15)*, 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., 1, 2, 3, 4, 10)*. All of these methods currently adjust the vehicle trip rate data (from largely suburban locations) provided in ITE's *Trip Generation Handbook (8)* 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.

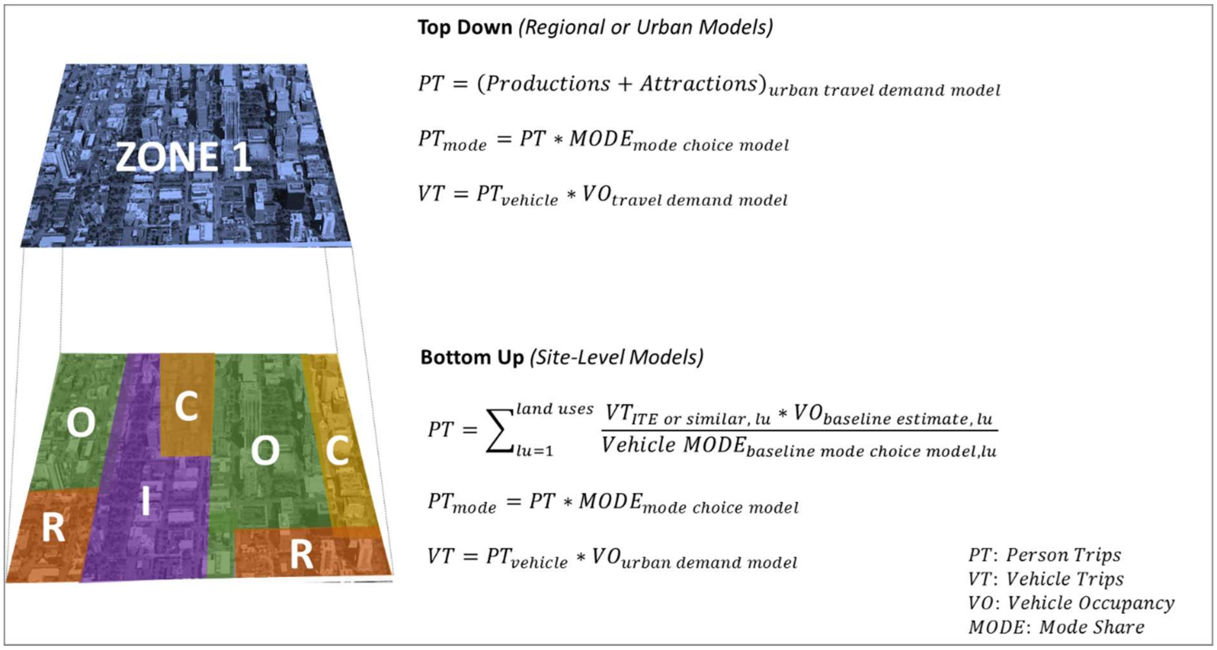

FIGURE 2 Area-wide person trip generation estimates

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 *(13, 16)*. 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 corresponds 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 *(17)* or trip generation data *(7)*. 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 *(18)*. 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 "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 *(19)*. However, the factors that impact mode choices are relatively well-developed and documented in the literature *(e.g., 20, 21)* compared to some aspects of transportation and the ability to consider non-motorized modes has been advancing *(22, 23)*.

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 book shop 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 in to 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 *(11, 24)*. 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 level of service was developed for the Highway Capacity Manual *(25)*, but there are still challenges to implementing these measures *(26)*. The various elements to consider in evaluating current and planned capacity are shown in FIGURE 3.

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., 27, 28)*. The City of Bellevue and the Puget Sound Regional Council, for example, has conducted a pilot project to develop and implement a method for evaluating multimodal concurrency *(24)*. 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 *(29)*. 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 *(27, pp. GP9-7)*. Adopting multi-objective policies allows (and sometimes forces) planners and analysts to more actively consider all travelers at the very scales of sustainable multiple planning (see TABLE 1 or *(28)*TABLE 1).

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, 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, 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 1 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 (28).

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. Thus some fair mechanism for apportioning the transportation costs relative to the overall system-wide burden imposed by the planned future development should be place, thus incorporating a second tier of area-wide scales (e.g. system-wide and some smaller nested geography). Agencies who 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 re-developed 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 at the transportation impact analysis done at the site level, which is presented in the next section.

Site-level Analysis

The framework shown in FIGURE 1 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 the site-level metrics beyond "trips generated" *(e.g., 8, 11)*. Although much of the focus of revised data collection methods has focused on mode share *(8)*, a need for person trip counts has been identified to promote the use of mode share data through understanding overall demand for activities (*see 11, 12, 30)*. 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 twelve traffic impact analyses, McRae et al *(18)* 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 is 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 (8)* and corresponding *Informational Report (9)*. 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 week day 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., 2, 4, 10)*—and is recommend by ITE *(8)*.

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 *(21)*. Several methods have already been developed to estimate mode shares focusing on site-level analysis specific to mixed-use developments *(4)* and infill *(2, 10)*. Alternative models are also used more broadly for evaluation changes in behavior of development and policies based on synthesized travel behavior studies *(21, 31, 32)*.

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 1). 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 level of service 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.

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 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. For area-wide analysis, this means understanding how the development fits into a broader planning picture. For site-level analysis, this means assessing both the travel demand as well as evaluating multimodal capacity. 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 in which 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 to 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 land scape by using on-going monitoring of sites to evaluate current approaches and expanding our ability to development 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 *(14, 24)*, and although the legal context of these agencies varies, 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 on-going 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.

REFERENCES

(1) Clifton, K. J., K. M. Currans and C. D. Muhs. Adjusting ITE's Trip Generation Handbook for Urban Context. *Journal of Transportation and Land Use*, Vol. 8, No. 1, 2015, pp. 5-29.

(2) Currans, K. M., and K. J. Clifton. Using Household Travel Surveys as a Method to Adjust ITE Trip Generation Rates. *Journal of Transport and Land Use*, Vol. 8, No. 1, 2015, pp. 85-119.

(3) Schneider, R. J., K. Shafizadeh and S. L. Handy. Method to Adjust Institute of Transportation Engineers Vehicle Trip Generation Estimates in Smart Growth Areas. *Journal of Transport and Land Use*, Vol. 8, No. 1, 2015, pp. 69-83.

(4) Ewing, R., M. Greenwald, M. Zhang, J. Walters, M. Feldman, R. Cervero, L. Frank and J. Thomas. Traffic Generated by Mixed-Use Developments--Six-Region Study Using Consistent Built Environmental Measures. *Journal of Urban Planning and Development*, Vol. 137, No. 3, pp. 248-261, 2011.

(5) Bochner, B. S., K. Hooper, B. Sperry and R. Dunphy. *Enhancing Internal Capture Estimation for Mixed-Use Developments*. Publication NCHRP Report 684. National Cooperative Highway Research Program: Transportation Research Board for the National Academies, Washington, D.C., 2011.

(6) Walters, J., B. Bochner and R. Ewing. *Getting Trip Generation Right: Eliminating the Bias Against Mixed Use Development*. American Planning Association, 2013.

(7) Millard-Ball, A. Phantom Trips: Overestimating the traffic impacts of new development. *Journal of Transport and Land Use*, Vol. 8, No. 1, 2015, pp. 1-19.

(8) Institute of Transportation Engineers (ITE). *ITE's Trip Generation Handbook: An ITE Recommended Practice, 3rd Edition*. Institute of Transportation Engineers, Washington, D.C., 2014.

(9) Institute of the Transportation Engineers (ITE). *ITE's Trip Generation Manual: An Informational Report, 9th Edition.* Institute of the Transportation Engineers, Washington, D.C., 2012.

(10) Daisa, J. M., M. Schmitt, P. Reinhofer, K. Hooper, B. Bochner and L. Schwartz. *Trip Generation Rates for Transportation Impact Analyses of Infill Developments*. Publication NCHRP Report 758. National Cooperative Highway Research Program: Transportation Research Board, Washington, D.C., 2013.

(11) Clifton, K. J., K. M. Currans and C. D. Muhs. Evolving the Institute of Transportation Engineers' Trip Generation Handbook: A Proposal for Collecting Multi-modal, Multi-context, Establishment-level Data. In *Transportation Research Record: Journal of the Transportation Research Board*, No. 2344, Transportation Research Board of the National Academies, Washington, D.C., 2013, pp. 107-117.

(12) Schneider, R. J., K. Shafizadeh, B. R. Sperry and S. L. Handy. Methodology to Gather Multimodal Trip Generation Data in Smart-Growth Areas. In *Transportation Research Record: Journal of the Transportation Research Board*, No. 2354, Transportation Research Board of the National Academies, Washington, D.C., 2013, pp. 68-85.

(13) Currans. K. M. *Improving Vehicle Trip Generation Estimations for Urban Contexts: A Method Using Household Travel Surveys to Adjust ITE Trip Generation Rates*. Masters Thesis. Portland State University, Portland, Oregon, 2013.

(14) San Francisco Planning Department. *Transportation Impact Analysis Guidelines for Environmental Review*. City and County of San Francisco, San Francisco, California, 2002.

(15) New York City. *City Environmental Quality Review (CEQR): Chapter 16 Transportation* Mayor's Office of Environmental Coordination, New York City, New York, 2014.

(16) Clifton, K. J., K. M. Currans, N. Larco and J. Wettach-Glosser. *Improving Trip Generation Methods for Livable Communities*. Transportation Research and Education Center, Portland, Oregon, 2016.

(17) Zhao, Y., and K. M. Kockelman. The propagation of uncertainty through travel demand models: An exploratory analysis. *The Annals of Regional Science*, Vol. 36, 2002, pp. 145-163.

(18) McRae, J., L. Bloomberg and D. Muldoon. *Best Practices for Traffic Impact Studies*. Publication FHWA-OR-RD-06-15. Oregon Department of Transportation, Salem, Oregon, 2003.

(19) Singleton, P., and K. J. Clifton. Pedestrians in Regional Travel Demand Forecasting Models: State of the Practice. Presented at the 92nd Annual Meeting of the Transportation Research Board, Washington, D.C., 2013.

(20) Cervero, R., and K. Kockelman. Travel Demand and the 3Ds: Density, Diversity, and Design. *Transportation Research Part D*, Vol. 2, No. 3, 1997, pp. 199-219.

(21) Ewing, R., and R. Cevero. Travel and the Built Environment: A Meta-Analysis, Journal of the American Planning Association, 2010, Vol. 76, No. 3.

(22) Broach, J., J. Dill and J. Gliebe. Where Do Cyclists Ride? A Route Choice Model Developed With Revealed Preference GPS Data. *Transportation Research Part A: Policy and Practice*, Vol. 46, No. 10, 2012, pp. 1730-1740.

(23) Clifton, K. J., P. A. Singleton, C. D. Muhs and R. J. Schneider. Representing Pedestrian Activity in Travel Demand Models: Framework and Application. *Journal of Transport Geography*, Vol. 52, 2016, pp. 111-122.

(24) Puget Sound Regional Council (PSRC). *PSRC and City of Bellevue Multimodal Concurrency Pilot Project*. Puget Sound Regional Council, Bellevue, Washington, 2009.

(25) United States National Research Council. *Highway Capacity Manual.* Transportation Research Board of the National Academies, Washington, D.C., 2010.

(26) Carter, P., F. Martin, M. Núñez, S. Peters, L. Raykin, J. Salinas and R. Milam. Complete Enough For Complete Streets? Sensitivity Testing of Multimodal Level of Service in the Highway Capacity Manual. In *Transportation Research Record: Journal of the Transportation Research Board*, No. 2395, Transportation Research Board of the National Academies, Washington, D.C., 2013, pp. 31-40.

(27) City of Portland. Comprehensive Plan Update, Goals and Policies (Proposed Draft); Chapter 9: Transportation. Portland, Oregon, 2014.

(28) Kittelson and Associates. Washington County Department of Land Use and Transportation: Multimodal Performance Measures and Standards. Washington County, Oregon, 2014.

(29) Singleton, Patrick A., and K. J. Clifton/ Incorporating public health in US long-range metropolitan transportation planning: A review of guidance statements and performance

measures. Presented at the 94th Annual Meeting of the Transportation Research Board, Washington, D.C., 2014.

(30) Dock, S., L. Cohen, J. D. Rogers, J. Henson, R. Weinberger, J. Schrieber and K. Ricks. Methodology to Gather Multimodal Urban Trip Generation Data. Presented at the 95th Annual Meeting of the Transportation Research Board, Washington, D.C., 2015.

(31) ENVIRON International Corporation. *California Air Districts, California Emissions Estimator Model (CalEEMod) User's Guide 2013.2*. California Air Pollution Control Officers Association (CAPCOA), South Coast, California, 2013.

(32) Nelson/Nygaard. *Crediting Low-Traffic Developments: Adjusting Site-Level Vehicle Trip Generation Using URBEMIS*. San Joaquin Valley Air Pollution Control District, California, 2005.