Trip Generation Rates for Transportation Impact Analyses of Infill Developments

DETAILS

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP REPORT 758

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FOREWORD

By Lawrence D. Goldstein
Staff Officer
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NCHRP Report 758: Trip Generation Rates for Transportation Impact Analyses of Infill Developments provides an easy-to-apply process for use by transportation professionals when estimating vehicular trip generation in built-up urban areas, incorporating the effects of site-specific, local, and area-wide land use and transportation characteristics on estimates of vehicular trip generation for proposed infill development. This process is based on the development and application of mode share and vehicle occupancy adjustment factors applied to conventional trip generation estimates using rates published by the Institute of Transportation Engineers (ITE). The study details two ways of deriving the adjustment factors: (1) collecting empirical data from proxy sites located in environments that represent the future context of the project being analyzed, and (2) extracting factors from household travel surveys.

The product of this research includes two components: (1) a final report that documents the background, research approach, the development and application of methods to estimate infill trip generation, and a recommended verification approach; and (2) a supplemental technical report that details the application of the household travel survey method. The combination of these two components offers a comprehensive analytical approach and a detailed set of application techniques and requirements to estimate infill development trip generation.

New development and redevelopment projects located near, or surrounded by, existing land uses are often termed urban or suburban "infill." Appropriate development and redevelopment in such areas are important strategies for revitalizing the nation's aging city and suburban cores, increasing efficient and cost-effective use of existing infrastructure (including streets, transit, and utilities), and expanding opportunities for housing, recreation, and economic growth in affected areas. During local land use review and development permitting processes, public agencies commonly require estimates of vehicle travel impacts associated with proposed land use projects, assessments of their potential contribution to traffic congestion, and identification of appropriate mitigation strategies. Common mitigation strategies include impact fees, proffered private developer contributions, special tax assessment districts, and specific facility improvements—all of which have the potential to affect the financial parameters that underwrite proposed new development.

Many agencies and jurisdictions are prioritizing the development of these infill, mixed-use, and transit-oriented-development (TOD) projects. In response, the need for improving and refining trip generation estimation methods applicable to an urban context is of increasing interest and importance. The process proposed as an outcome of this research is specifically designed for use by members of the transportation planning and traffic engineering profession who prepare and review site transportation impact analyses (TIAs). This group of users will appreciate the fact that the method builds on conventional techniques and resources with which they are familiar, not requiring a significant investment in time devoted to learning new techniques.

In developing traffic and transportation impact analyses for urban and suburban infill projects, professionals have often relied on ITE published trip generation rates for various types of land use. The ITE data, however, are predominantly representative of suburban contexts and their automobile-dependent land use patterns and transportation networks and typically do not take into account variations in type and location (suburban versus urban) of proposed land uses, proximity of transit service, and the existence of pedestrian and bicycle facilities. The common use of suburban-focused vehicular trip generation data in the preparation of TIAs, combined with a lack of information and techniques on how and when to adjust the data, has often resulted in an application of conventional trip generation rates to proposed infill development, even in places that are compact, highly walkable, and transit-rich. This use of conventional data can overpredict vehicular traffic impacts, resulting in possible mitigations that negatively affect use of transit, bicycle, and pedestrian facilities in the infill project area. Inaccurate data may also result in excessive traffic mitigation fees or requirements for additional infrastructure that can hinder the type of development that promotes lower automobile use.

Applying the methods presented in this report will contribute to a greater understanding of transportation characteristics of infill development, providing transportation engineers, public transit professionals, city planners, and decision makers with the facts they need to plan and implement infill development effectively. The research offers a systematic and methodical procedure for analyzing potential traffic impacts in urban and urbanizing locales. In support of this process, agencies seeking a consistent and uniform procedure for analyzing infill development in their community can develop and validate a local database of infill trip generation rates by sponsoring local infill trip generation studies (using the proxy site method) or extracting region-specific travel data to develop local infill trip rates (using the household travel survey method).

Validating the output of the methodology presented in this research is important; however, the research concluded that a definitive validation required more resources than were available. The validation process demonstrated that the proposed method produces consistently lower estimates of infill trip generation, ranging from ½ to ⅔ of estimates based on conventional data—a finding that is consistent with other research. Based on this remaining need, the study concludes with specific recommendations for future research on the travel characteristics of infill development and the identified need for a commitment by the transportation profession to contribute empirical data for a more complete and definitive validation of the methodology.

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Note: Many of the photographs, figures, and tables in this report have been converted from color to grayscale for printing. The electronic version of the report (posted on the Web at www.trb.org) retains the color versions.

SUMMARY

The objective of this research was to develop an easily applied methodology to estimate automobile trip generation and mode shares of non-vehicular trips that can be used in the preparation of site-specific transportation impact analyses of infill development projects located within existing higher-density built-up areas.

The primary source of data and methods for estimating automobile trips in preparing transportation impact analyses is the Institute of Transportation Engineers' (ITE) *Trip Generation Manual.* The majority of the data making up the manual are from automobile counts conducted at single-use, suburban, and exurban sites with limited pedestrian, bicycle, and transit activity. Although the manual is accepted as valid for sites in the same context from which the data were collected, it is less applicable to urban and urbanizing sites with moderate to extensive use of non-automobile modes of transportation.

Urban and suburban places have important differences in trip generation because of significant contrasts in density of development, street networks, building types and height, and availability of multimodal transportation options. Regardless of these differences, the ITE *Trip Generation Manual* remains the primary, and often mandatory, resource for estimating the trip generation of infill development for transportation impact analyses.

To achieve the research objective stated in the first paragraph, this study initially focused on the current state of the practice in trip generation for site impact analyses, as well as recent efforts to develop infill or smart growth trip generation estimation methods. Key findings from the initial review include:

- There is no standardized and nationally accepted infill trip estimation methodology.
- There are limited options for agencies and practitioners when estimating the site-specific traffic impacts of infill development.
- Recently published and unpublished research on estimating infill trip generation provides an array of approaches from which can be developed an estimation methodology that is compatible with current impact analysis practice.

This study recommends an approach that adjusts trip generation estimates based on data in the ITE *Trip Generation Manual* using mode share and vehicle occupancy as adjustment factors to more accurately reflect the travel characteristics of the context in which the proposed project is located. The research team divided the approach into two methods for deriving the adjustment factors that are applied to conventional trip generation data:

1. Proxy site method – Adjustment factors are derived from data collected from a site or sites that serve as a proxy for the proposed project's land use in the context of urban infill development. There are two variants of the proxy site method:
   (a) Minimum data collection – Derives adjustment factors more quickly and less expensively than the other methods by collecting only the essential minimum data and using basic techniques to survey a proxy site or sites within contexts similar to the proposed project.

(b) Comprehensive data collection – Derives adjustment factors from data collected using multiple techniques to survey a proxy site or sites within contexts similar to the proposed project. This variation is used when the complexity of the site or its surrounding context precludes the minimum data collection variant, or when more detailed traveler, site, or demographic information is desired.

2. Travel survey method – Extracts mode share and vehicle occupancy adjustment factors for a particular land use and context from regional household travel survey data for the metropolitan region within which the practitioner is preparing a study. This method has applications and limitations different from those of the proxy site method. While it can be used to estimate infill trip generation, this method is best suited to broader, more macroscopic applications.

The recommended approach uses person trips as the common denominator between conventional and infill land uses. This concept—that a particular land use generates an equal number of person trips whether it is located in a suburban context or an urban context—is supported by common practice for infill trip generation. Based on this relationship, the remainder of the approach is a simple exercise in conversion: from conventional automobile trips to person trips, and from person trips to infill vehicle trips. The approach can be applied to any of the land use categories in the ITE *Trip Generation Manual,* making it compatible with current practice in preparing impact analyses.

This study documents the typical forms of confirmation used to evaluate and demonstrate a methodology's ability to predict urban infill trip generation: verification and validation. The verification process demonstrates that the methodology was appropriately developed and that there are no gross errors or oversights in the underlying theory.

Verification and validation tests of the proxy site method used empirical data for sites in the Washington, D.C., area collected as part of this study as well as data obtained from a prior California Department of Transportation study on urban infill trip generation (1). The travel survey method was tested using adjustment factors derived from household travel survey data obtained from the Metropolitan Washington Council of Governments for the Washington, D.C., region and from the Metropolitan Transportation Commission data for the San Francisco Bay Area.

Although the comparison of the method's predicted infill trips to actual trips was inconclusive due to small sample sizes, the research team did note that the method predicts consistently lower vehicle-trip estimates than the trips estimated using conventional ITE data, ranging from two-thirds to three-quarters of ITE estimates, a finding supported by other research on infill trip generation methods (2).

Validation of the recommended methodology is anticipated to occur over time as transportation professionals contribute data from their testing of the methodology or as a result of their work on infill development projects.

This report includes ideas regarding the collection of site data, based on the lessons learned in this study, to validate the methodology and for applying the method in impact analyses, and recommendations for future research to demonstrate the validity of the underlying assumption that the person trips generated by sites of similar size and land use type are equal regardless of context. Furthermore, this report presents a method of extracting mode share and vehicle occupancy from readily available household travel survey data—a methodological resource that has application in many areas of transportation planning.

CHAPTER 1

Background

This chapter discusses the rationale for undertaking this research study, presents the study's objective, and summarizes the three major work activities that formed the basis of this study.

1.1 Problem Statement

In the United States, the Institute of Transportation Engineers' (ITE) *Trip Generation Manual* (3) is the primary source of data and methods for estimating vehicle trips in the performance of traffic impact analyses. The ITE *Trip Generation Manual* was first published in 1976 and is now in its ninth edition. The manual has undergone several updates that have included the addition of new land uses, land-use–specific refinements resulting from additional data collection, and revised and expanded estimation methodologies. The majority of the data included in the ITE *Trip Generation Manual* is based on automobile counts conducted at single-use, suburban, and exurban sites with limited pedestrian, bicycle, and transit activity. Although this resource is commonly accepted as valid for sites in the contextual settings from which the data were collected (i.e., suburban and exurban communities), it is less easily applied to urban and urbanizing sites with moderate to extensive pedestrian, bicycle, and transit activity.

Suburban and urban sites commonly have important differences in trip generation that result from their localized circumstances, such as zoning ordinances that segregate uses, the diversity and mix of land use types, site design, density, and the availability of multimodal transportation options. Accordingly, the data on which most of the land uses in the ITE *Trip Generation Manual* are based are not directly applicable to more urbanized uses.

Irrespective of these limitations, the ITE *Trip Generation Manual* is still the principal resource for estimating the trip generation of developments located in contexts not represented by the underlying data. In these cases, preparers of traffic impact analyses may choose to adjust ITE trip generation rates using local factors or other published sources of information to better reflect the local circumstances. However, many choose, or are required, to use the rates directly from ITE without modification.

Given that many agencies and jurisdictions are prioritizing the development of infill, mixed-use, and transit-oriented development (TOD), the refinement of trip generation methods and data for urban contexts is of increasing interest. Within the transportation profession, there have been several noteworthy efforts to advance this area of practice and its underlying research. However, among practitioners there is still not a commonly accepted best-practice approach to trip generation for developments in urban contexts. As such, there is the continuing need to provide transportation professionals credible trip generation methods to better assess the impacts and benefits of infill development.

1.2 Research Objective

This research study responds to the challenges experienced by public agencies and practitioners in evaluating traffic impacts of development or redevelopment projects located in areas that are substantially built up. This type of development, often called infill development, occurs in urban and adjacent transitional areas. The overall objective of this research was to develop an easily applied methodology to estimate automobile trip generation and mode share of non-vehicular trips that can be used in the preparation of site-specific transportation impact analyses of infill development projects located within existing higher-density built-up areas.

1.3 Scope of Study

This study was divided into multiple tasks, each of which was detailed in working papers reviewed by a research panel of peers from the transportation profession. These tasks were carried out over the course of the following three major work activities:

1. The state of the practice and current research on methods for estimating and using trip generation in determining transportation impacts of proposed infill development were assessed. Identified trip estimation methods were subsequently categorized into discrete candidate approaches and evaluated to determine their ability to meet the research objective. Based on the outcome of this analysis, an approach for estimating infill trip generation was selected.
2. The selected approach and the information gained from evaluating alternative approaches were used as a foundation for proposing a method consistent with the requirements, resources, and capabilities normally available for preparing transportation impact analyses.
3. The sources for obtaining or collecting required input data were identified, and the validity of the proposed method was evaluated.

The research panel actively participated in the review and evaluation of study progress and provided direction for data collection and analysis elements of the study.

CHAPTER 2

State of the Practice

This chapter provides an overview of the knowledge and understanding on which this research study was undertaken. Specifically, this chapter includes discussion on (a) the importance of trip generation, (b) defining infill development for the purpose of this study, (c) current methods for estimating infill trip generation, and (d) recent research on infill trip generation estimation methods.

2.1 The Importance of Trip Generation

Estimated vehicular trips are important input for many analysis and decision-making processes. Because subtle changes in estimates can have significant impacts, trip generation is a pivotal concern in planning for a development and to urban planning in general. The results of trip generation are commonly used in many analysis capacities, including those to:

- Inform decision makers on the impacts or benefits of a development through mandated environmental impact statements or reports,
- Determine or evaluate short- or long-range capital improvement investments,
- Identify the traffic impacts and required mitigation measures as part of the development entitlement process,
- Predict the effects of congestion management policies such as congestion pricing and travel demand management (TDM) programs,
- Determine site vehicular access needs as well as associated roadway and site-plan modifications and improvements, and
- Assess impact fees on new development to fund infrastructure improvements.

The decisions that result from these activities can result in a variety of impacts, including those that can affect local government, private investment, and the public. These effects can be far reaching and affect a variety of interests, including those related to fiscal, environmental, quality of life, local circulation and access, and related economic development concerns. Impacts can also affect other transportation modes either directly or indirectly. Increasingly, there is concern that required mitigations can result in unintended consequences such as adversely affecting the ability of people to walk, bicycle, or use public transportation as increasingly larger vehicular facilities reduce or negatively affect opportunities for nonmotorized modes. Transportation facility layout or size can also cause significant direct or indirect effects that often extend beyond the immediate area of a development. Because the magnitude of trips directly affects analysis results that can have far-reaching implications, the accuracy of estimating trip generation is an important consideration.

It is understood by the transportation profession that the trip generation rates published by ITE are representative of their underlying data. Accordingly, the trip generation rates can be biased by the context in which the underlying data collection locations existed. In the case of the ITE *Trip Generation Manual,* much of the data have been collected at primarily single-use suburban developments that lack transit service and that are either difficult to access by walking or bicycling or are in areas where these modes are not extensively used. The recognition of this data bias has resulted in a common belief among practitioners that ITE trip generation rates overpredict vehicular traffic impacts for infill development projects, particularly for those in urban areas served by transit with good pedestrian and bicycle access.

2.2 Defining Infill Development

In order to properly establish the current state of the practice of trip generation for infill development, a common definition of *infill* first needed to be established. For the purposes of this study, the definition was determined to need to be both understandable and definable in an objective manner. The definition also needed to address the two ways practitioners were envisioned to use it, namely: (a) to identify or qualify the context in which the subject of their study would be developed, or (b) to locate an existing context that represents the future environment in which the subject of their study would exist.

Initial efforts to establish this definition by the research team took the form of a survey of professionals and a literature review.

2.2.1 Survey of Professional Organizations

As an early part of this project, a questionnaire was sent to a cross-section of practitioners and agencies. Participants were asked to provide a definition of *infill development.* While answers varied from person to person, the majority of the responses were a variation of one of the following definitions:

- Development/redevelopment of vacant or underutilized parcels within a primarily developed or built-out area.
- Use of vacant land within a predominately developed area that contains existing public services and infrastructure but may require improvements to meet current development standards.
- Development/redevelopment of a nearly built-out area generally focused in moderate- to high-density urban, suburban, or former industrial areas.
- Adaptive reuse of existing structures or infrastructure, often resulting in greater intensity of use through higher densities.

Survey responses stated that transit proximity, TOD, and mixed-use development are common attributes associated with infill development. Sources of infill definitions cited by the survey participants included those of municipal agencies and professional organizations, including the Urban Land Institute, Congress for the New Urbanism, and the American Planning Association. Most survey respondents (78%) cited their own professional or personal perspective and experience as the source of their definition of infill development.

2.2.2 Literature Review of Infill Development Definitions and Context

Within the urban planning and transportation planning communities and among more mainstream literature there exist a multitude of definitions for the terms *urban infill* and *infill development.* However, in order to best relate to the application a typical practitioner might encounter, the literature review focused on typical written definitions as defined by statute, agencies, and practitioners. This review resulted in the finding that even among similar agencies there can be significant differences in the definition of infill. As demonstrated by the example definitions in Table 2.1, definitions are often created for a specific purpose that may relate to the circumstances of a specific geographic area. As a result, definitions often include quantifiable criteria that may not be transferable to other locales without substantial modification.

Table 2.1. Example definitions of urban infill.

Urban infill is the practice of developing vacant or underutilized properties within an urban area rather than undeveloped land in more rural areas (greenfield). Infill helps to prevent sprawl and can aid in economic revitalization. Source: United States Environmental Protection Agency.
Urban infill means the development of vacant parcels in otherwise built-up areas where public facilities such as sewer systems, roads, schools, and recreation areas are already in place, and the average residential density is at least five dwelling units per acre, the average nonresidential intensity is at least a floor area ratio (FAR) of 1.0, and vacant, developable land does not constitute more than 10% of the area. Source: State of Florida, 2007 Statutes and Constitution.
An infill opportunity zone is designated by a city or county and zoned for new compact residential or mixed-use development within 1/3 mile of specified transportation sites in counties with a population of over 400,000. The mixed-use development zoning consists of three or more land uses that facilitate significant human interaction in close proximity, with residential use as the primary land use supported by other land uses such as office, hotel, health care, hospital, entertainment, restaurant, retail, and service uses. The transit service serving the site has maximum scheduled headways of 15 min. for at least 5 hours per day. Source: State of California, Senate Bill 1636, Congestion Management: Infill Opportunity Zones, 2002.

2.2.3 Definition of Infill Development

Based on the survey responses, literature review, and the study objective, the research team selected the following definition of infill development for the proposed methodology (4):

> Infill development or redevelopment is located in fully built areas, often in and around business districts; is walkable; is served by convenient/ frequent transit; is commonly served by designated bicycle facilities; and generates significant non-automobile mode shares.

Because of the prevalence of non-automobile trips in these areas, adjustments to data in the ITE *Trip Generation Manual* are appropriate.

2.3 Current Infill Trip Generation Practices

Of the agency guidelines identified over the course of this study, nearly all require or support the use of ITE trip generation estimates in preparing traffic impact analyses. Some of these agencies allow trip generation reductions for types of development typically found in urban infill areas (such as high-density housing, mixed use, and TOD), but only a few of the agencies provide quantitative adjustment factors or methods for adjusting trip generation estimates for infill development. Even in urban infill areas, adjustment to ITE trip generation estimates is considered an exception and typically requires approval from the agency overseeing the preparation of the traffic impact analysis. In general, guidelines are provided for the following techniques:

- Adjusting standard trip generation rates based on transit use or mixed-use internal capture.
- Using or developing local trip generation or mode split data.
- Creating exceptions to, or revising, current transportation standards.
- Developing multimodal approaches to conventional level-of-service analysis.

The survey of professional organizations and practitioners mirrored these findings, with the majority of respondents (68%) stating that trip generation adjustments must be justified and approved by the reviewing agency on a case-by-case basis.

2.4 Research in Estimating the Trip Generation of Infill Development

The research team reviewed recently published and unpublished releases of methods for estimating infill trip generation to identify the underlying approach for each estimation methodology. The six estimation methods the research team reviewed were determined to be based on one of the following approaches:

- **Direct estimation based on regression analysis –** Methods that estimate trip generation with derived regression equations using a single type or multiple types of data as independent variables.
- **Direct estimation based on empirical data –** Methods that directly determine trip generation or derive rates through collection of data at sites with similar characteristics to a proposed development site.
- **ITE rate adjustment based on regression –** Methods that use various types of equations and data to develop factors that are applied to ITE trip generation rates or directly to trip estimates.
- **ITE rate adjustment based on empirical data** – Methods that apply factors to ITE trip generation rates or directly to trip estimates derived from data collected at sites with similar characteristics to a proposed development site.

Table 2.2 summarizes the key attributes of the six methods reviewed for each of these approaches to estimating infill trip generation. As shown, four of the six methods use adjustments to ITE trip generation rates or directly adjust estimates derived from ITE trip generation rates, while the remaining two perform direct estimations of infill trip generation. Each method, even within the same approach category, employs a different technique using a unique set of variables.

One commonality of the methods is that they all consider the context in which the study site is located. Methods using regression analysis correlate contextual characteristics with site trip generation, while methods based on empirical data select sites for data collection that are located in contexts with similar characteristics to the subject site.

2.5 Trends in Estimating Trip Generation

Over the past two decades, the practice of estimating trip generation for new development has gradually shifted from focusing almost entirely on vehicle trips to estimating multimodal travel based on context. This change in the practice is in response to a shift in land use planning focus in the United States, which now increasingly emphasizes smart growth, transit-oriented, infill, and traditional neighborhood development. This is resulting in development in many locations that is higher in density, more diverse in the mix of land uses, more compact, increasing in the quality and frequency of public transportation, and more walkable and bicycle friendly than the suburban pattern of segregated single land use development on which the ITE *Trip Generation Manual* is primarily based. Many agencies have made changes to their zoning ordinances to allow or encourage some of these development types.

As the primary source of trip generation data and methods in the United States, ITE has significant influence over the practice of estimating trip generation through publication of its recommended practices and informational reports. In 2012, ITE formed subcommittees to develop new chapters for the third edition update of the *Trip Generation Handbook* (5). The handbook is ITE's recommended practice on estimating trip generation. The subcommittees are considering a variety of content updates, including those related to improved methods for estimating (a) multi-use internal capture, (b) pedestrian and bicycle travel, and (c) trip generation of infill development. Additionally, the subcommittee will be considering data collection techniques and the provision of further guidance on conducting local trip generation studies.

The upcoming update is also expected to address whether the concept of person trips will become the fundamental basis for evaluating site and transportation impacts. Person trips, combined with the percentage breakdown of travel by mode, produce a broader spectrum of travel data that can be used to facilitate more comprehensive analysis than is typically

Table 2.2. Assessment of recent research in methods of estimating trip generation of infill development.

Approach Category	Example Method(s)/Source	How Method Works	Data Requirements	Advantages	Disadvantages
Direct estimation based on regression analysis	Trip generation for smart growth (7). Originally developed for the Environmental Protection Agency for smart growth and mixed-use development.	Regression analysis based on numerous context and other descriptive variables. Estimates probability of non-automobile travel and adjusts project trips calculated with standard trip generation rates. Developed from household travel survey (HTS) data from eight metropolitan planning organizations (MPOs). Validated using mixed-use areas in the San Diego area.	Vehicle-trip generation of study site based on ITE rates. Substantial area-wide data generally available from multiple sources. Some data requires significant research or computation of values.	Calculates reductions for mixed-use as well as mode-share reductions in infill areas. A validated methodology for the San Diego region.	Estimates area-wide trip generation. Not applicable to site-level (unless site is a large, mixed-use site) or specific land use analysis. Highly data intensive. Validated only for the San Diego region.
Direct estimation based on empirical data	California infill trip generation study (1).	Derives trip generation rates for specific site land uses from person-trip cordon counts plus intercept surveys to determine mode-share and other data.	Comprehensive cordon counts and intercept surveys for a minimum of 4 hours per day, person counts at all site entries. Vehicle counts (if feasible).	Ability to collect multiple types of data, including travel, demographics, parking, cost, and policy related. Transparent process with high credibility. If trip rate database developed by researchers, negligible cost to use method.	Highly labor intensive and disruptive to site, so permission to survey tenants is challenging. Relatively high cost per site; best if sponsored through funding source. No standardized data collection procedure. Many years before database is usable.
ITE rate adjustment based on regression analysis	Urban context-based trip rate adjustment (8).	Uses regression analysis and the Portland-region Urban Living Infrastructure indicator (a measure of context) to develop adjustments to ITE rates for high-turnover (sit-down) restaurants, 24-hour convenience markets, and drinking establishments.	Data for application requires determination of the Urban Living Infrastructure indicator requiring eight readily available variables, or use of a lookup table with less accuracy. Method correlates well with numerous easily obtained measures of context.	Performs better than ITE rates in predicting trip generation of the subject uses in the Portland region. Method based on data collected at 78 sites and verified using data from 34 additional sites. Urban Living Infrastructure indicator or other measures of urban context may be used with similar results.	Substantial data collection required to expand approach for additional land uses; currently only valid for three categories. Further, method needs evidence of transferability to other geographic regions, or requires data collection and validation in areas outside the Portland region.
ITE rate adjustment based on regression analysis or data extracted from surveys	HTS-based trip rate adjustment. Portland State University Dept. of Civil and Environmental	Method uses data from travel surveys in a regional-scale model for predicting context-based adjustment factor (mode share) applied to ITE trip generation at	Data for application requires determination of vehicle mode share for the urban context under study using equations, or using a lookup	The use of HTS data to develop mode share and vehicle occupancy factors is valid within its stated limitations and within the geographic constraints of the HTS.	A valid method for broader professional use if context-based factors derived from Seattle region HTS data are found to be transferable to other regions.

	Engineering (8).	the site level of development. The method divides HTS mode-share data into eight context classifications that serve as the variable for the model.	table with less accuracy.	Eight context classifications provide broader context variation than other methods. Context classifications control for socio-demographic variations.	Method currently only valid in the Seattle region where the HTS data were obtained.
ITE rate adjustment based on regression analysis	Smart growth trip generation (9).	Method uses limited site person-trip travel survey data to develop multivariate regression equations to adjust ITE rates. Adjustment factors are based on characteristics of the proposed development and its surrounding context. Uses a linear regression equation with the adjustment as the dependent variable and site and context characteristics as the independent variables.	Requires person counts and intercept surveys. Method validated for, and applicable to, multifamily residential, office, and limited restaurant and retail (not yet available).	The method uses vehicle-trip counts and site/context data from 50 smart growth sites in California. According to the model developers, even though the model is based on, and validated with, California person-trip generation data, it is believed to be transferrable to other urban locations.	The model is limited to the uses defined in the validation process (multifamily residential, office, and limited restaurant and retail). Applicable study sites and surrounding context must conform to prescriptive criteria defining *smart growth*. For use with other land uses, data collection is required to expand the model. The model may not be transferable to regions outside of California.
ITE rate adjustment based on empirical data	Rate adjustment method based on mode share and vehicle occupancy factors (4).	Uses limited vehicle and person-trip cordon counts and vehicle occupancy count equations to adjust ITE rates. Uses data collected to develop mode share and occupancy adjustment factors to apply to baseline ITE trip rates for any land use category (LUC) in the ITE *Trip Generation Manual*.	Minimum data required include average vehicle occupancy and percentage automobile mode share. Requires data collection at (1) site(s) representing baseline ITE LUC, and (2) a site located in a similar context as proposed infill development. Depending on site, context, and type of data needed, data collection may require cordon counts of person trips and traveler surveys.	Method is easy to comprehend, and computational procedure is transparent. With minimum data collection, the method is a low-effort/low-cost procedure to derive mode share and vehicle occupancy factors. Complex sites in more urban contexts may require intercept surveys. Method is consistent with ITE's recommended procedures for developing local trip rates.	Method in its simplest form is applicable to sites with exclusive on-site parking. Where off-site and on-street parking is used, or where a detailed mode-share breakdown is desired, the method requires traveler surveys that increase effort and cost. Selection of sites relies on user judgment, so risks associated with the method include collecting too little data or data at poorly selected sites, as well the potential for collecting data in an inappropriate context resulting in over- or underprediction of trips.

carried out under current typical traffic impact analysis procedures. Ultimately, this could lead the profession to develop a person-trip generation database similar to the TRICS system in use in the United Kingdom and Ireland (6).

2.6 Summary and Conclusions on the State of the Practice

The following is a summary of the key findings of the review of the state of the practice in estimating infill trip generation:

- While some public agencies employ methods to evaluate traffic impacts of infill development in urban areas, there is no standardized and nationally accepted methodology, and there is only limited guidance or data specifically attributable to infill development.
- A number of agencies permit trip generation reductions for development in urban areas, but they require supporting information to justify reductions based on proximity to transit or mixed-use development. Supporting information often takes the form of local trip generation or mode-share studies.
- A small number of agencies provide local trip generation rates or provide specific methodologies for estimating trip generation.
- The number of recent research projects that have developed methods of estimating trip generation for infill or smart growth development is an indicator of the transportation profession's desire for methods to evaluate the impacts—and the benefits—of current trends in land use development.
- Most jurisdictions in the United States take one of three approaches for evaluating site-specific traffic impacts of infill development (or associated forms such as transit-oriented and mixed-use development): (a) use the established trip generation data in the ITE *Trip Generation Manual*, with reductions for internal capture based on the methodology in the ITE *Trip Generation Handbook;* (b) allow the application of pre-established maximum trip reductions for mixed-use internal capture and proximity to transit subject to the approval of the reviewing agency; and (c) allow development of an alternative approach to estimate traffic generation on a case-by-case basis along with the provision of supporting data.

CHAPTER 3

Research Approach

This chapter presents analysis used by the research team to select an approach to estimating infill trip generation. This approach serves as the foundation for the detailed estimation methods developed in this research study.

The review of the methods presented in Table 2.2 established an understanding of the features, requirements, and limitations that may be expected from estimation methods developed under each of the broader approach categories. This understanding was used as input to develop the criteria for selecting an approach for estimating infill trip generation and as input into the development of the proposed methods described in Chapter 4.

The selection of an approach has fundamental implications for the development of an infill trip generation method, including considerations such as the amount of initial data required, the level of effort the practitioner may need to invest in using the method, and other significant attributes that affect the viability of the resulting proposed method.

3.1 Basis for Selecting an Approach

Evaluation criteria were established to determine which of the approach categories would best meet the research objective of this study. The evaluation criteria generally fall into one of the following areas:

The ability to produce required information for use in traffic impact analyses. This group of criteria seeks to ensure that the proposed method produces data that conform to the current practice in site and traffic impact analysis. At a minimum, the practice requires any trip generation method to estimate morning and afternoon peak hour directional vehicle trips for a given land use category (LUC) using commonly available units of development such as building floor area, employees, or dwelling units (independent variables). So that the proposed methodology can meet the needs of emerging multimodal impact analysis techniques, it should use person trips as the common denominator when converting between conventional ITE vehicle-trip data and infill trip data and as a basis for determining peak hour mode share of infill development. This approach will also support emerging measures of effectiveness that define capacity in terms of person throughput and that consider multiple modes rather than automobile throughput.

Ease of use. This group of criteria assesses the ease of using the proposed method by the practitioner. A method's simplicity and convenience promotes its continued use as a tool and its eventual adoption by practitioners and agencies as the state of the practice. The criteria used to evaluate ease of use by practitioners favor approaches that are intuitive, expand on but do not replace established methodologies, and use data familiar to the practitioner that are locally attainable.

Credibility of an approach in terms of its reliability and consistency of performance. This criterion gives credence to approaches that give consistent and repeatable results while remaining sensitive to variations in factors that the user expects to result in a different outcome.

The level of effort required to further develop or expand methodologies within an approach category to fully meet the research objective. These criteria are intended to determine the likely feasibility of methodologies based on the level of effort that it will take to expand/develop the methods to meet the other requirements.

For example, a method based on an approach that directly estimates infill trip generation using multivariate regression equations, with readily available input data, and that is validated to accurately predict trips at a very high level of confidence is a promising method. Yet, if this method has only been developed for one LUC and has only been validated in one county of the United States, it is not a practical nor useful method for the profession in general and would likely require substantial development to be universally applicable. The level of effort and cost to fully develop an approach into a method with widespread usability is a critical determinant of its feasibility.

The criteria considered by the research team in identifying approaches that result in estimation methods with long-term potential to serve the profession are:

1. The approach is compatible with existing traffic impact analysis methods (i.e., ability to estimate peak hour, directional-dependent variables).
2. The approach uses person trips as the common denominator when converting between baseline ITE vehicle-trip data and infill trip data, and as a basis for determining peak hour mode share of infill development.
3. The approach is adaptable to meet the needs of emerging multimodal impact analysis techniques.
4. Input data needed to apply the approach are readily available, or the ease and cost of collecting and applying the data are reasonable.
5. The approach requires no specialized skills or investment in training or software in order to estimate infill trip generation.
6. The approach applies to the land uses in the ITE *Trip Generation Manual* and has few, if any, restrictions on land use categories and geography.
7. Computations used in the approach are intuitive to the user and transparent by way of documentation.
8. There is a reasonable cost for collecting data necessary to develop and validate the methodology.
9. The approach has the ability to take advantage of existing trip generation databases or other readily available data used as input to the method.
10. The principles of development and application of the approach can be described to laypeople.
11. The approach would have likely acceptance by members of the transportation planning and traffic engineering profession who prepare and review site traffic impact analyses.
12. The approach allows for easy addition to or expansion of the database (i.e., new data points or new land uses) once original database is established.

Table 3.1 compares the candidate approaches against the selection criteria.

3.2 Selection of an Approach and Conclusion

The research team selected an approach on which to base the proposed methodology for estimating infill trip generation: (a) use the research objective and associated selection criteria presented previously, (b) review recent research on infill trip generation estimation methods, and (c) use the research team's collective experience in estimating trip generation for numerous types of development and preparing site-specific transportation impact analyses.

The research team selected the approach of using ITE rate adjustment based on empirical data, given that the approach met the research objective and, to varying degrees, all of the selection criteria. Specifically, some of the more critical considerations that drove the selection were:

- **The approach has compatibility with existing traffic impact methods.** The selected approach is essentially an enhancement of the trip generation step in the well-established four-step transportation modeling process (trip generation, trip distribution, mode choice, and trip assignment). The approach plugs in to the standard methods practitioners already use, so the learning curve is minimal.
- **Input data needed are readily available, or the effort and cost of collecting and applying the data are reasonable.** The data required, and the methods of acquiring it, are familiar to the practitioner who prepares traffic impact analyses. The data collection procedures in ITE's guidance on conducting trip generation studies (3) are sufficient. The area where users may need assistance is in selecting data collection sites in the appropriate context—a topic addressed in this report.
- **The approach uses person trips as the common denominator when converting between baseline ITE vehicle-trip data and infill trip data.** Through simple conversion, the use of person trips to derive vehicle trips and estimate the pedestrian, bicycle, and transit passenger trip generation of infill development significantly increases the robustness of the site travel characteristics and better informs the process of selecting appropriate transportation solutions than through conventional impact analyses.
- **The approach applies to the land uses in the ITE *Trip Generation Manual* and has few, if any, restrictions on land use categories and applicable geography.** The approach of employing empirical data provides the practitioner with maximum flexibility in that there are no limitations or constraints in regard to land use classification or geography. Even the step of collecting data at similar sites is consistent with the conventional impact analysis process (e.g., field collection of vehicular turning movement data, site reconnaissance).
- **It is easy to add to or expand the database (i.e., new data points or new land uses) once original database is established.** This approach does not require expansion of the existing ITE trip generation database or the need to add land use classifications. Practitioners may choose to establish a new database of context-sensitive person-trip and mode-share data for specific land uses, including a uniform method of classifying context.

While the research panel supported the selection of the ITE rate adjustment approach using empirical data from proxy sites, it also encouraged exploration of an alternate method

Table 3.1. Comparison of approach categories against selection criteria.

Criteria Grouping	Criteria	Direct Estimation Based on Regression Analysis	Direct Estimation Based on Empirical Data	ITE Rate Adjustment Based on Regression Analysis	ITE Rate Adjustment Based on Empirical Data	
					Extracted from HTSs	Collected at Proxy Sites
Ability to produce required information for use in established traffic impact analyses procedures	(1) Approach is compatible with existing traffic impact analysis methods (i.e., ability to estimate peak hour, directional-dependent variables). (2) Approach uses person trips as the common denominator when converting between baseline ITE vehicle-trip data and infill trip data, and as a basis for determining peak hour mode share of infill development. (3) Approach is adaptable to meet the needs of emerging multimodal impact analysis techniques.	Approaches that require input from regional HTS data or geographic information systems (GIS) data may not yield adequate sample size at the resolution of the peak hour by direction. Data from these sources may be highly limited in categories of land use. May require time/cost to understand database and learn to extract information. Trip cordon counts are compatible, and the most common form of trip data are used.	Person-trip cordon counts or site-/building-specific traffic or multimodal counts are compatible and are the most common form of trip data used. Traveler surveys may be required if detailed mode-share data are desired or if site does not fully accommodate its parking demand or if the site has a substantial number of linked trips by drivers who park once and visit multiple sites. Survey costs at complicated sites may be significant.	Highly compatible if applied to traditional vehicle or person-trip generation rates or equations. Regression analysis may be limited to a small number of common land use categories.	Survey-extracted data may be limited to a small number of common land use categories. The number of records in travel survey database may result in statistically insignificant sample size when extracting data at the finest grain of peak hour by direction. May require time/cost to understand database and learn to extract information.	Highly compatible if analyst is collecting data; exact type of data can be collected on an as-needed basis. Minimum required data are percentage non-automobile mode share, average vehicle occupancy, and peak hour person-trip cordon count at building. Requires selection of highly similar site within highly similar context representing project site being studied.
Ease of use for practitioner to apply	(4) Input data needed to apply the approach are readily available, or the ease and cost of collecting and applying the data are reasonable. (5) Approach requires no specialized skills or investment in training or software in order to estimate infill trip generation.	Uses cordon count or traveler interview data. Correlation of variables and validation may be limited to specific land uses and geographic areas. Independent variable data used in regression analysis usually will come from MPO or other local and reliable GIS databases.	Use of rates developed by others with site and context criteria matching project is the least costly and time-consuming method. Developing trip rates using practitioner-collected data; high-cost and time-consuming method. Data collection may include cordon person or multimodal trip counts, site-specific traffic counts, traveler surveys, and independent variable data describing site and context.	Traveler interview data or site-specific traffic counts must quantify differences between typical (suburban) and infill development. Correlation of variables and validation may be limited to specific land uses and geographic areas.	If adjustment factors representing the appropriate context have already been extracted from travel survey database, then the method is simple to apply. If not, the ease of the extraction process can be moderate to difficult. Requires familiarity with survey database, and being moderately skilled at manipulating large databases, special training, or software may be required.	Requires collection of data to develop adjustment factors for baseline ITE data and infill data. Minimum required data are percentage non-automobile mode share, average vehicle occupancy, and peak hour person-trip cordon count at building. Requires general skills in planning, executing, and reviewing data collection efforts and summarizing results.

(continued on next page)

Table 3.1. (Continued).

Criteria Grouping	Criteria	Direct Estimation Based on Regression Analysis	Direct Estimation Based on Empirical Data	ITE Rate Adjustment Based on Regression Analysis	ITE Rate Adjustment Based on Empirical Data	
					Extracted from HTSs	Collected at Proxy Sites
Credibility of approach in terms of reliability and consistency of performance	(6) Approach applies to the land uses in ITE *Trip Generation Manual* and has few, if any, restrictions on land use categories and geography. (7) Computations used in the approach are intuitive to the user and transparent by way of documentation.	Depends on specific data used in regression model and how well the model has been validated. Use statistically significant sample size for determining desired standard error.	Acquiring permission to survey individual sites can add significantly to cost. Selection of sites and intercept surveys may be costly, but once obtained, it is easy to update database.	If method is validated, this approach is a credible and reliable estimation method. Method applies to the land uses in the ITE *Trip Generation Manual*, but may be restricted in terms of land uses and geographic applicability. .	Travel survey is a highly credible source of data. Extraction method is limited to a few common land use categories if from an activity-based survey. Traditional origin–destination survey can also be used if the land use at the origin or destination is recorded.	Applicable to any ITE LUC. No geographic limitations. Important to ensure that site and context characteristics of selected proxy sites are highly similar and consistent with project site and ultimate context characteristics.
Anticipated effort to further develop or expand method to meet the research objective	(8) There is a reasonable cost for collecting data necessary to develop and validate methodology. (9) Approach has the ability to take advantage of existing trip generation database(s) or other readily available data used as input to the method. (10) The principles of development and application of the approach can be described to laypeople. (11) Approach would have likely acceptance by members of the transportation planning and traffic engineering profession who prepare and review site traffic impact analyses. (12) Approach allows for easy addition to or expansion of the database (i.e., new data points or new land uses) once original database is established.	Of the four methods, typically requires most data to analyze, along with rate adjustment method using data extracted from surveys. May require significant time to obtain travel surveys from MPOs (typically done every 10 years) or cost to researchers to conduct surveys explicitly to expand method. Ease of explanation varies with complexity of the correlation of independent variables; multivariate correlations more difficult. Principles are readily understood by technical practitioners but are less understandable to policy-oriented reviewers. Cost most associated with data needed for independent variables. Negligible cost for actual application of tool once independent variables are available.	Easiest method to understand and explain to the layperson, decision maker, and policy-oriented reviewer. Low-cost, easily applied solution for estimating infill trip generation, but collecting empirical data at sites can be challenging and costly. Cost of independent variable data usually very low; available from developer or property owner. Negligible cost for actual application of tool once independent variables are available. Can use or add to existing trip generation databases if generated using same methodology. Highly credible method; mirrors current ITE trip generation database	Analysis cost for regression analysis may be similar for any method based on regression, but depending on the number of independent variables and the extent of validation. Use ITE recommendation of collecting data for at least three or five sites per LUC. Use statistically significant sample size for determining desired standard error. In general, regression analysis is moderately difficult for the layperson to grasp. Regression methods have high likelihood of being perceived as credible by profession.	Data extraction from surveys uses existing databases usually available to agencies and consultants. Once data have been extracted for a specific land use within a specific regional context, this need not be repeated if the analyst releases the findings for general use. Explaining the concept of extracting mode share from travel surveys is relatively straightforward, but the actual application of the procedure can be challenging.	There is a cost associated with collecting data at proxy sites, but selecting to collect the minimum required data keeps the cost reasonable. Method is easiest of all four methods to explain, and its computational procedure is simple and transparent to reviewers. Because the method starts with an existing credible source of trip generation data, and since the practitioner selects proxy sites and oversees data collection, this method has high probability of professional acceptance. It is not necessary to add to any database; however, practitioners will likely maintain libraries of well-documented proxy site data for use on future impact analyses or for others to use if site meets their criteria.

Notes:

Examples of independent variables used in a regression analysis are development units by land use, population or employment within development, development characteristics, income levels, vehicle ownership, parking spaces, transit availability, and service.

that develops adjustment factors from the empirical data contained in activity-based household travel surveys (HTSs). Although this second method does not fully meet the research objective or meet all of the selection criteria, it does address gaps in the application of the first method regarding certain types of transportation studies and scale beyond a single site. Thus, the two methods are intended to be employed under different circumstances. In particular, the second method is primarily intended to address:

- Adjustment factors for broad classifications of context for use in large-scale impact analyses (region-wide, citywide, or of several hundred acres or more);
- Pre-established adjustment factors in guidelines for preparing impact analyses for a specific geographic region for consistency and so that practitioners are not required to extract data from HTS databases; and
- When there are no sites similar to the proposed infill development within the same context as the proposed project from which empirical data may reasonably be collected.

3.3 Summary and Conclusion

Chapter 3 has documented the process that the research team employed to select the approach and specific methods to develop as part of this research study. The selection process and direction received from the research panel resulted in two methods employing the approach category of ITE rate adjustment based on empirical data.

1. Proxy site method – Based on the collection of data at site(s) with similar characteristics and located in similar contexts as the infill development site (the project being studied). The research team developed two variations of this method:
   (a) The minimum data collection variant outlines an expedited procedure that collects from a proxy site or sites the minimum required data to develop adjustment factors.
   (b) The comprehensive data collection variant is used when a proxy site is situated such that the collection of the minimum required data is not feasible, or when more detailed information about the proxy site's travel characteristics is desired.
2. Household travel survey method – Derives adjustment factors from empirical data found in the database of a regional HTS. Rather than using data from a specific proxy site or sites in locations representing a project's context, the process in this method extracts data representing the desired context from an area at the scale of the traffic analysis zone (TAZ). Data may be extracted from a single TAZ, multiple TAZs, or all of the region's TAZs representing the desired context. Extraction of data representing specific land uses is based on the activities and trip purposes recorded by the travelers during the survey. A summary of the proposed methods is presented in Table 3.2. Chapter 4 describes the development of the methods and provides guidelines for their application in deriving adjustment factors for baseline ITE trip generation data.

Table 3.2. Summary of methodological approach and application criteria.

Method Title and Summary		Description	When to Use
Method #1	**Proxy site method (minimum data collection) for infill adjustment of ITE trip generation data** *Adjustment factors derived from the essential minimum empirical data collected through observation and simple cordon counts of proxy sites, and within contexts, similar to the proposed infill development (project).*	Uses a process to adjust ITE peak hour trip generation rates or trips calculated from ITE vehicle-trip rates. Adjustment factors (mode share and average vehicle occupancy) are derived from surveys at existing sites with the same land uses as the project being studied and located within a context with similar characteristics to the existing or future context(s) in which the project will be located. The objective of collecting the essential minimum data is to collect the least amount of site data that produces reasonable estimates of the percentage of non-automobile mode of travel to/from the proxy site—usually counts conducted at site driveways and building entries. This minimum level of data collection allows a practitioner to use this methodology more quickly, less expensively, and at more sites than the other methods identified in this report.	**Use this method when:** 1. Developing adjustment factors for baseline ITE vehicle-trip generation data as part of the process to convert vehicle-trip data to person-trip data. 2. Estimating peak hour trip generation for infill development as part of the site or transportation impact analysis process when proxy sites are similar to the proposed project and its surrounding context. 3. The location, orientation, site layout, and characteristics of the proxy sites are conducive for collecting the required minimum data.
	Proxy site method (comprehensive data collection) for infill adjustment of ITE trip generation data *Adjustment factors derived from empirical traveler data collected at proxy sites in contexts similar to the proposed infill development (project) using a variety of survey instruments ranging from cordon counts to intercept surveys.*	Uses a process to adjust ITE peak hour trip generation rates or trips calculated from ITE vehicle-trip rates. Similar to the minimum data collection method, the adjustment factors (mode share and average vehicle occupancy) in the comprehensive data collection method are derived from surveys conducted at sites with similar characteristics to the proposed project except that this method can obtain more detailed information, such as mode share, trip purpose, pass-by trips, trip length, parking location and cost, traveler preferences, and traveler demographics, to name a few common types of data. The survey instruments used to collect traveler data include conventional vehicle counts at site driveways, person-trip counts at building entries, random sample intercept surveys of travelers using the site, mail-in surveys, and surveys using other innovative techniques.	**Use this method when:** 1. A detailed breakdown of mode share other than by automobile/non-automobile is desired, or the practitioner desires traveler data that cannot be obtained from counts. 2. The proxy site or sites do not have exclusive parking facilities or are located where there are nearby but unobservable public or private parking structures, below-ground garages, and street parking. 3. The proxy site or sites experience a high level of linked trips, where travelers who drive park once and walk to multiple sites, and if the practitioner desires to determine the site's demand for primary versus secondary linked trips. 4. The proxy site has a nearby but unobservable rail station or transit hub, and transit mode share is desired.
Method #2	**Household travel survey method for infill adjustment of ITE trip generation data** *Adjustment factors extracted from the linked-trip database of a regional HTS. Data are extracted at the geographic scale of the TAZ and filtered by attributes representative of varying contexts.*	Uses a process to adjust ITE peak hour vehicle-trip generation rates (or direct adjustment of trips). Adjustment factors (mode share and average vehicle occupancy) are derived by extracting certain data from the linked-trip database resulting from a regional HTS. The data are extracted from groupings of TAZs with similar characteristics to the existing or future land use, site, and context(s) in which the proposed project will be located. Extraction filters data by attributes representative of context, land use, mode of travel, time of day, and direction. Mode share and vehicle occupancy data extracted from HTSs can reflect a specific but limited number of land use categories. This method requires having or developing a familiarity with travel surveys, GIS systems, and database manipulation in order to cost-effectively extract the necessary data. In addition, to access the linked-trip database, it is necessary to obtain detailed documentation of the survey's structure and especially the databases' library of variables and their definitions.	**Use this method when:** 1. Developing adjustment factors for broad classifications of context for use in large-scale impact analyses (region-wide, citywide, or large districts). 2. Preparing a lookup table of adjustment factors for different context categories to be included in guidelines for preparing impact analyses for a specific geographic region. 3. There are no sites similar to the proposed project and within the same context as the proposed project from which empirical data may reasonably be collected.

CHAPTER 4

Development and Application of Methods for Estimating Infill Trip Generation

Chapter 3 summarized the process the research team employed to select the approach used as the basis for developing the estimation methods described in this chapter. The following sections present two proposed methods, both of which are based on the selected approach—baseline ITE rate adjustment based on empirical data. While both methods use the same computational procedure, they derive adjustment factors in different ways and are applied under different conditions.

This chapter:

- Presents an overview of the selected approach and the procedures for applying the two estimation methods,
- Defines a system of context classifications and provides guidance for qualifying a site as infill and for selecting appropriate proxy sites, and
- Describes the development of adjustment factors for both methods.

4.1 Overview of Approach

Figure 4.1 illustrates the overall approach for estimating infill vehicle-trip generation based on adjusting baseline ITE vehicle-trip data. As shown, person trips are the common denominator allowing the conversion between baseline ITE and infill trip generation. The methods of deriving the adjustment factors, described in the subsequent sections of this chapter, are represented by the infill data input boxes (Steps 1 and 3) in Figure 4.1.

The approach has five primary steps:

1. Baseline ITE trip generation data are used to estimate the vehicular trip generation of the proposed infill development.
2. Baseline mode share and vehicle occupancy adjustment factors are used to convert baseline vehicle-trip estimates to baseline person trips.
3. An infill mode-share adjustment factor representing the appropriate context is used to convert baseline person trips to infill person trips where the person travels by automobile.
4. An infill vehicle occupancy adjustment factor representing the appropriate context is used to convert infill person trips where the person travels by automobile to infill vehicle trips.
5. Infill vehicle trips are used in the evaluation of site traffic impacts.

The use of person trips as the common denominator between baseline ITE data and infill data underscores an important assumption in this research study: that land uses in single-use suburban environments (baseline sites) generate approximately the same quantity of person trips as land uses in dense urban environments (infill sites).

The assumption that the quantity of person trips generated by a unit of development for a given LUC (e.g., 1,000 gross square feet of floor area, a multifamily dwelling unit, or one seat in a movie theater) is the same regardless of context has been historically supported by land use planners and economists, who often use average employment densities to convert employees to building floor area and vice versa. For example, the amount of floor area per employee for an office building typically ranges from 250 ft^2 to 400 ft^2. Variations substantially outside of this range are usually associated with the type of land use and not the context in which the land use is located. The research team analyzed person trips per household in one metropolitan area and found that, statistically, there were no significant differences in trips between households in different contexts (10). While variability from site to site is expected, on average, ITE data, land use data, and socio-demographic data support the assumption that person trips remain constant across the spectrum of contexts.

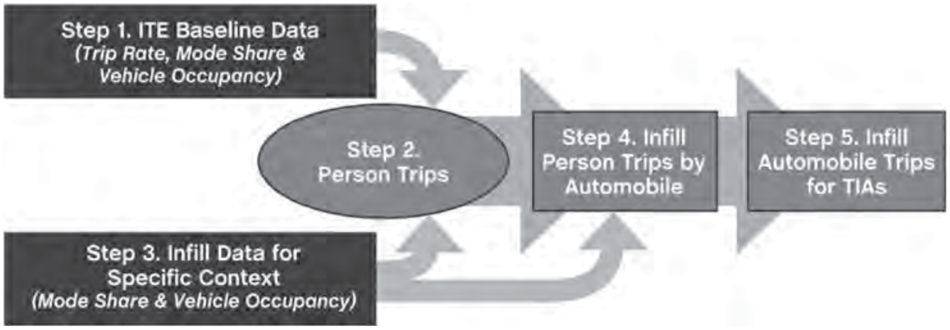


Diagram representing the approach for estimating vehicle trip generation for infill development based on adjusting ITE baseline trip generation data. The infill data used in the process can be derived from the methods described in this chapter. Note: TIAs = transportation impact analyses.

Figure 4.1. Approach for estimating vehicle trip generation.

4.2 Proposed Methodology

This report proposes an approach of adjusting ITE trip generation data (rates or trips) using a single computational procedure that employs baseline and infill adjustment factors consisting of (a) mode share or percentage of trips made by non-automobile modes, and (b) average vehicle occupancy. The derivation of these adjustment factors under this proposed approach may result from one of two methods, depending on the type of impact analysis or study for which the practitioner is estimating infill trip generation. Table 3.2 summarized the methods, including guidance on which method to use under different conditions.

1. Proxy site method – Uses empirical data collected from a site or sites that serve as a proxy for the proposed project to obtain mode share and vehicle occupancy to adjust baseline ITE trip generation data. There are two variants of the proxy site method:
   (a) Minimum data collection – Allows the practitioner to derive adjustment factors more quickly and less expensively than the other methods identified in this report. A reduction in the time and effort to collect data may be achieved by requiring collection of only the essential minimum data and using basic techniques to survey proxy sites within contexts similar to the proposed project. Not all proxy sites qualify for the minimum data collection variant.
   (b) Comprehensive data collection – Derives adjustment factors from data collected using multiple techniques to survey proxy sites within contexts similar to the proposed project. This variation of the proxy site method is used when the complexity of the site or its surrounding context precludes the minimum data collection variant, or when more detailed traveler, site, or demographic information is desired.
2. Household travel survey method – Derives mode share and average vehicle occupancy for a particular land use and context by extracting data from the linked-trip database of a regional HTS conducted for the metropolitan region within which the practitioner is preparing a study. The household travel survey method has applications and limitations that are different from those of the proxy site method. While it can be used to estimate infill trip generation, the household travel survey method is applicable in broader, more macroscopic circumstances, as described later in this chapter.

4.3 Application of the Proxy Site Method

Step 1: Determine the study area context and identify the infill proxy site

Qualifying a proposed project as infill development requires examining the development site itself as well as the context within which the site is located. To do this, the practitioner needs to be able to distinguish between a site having travel characteristics consistent with baseline ITE data and a site whose travel characteristics are more varied. Most of this distinction is found in the attributes describing the surrounding context.

Because there is not a common definition of infill development, nor are there widely accepted quantifiable metrics to define different types of context, the practitioner is compelled to employ subjective methods to determine if a study site is infill. The application of subjective methods is complicated by the fact that human perceptions of the built environment vary greatly as a result of a variety of biases, including local conditions. Considering this and the likelihood that quantifying classes of context at a national scale would be difficult to apply consistently and thus would lack credibility, the research team chose to present a flexible and adaptable system for classifying context. The primary requirement of the system is consistency in its application, especially when comparing potential proxy sites with the proposed project being studied by the practitioner.

Qualifying a site as infill development starts with the definition selected for this research study in Chapter 2:

> Infill development or redevelopment is located in fully built areas, often in and around business districts; is walkable; is served by convenient frequent transit; is commonly served by designated bicycle facilities; and generates significant non-automobile mode shares.

Using this definition as a qualitative benchmark, the practitioner documents the attributes of the proposed development and the attributes of the ultimate context in which the development will be located. The documented attributes are used subsequently to identify proxy sites, but also may be retained for building a database of project attributes and their associated proxy sites for use by others.

The following are examples of attributes for describing context that are typically available in local planning and regulatory documents, extracted from existing databases, or observed in the field:

- General or comprehensive plan land use and zoning designations.
- Residential or employee densities in the surrounding district.
- Maximum allowable floor area ratio (FAR) applicable to the site.
- Minimum required setback from public right-of-way (a measure of distinguishing between automobile- and pedestrian-oriented development standards).
- Off-street parking requirements, allowances for off-site parking and street parking, and so forth.
- Public and private parking systems in proximity to site, number of spaces, utilization, and costs.
- Existing and planned transit system serving site and vicinity (routes, stations, frequencies).
- Existing and planned bicycle facilities in vicinity of site and connections to regional system.
- Measures of walkability (qualitative or quantitative).

The following are examples of attributes for describing a proposed infill development project as well as describing an appropriate proxy site. These attributes are obtained from a combination of the developer and local planning and regulatory documents:

- Project size, number of units, floor area, or expected number of employees.
- Project density or FAR.
- ITE LUC and general or comprehensive plan and zoning designations.
- Preliminary site layout, building orientation, parking spaces, and parking facility orientation.
- Walking distance to nearest rail or high-frequency bus transit station or stop.
- Proximity to nearest bicycle facilities, and identification of obstacles and barriers to bicycling.
- Site pedestrian access.

The underlying assumption of the proxy site method is that similar uses in similar contexts will have similar trip-making characteristics. As such, being able to determine that the study area and the proxy site are located in similar contexts is a basic requirement.

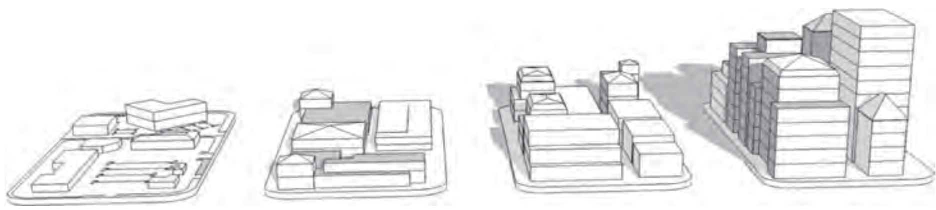
The combination of area type and type of public transportation designates the context for use in the proposed methodology and determines whether the method is applicable given the conditions of the study area. In the Institute of Transportation Engineers' recommended practice, *Designing Walkable Urban Thoroughfares: A Context Sensitive Approach* (11), the definition of urban areas is based on the concept of "context zones." Context zones are a discreet set of development-intensity–based categories on a scale ranging from the most rural or undeveloped area to the most urban or developed area. Although the *Designing Walkable Urban Thoroughfares* recommended practice was developed for the purposes of thoroughfare design, the context zone system is a useful method for stratifying urban areas whose unique characteristics may affect trip generation. The four zones used to define urban context, listed in increasingly urban conditions, are:

- Suburban center (CZ-3),
- General urban (CZ-4),
- Urban center (CZ-5), and
- Urban core (CZ-6).

Any context that does not fall into one of these four designations is either a special district, such as a university campus or an airport, or the context is single-use suburban, exurban, or rural, with little or no transit service, and should be analyzed using conventional ITE trip generation rates.

The four designations listed previously can be applied to numerous contexts. For example, a suburban town with a population of 40,000 can have the equivalent of an urban core, but the trip generation characteristics of development in this community could be far different from development in the urban core of a large metropolitan city with a population exceeding 1,000,000. Therefore, the research team further narrowed the definition by including the type of public transportation serving the subject area. Contexts that qualify for infill development are served by rail or high-frequency bus transit (12). Contexts served only by conventional low-frequency bus transit, even when in close proximity to the proxy site, do not qualify. Figure 4.2 presents diagrams and describes characteristics representing the contexts used in this research study. The diagrams are not intended to visually match a given study area but to illustrate the difference in the key physical site and building attributes between the categories. The characteristics described in Figure 4.2 may assist practitioners in consistent identification of context. Finally, the following qualitative attributes may be used as general descriptors of areas qualifying for infill development:

(a) **Compactness** – A monocentric form of development pattern in which the metropolitan area of study has a concentration of its population within a specified distance of the urban core. Compactness is also represented by a



Context Zone Characteristics	Suburban	General Urban	Urban Center	Urban Core
Land use	Low-density, single-use development. Some horizontally mixed-use development, but mostly segregated. Many auto-oriented uses such as big-box retail and drive-through restaurants.	Moderate-density mix of single- and mixed-use development. Some auto-oriented uses focused on office parks and urban shopping centers.	Moderate- to high-density development. High building coverage of property, with open space between buildings.	High- to very high-density development. Very high building coverage of property, often with buildings attached.
Orientation of building on site	Buildings have large setbacks from street. Buildings oriented toward parking rather than street.	Buildings primarily oriented toward street, but some oriented toward parking lots.	Buildings integrated into the sidewalk with stoops, arcades, and cafes.	Buildings integrated into the sidewalk with stoops, arcades, and cafes.
Building height and separation	Typically one- to two-story buildings. Buildings do not form a street wall or street enclosure, creating a sense of wide, open space.	Mid-rise buildings of one to four stories that partially create a sense of definition. Usually space between buildings reduces the sense of enclosure of the street.	Mid-rise to high-rise buildings. Buildings create definition but may have spaces that reduce the sense of enclosure of the street. High diversity of scale and variety of buildings.	Tall, high-rise buildings are common. Buildings create definition and a street-wall enclosure. Very high diversity of scale and variety of buildings.
Pedestrian access	Indirect or nonexistent pedestrian connection to building entries from street.	Mix of direct and indirect access to building entries from street.	Direct pedestrian connection to building entries from street.	Direct pedestrian connection to building entries from street.
Parking	Primarily in surface lots between buildings and street. Zoning requires all required parking to be contained on site and exclusive to the site.	Mixture of surface and structured parking. Off-site and on-street parking may be allowed in lieu of exclusive on-site parking.	Predominantly structured parking. Off-site and on-street parking may be allowed in lieu of exclusive on-site parking. Parking may be accessed by alleys.	Predominantly structured and underground parking, both private and public. Parking typically accessed by alleys.

Notes:
Adapted from *Designing Walkable Urban Thoroughfares: A Context Sensitive Approach. An ITE Recommended Practice*. The Institute of Transportation Engineers. Washington, D.C., 2010.
See Appendix A for a more thorough description of each context zone.

Figure 4.2. Diagrammatic description of context zones.

large proportion of a metropolitan area's land being built up (covered with buildings and infrastructure) relative to the total land area.

(b) **Fully built area** – Defined as an area with only a fraction (typically less than 10%) of its land being undeveloped, excluding water bodies and land designated for conservation use, natural preservation, public road rights-of-way, and recreation.

(c) **A mix of residential and employment** – Defined as an area having a generally balanced ratio of jobs to housing units. Contexts where either jobs or housing represent a significant proportion of the land use (e.g., 70% to 100%) have a poor mix and generally will not experience the same level of trip capture as a context with a balanced mix. This attribute may be determined qualitatively by simply observing the mix of uses within the study area, or it may be calculated using available data.

(d) **A continuous and interconnected pedestrian circulation system** – Referring to a walkable pattern of blocks and streets having continuous sidewalks and intersection crossings with few or no major obstacles to pedestrian circulation within the study area such as freeways, waterways without crossings, or extreme topography. This attribute can be visually ascertained or can be measured through a connectivity index (e.g., a minimum number of intersections per square mile).

(e) **Sites located within walking distance of rail station or a high-frequency bus rout**e – This attribute establishes access to public transit but does not necessarily limit the study sites to TOD. For purposes of assessing proxy sites, the maximum walking distance to a rail station is generally considered one-half of a mile, while the walking distance to a high-frequency bus stop (headways of typically no more than 20 minutes) is considered one-quarter of a mile.

Appendix A contains a more thorough description of each of the four context zones used in this report.

Step 2: Convert baseline ITE vehicle-trip generation to baseline ITE person-trip generation

Start with vehicle-trip generation data from the ITE *Trip Generation Manual* for the land use classification for which trip generation estimates are desired.

The ITE *Trip Generation Manual* contains guidance on estimating vehicle-trip generation. The directions can be found in Volume 1 of the ITE *Trip Generation Manual*—User's Guide and Handbook. To convert baseline ITE vehicle trips to baseline ITE person-vehicle trips (person trips employing an automobile mode of travel) requires knowledge of two factors: (1) the percentage of trips made by non-vehicle modes of travel represented by the baseline ITE trip generation estimate, and (2) the vehicle occupancy assumed in the baseline ITE trip generation estimate. Referring to the majority of the baseline ITE trip generation data, the most recent version of the User's Guide in the *Trip Generation Manual* (3) states:

> Data were primarily collected at suburban locations having little or no transit service, nearby pedestrian amenities, or travel demand management (TDM) programs.

However, the term "little or no" implies that there may be some trips, albeit a small fraction of the total trips made by transit, walking, or bicycling inherent in the trip generation rates.

Adjustment factors for baseline ITE trip generation data may be derived from other conventional trip generation studies that have the data or may be or collected by the user following the proxy site method. These approaches are described further in the section on deriving infill adjustment factors.

The conversion of ITE vehicle trips to ITE person trips uses Equation #1:

$$\text{Person-Trips}_{\text{BASELINE}} = \frac{\text{VehTrips}_{\text{BASELINE}} \times \text{VehOcc}_{\text{BASELINE}}}{\left[100\% - \left(\begin{array}{c}\%\text{Transit}_{\text{BASELINE}} \\ +\,\%\text{WalkBicycle}_{\text{BASELINE}}\end{array}\right)\right]}$$

Where:

- $\text{Person-Trips}_{BASELINE}$ = baseline ITE vehicle-trip estimates converted to baseline ITE person trips by all modes of travel;
- $\text{VehTrips}_{BASELINE}$ = Vehicle-trip generation estimate from the ITE *Trip Generation Manual* for the subject site;
- $\text{VehOcc}_{BASELINE}$ = Average baseline ITE vehicle occupancy in the baseline ITE trip generation estimate, as input by the user;
- $\%\text{Transit}_{BASELINE}$ = Average transit mode share assumed in ITE trip generation rates; and
- $\%\text{WalkBicycle}_{BASELINE}$ = Average walk and bicycle mode share assumed in ITE trip generation rates.

Alternatively, the last two values in the equation may be replaced with the single value: $\%\text{NonAutomobile}_{BASELINE}$.

Step 3: Convert baseline ITE person-trip generation to infill person-vehicle-trip generation

This step converts the baseline ITE person-trips estimate from Step 2 into the equivalent number of person trips using an automobile mode share in infill areas. Step 3 converts the baseline ITE person-trip estimates to infill person-vehicle trips using Equation #2:

$$\text{Person-Vehicle-Trips}_{\text{INFILL}} = \text{Person-Trips}_{\text{BASELINE}} \times [100\% - (\%\text{Transit}_{\text{INFILL}} + \%\text{WalkBicycle}_{\text{INFILL}})]$$

Where:

- $\text{Person-Vehicle-Trips}_{INFILL}$ = Infill person trips using vehicular mode of travel;
- $\text{Person-Trips}_{BASELINE}$ = Baseline ITE vehicle trips converted to baseline ITE $\text{person-trips}_{BASELINE}$ from Step 2;
- $\%\text{Transit}_{\text{INFILL}}$ = Average transit mode share applicable for specific infill area based on data collected in the proposed methodology (see section on developing adjustment factors); and
- $\%\text{WalkBicycle}_{\text{INFILL}}$ = Average walk and bicycle mode share for specific infill area based on data collected in the proposed methodology (see section on developing adjustment factors).

Alternatively, the last two values in the equation may be replaced with the single value: $\%\text{NonAutomobile}_{INFILL}$. Determination of the applicable transit and walk/bicycle mode shares, or the percentage of all trips by other than an automobile, is the critical part of this step and requires input from one of the proxy site methods.

Step 4: Convert infill person-vehicle trips to infill vehicle trips

The proposed methodology culminates in the calculation of vehicle-trip generation for the infill site. These adjusted vehicle-trip generation estimates are then used in the conventional traffic impact analysis process. The final conversion uses Equation #3:

$$\text{Vehicle-Trips}_{\text{INFILL}} = \frac{\text{Person-Vehicle-Trips}_{\text{INFILL}}}{\text{VehOcc}_{\text{INFILL}}}$$

Where:

- $\text{Vehicle-Trips}_{\text{INFILL}}$ = Vehicular trip generation adjusted for urban infill conditions;
- $\text{Person-Vehicle-Trips}_{\text{INFILL}}$ = Infill person trips using vehicle mode of travel resulting from Step 3; and
- $\text{VehOcc}_{\text{INFILL}}$ = Persons per vehicle based on local data collection.

4.4 Developing Adjustment Factors for the Proxy Site Method

The computational procedure described previously requires obtaining or deriving mode share and vehicle occupancy adjustment factors for baseline and infill equations. Baseline ITE adjustment factors are not context-specific and may be obtained from the literature, extracted from data collection conducted by others, or collected directly by the user.

Infill adjustment factors are context-specific and need to be derived from carefully selected proxy sites in order for the estimation approach to produce reasonably accurate and credible results.

This section describes data requirements for the variants of the proxy site method (minimum data collection and comprehensive data collection). In addition, this section:

- Provides guidance on selecting proxy sites,
- Identifies the conditions that warrant the use of either of the method's variants, and
- Describes the pre-survey planning that results in the most effective use of limited resources.

4.4.1 Baseline Adjustment Factors

Sources of baseline adjustment factors include technical literature, mode-share studies of baseline land uses, and original data collection documentation. Baseline data may also be newly collected at sites that represent ITE baseline conditions. The research team identified several specific sources for obtaining baseline data adjustment factors, including:

- Data in the ITE *Trip Generation Manual* or other original studies to determine if non-automobile mode share and vehicle occupancy data were included in the studies. For example, some sources of trip generation rates, such as the Trip End Progress Reports from the California Department of Transportation, contain data on transit, walk, and bicycle modes and vehicle occupancies for certain uses.
- Non-ITE trip generation data of isolated suburban land uses that contain non-automobile mode share and vehicle occupancy data. These data are frequently collected for traffic impact studies and filed away or retained as proprietary information.
- Estimated values for transit, walk, and bicycle mode share and vehicle occupancy using regional HTS data.
- Data collection for mode share and vehicle occupancy at sites similar to the site represented in the ITE trip generation land use categories using the proxy site method.

In the event that these sources fail to provide applicable data, a conservative approach assuming zero transit, walk, or bicycle trips, and a low vehicle occupancy (a range of 1.02 to 1.05 persons/vehicle), is recommended for use.

4.4.2 Guidelines for Selecting a Proxy Site

Selecting an appropriate proxy site for collecting data is one of the most important aspects of the method. A poorly selected site could result in the significant under- or over-estimation of infill trips. The following guidelines are provided to help the user select proxy sites:

- Create a list of the attributes of the proposed project site and its surrounding context representing a time at build out of the project, to the extent this information can be documented (particularly regarding the surrounding context) without speculation. The attributes need to be measurable/observable without undue effort. The context attributes shown in Figure 4.2 can be used as a basis for establishing these attributes.
- The selected site should substantially represent the proposed project in terms of attributes such as land use, size of development, density or FAR, mix of uses (if applicable), parking supply and proposed parking costs, vacancy rate, and maturity of the development. The user must be able to obtain critical independent variable information about the site, such as gross leasable floor area, or number of dwelling units.
- The user should attempt to locate a proxy site within proximity of the proposed project. If this is not possible, the selected site should be located in a context that substantially represents the baseline or infill context (or future infill context) of the project, including network density; type, proximity, and frequency of transit services; level of walkability and bicycle accommodation; density of surrounding land uses; and similar amount and availability of off-site parking. See list of context attributes in Step 1 as an example.
- GIS mapping may be used to identify physical, regulatory, and demographic attributes as the context of the proposed project. Use queries to map TAZs or census tracts/blocks that might contain the desired attributes for proxy sites.
- Use navigational mapping software or websites (e.g., Google Earth) to search and plot the location of businesses or places of similar land use types as the proposed project. Walk Score or similar tools can be used to locate neighborhoods or districts with similar walkability traits as a starting point for searching for proxy sites.
- While data collected from multiple sites are statistically more robust, data collected from a single proxy site may be acceptable as long as the survey planning identifies sites with average to above-average activity, collects data on days and time periods typically representing the peak hours of the land use being studied, and avoids times that may significantly affect the data, such as holidays, nearby closures of major streets, or days when large special events occur nearby.

4.4.3 Infill Adjustment Factors

If mode share and vehicle occupancy data reflecting both the land use and the context of the proposed project are readily available, then they may be used directly. If the data are not available, the user may collect the data at a site or sites representative of the subject land use and within the same type of context as the proposed development. Following is an overview of the user data collection requirements for each of the two variants of the proxy method:

- **For the minimum data collection variant**, the site must be configured with its own exclusive parking supply oriented so that vehicles entering or exiting can be observed and counted. The site's parking should be sufficient and convenient enough so that site users have no need to park off-site and walk to the site, ensuring full capture of the site's traffic generation. The site must be oriented so that observers can view all entrances, including rear and employee-only entrances. The minimum data collection required for the minimum data collection variant is:
  - Vehicles entering/exiting site during the a.m. or p.m. peak period of adjacent street traffic.
  - Number of persons entering and exiting all entries to the subject building(s) on the site, and
  - The number of persons in vehicles entering or exiting the site.

For the comprehensive data collection variant, there are few restrictions on the physical configuration of the site's buildings and parking because intercept surveys capture trips that cannot be observed or easily counted. Guidance for collecting data using the comprehensive data collection variant is as follows:

- It may be necessary to gain the permission of the proxy site owner/management to conduct intercept surveys of the site's employees, visitors, or customers.
- The site's access points must be oriented so that observers can view all entrances, including rear and employee-only entrances, or observers need to be placed at every building entrance to ensure a thorough count of person trips.
- A good resource for planning site-specific comprehensive travel surveys, including strategies for selecting sites and gaining management permission, setting up survey personnel, innovative tools to improve participation in surveys, and lessons learned, is *Trip-Generation Rates for Urban Infill Land Uses in California, Phase 2: Data Collection, Final Report* (1).

- The comprehensive data collection variant does not have the same minimum requirement for data collection as the minimum data collection variant. By definition, the comprehensive data collection variant is used when more data is desired at a study site. Its intent is to expand data collection and the use of survey instruments when circumstances dictate the need for more information or an alternative approach. The types of survey instruments that may be considered for this method include:
  - Random sampling intercept surveys to determine mode share, distance traveled to the site, and pass-by trips, and to document traveler demographics for cross-referencing;
  - Person-trip cordon counts at building entries;
  - Origin–destination surveys conducted by questionnaire or by observing trips between site and transit, off-site parking, and other land uses;
  - Vehicle occupancy counts; and
  - Automatic machine vehicle counts or video data collection.

4.4.4 When to Use Proxy Site Method Variants

The minimum data collection variant serves as the default methodology for collecting data from proxy sites to derive adjustment factors. Unless additional data are desired or there are challenges in collecting the necessary data from the proxy site, the minimum data collection variant is sufficient for most applications.

The comprehensive data collection variant is employed under the following conditions:

- When a detailed breakdown of mode share other than automobile/non-automobile mode of travel is desired, or the practitioner desires traveler data that cannot be obtained from counts or observation;
- When the proxy sites do not have exclusive parking facilities, or the proxy sites are located where there is nearby but unobservable public or private parking structures, below-ground garages, and street parking where proxy site users are parking and walking onto the site;
- When the proxy sites experience a high level of linked trips, where travelers who drive park once and walk to multiple sites, and if the practitioner desires to determine the site's demand for primary versus secondary linked trips; or
- When the proxy sites have a nearby but unobservable rail station or transit hub, and the site's transit mode share by type of transit is desired.

4.4.5 Considerations for Site Impact Analysis Planning Horizons

Site impact analyses typically evaluate a proposed project under a range of time-based scenarios often referred to as *planning horizons.* Planning horizons can range from the current year to 20 years or more in the future, or whatever period of time the proposed project would take to fully build out.

The scenarios developed under these timeframes evaluate the effects or impacts of the traffic generated by the proposed project when combined with current transportation conditions and when combined with the cumulative traffic forecasted to occur in the future. Traditionally, the analysis of planning horizons identifies near-term, project-specific impacts (impacts caused solely by the project and for which the project is solely responsible for mitigating) and long-term cumulative impacts (impacts caused by the cumulative growth in traffic to which the project contributes and is responsible for mitigating its share of the impact).

When selecting a proxy site or sites, the practitioner needs to consider the planning horizons of the impact analysis being prepared and choose a site or sites within contexts that represent the desired planning horizon. This may require selecting sites in multiple contexts if the proposed project is located in an area expected to undergo substantial change over time. Conversely, if the proposed project is located in a fully built environment with little expected change over time, the practitioner can select one context that represents both current and future conditions.

4.5 Application of the Household Travel Survey Method

Infill adjustment factors may be derived for sites proposed within metropolitan areas that have current HTS data. This method of deriving mode share and auto occupancy is limited to the land use categories that can be deduced from HTS linked-trip data—essentially only the general categories (e.g., retail, office, multifamily housing) because the data from the surveys do not always distinguish between land use subcategories (i.e., grocery store versus home improvement center). However, HTS data can provide adjustment factors for all context types, and more importantly, they can identify differences in the adjustment factors within each context type due to geographic location and socio-demographic characteristics within a region.

This method will result in adjustment factors for general land use categories within any context type, either (a) averaged across the metropolitan region, or (b) specific to any TAZ located in the region.

Although this method can be used to generate the adjustment factors used in traffic impact analyses of infill development, it can be also be used for broader types of analyses, including:

- Creation of a region- or area-wide database of mode share and vehicle occupancies by TAZ (representing the context within the TAZ) for adjusting ITE trip generation rates for

sites in different locations in the region to ensure consistency in infill development traffic impact studies within the region or area;
- Scenario analyses comparing the transportation benefits or impacts of shifting growth in development between urban infill and suburban or greenfield locations;
- Studies of large-scale activity centers requiring an understanding of how the center's mode share is influenced by its location within the region, proximity to transit, and other built-environment characteristics; and
- Development of local or regional trip generation rates and mode shares covering a range of contexts for inclusion in agency traffic impact analyses guidelines.

4.5.1 Required Data for the Household Travel Survey Method

The data normally available from an HTS to use for the household travel survey method can be divided into four categories:

- Household data – Characteristics of the household and its location.
- Person data – Demographic, socioeconomic, and employment information for one or more members of the household.
- Vehicle data – Type, ownership, and usage of private vehicles available to household members.
- Travel and activity data – Detailed travel, activities, and origins/destinations of the daily trips by one or more household members.

The minimum required data for estimating infill trip generation adjustments are listed in Table 4.1, which describes the required variables and how they are used in deriving the adjustment factors. These variables are generally standard in travel surveys and should be available, in one form or another, from all the major metropolitan areas. The linked trip data contain numerous other variables and helpful information for cross-referencing household, person, vehicle, and activity data.

Typically, HTSs record individual segments of each trip separately every time the traveler stops for a specific purpose on the way to an ultimate destination, including when changing modes. For example, driving from home to the train station, taking the train, and walking to the workplace are three segments of a single trip, each using a different mode of travel. These are called *unlinked trips.* However, the travel described here is actually one home-based work trip using rail transit as the primary mode of travel. Driving to the train station and walking to the workplace are secondary. The consolidation to a single trip purpose by a single mode describes a linked trip.

Household travel survey records of unlinked trips are manipulated to produce linked trips. The linked trip data contain multiple variables from the four categories of data: household, person, vehicle, and travel/activity. Linked trip data are made up of individual trip records, each of which represents one person's travel for an activity by the primary mode of travel. Each trip record is identified by a general trip purpose [e.g., home-based work, home-based shopping, non–home-based trips, start and end time of travel, mode of travel, passengers (if by auto), mode of access to primary travel mode, origin and destination activities and place, and numerous other data].

Table 4.1. Linked trip data variables in deriving adjustment factors.

HTS Variable	Definition
Origin activity purpose/ destination activity purpose or origin land use/destination land use	Provides the activity purpose or land use of the origin and the destination of the trip – used to associate the trip with a particular land use.
General purpose	Provides home-based and non–home-based trip information – used to cross-check data and to populate adjustment factors when using travel demand forecasting model data.
Primary mode of travel	Provides the primary mode of travel for individual trip records (ignoring mode of access) – used to develop adjustment factor mode split.
Origin TAZ/destination TAZ	Provides the zone of the origin and the destination of the trip – first used to identify trip records within TAZs designated as general urban/urban center, then used to classify the trip as inbound or outbound in the extraction of peak hour records. If available, an address can be used to determine the origin or destination zone.
Day of trip	Identifies the day the trip occurred – used to classify trips as weekday or weekend.
Start time/end time	Starting and ending time of the trip – used to classify trips in either a.m. or p.m. peak period.
Number in vehicle	Provides the number of people in a vehicle – used to determine vehicle occupancy.

Based on a review of the data variables contained in the various categories of data, the research team determined that the linked trip data contained the appropriate information for deriving mode split and vehicle occupancy for various land uses and time periods. Linked trip data were selected as the best source of data because their trip records were cross-referenced to the variables needed to calculate the adjustment factors.

4.6 Data from the San Francisco Bay Area

The research team initially assessed the travel survey data from one selected metropolitan area to determine if adequate information could be extracted from the available records to generate the adjustments factors by LUC. The research team selected the HTS data from the Metropolitan Transportation Commission's (MTC) 2000 Bay Area Travel Survey (BATS). This activity-based survey was conducted with over 15,000 households in the nine-county Bay Area, which had a year-2000 population of 6,800,000 in nearly 2,500,000 households. The survey data were readily available, well documented, and summarized by MTC for cross-checking against the resulting adjustment factors. In addition, GIS data were readily available that provided information about TAZs, proximity to transit (rail and bus), and available transit headway data.

4.6.1 Variables in the Household Travel Survey Method

The research team selected four land use categories for the development of adjustment factors using the household travel survey method. They are residential, restaurant, retail, and office. Because the available data are activity-based and not place-based, the type of land use at the origin or destination of the trip needs to be inferred from the trip records. The linked trip data contain a variable for the activity purpose at both ends of the linked trip. From the available choices, the investigators selected those activities that best represented an activity at a specific land use. Missing from the HTS data are trips made by delivery or service people, with the exception of survey participants who are employed in these fields. This is a potential source of error in estimating actual trips but is not a significant error in calculating mode split or vehicle occupancy. The activities used to determine land uses associated with trips are described in the following.

4.6.1.1 Residential Land Uses

Residential-related trips were selected from the trip records with an origin purpose or a destination purpose classified as "home." The majority of the records for residential-related activities are from the residents themselves.

Residential trip records do not record delivery, services, or guest trips unless recorded by another participant. This should not significantly affect the derivation of mode split or vehicle occupancy of residential uses.

4.6.1.2 Restaurant Land Uses

Restaurant-related trips were selected from the trip records with an origin purpose or a destination purpose classified as "meals" or an origin activity or a destination activity classified as "eat a meal outside of home or work." The trip records only include patron trips.

Restaurant trip records do not capture employee, delivery, or service trips unless recorded by another participant. This may affect calculation of the mode split or vehicle occupancy. Employee-related trips are captured in the "work" trip purpose.

4.6.1.3 Retail or Shopping Center Land Uses

Trips related to retail or shopping centers were selected from the trip records with an origin purpose or a destination purpose classified as "shopping away from the home," "personal services/bank/government," or "shop." The "personal services/bank/government" purpose includes barber, beauty shop, dry cleaning, banking, and government services. The trip records include only patron trips.

Retail trip records do not capture employee, delivery, or service trips unless recorded by another participant. This may affect calculation of the mode split or vehicle occupancy. Employee-related trips are captured in the "work" trip purpose.

4.6.1.4 Office Land Uses

Office-related trips were selected from the trip records with an origin purpose or a destination purpose classified as "work or work related." These trip records include all work trips and do not classify the origin or destination as "office." At least under the MTC variables, there is no reasonable way to separate work trips from those specific to an office building except by reviewing the participant's comments. However, this was not deemed a practical or accurate way to isolate office-building–related trips. While this is a potential source of error and inaccuracy, its use was appropriate because the resulting mode split and vehicle occupancy represents work-related trips for all land uses, including office buildings. Further, a comparison of the resulting mode splits and vehicle occupancies looks reasonable compared to generalized work mode splits for the entire region or within ½ mile of rail stations as published by MTC. Therefore, while use of the work or work-related trip purpose captures trip records to non-office locations, the data appear to reasonably represent work trips to office land uses.

4.6.1.5 Limitations of the Office Data

MTC's activity at origin or destination does not distinguish work or work-related trips by type of workplace except through participant comments.

4.7 Procedure for Applying the Household Travel Survey Method

4.7.1 Determining Context

Context, as used in development of adjustment factors using HTS data, is made up of:

- Density, intensity, and mix of the surrounding land uses;
- The type of, frequency of, and proximity to transit;
- Compactness of the surrounding land uses; and
- Access to a contiguous and interconnected urban street system.

In the proxy method, context is determined by comparing the actual built environment with attributes delineating four context categories. In the household travel survey method, context is determined at the scale of the TAZ using GIS and measures of urban intensity such as population and employment densities. This process is explained in the following sections.

The household travel survey method was developed and tested under two context categories within the nine-county metropolitan San Francisco Bay Area. The research team chose to develop and test the household travel survey method within general urban and urban-center contexts and used GIS to filter out the TAZs in the metropolitan Bay Area representing these two contexts. The criteria used to identify TAZs that were predominantly composed of these two contexts were from research to develop trip generation rates for infill development in California (1).

The California study used the density of residential units, the density of employees, or the density of both to define the intensity of urban TAZs. The combination of residential and employment densities identified TAZs composed of mixed-use development, and the balance or imbalance of the ratio of jobs to housing indicated the degree to which trip internalization would occur.

The criteria from the California research were used to identify TAZs in the San Francisco Bay Area that met the definition of general urban/urban center (GU/UC)—a range of housing and employee densities from suburban to urban core. To set the upper limit of these two contexts' densities, the lower limit of density in known urban core contexts was used. In the initial example of the San Francisco Bay Area, the known urban cores of San Francisco and Oakland's central business districts were used. Year-2000 census data were used to determine residential density, and MTC's year-2000 employment database (used in travel demand forecasting) was used to determine employment density.

The upper limits of suburban-center densities were used to determine the lower limit of general urban/urban-center context densities. Suburban densities range greatly, so the research team considered an array of criteria for suburban areas but selected the criterion documented in note 6 (see Notes and Citations section) to establish the lower limit of the GU/UC contexts.

These density criteria and a combination of the criteria were used to isolate the Bay Area TAZs that meet individual housing or employee density criteria or both. This resulted in a relatively small number of TAZs when compared to the entire nine-county Bay Area, but the TAZs produced an adequate number of trip records to determine the viability of the extraction process. These zones were the initial pool for a series of steps that incrementally reduced the pool and the eventual size of the sample trip records.

4.7.2 Transit Type, Frequency, and Proximity

Adjustment factors were developed for GU/UC land uses within ½ mile of a rail (or ferry) station and within ¼ mile of a high-frequency bus corridor (defined as a line or combination of bus or bus rapid transit lines with a maximum 15-min headway for 6 or more hours of the day). For the San Francisco Bay Area, GIS was used to map rail and ferry stations and to identify a ½-mile walk buffer around each station. A similar analysis was prepared for high-frequency bus lines (13).

4.7.3 Other Criteria

The remaining two criteria for selecting TAZs that represent the specified type of urban context are "compactness" and "contiguous and continuous urban street system." These two criteria cannot be distilled from the household travel survey method data, and for all practical purposes are qualitative rather than quantitative. The intent of these criteria is to enable the analyst to confirm that the site is located within a walkable area—defined as an area with pedestrian facilities throughout a study area that is compact enough and diverse enough for most daily needs to be met by walking.

4.7.4 Selecting the Geographic Units of Data

The unit of geography used for tabulating HTS data is typically a form of known zonal system. Most HTS databases contain cross-references for multiple zone systems such as census tracts, census block groups, census blocks, public-use microdata areas, and TAZs. Most of the geographic units are too large and relatively unknown to those who prepare traffic impact analyses to be considered for the level of data manipulation needed in the proposed methodology. Therefore, the geographic unit of TAZ was chosen for the following reasons:

- TAZs are often the smallest scale of geographic zones in urban areas, with the exception of census block groups or blocks, providing a reasonable resolution for focusing on trip records meeting transit proximity criteria.
- Trip origins and destinations in the linked-trip database are identified primarily by TAZ.
- Census data, as summarized by MTC in the 2000 BATS, can be aggregated at the TAZ level.
- Existing and future land use and demographic information (for use in travel demand models) are aggregated by TAZ and are useful for developing adjustment factors for future site conditions.

4.7.5 Extracting Mode-Share Adjustment Factors

Extracting the adjustment factors from a linked-trip database involves the following major activities:

- Begin with a linked-trip database of all daily travel in which each record contains a trip that has at least one trip end originating in or destined to a TAZ that meets context criteria.
- Use the activity purpose at trip origins and destinations to extract records with activities that represent the four proposed study land uses (residential, restaurant, retail, and office).
- Identify TAZs within a ½-mile walk buffer of rail/ferry stations or within a ¼-mile walk buffer of bus routes or

Table 4.2. Summary of linked trip records at each level of extraction.

GU/UC Subdivision of Records	Number of Linked Trip Records			
	Residential	Restaurant	Retail	Office
Entire Bay Area	176,083	36,827	67,295	72,275
GU/UC areas	23,763	6,123	9,086	11,154
Weekday (all GU/UC records)	20,983	5,143	7,605	10,755
Weekday – HF bus	20,372	5,044	7,354	10,519
Weekday – rail	12,787	3,303	4,501	7,007
Weekday – HF bus – a.m. peak hour	4,802	442	411	2,800
Weekday – HF bus – a.m. peak hour – inbound	256	379	374	2,751
Inbound percentage	5%	86%	88%	97%
Weekday – HF bus – a.m. peak hour – outbound	4,625	63	53	88
Outbound percentage	95%	14%	12%	3%
Weekday – HF bus – p.m. peak hour	3,975	616	1,318	2,708
Weekday – HF bus – p.m. peak hour – inbound	2,955	455	901	205
Inbound percentage	73%	72%	64%	7%
Weekday – HF bus – p.m. peak hour – outbound	1,100	173	516	2,591
Outbound percentage	27%	28%	36%	93%
Weekday – rail – a.m. peak	2,962	257	260	1,806
Weekday – rail – a.m. peak – inbound	156	215	237	1,774
Inbound percentage	5%	84%	88%	97%
Weekday – rail – a.m. peak – outbound	2,855	42	33	62
Outbound percentage	95%	16%	12%	3%
Weekday – rail – p.m. peak	2,506	394	803	1,793
Weekday – rail – p.m. peak – inbound	1,844	300	557	153
Inbound percentage	72%	74%	65%	8%
Weekday – rail – p.m. peak – outbound	711	105	306	1,710
Outbound percentage	28%	26%	35%	92%

Notes:

Peak hour trips based on trip records, not trip ends; therefore, total peak hour does not equal the sum of inbound and outbound.

HF bus = Proximity to high-frequency (HF) bus route stop (¼-mile walk buffer). Rail = Proximity to rail station (½-mile walk buffer).

corridors that meet transit proximity criteria, and extract records that have at least one trip end within these zones.
- Separate weekday from weekend trip records.
- Extract records in which at least one trip end begins or ends during a defined peak hour of adjacent street traffic (a.m. and p.m.) from the daily set of trip records.
- Using the appropriate variables as a filter, separate the records representing inbound and outbound trips.
- Separate the resulting hourly records for each LUC by primary mode of access.

Starting with a linked-trip database of a finite number of trips, each step in the sequence extracts records and reduces the number of records available for the next step. The analyst needs to review the number of records resulting from the extraction process for each land use category and mode of travel and determine whether the number of records provides a reasonable base from which to calculate relative mode shares. In the development of this process, the research team did not attempt to ensure that the results contained a statistically significant number of records. Table 4.2 summarizes the number of records resulting after each step of the extraction process.

4.7.6 Estimated Mode Share by Land Use

The trip records for each LUC were aggregated by mode to determine mode-share percentages for transit (rail and bus) and walk/bicycle. The values in Table 4.3 are the p.m. peak hour adjustment factors derived for GU/UC contexts in proximity to rail stations and high-frequency bus route stops.

4.7.7 Estimated Vehicle Occupancy Adjustment Factors

In addition to mode share, Table 4.3 presents the vehicle occupancy adjustment factors derived from the 2000 BATS data, for use in converting between infill person trips by automobile and infill vehicle trips.

Table 4.3. Example mode share and vehicle occupancy adjustment factors for the San Francisco Bay Area.

Infill Adjustment Factors for GU/UC Contexts	Within Walking Distance Of:			
	High-Frequency Bus Stop		Rail Station	
	a.m.	p.m.	a.m.	p.m.
Multifamily Residential (ITE LUC 223)				
Transit	20.2%	17.5%	19.3%	16.2%
Walk/bicycle	13.4%	13.3%	13.2%	13.7%
Vehicle occupancy	1.61	1.60	1.58	1.61
General Office (ITE LUC 710)				
Transit	23.6%	22.4%	20.6%	20.6%
Walk/bicycle	8.4%	8.7%	9.1%	9.4%
Vehicle occupancy	1.36	1.27	1.35	1.27
Retail/Shopping Center (ITE LUC 820)				
Transit	12.7%	10.7%	13.1%	11.7%
Walk/bicycle	11.4%	15.3%	12.3%	16.3%
Vehicle occupancy	1.50	1.49	1.55	1.53
Quality (Sit-Down) Restaurant (ITE LUC 932)				
Transit	26.7%	14.3%	25.3%	15.5%
Walk/bicycle	20.8%	16.6%	20.6%	19.8%
Vehicle occupancy	1.37	2.07	1.44	2.13

Source: Mode share and vehicle occupancy adjustment factors were extracted from linked-trip data records developed from the 2000 Bay Area Travel Survey, Metropolitan Transportation Commission.

CHAPTER 5

Confirming the Proposed Approach for Estimating Infill Trip Generation

The research team identified two types of confirmation as evidence of the approach's ability to predict urban infill trip generation and to demonstrate its validity to the transportation profession:

1. **Verification** – A process that focuses on ensuring that the proposed methodology was correctly developed (e.g., the process/equations were correctly translated, the expected variables cancel) and that there are no gross errors or oversights in the theory, the translation of the theory into a procedure, or the implementation of the procedure. The research team is confident that this form of estimating infill trip generation is easily verified, although aspects of the proposed method may require further research.
2. **Validation** – The act of demonstrating, at a reasonable level of confidence, that the methodologies' predictions are able to repeatedly match empirical data—in this case, vehicle traffic generation of infill development. Validation requires a substantial amount of empirical data, representing a wide range of contexts, to show statistical significance. Ample empirical data help to smooth out the peaks and valleys typically found in small datasets, as well as help to isolate anomalies and outliers in the data. One of the challenges for this research study was a lack of resources to collect data in sufficient amounts to validate the methodology. Validation of the proposed methodology will take time as members of the transportation profession contribute data from their own research or as a result of their work on development projects.

Validation procedures take into consideration the following:

- **Selecting and surveying sites for validation.** This step involves the selection of one or more existing developments for which the estimation method will be tested. For validation, data need to be collected at a minimum of five sites. Data for the selected validation sites will have either already been collected or will be collected once selected. While difficult to find in more urban contexts (urban center and urban core), the ideal site for validation has self-contained and exclusive parking for users of the site and is designed so that all of the traffic generated by the site can be counted automatically. If this is not possible, manual data collection is sufficient. It is essential to obtain accurate data regarding the site's occupied units of development (e.g., dwelling units, gross floor area, and gross leasable floor area) and other relevant information representing the time the count data are collected. The person planning and implementing the data collection should be familiar with ITE's procedures for conducting local trip generation studies (4, 14).
- **Assemble data needed to validate method.** The minimum data to validate a site are (a) the number of vehicle trips generated by the site during a 2- or 3-hour period typically encompassing the peak hour (15), (b) the development units representing the independent variable used to estimate vehicle trips and the vacancy rate of development units, (c) the land use and transportation characteristics used to describe context in which the site is located, and (d) the data needed to apply the methods outlined in Chapter 4 (baseline and infill mode share and vehicle occupancy).
- **Estimate infill vehicular trip generation.** Use the desired method from Chapter 4 (proxy site method or household travel survey method) to predict the site's vehicular trip generation.
- **Evaluate the method's performance.** Compare predicted to actual trip generation data for each validation sample or compare to the average of the data collected from multiple validation sites, apply applicable statistical tests to assess accuracy of validation results, assess the validity of the method for the subject under study, and identify any needs for adjustments or additional data in the proposed method.

5.1 Selecting a Method for Verification

Any of the context classifications presented in this report, if also meeting transit proximity criteria, can have development that qualifies as infill. Therefore, the approach and the methods of applying the approach presented in this report needed to be applicable across a spectrum of contexts. Testing and verification of the approach focused on (a) the household travel survey method of deriving adjustment factors, and (b) contexts that span the GU/UC classifications, for the following reasons:

- Extracting the adjustment factors from HTS data in the household travel survey method is the most complex of the methods, and the verification process was an opportunity for the research team to derive adjustment factors from a second source of HTS linked-trip data.
- GU/UC contexts (commonly called midtown or downtown fringe) make up a large portion of urbanized metropolitan areas—areas significantly larger than urban core contexts—and, therefore, GU/UC contexts are applicable to a greater number of potential validation sites.
- GU/UC areas represent the middle of the range of infill area types (from urban core to suburban center), but the criteria for identifying GU/UC areas spans a broad spectrum, eliminating the potential hindrance of a limited source of validation sites using a single narrowly defined context.
- Given the limited resources for the verification step, the research team selected to maximize the number of sites in a combined context zone rather than spread the limited resources over all of the context zones.

Although the testing of the household travel survey method was limited to general urban and urban-center contexts, the method is applicable to the extremes ranging from suburban center to urban core. The research team anticipates that use by the transportation profession of the methods presented in this report will help identify ways of improving the methods and produce data for future verification and validation of the methods for the full range of contexts.

5.2 Verifying the Travel Survey Method: A Case Study from Metropolitan Washington, D.C.

The research team evaluated five metropolitan areas that had current HTSs for use in verifying the travel survey method. The team selected the Washington, D.C., metropolitan area, whose metropolitan planning organization (MPO)—the Metropolitan Washington Council of Governments (MWCOG)—is the source for the HTS data. The Washington, D.C., HTS surveyed 11,000 households and contains a database of approximately 88,000 linked trips.

A principal reason for selecting the Washington, D.C., HTS was the recency of its survey, which was completed in 2008. This is an important consideration given that the verification process relies on 2011 traffic count data (counted in conjunction with this research study). Survey data substantially older than the counts would make it difficult to reconcile differences between the predicted and actual trip generation of the sites.

5.3 Application of the Method and Results of the Verification

Data were collected at a limited number of sites for testing the reasonableness of the method's results, for verifying the method's procedures and computations, and to serve as a catalyst for continued data collection for future validation.

Verifying the method included a reasonableness review of the procedures and results of the method based on sound engineering practice and the experience of the research team. Although this form of verification does not yield a definitive answer, the results support the research team's confidence that the procedures and data used in the method will produce consistent, logical, and reasonably accurate results that professional peers and users of the method will find credible.

5.3.1 Expected Results of the Case Study Analysis

The research team reviewed much of the literature on the travel characteristics of urban infill development and has itself conducted focused research on the theorem that development in urban contexts generate less traffic than the same development in suburban contexts. While the principal investigator and the members of the research team, in their professional judgment and their personal opinions, have confidence that the theorem is correct, they seek empirical data that can be linked statistically to their model and require validation through consistent and reproducible predictions. Following are the research team's two most prominent theoretical expectations from the case study:

- Land uses in urban contexts qualifying as infill, in proximity to rail or high-frequency bus transit, demonstrate measurably lower vehicular trip generation than an equal type and size of development in suburban contexts or urban contexts that do not qualify as infill.
- Trip estimates derived from land uses in suburban contexts will be consistent with the land uses' trip generation using baseline rates or regression equations published in the ITE *Trip Generation Manual.*

Case study sites were identified using the guidelines presented in Chapter 4, and data were collected consistent with the procedures for deriving the adjustment factors using the minimum data collection variant. Data collected at the case study sites included:

- Vehicle counts at driveways of parking facilities exclusive to the site,
- Vehicle occupancy,
- Person trips entering and exiting the site's building,
- Observation of mode of access, and
- General observation of site conditions and surrounding context.

With empirical data available, the research team was able to compare predicted and surveyed results of the household travel survey method. A secondary objective of the data collection was to refine the data collection protocol for the proxy site method.

5.3.2 Summary of Findings

The following sections contain brief overviews of the results of applying the household travel survey method to the four land use categories used to develop the example adjustment factors from the HTS data presented in Chapter 4.

5.4 Derived Adjustment Factors

Table 5.1 presents the methodology-derived adjustment factors (mode share and vehicle occupancy) for the GU/UC context zones by land use category and proximity to transit. The research team reviewed these findings for reasonableness. The MWCOG has not published a report summarizing the findings of their HTS, so the research team could not compare its findings on mode share and vehicle occupancy with mode-share cross-references to land use, trip purpose, or context prepared by MWCOG.

Table 5.1. Mode share and vehicle occupancy adjustment factors for Washington, D.C.

Infill Adjustment Factors for GU/UC Contexts	Within Walking Distance Of:			
	High-Frequency Bus Stop		Rail Station	
	a.m.	p.m.	a.m.	p.m.
Residential Case Study Sites (ITE LUC 220)				
Transit	27.3%	24.0%	32.5%	27.7%
Walk/bicycle	11.3%	13.4%	12.9%	15.8%
Vehicle occupancy	1.27	1.32	1.30	1.34
General Office Case Study Sites (ITE LUC 710)				
Transit	33.4%	31.0%	38.8%	35.6%
Walk/bicycle	9.8%	10.4%	11.9%	12.5%
Vehicle occupancy	1.13	1.16	1.15	1.17
Retail/Shopping Center Case Study Sites (ITE LUC 820)				
Transit	15.4%	13.5%	19.7%	16.5%
Walk/bicycle	29.6%	19.0%	35.4%	22.8%
Vehicle occupancy	1.20	1.36	1.16	1.36
Restaurant Case Study Sites (ITE LUC 932)				
Transit	10.4%	13.8%	12.2%	16.1%
Walk/bicycle	29.9%	17.6%	38.8%	22.4%
Vehicle occupancy	1.36	1.71	1.35	1.69

Source:
Mode share and vehicle occupancy adjustment factors were extracted from linked trip data records developed from the 2004 MWCOG HTS.

5.4.1 Residential Land Use Category

The results in Table 5.2 show that the method results in substantially higher peak hour trip generation at the three residential infill case study sites when compared to the actual trips. The results range from a factor of two to as high as nearly three and a half times the actual trips. The research team expected that the method would overpredict or underpredict, but did not expect the large differences shown in Table 5.2.

The three residential test sites generate low volumes of traffic, so the percentage difference between the predicted and actual trips can be misleadingly large. For example, the Columbia Uptown residential test site was determined to generate 13 vehicle trips in the a.m. peak hour, while the method predicts the a.m. peak hour to be 25 trips. The absolute difference of 12 trips remains a small number, but the percentage difference of 92% appears large.

The research team considered that magnitude of the difference between predicted and actual vehicle trips might be an anomaly or magnification of error related to the small number of actual trips. But because all of the residential sites had low actual vehicle trips, the research team was unable to confirm a magnification of error.

When compared to trips estimated using ITE trip generation rates, the method predicts about one-third to one-half fewer trips at all three study sites, as the research team expected. The difference between the predicted and ITE trip

Table 5.2. Comparison of actual versus predicted peak hour vehicle-trip generation (residential sites).

Residential Sites	Columbia Uptown		The Lencshire House		The Beauregard		Average of Residential Sites	
	90 DUs		125 DUs		45 DUs		87 DUs	
	a.m.	p.m.	a.m.	p.m.	a.m.	p.m.	a.m.	p.m.
Predicted vehicle trips	25	30	39	47	10	12	25	30
Actual vehicle trips	13	12	19	14	7	6	13	11
Vehicle trips based on ITE avg. rates	40	47	55	65	20	23	38	45
Percent diff. (predicted vs. actual)	92%	150%	105%	236%	43%	100%	90%	178%
Percent diff. (Predicted vs. ITE)	-38%	-36%	-29%	-28%	-50%	-48%	-36%	-34%

Note: DUs = dwelling units.

generation estimates appeared reasonable to the research team and, in fact, is similar to the findings from other research (2). The research team concludes that the difference between predicted and actual vehicle-trip generation is great enough for the investigators to find the results inconclusive without data from additional sites.

5.4.2 Office Land Use Category

The results of the comparison of the office case study sites are shown in Table 5.3. Similar to the residential sites, applying the methodology to the office sites results in a relatively consistent infill automobile mode share in the site's respective TAZs (see Table 5.1). The method consistently overpredicts both a.m. and p.m. peak hour vehicle-trip generation when compared to the actual trips. Although the overprediction of the office sites is not as great as shown for the residential sites, application of the method results in predictions greater than 60% over actual trips.

Also similar to the residential case study sites, the methodology predicts peak hour trip generation at about one-half of the trips estimated using ITE rates. As with the residential sites, the research team concludes that the difference between actual and predicted trip generation varies enough to find the results inconclusive without data from additional office sites.

Despite the inconclusiveness of the method's predictions when compared to surveys, it is clear that the selected sites (all close to rail stations), if analyzed using ITE trip generation rates, would result in overestimation.

However, in all cases the method's estimates are much closer to what was observed in the field than to what was estimated using ITE rates. The comparison of the office site's actual trip generation with ITE trip generation estimates triggered further investigation. The research team expected that trip estimates for office buildings in GU/UC contexts would be lower than those in suburban contexts (the context presumed to be represented by ITE trip generation rates), but not to the extent observed in Table 5.3.

Table 5.3. Comparison of actual versus predicted peak hour vehicle-trip generation (office sites).

Office Sites	1920 N Street NW		1616 N Fort Myer Drive		1200 Wilson Boulevard		Average of Office Sites	
	114 KSF		303 KSF		146 KSF		188 KSF	
	a.m.	p.m.	a.m.	p.m.	a.m.	p.m.	a.m.	p.m.
Predicted vehicle trips	85	84	222	222	107	107	138	138
Actual vehicle trips	43	51	134	134	65	67	81	84
Vehicle trips based on ITE avg. rates	177	170	470	452	226	218	291	280
Percent diff. (predicted vs. actual)	98%	65%	66%	66%	65%	60%	71%	64%
Percent diff. (predicted vs. ITE)	-52%	-51%	-53%	-51%	-53%	-51%	-53%	-51%

Note: KSF = thousand square feet.

Table 5.4. Comparison of actual versus predicted peak hour vehicle-trip generation (retail sites).

Retail Sites	1315 N. Rhode Island Ave. NE		819 H Street NE		Average of Retail Sites	
	36 KSF		37 KSF		37 KSF	
	a.m.	p.m.	a.m.	p.m.	a.m.	p.m.
Predicted vehicle trips	21	81	21	84	21	83
Actual vehicle trips	43	73	164	198	104	136
Vehicle trips based on ITE equation	84	212	86	217	85	215
Percent difference (predicted vs. actual)	-51%	11%	-87%	-58%	-80%	-39%
Percent diff. (predicted vs. ITE)	-75%	-62%	-76%	-61%	-75%	-62%

5.4.3 Retail and Restaurant Land Use Categories

Table 5.4 and Table 5.5 compare predicted with actual peak hour vehicle trips for the retail and restaurant land use categories, respectively. The application of the method to the two retail sites resulted in an outcome that was different from the outcome observed for office sites. The investigators expected the method to overpredict compared to actual vehicle trips, and expected the predicted trips to be substantially lower than trips estimated using ITE rates.

The expected pattern for predicted versus actual did not occur, and instead the results shown in Table 5.4 are quite variable. The predicted trips for one of the case study sites are relatively close in the p.m. peak hour (a difference of 11%), while the a.m. peak hour is predicted about 51% lower than actual. At the second site, the predicted trips are 58% to 87% lower than the actual trips.

The comparison of predicted to estimated trips using ITE data shows that the method produces consistently lower trip estimates, ranging from two-thirds to three-quarters of the ITE estimates—a finding the researchers did not expect.

The unexpected comparison between predicted and actual trips spurred further investigation of the data. The research team found a potential reason for the unusually large underestimation at the 819 H Street site: the mix of retail establishments in the actual shopping center—in particular, a fast food restaurant, a pharmacy, dry cleaners, and a convenience store, which are all high traffic-generating uses by themselves (and high morning traffic generators). These uses, typically, do not experience much internalization of trips between them, and the combination of high-generating uses and little internal capture of trips will result in a high vehicle-trip generation.

In summary, the research team finds the comparison of the retail sites inconclusive because of the small sample size, the high variability between predicted and actual trips, and the variability when compared to ITE methods of estimating trip generation. In retrospect, the research team believes the criteria for selecting retail case study sites should be more restrictive on the type and compatibility of uses within multi-use shopping centers. Future verification of the method could include trip generation estimates of individual land uses, as well as estimating trips for shopping as a single use. Only one restau-

Table 5.5. Comparison of actual versus predicted peak hour vehicle-trip generation (restaurant site).

Restaurant Site	1333 Rhode Island Avenue NE	
	2.4 KSF	2.4 KSF
	a.m. Peak Hour	p.m. Peak Hour
Predicted vehicle trips	24	19
Actual vehicle trips	9	8
Vehicle trips based on ITE avg. rates	28	27
Percent diff. (predicted vs. actual)	167%	138%
Percent diff. (predicted vs. ITE)	-14%	-30%

rant site was included in the data collection site, and this fact alone makes any findings inconclusive. However, the research team wanted to see if the method resulted in the same pattern of overpredicting surveys and estimating substantially lower trips that ITE data produces, such as seen with residential and office uses, or if the method would produce inconsistent and widely variable findings like those observed in the retail sites. The data in Table 5.5 show that the single-restaurant data follow the same pattern as the residential and office data—the method overpredicting trips compared to surveys and having substantially lower trip estimates compared to average ITE trip generation rates.

5.5 Application of the Approach Using Data from the San Francisco Bay Area Household Travel Survey

The research team conducted a second verification analysis using the adjustment factors extracted from the 2000 Bay Area travel survey during the development of the household travel survey method and surveyed trip generation data for several sites in the San Francisco Bay Area collected as part of a previous infill trip generation study (16). Table 5.6 presents the mode share and vehicle occupancy adjustment factors subdivided by proximity to rail and high-frequency bus transit and representing the context of GU/UC in the San Francisco Bay Area. The factors in Table 5.6 are a slightly modified version of the factors presented in Chapter 4 (Table 4.3). An additional LUC has been added to provide data for an LUC of coffee shop or bagel/donut shop.

In contrast to the minimum data collection variant used for collecting data at the Washington, D.C., study sites, the San Francisco Bay Area study sites were selected as part of the California urban infill trip generation study (1) that used the approach of direct estimation of trip generation based on empirical data. The objective of the California study was to develop trip generation rates for each of the land use categories being studied. The data collection methodology used the techniques listed under the comprehensive data collection variant, which include cordon counts of person trips, automobile counts at driveways, and randomly sampling intercept surveys to obtain mode share and other information. Vehicle occupancy data were not collected as part of the California study.

Seven of the California study sites (which are all located in the San Francisco Bay Area) were selected for this verification analysis. The seven sites were one multifamily residential apartment building, one general office building, retail (in the form of one copy shop and one florist on the ground floors of mixed-use buildings), one quality (sit-down) restaurant, one local coffee shop, and one bagel shop.

Table 5.6. Mode share and vehicle occupancy adjustment factors for the San Francisco Bay Area.[1]

Infill Adjustment Factors for GU/UC Contexts	Within Walking Distance Of:			
	High-Frequency Bus Stop		Rail Station	
	a.m.	p.m.	a.m.	p.m.
Multifamily Residential (ITE LUC 223)				
Transit	20.2%	17.5%	19.3%	16.2%
Walk/bicycle	13.4%	13.3%	13.2%	13.7%
Vehicle occupancy	1.61	1.60	1.58	1.61
General Office (ITE LUC 710)				
Transit	23.6%	22.4%	20.6%	20.6%
Walk/bicycle	8.4%	8.7%	9.1%	9.4%
Vehicle occupancy	1.36	1.27	1.35	1.27
Retail/Shopping Center (ITE LUC 820)				
Transit	12.7%	10.7%	13.1%	11.7%
Walk/bicycle	11.4%	15.3%	12.3%	16.3%
Vehicle occupancy	1.50	1.49	1.55	1.53
Quality (Sit-Down) Restaurant (ITE LUC 932)				
Transit	26.7%	14.3%	25.3%	15.5%
Walk/bicycle	20.8%	16.6%	20.6%	19.8%
Vehicle occupancy	1.37	2.07	1.44	2.13
Coffee Shop and Bagel/Donut Shop (ITE LUC's 936 and 939)[2]				
Transit	23.6%	22.4%	20.6%	20.6%
Walk/bicycle	8.4%	8.7%	9.1%	9.4%
Vehicle occupancy	1.36	1.27	1.35	1.27

[1] Mode share and vehicle occupancy adjustment factors were extracted from linked trip data records developed from the 2000 Bay Area travel survey, Metropolitan Transportation Commission.
[2] Coffee shop and bagel/donut shop land use categories are too specific to extract mode share and vehicle occupancy factors from the travel survey data. Therefore, general office factors were used as representative of the primary trip purpose of people who use these categories.

5.5.1 Findings and Overall Conclusions of the Analysis

Table 5.7 presents the results of the trip generation analysis. The table is organized with the three right-most pairs of columns showing the predicted infill vehicle trips, the actual infill vehicle trips, and trips estimated using baseline ITE trip generation rates. The rows following the trip comparison present the percentage difference between the predicted and actual trips and between the predicted and ITE estimated trips.

Unlike the Washington, D.C., verification analysis, there is no discernible pattern of predicted trips overestimated when compared to actual trips and underestimated when compared

Table 5.7. Comparison of actual versus predicted peak hour infill vehicle-trip generation.

Site/Location	ITE (LUC)	Size	Units	Context	Predicted Infill Vehicle Trips a.m.	Predicted Infill Vehicle Trips p.m.	Actual Infill Vehicle Trips a.m.	Actual Infill Vehicle Trips p.m.	ITE Rate/Equation Estimate[1] Infill Vehicle Trips a.m.	ITE Rate/Equation Estimate[1] Infill Vehicle Trips p.m.
Multifamily residential	LUC 223	99	DUs	Urban center	16	20	4	28	30	39
2116 Allston Way, Berkeley, CA	Percentage diff. (predicted vs. actual)								304%	-28%
	Percentage diff. (predicted vs. ITE rate based)								-47%	-49%
General office building	LUC 710	120.000	KSF	Urban center	106	110	145	110	186	179
388 Sutter Street, San Francisco, CA	Percentage diff. (predicted vs. actual)								-27%	0%
	Percentage diff. (predicted vs. ITE rate based)								-43%	-39%
Retail (copy center)	LUC 820	3.000	KSF	Urban center	2	5	n/a	12	3	7
2111 University Avenue, Berkeley, CA	Percentage diff. (predicted vs. actual)								n/a	-58%
	Percentage Diff. (Predicted vs. ITE Rate Based)								-33%	-29%
Retail (florist)	LUC 820	2.400	KSF	Urban center	2	4	2	7	2	6
2004 University Avenue, Berkeley, CA	Percentage diff. (predicted vs. actual)								-2%	-43%
	Percentage diff. (predicted vs. ITE rate based)								0%	-33%
Quality (sit-down) restaurant[2]	LUC 932	3.000	KSF	Urban center	11	7	14	13	17	12
337 3rd Street, San Francisco, CA	Percentage diff. (predicted vs. actual)								-20%	-44%
	Percentage diff. (predicted vs. ITE rate based)								-34%	-42%
Coffee shop[3]	LUC 936	4.500	KSF	Urban center	309	115	81	35	528	183
1910 Oxford Street, Berkeley, CA	Percentage diff. (predicted vs. actual)								284%	226%
	Percentage diff. (predicted vs. ITE rate based)								-41%	-37%
Bagel/donut shop[3]	LUC 939	5.000	KSF	Urban center	206	88	18	42	351	140
1370 University Avenue, Berkeley, CA	Percentage diff. (predicted vs. actual)								1044%	108%
	Percentage diff. (predicted vs. ITE rate based)								-41%	-37%

Notes: [1] Retail, quality restaurant, coffee shop, and bagel/donut shop trips estimated using ITE rates or equations are new trips and exclude pass-by trips.
[2] Quality restaurant: a.m. peak represents the morning peak hour of the generator, and not the peak of the adjacent street traffic.
[3] Analysis uses general office adjustment factors based on an assumption that coffee shop and bagel/donut customer trips are composed predominantly of work trip purposes.

to ITE trip estimates. The surveys of many of the sites produced low traffic volumes, potentially introducing an exaggerated percentage difference based on a small number of trips.

The method consistently results in a lower number of trips, by one-third to one-half of trips estimated using ITE rates, similar to the findings of the Washington, D.C., analysis for residential and office land uses.

In general, the method consistently predicts closer to the actual number of trips in the San Francisco Bay Area analysis than in the Washington, D.C., analysis.

As a reasonableness check, the research team again compared the percentage difference between predicted and ITE estimates of the residential site with other published sources (17). This study and other research support a similar conclusion that, at least for residential uses, the use of ITE rates in estimating infill trip generation results in an overestimation of one-third to one-half. The research team anticipates that with more site data, the method presented in this report will produce results similar to those in other studies of infill development or TOD that are based on empirical data.

CHAPTER 6

Conclusions and Recommendations

The research team concludes that the fundamental approach of adjusting baseline ITE trip generation data with factors derived from empirical data, or with factors extracted from HTSs, is logical and intuitive to users and can be a useful tool for estimating trip generation in traffic impact analyses of urban infill development. This conclusion is despite the fact that there were insufficient study sites to validate the proposed methodology or draw definitive conclusions on the accuracy of the method's estimates of infill trip generation.

6.1 Principal Conclusion

Based on the review of the data and analyses summarized in Chapters 4 and 5, the research team draws the following conclusion:

> Basing the approach on the collection of empirical data, as well as an alternate method to extract data from travel surveys, the proposed methodology meets the research objective.

In Chapter 1, the research objective was stated as:

> Develop an easily applied methodology to estimate automobile trip generation and mode share of non-vehicular trips that can be used in the preparation of site-specific transportation impact analyses of infill development projects located within existing higher-density built-up areas.

The research team believes this objective has been met based on the following four reasons:

(1) The method has compatibility with existing traffic impact analysis methods (i.e., ability to estimate peak hour, directional-dependent variables).

The method recommended in this report directly modifies the data most commonly used (and frequently required by agencies) in preparing traffic impact studies—ITE trip generation rates. As an adjustment factor to one variable in the process, derived using common techniques familiar to the transportation professional, the method does not materially alter the established procedures for preparing impact studies.

(2) The method applies to the land uses in the ITE *Trip Generation Manual* and has few, if any, restrictions on land use categories and geography.

The proxy method uses an adjustment factor applied to baseline ITE trip generation data and, therefore, may be used with any of the land use categories in the ITE *Trip Generation Manual* as long as the user has or collects the required data from a site or sites with the same land use and other similar characteristics. The use of the household travel survey method for deriving adjustment factors, however, is restricted to metropolitan areas that have current travel surveys and limits land use categories to general common categories such as residential, school, office, retail, and restaurant.

(3) Input data needed to apply the method are readily available, or the ease and cost of collecting and applying the data are reasonable.

Practitioners who regularly prepare traffic impact studies are familiar with collecting the type of data required under the minimum data collection and comprehensive data collection variants. Once the data have been acquired, application of the data uses a simple and transparent process. The household travel survey method requires having or learning specialized skills in database manipulation, and because the structure of travel surveys varies widely from region to region, extracting data from a survey in a specific universal procedure cannot be prescribed.

(4) The method would likely be accepted by members of the transportation planning and traffic engineering profession who prepare and review site traffic impact analyses.

The research team is confident the recommended method will be accepted by the profession due to the following reasons:

- The overall approach and methodological variations for obtaining data are compatible with the current practice of preparing impact studies and do not require a significant shift in paradigm to use.
- The method is simple in its structure, transparent in its computations, and intuitive to the user familiar with preparing impact studies.
- The method is easy to document and justify in a traffic impact study, and is simple to describe to laypeople and decision makers.

6.2 Additional Conclusions

The sample of case studies is too small to be conclusive. The ITE *Trip Generation Manual's* User's Guide and Handbook recommends collecting data from at least five sites for each LUC to test the validity of local trip generation rates. A sample size of five sites per LUC per context would require 60 or more to perform a complete verification and validation analysis (i.e., 5 validation sites X 4 land use categories X 3 context categories). In this research study, 14 sites were studied for four LUCs.

Additional data collection may have achieved the minimum sample size recommended by ITE if the case study sites had been located in more consistent contexts. However, because of contextual inconsistencies, none of the four LUCs have a sample size sufficient for the investigators to conclude that the proposed estimation method is either valid or invalid.

The analysis of case study sites lacked sufficient empirical vehicle occupancy data. The testing and verification of the method assumed values for baseline vehicle occupancies in the computation to convert ITE trip rates to person-trip rates. For some infill sites, vehicle occupancy data were either not collected or were collected informally. The results, therefore, lacked sufficient empirical data on vehicle occupancy representing the ITE baseline data due to limited resources to conduct comprehensive surveys, so that Step 4, converting infill person-vehicle trips to infill vehicle trips (18), had to rely on assumed vehicle occupancies (from the ITE *Trip Generation Manual* and other sources) for most of the sites. The use of ITE published vehicle occupancies, while acceptable in a validated estimation model, adds uncertainty to the results of these initial tests.

Small sample size cannot show the distribution of data or meaningful calculation of statistical measures. The data in the ITE *Trip Generation Manual* typically show a scatter of data points above and below the actual trip generation value. Larger sample sizes allow for the calculation of the mean and standard deviation of the samples, as well as for checking for anomalies and abnormal distribution patterns. The data collected for the 14 case study sites are anticipated to show similar scatter from a known mean rate, but not with the limited data points that exist. With a robust database of case study sites, the method can be compared with other known data patterns, and more definitive conclusions can be drawn.

Determining consistency in context and land use characteristics for selected case study sites is a critical task in validating the method. Case study sites need to be carefully selected so as to be as consistent as possible in context and be similar in some other development characteristics to suburban examples representative of ITE data. Inconsistency in context or the specific characteristics of an individual LUC can greatly affect the outcome of the validation tests. This is largely a qualitative assessment that is difficult to conduct remotely and should be conducted by an experienced transportation professional in the field.

6.3 Future Research

The following are the research team's primary recommendations for future research, as well as several secondary recommendations, developed during the verification process.

The primary recommendation of the research team is to focus future research on validating one LUC in one urban context in one metropolitan area. This will produce a more definitive conclusion on whether the method can be validated for a given use, while minimizing the required resources. Future research efforts could include validation of both the proxy site and the household travel survey methods concurrently, and then compare the results. Based on the quantity and quality of data collected to date, the research team recommends starting with the residential LUC, in a GU/UC context, within the Washington, D.C., metropolitan area. Validation and proxy site data collection can add to the data already collected in this study. In validating the household travel survey method, future researchers may choose to use the mode share and average vehicle occupancy data that were extracted and summarized in this study, or could begin anew and extract the data independent of this study (with consistent use of criteria defining context) allowing for a comparison of extraction methods and resulting adjustment factors.

Future validation of single land use categories with single contexts could include a minimum of five sites (and preferably up to 30) for the selected LUC and the selected context. The minimum travel and site-related data suggested for future validation of the methodology are:

- Full-cordon person-trip counts by mode entering site building(s), or at least a cordon count of persons using automobile and persons using non-automobile modes of travel.

- Vehicle occupancy of at least 25% to 50% of the automobiles accessing the site during the survey period (collection of enough vehicle occupancy data to ensure adequate data are available for each hour of the survey period).
- Collection of mode share and vehicle occupancy data for sites representing baseline ITE trip data within the same metropolitan region as the infill data collection described previously.
- The percentage of occupied development units (e.g., floor area, dwelling units) at the time of the surveys for both the infill and baseline ITE validation sites.

The following secondary research recommendations are related to further developing the data and analysis included within this study:

- Expand upon the work performed in this research study to develop mode share and vehicle occupancy adjustment factors for suburban contexts of the Washington, D.C., and San Francisco Bay Area HTSs to be used as initial default factors for converting baseline ITE trip generation estimates to person-trip estimates.
- Compare the Washington, D.C., residential and office mode-share data to 2010 census journey-to-work data for the census blocks in which the study sites are located. Assess whether the census data can also be used (with sufficient accuracy) for other work-related site trip generation estimates and which ITE land use classifications could be covered. With knowledge of the proportion of commute trips within the peak hours, the comparison could be normalized and could provide a quantitative check on the household travel survey method's predictive capability.
- Validation of the household travel survey method may be done using the same validation sites to compare the effect of adjustment factors derived with and without the use of the HTS expansion and weighting factors. This requires applying the expansion and weighting factors to the subset of data extracted for a specific context (before any further extraction of data for land use, time of day, mode of travel, etc.) and deriving mode share and vehicle occupancy from the expanded and weighted data as well as the non-expanded and non-weighted data. Using the same validation sites, the predicted versus actual results between the adjustment factors from the expanded/weighted data and the non-expanded/non-weighted data are compared. If shown to affect the results of the validation significantly in either direction, a validation process comparing the effects of weighting and expansion may be implemented in parallel until enough sites have been analyzed to determine if expanding and weighting the travel survey data have a significant effect on the method's accuracy, either positively or negatively.
- Review and compare data on person trips per household in various contexts from Washington, D.C., and other HTS data from metropolitan areas throughout the United States to determine a relationship between person trips and context. A preliminary statistical assessment using the San Francisco 2000 BATS data may be used as an example of one method of determining this relationship (19).

Notes and Citations

1. Kimley-Horn and Associates, Inc. *Trip-Generation Rates for Urban Infill Land Uses in California, Phase 2: Data Collection, Final Report.* California Department of Transportation. June 2009.
2. Arrington, G. and Cervero, R. *TCRP Report 128: Effects of TOD on Housing, Parking, and Travel.* Transportation Research Board of the National Academies, Washington, D.C., 2008. This research study collected vehicle trip data at 18 residential TODs in major metropolitan areas of the United States, including five residential apartment developments in the Washington, D.C., area. Based on daily trip generation, the research study presented a comparison between empirical data and estimates using baseline ITE trip generation rates. The unweighted average percent difference between actual and ITE rate data was about 47%, with a range of 30% to 92%.
3. Institute of Transportation Engineers. *Trip Generation Manual,* 9th Edition, Volume 1: User's Guide and Handbook. Institute of Transportation Engineers. Washington, D.C., 2012.
4. Bochner, B., Chair, Subcommittee on Chapter 11, Trip Generation for Urban Infill/Redevelopment, for the third edition update to the *Trip Generation Handbook.* Institute of Transportation Engineers, Washington, D.C., 2012.
5. Institute of Transportation Engineers. *Trip Generation Handbook: An ITE Recommended Practice.* 2nd Edition. Washington, D.C.: ITE, 2008.
6. TRICS is a comprehensive database considered the national standard for trip generation data and analysis methods in the United Kingdom and Ireland. It is used in their transport assessment process—a process similar to traffic impact analyses in the United States. The database is composed of studies of individual land use sites, similar to ITE's *Trip Generation Manual,* but provides extensive details on the physical, travel, and contextual characteristics of each site. TRICS uses an interactive database allowing users to add data, view data for sites, and combine site data in order to conduct impact analyses.
7. Fehr & Peers Associates, Inc. *Trip Generation for Smart Growth,* San Diego Association of Governments, 2010.
8. Clifton, K. J., Currans, K. M., and Muhs, C. D. *Contextual Influences on Trip Generation.* Portland, OR; Oregon Transportation Research and Education Consortium Research Report (OTREC-RR-12-13), November 2012.
9. Shafizadeh, K., Schneider, R., and Handy, S. *Methodology for Adjusting ITE Trip Generation Estimates for Smart Growth Projects, Outline for Submission to ITE.* California State University, Sacramento, Department of Civil Engineering, University of California, Davis, Institute for Transportation Studies, University of California, Davis, Department of Environmental Science and Policy. August 31, 2012. Handy, S., Shafizadeh, K., and Schneider, R. *California Smart-Growth Trip Generation Rates Study,* University of California, Davis for the California Department of Transportation, Draft, February 2013, pp. 1, 7–9, Appendix F.
10. The research team assessed data from the 2000 San Francisco Bay Area Travel Survey (Regional Travel Characteristics Report, Volume I, Metropolitan Transportation Commission, August 2004) comparing person trips per household by context type (see Table 3.12.1C, 2000 Regional Weekday Trips per Household by Population Density Category). Five context types were defined by population density and categorized as urban core, urban, suburban, rural-suburban, and rural. The research team conducted a statistical analysis on the person-trip values and found the variation (all values, except one, fell within one standard deviation of the mean, while one fell within two standard deviations of the mean) to be statistically insignificant.
11. Daisa, James M., et al. *Designing Walkable Urban Thoroughfares: A Context Sensitive Approach* (An ITE Recommended Practice). Institute of Transportation Engineers, Washington, D.C., 2010.
12. For purposes of qualifying a context for infill development, it must be served by rail transit or high-frequency bus transit.
    (a) High-frequency bus transit is defined as service with a maximum headway of 15 min for a minimum of 6 hours/day. This includes services commonly referred to as "rapid transit" and "bus rapid transit." A corridor served by multiple bus lines that serve the same corridor origins and destinations can meet the high-frequency definition if the collective headways of the lines equal a maximum of 15 min.
    (b) Rail transit is defined as a network of rail lines providing passengers access to a greater geographic coverage of the region and the city being studied than a single line. Transfers from one line to another may be necessary, but transfers occur at stations requiring minimal deviation. Rail transit may also be defined as a single rail line serving one corridor. This type of rail service is typically termed "commuter rail," and it connects a city center with multiple suburban centers. Lines typically have one or two stops in each city being served. Systems generally attract more riders than lines do.
13. The MTC provides GIS files that include a layer file containing geocoded bus stops and an attribute file with information (including

headways) for each route serving the stop. The bus route data were from the year 2000, consistent with the 2000 BATS data.

14. Institute of Transportation Engineers. *Transportation Impact Analyses for Site Development: An ITE Recommended Practice.* Chapter 5: Site Traffic Generation. Washington, D.C., 2010.
15. Development sites containing the same land uses and located in very similar contexts can have different peak hours of trip generation. Data collection for the purposes of validation needs to extend for a 2-hour period, or preferably a 3-hour period, during the traditional morning and afternoon commute peaks at both the validation site and the proxy site (if using the proxy site method). In this manner, a site with early peaking characteristics can be matched with a site having late peaking characteristics.
16. Association of Bay Area Governments, Kimley-Horn and Associates, Inc., and Economic & Planning Systems. *Trip-Generation Rates for Urban Infill Land Uses in California: Phase 1: Data Collection Methodology and Pilot Application – Final Report.* Sacramento, California: California Department of Transportation, 2008, and Kimley-Horn and Associates, Inc. *Trip-Generation Rates for Urban Infill Land Uses in California, Phase 2: Data Collection, Final Report.* Sacramento, California: California Department of Transportation, June 2009.
17. Arrington, G. and Cervero, R. *TCRP Report 128: Effects of TOD on Housing, Parking, and Travel,* Transportation Research Board of the National Academies, Washington, D.C., 2008.
18. Step 4, converting infill person auto trips to infill vehicle trips using Equation #3: $\text{Vehicle-Trips}_{\text{INFILL}} = \text{Person-Vehicle-Trips}_{\text{INFILL}} / \text{VehOcc}_{\text{INFILL}}$ = Persons per vehicle based on local data (or default value). See Draft Report: NCHRP Project 8-66, Trip Generation Rates for Transportation Impact Analyses of Infill Developments, Draft Revised Phase 1 Methodology, July 15, 2010.
19. As described in endnote 10, the research team determined the variation in person trips between different contexts statistically insignificant. The team based this conclusion on data from the 2000 San Francisco Bay Area Travel Survey (Regional Travel Characteristics Report, Volume I, Metropolitan Transportation Commission, August 2004) comparing person trips per household by context type (see Table 3.12.1C, 2000 Regional Weekday Trips per Household by Population Density Category).

APPENDIX A

Predominant Characteristics of Context Zones

Appendix A
Predominant Characteristics of Context Zones

Urban Core (CZ-6)

General Characteristics

A city center area often termed as a *downtown* or *central business district* and that may serve as the primary regional central business district of the entire metropolitan area. An urban core is historically the region's major employment center, characterized by the tallest buildings and the greatest variety, density, and intensity of any context.

Development Pattern

Urban-core contexts are built on the urban block patterns that historically formed the first urbanized development. Urban-core contexts often have formally planned civic areas and numerous regional destinations, including governmental, cultural, social, institutional, and retail destinations. Urban core is the least naturalistic zone type; the landscape that exists is usually formal and contained in plazas or urban parks; street trees are uniformly spaced, usually within sidewalks in grated tree wells, and sometimes are absent. The development pattern of urban core is primarily historic and is formed, in part or in whole, by the city's original platting of streets, usually a grid of pedestrian-scaled blocks making the area, or each district within the area, both compact and walkable.

Land Use and Building Types

Typical land uses are a mixture of high-intensity and high-density residential, office, commercial retail, entertainment, dining, lodging, civic, and institutional uses such as museums, theaters, government buildings, and institutions of higher learning. Auto-oriented uses such as repair, big-box retail, and drive-thru restaurants are rare. Typical building types are high- and medium-rise apartment and office towers, large hotels, and unique or historic civic buildings and monuments. Some vertically mixed-use buildings, mostly attached, form a street wall with little or zero setback.

Parking

Parking in urban cores is primarily in private structured or underground garages providing limited capacity for building tenants, or in large public or private paid parking facilities. Older buildings on traditional narrow lots usually cannot provide on-site parking and rely on publicly available parking. Few individual buildings/sites have exclusive parking, and many sites have no parking at all. Surface parking lots are rare in urban cores, usually occupying one-quarter to one-half of a traditional city block and having extremely limited capacity. Parking charges vary by metropolitan area, depending on metro population, but in general, charges in the urban core are the highest relative to elsewhere in the region.

Transit/Multimodal Transportation

The urban core is often the nexus of multiple transit systems and technologies. There may be a single, or primary, intermodal hub connecting commuter and light rail, ferry, and multiple bus agencies. Commuter rail stations are often underground, shared with or at a different level from the city's subway system. If the city has a streetcar system, it is usually in the urban core. Major streets in urban cores are often transit-priority streets with closely spaced stations served by multiple high-frequency transit lines. Because of the magnitude of pedestrian travel, nearly all of the streets in the urban core have wide sidewalks, often lined with street trees within tree wells. Signalized intersection crossings provide pedestrian indication concurrent with vehicle traffic, so there is no need for pedestrians to actuate a pedestrian walk phase. Some cities provide bike lane systems in the urban core, but because of right-of-way constraints, most make extensive use of shared lane facilities.

Appendix A
Predominant Characteristics of Context Zones (Cont.)

Urban Center (CZ-5)

General Characteristics

Contexts ranging from intensely developed compact centers to large districts with moderate to highly dense concentrations of commercial and residential land uses, characterized by large-scale office and residential towers in a compact central area surrounded by gradually lower-scale and lower-height buildings of various types that accommodate retail, offices, row houses, and apartments, all served by multiple transportation options.

Development Pattern

Urban centers typically have a compact network of streets, with uniform street tree plantings on wide sidewalks, and buildings set close to street frontages. Urban centers are sometime referred to as *edge cities* because they began as suburban centers at the fringe of metropolitan areas but rapidly grew into large-scale employment and activity centers in their own right.

Land Use and Building Types

Typical land uses are medium- to high-density residential and commercial uses (e.g., retail, restaurant, office, lodging), civic facilities, and older light or general industrial uses, especially near waterfronts or ports. Typical building types are townhouses, older mid-rise and newer high-rise apartment buildings, shop-front buildings and office buildings exceeding 10 stories, hotels, schools and universities, and older one- to three-story industrial buildings interspersed throughout the area, often converted to housing or commercial uses. TOD is encouraged adjacent to rail stations or intermodal centers.

Parking

Many sites in urban centers provide some on-site parking complemented by large public or private structures providing paid parking. Small surface parking lots may exist within urban centers, while larger surface parking lots are typically located at the fringes of the area. Urban-center contexts often promote a park-once-and-walk environment.

Transit/Multimodal Transportation

Most of the urban-center context is within walking distance of local, regional, or metro transit service. Often served by several lines of commuter rail systems that feed outlying suburbs, but also may be served by light rail transit connecting urban centers to the urban core or connecting multiple centers. Urban-center contexts may be served by bus rapid transit or multiple high-frequency bus lines within a single corridor. Urban centers generally are walkable, with connected networks of sidewalks and few significant barriers to walking (i.e., freeways, freight railways). They may have comprehensive bicycle networks that provide local, regional, and inter-regional connectivity, although within the urban center, shared lanes may be used in lieu of bike lanes.

Appendix A
Predominant Characteristics of Context Zones (Cont.)

General Urban (CZ-4)

General Characteristics

Primarily low- to moderate-density residential and commercial nodes that serve large single-family residential areas or in concentric rings bordering more urbanized urban-center and urban-core contexts. Horizontal mixed-use development is typically confined to corner locations or planned unit developments in low-density residential areas. General urban contexts usually have little to no undeveloped land, but may have many underutilized parcels.

Development Pattern

Development pattern composed of a mix of traditional pedestrian-scaled urban blocks, larger auto-scaled blocks, and expansive superblocks. General urban contexts often are the transitional area between urban-center/urban-core and suburban-center areas and may contain a combination of traditional urban street grids and hierarchical collectors and arterials, reflecting the advent of the functional classification system.

Land Use and Building Types

Typical land uses are low- to medium-density multifamily residential and a diverse mix of small office buildings and entertainment, civic, retail, cultural, sports, and lodging facilities. General urban contexts often contain land uses and structures that are not practical to develop within urban-center and urban-core areas, such as arenas, stadiums, and large-scale entertainment and shopping activity centers. Typical building types are apartments and townhouses; single-story retail stores as part of regional, community, and neighborhood shopping centers; individual office buildings (which may have ground floor retail) usually less than six stories in height; and compact business parks.

Parking

Sites are usually required to provide exclusive parking meeting zoning code requirements—often surface parking. Public parking is usually in the form of on-street parking. In more intensely developed general urban contexts, on-site parking may be oriented to the side or rear of buildings or in structured private garages where a fee is charged.

Transit/Multimodal Transportation

Because general urban contexts often form rings of development between urban-core/urban-center and suburban-center contexts, they often benefit from the significant amount of transit that passes through while connecting the termini, which may include commuter rail and light rail transit systems connecting multiple centers and passing through general urban contexts. Bus rapid transit or multiple high-frequency bus lines will often travel within the same major corridors passing through general urban contexts. Urban centers generally are walkable, with connected networks of sidewalks, but may have more barriers to walking than more urban contexts, such as major arterials, freeways, and freight railways. They may have comprehensive bicycle networks that provide local, regional, and inter-regional connectivity, although within the urban center, shared lanes may be used in lieu of bike lanes. Small, isolated islands of general urban context (such as a shopping center primarily serving surrounding single-family neighborhoods) may not be served by rail or high-frequency bus transit, or may be too distant from these services. These contexts do not qualify for the methods used in this research study.

Appendix A
Predominant Characteristics of Context Zones (Cont.)

Suburban Center (CZ-3)

General Characteristics

Suburban communities generally are composed primarily of low- to medium-density single-family residential neighborhoods, with a commercial/retail or traditional mixed-use downtown, and areas of concentrated multifamily housing, commercial office, or retail segregated by conventional zoning. Suburban centers are usually the highest density and intensity areas within suburban communities and often are the community's traditional downtown. A dominant characteristic of a suburban community is its landscape (lawns and trees) when compared to the hardscape and urban forestry of more urban contexts.

Development Pattern

Suburban contexts are represented by post–World War II towns that, fueled by access to automobiles, rapidly grew concentrically around the central city of most metropolitan areas of the country. Built around traditional small-town street networks, the development patterns from the 1950s are strongly influenced by zoning and the functional classification system—predominantly segregated land uses connected by a hierarchy of streets. Suburban contexts have walkable development patterns within neighborhoods but are often too widespread to walk for everyday needs. Suburban centers are a context within suburban communities typically composed of a mix of land uses, including residential, that either predate zoning (e.g., downtowns) or planned large-scale activity centers.

Land Use and Building Types

Residential uses in suburban centers are usually in the form of townhomes, condominiums, and low- to mid-rise apartment buildings. Commercial land uses include large office parks with widely spaced buildings in landscaped complexes or integrated within the built fabric of the community, are interspersed with retail, and may be bordered by high-density housing. Retail ranges from neighborhood and community shopping centers serving residential areas to large regional shopping malls surrounded by surface or structured parking. Retail is also located in strip commercial centers along arterials and expressways or in big box centers. Except in the most intensely developed centers, buildings in suburban contexts are generally low-scale (one to three stories), horizontally mixed, have large setbacks from the street, and often are fronted by surface parking.

Parking

Parking in suburban centers is predominantly private lots oriented to streets, and garages in more intensely developed areas. Parking, as required in conventional zoning, is nearly always exclusive to the development site. Parking is typically free, but where a fee is charged, it is usually lower than in the urban core. On-street parking is typically underutilized because of convenience of on-site parking, except in higher-density suburban centers such as downtowns. Suburban centers that make up downtowns or small activity centers may employ a public parking strategy consisting of public lots/garages and metered on-street parking.

Transit/Multimodal Transportation

Suburban contexts are often bedroom communities for job-rich city centers and may be located on commuter rail lines, while high-frequency bus transit in suburban contexts emphasizes longer distance express routes geared toward commuters. Suburban centers are walkable, with networks of sidewalks or off-street paths, but long distances or lack of land use diversity discourages more than localized pedestrian usage. The bicycle network is typically for longer trip lengths to connect districts and inter-regional destinations, or for recreation (e.g., bike paths, multi-use trails, and bike lanes on arterial street systems).

SUPPLEMENTAL TECHNICAL REPORT

CONTENTS

CHAPTER 1

Introduction

This technical report supplements *NCHRP Report 758: Trip Generation Rates for Transportation Impact Analyses of Infill Developments*. It is a consolidation of interim reports prepared during the development of the recommended methodology for estimating vehicular trip generation of infill development. Specifically, this report describes the procedure the research team used to extract data from HTSs and the use of the data to derive factors used in the methodology.

The objective of the research presented in *NCHRP Report 758* is to develop an easily applied methodology to estimate automobile trip generation and mode shares of non-vehicular trips that can be used in the preparation of site-specific transportation impact analyses of infill development projects located within existing higher-density built-up areas.

CHAPTER 2

Overview of the Trip Generation Methodology for Infill Development

The following overview of the methodology is paraphrased from Chapter 3 of the report.

The research team selected an approach for estimating the trip generation of infill development categorized as "ITE rate adjustment based on empirical data," as described in the main body of the report. This approach met the research objective and, to varying degrees, all of the selection criteria. One of the predominant reasons this approach was selected is because it can be applied to the land uses in the ITE *Trip Generation Manual*[1] and has few, if any, restrictions on land use categories and applicable geography. The approach of employing empirical data provides the practitioner with flexibility in that there are no limitations or constraints in regards to land use classification or geography. Conceptually, the approach can be described with the following simplistic equation:

$$\text{Auto\_Trips}_{(\text{INFILL})} = \text{Auto\_Trips}_{(\text{ITE})} \times \text{Adjustment\_Factor}_{(\text{INFILL})}$$

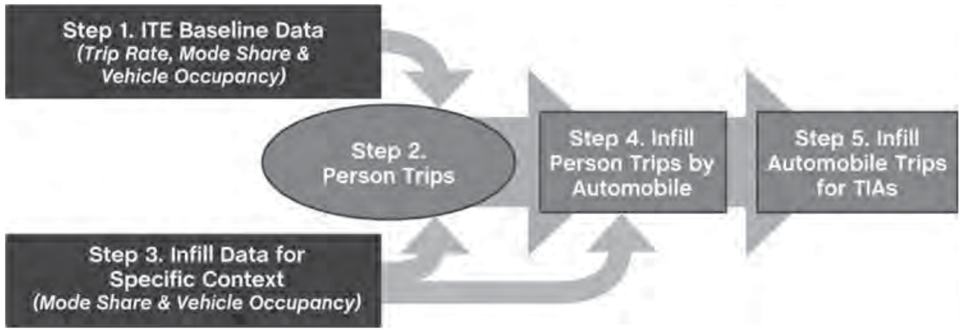
The recommended methodology applies adjustment factors to data from the ITE *Trip Generation Manual,* resulting in a relatively straightforward conversion of data representative of isolated automobile-dominated suburban land uses to data representative of dense urban areas served by extensive multimodal transportation systems. The selection process and subsequent development of the approach resulted in two ways to develop the adjustment factors employed by the approach:

1. **Proxy site method** – Adjustment factors are based on data collected at sites with similar characteristics and located in similar contexts as the proposed infill development site (the project being studied). The research team developed procedures for identifying proxy sites and obtaining the required data to develop the adjustment factors applied in the methodology.
2. **Household travel survey method** – Adjustment factors derived from empirical data found in the database of a regional HTS. This method extracts data representing the desired infill land use and context within physical areas at the scale of the TAZ. Extraction of data representing specific land uses is based on the activities and trip purposes recorded by the travelers during the survey.

As shown in Figure 2.1, the approach is made up of five primary steps:

1. Baseline ITE trip generation data are used to estimate the vehicular trip generation of the proposed infill development.
2. Baseline mode share and vehicle occupancy adjustment factors are used to convert baseline vehicle-trip estimates to baseline person trips.
3. An infill mode share adjustment factor representing the appropriate context is used to convert baseline person trips to infill person trips for those who travel by automobile.
4. An infill vehicle occupancy adjustment factor representing the appropriate context is used to convert infill person trips for those who travel by automobile to infill vehicle trips.
5. Infill vehicle trips are used in the evaluation of site traffic impacts.

This supplemental technical report describes the procedures used to develop the infill mode share and vehicle occupancy adjustment factors using the household travel survey method described in the main report.



Note: TIAs = transportation impact analyses.

Figure 2.1. Approach for estimating vehicle trip generation.

CHAPTER 3

Application of the Household Travel Survey Method

The following description of the use of the household travel survey method is paraphrased from Chapter 3 and 4 of the report.

Infill adjustment factors may be derived for sites proposed within metropolitan areas that have current HTS data. This method of deriving mode share and auto occupancy is limited to the land use categories that can be deduced from HTS linked-trip data—essentially only the general categories (e.g., retail, office, multifamily housing, etc.) because the data from the surveys do not always distinguish between land use subcategories (i.e., grocery store versus home improvement center). However, HTS data can provide adjustment factors for all context types and, more importantly, can identify differences in the adjustment factors within each context type due to geographic location and varying socio-demographic characteristics within a region.

This method will result in adjustment factors for general land use categories within any context type either (a) averaged across the metropolitan region, or (b) specific to any TAZ located in the region.

Although this method can be used to generate the adjustment factors used in traffic impact analyses of infill development, it can also be used for broader types of analyses, including:

- Creation of a region- or area-wide database of mode share and vehicle occupancies by TAZ (representing the context within the TAZ) for adjusting ITE trip generation rates for sites in different locations in the region to ensure consistency in infill development traffic impact studies within the region or area.
- Scenario analyses comparing the transportation benefits or impacts of shifting growth in development between urban infill and suburban or greenfield locations.
- Studies of large-scale activity centers requiring an understanding of how the center's mode share is influenced by its location within the region, proximity to transit, and other built environment characteristics.
- Development of local or regional trip generation rates and mode shares covering a range of contexts for inclusion in agency traffic impact analyses guidelines.

3.1 Background and Source of Surveys

Household travel surveys provide information at the regional level on the relationships between the characteristics of personal travel and the demographics of the traveler. They are used to identify travel patterns and to provide the necessary data to support the development, calibration, and validation of regional travel forecasting models. Analysis of the data at different scales can be used for more detailed subregional studies and research. Surveys include demographic characteristics of households, people, and vehicles, as well as detailed information on the daily activities of individuals in a household and their mode of travel for all purposes. Data are collected from a sample of households in the study area and expanded to provide regional estimates of trips and miles by travel mode, trip purpose, and other household characteristics.

Household travel surveys are typically conducted by MPOs—agencies responsible for maintaining regional travel data as well as developing and maintaining travel demand forecasting models. Household travel surveys have evolved over the past 50 years, but the state of the practice today is the travel-/activity-based survey, which is considered the best source of household and person-trip generation data by mode for the regions that have conducted these surveys. This type of survey focuses on each activity throughout the day and records trip details to and from each activity. (Data are gathered on the basis of trip-end activities.) The methodology proposed in this report is based on the use of travel-/activity-based household travel surveys.

There are two national-scale travel surveys: the National Household Travel Survey (NHTS) and the Nationwide Personal Transportation Survey (NPTS). While these national-scale surveys provide some useful information, they are not representative at the scale of the region, city, or urbanized area. In fact, according to the *Travel Survey Manual:*[2]

"It has long been determined by most metropolitan regions that data collected in one region has little relevance to another region. While there is no doubt that there will be local contextual issues that may make transfer of data difficult or inappropriate at times, the major reason for this perception is that each household travel survey is usually sufficiently different in design and execution from any other survey, resulting in comparisons from region to region that are completely obscured by methodological and implementation differences."

This statement, referring to a lack of survey standardization, in part informs the recommendations of this proposed methodology. Many of the metropolitan areas of the United States have conducted relatively recent household travel surveys, most coinciding with the 2000 census. Some regions, such as the San Francisco Bay Area, conduct surveys every 10 years. The availability of recent surveys (no older than year 2000) is an important factor in the recommendation and proposed organization of the methodology. Appendix A of this technical report contains summary information on the household travel surveys that were reviewed as part of this study.

3.2 Practitioner Need for Broad Applicability

Maximizing the value of the proposed methodology to practitioners who prepare urban traffic impact studies requires that the method be applicable over a wide range of metropolitan areas. A method based on data aggregated at the national scale (weighted average of adjustment factors from multiple metropolitan areas) is simple to use and can be applied by the practitioner regardless of its location in the United States. This method is similar to the use of trip generation rates published by ITE. The simplicity of using ITE trip generation rates is one of the reasons for its popularity and widespread use. However, data aggregated at the national scale cannot credibly reflect the unique characteristics of individual urban areas.

In contrast to adjustment factors derived from national averages are factors derived from local data from the practitioner's study area. Local scales may range from a relatively compact district surrounding a transit station (such as a handful of TAZs) to the entire metropolitan area composed of multiple cities and including the study area. The benefit of adjustment factors derived from local survey data is a better representation of the actual conditions the practitioner is studying. The downside is a smaller set of trip records and loss of precision inherent in smaller samples.

In recommending a scale of data aggregation, the investigators considered the needs of the practitioner, the precision of the survey results (i.e., number of trip records), applicability over a broad range of urban areas, ease of use by the practitioner, availability of data, and the effort and budget required to prepare the factors so that the methodology is immediately usable by practitioners. There is an inherent trade-off between the higher precision gained from a large number of trip records aggregated from multiple metropolitan areas and the lower precision of a smaller amount of data representing the practitioner's actual study area or, at least, metropolitan area.

3.3 Required Data for the Household Travel Survey Method

The data commonly available from a HTS to use the household travel survey method can be divided into four categories:

1. Household data – Characteristics of the household and its location.
2. Person data – Demographic, socioeconomic, and employment information for one or more members of the household.
3. Vehicle data – Type, ownership, and usage of private vehicles available to household members.
4. Travel and activity data – Detailed travel, activities, and origins/destinations of the daily trips by one or more household members.

The minimum required data for estimating infill trip generation adjustments are listed in Table 3.1, which describes the required variables and how they are used in deriving the adjustment factors. These variables are generally standard in travel surveys and should be available, in one form or another, from all the major metropolitan areas. The linked-trip data contain many other variables and helpful information for cross-referencing household, person, vehicle, and activity data. Typically, a household travel survey records individual segments of each trip separately every time the traveler stops for a specific purpose on the way to an ultimate destination, including when changing modes. For example, driving from home to the train station, taking the train, and walking to the workplace are three segments of a single trip, each using a different mode of travel. These are called "unlinked trips." However, the travel described here is actually one home-based work trip using rail transit as the primary mode of travel. Driving to the train station and walking to the workplace are secondary. The consolidation to a single trip purpose by a single mode describes a linked trip.

Household travel survey records of unlinked trips are manipulated to produce linked trips. The linked-trip data contain

Table 3.1. Linked-trip data variables in deriving adjustment factors.

HTS Variable	Definition
Origin activity/destination activity or origin land use/destination land use	Provides the activity purpose or land use of the origin and the destination of the trip. Used to associate the trip with a particular land use.
General purpose	Provides home-based and non–home-based trip information. Used to cross-check data and to populate adjustment factors when using travel demand forecasting model data.
Primary mode of travel	Provides the primary mode of travel for individual trip records (ignoring mode of access). Used to develop adjustment factor mode split.
Origin TAZ/destination TAZ	Provides the zone of the origin and the destination of the trip. First used to identify trip records within TAZs designated as general urban/urban center, then used to classify the trip as inbound or outbound in the extraction of peak hour records. If available, an address can be used to determine the origin or destination zone.
Day of trip	Identifies the day the trip occurred. Used to classify trips as weekday or weekend.
Start time/end time	Starting and ending time of the trip. Used to classify trips in either a.m. or p.m. peak period.
Number in vehicle	Provides the number of people in a vehicle. Used to determine vehicle occupancy.

multiple variables from the four categories of data: household, person, vehicle, and travel/activity. Linked-trip data are made up of individual trip records, each of which represents one person's travel for an activity by the primary mode of travel. Each trip record is identified by a general trip purpose [e.g., home-based work (HBW), home-based shopping (HBS), non–home-based (NHB), start and end time of travel, mode of travel, passengers (if by auto), mode of access to primary travel mode, origin and destination activities and place, and numerous other data].

Based on a review of the data, the research team determined that the linked-trip data contained the appropriate information for deriving mode split and vehicle occupancy for various land uses and time periods. Linked-trip data were selected as the best source of data because their trip records were cross-referenced to the variables needed to calculate the adjustment factors.

3.4 Linked-Trip Data

By their nature, travel/activity surveys report individual segments of each trip separately every time the traveler stops for a specific purpose on the way to an ultimate destination, including when changing modes. Each segment is an intermediate part (with an intermediate mode) of an entire trip sequence making up one trip from the origin to the destination for a primary purpose (e.g., home-based work trip). For example, driving from home to the train station, taking the train, and walking to the workplace are three segments of a single trip with a home-based work trip purpose and with rail transit as the primary mode of travel and walking as the mode of access to/from transit. The access to transit mode is secondary and ignored for most purposes.

MTC's 2000 Bay Area Travel Survey (2000 BATS), which was used as the primary source of data to develop and evaluate the proposed methodology, includes records of unlinked trips that can be aggregated to produce linked trips. The linked-trip data contain multiple variables from the four categories of data; household, person, vehicle, and travel/activity. Linked-trip data from the 2000 BATS were made up of individual trip records, each of which represented one person's travel for an activity by the primary mode of travel. Each trip record is identified by a general trip purpose (e.g., HBW, HBS, NHB), start and end time of travel, mode of travel, passengers (if by auto), mode of access to primary travel mode, origin and destination activities and place, and numerous other data.

During the initial assessment of the 2000 BATS data, the investigators determined that the linked-trip data contained the appropriate information for deriving mode split and vehicle occupancy for the land uses and time periods required for the study.

3.5 Geographic Units of Urban Area Data

The unit of geography used for household travel data is typically some form of zone system. Most regions are divided into multiple zone systems of varying scales, including the standard census geographic units of census tracts, block groups, and blocks. In the 2000 BATS, the following geographic units (number of units is included in the parenthesis) were determined to be available:

- Census block (76,250),
- Census block group,
- Census tract (1,405),
- Census transportation planning product TAZs (4,070),
- PUMA – public-use microdata area (54),
- Super-PUMA districts (9),

- Super-districts (34), and
- MTC TAZs (1,454).

To develop and evaluate the proposed methodology, MTC's 1,454 zone TAZ system was selected as the geographic unit for the following reasons:

- TAZs are the smallest scale of district in urban areas, with the exception of census block group or blocks, providing a reasonable resolution for focusing on trip records meeting transit proximity criteria.
- Trip origins and destinations are identified by TAZ.
- Census data, as summarized by MTC, corresponds to TAZs.
- Existing and future land use and demographic information (for use in travel demand models) is aggregated by TAZ and useful in the proposed methodology for evaluating future site conditions.

CHAPTER 4

Example Adjustment Factors Using San Francisco Bay Area Travel Survey Data

This chapter provides a detailed example of how mode split and vehicle occupancy adjustment factors are derived from household travel survey data. As described in the previous chapter, the investigators selected the household travel survey data from the 2000 BATS. This activity-based survey was conducted with over 15,000 households in the nine-county Bay Area with a year-2000 population of 6,800,000 in nearly 2,500,000 households. The data are readily available, well-documented, and summarized by MTC for cross-checking against the resulting adjustment factors.

Wherever possible, the investigators identify the limitations of the data or the process. This example is based on using data aggregated at the TAZ level for contexts classified as general urban and urban center within the Bay Area. Additional discussion on the classification of context zones is provided in the main body of the report.

4.1 Household Travel Survey Data

MTC's household travel survey data are contained in four primary datasets: person, household, vehicle, and travel/activity. Additionally, MTC releases unlinked and linked-trip data. Linked-trip data were selected as the best source of data because their trip records were cross-referenced to the variables needed to calculate the adjustment factors. The linked-trip dataset contains many other variables and helpful information for cross-reference to the household, person, vehicle, and activity datasets.

4.2 Defining General Urban and Urban Center Context

A comprehensive literature review of quantifying urban area designations is included in research conducted in California (*Trip-Generation Rates for Urban Infill Land Uses in California, Phase 2: Data Collection, Final Report*[3]). The California research identified a definition of "urban" based on the density of residential dwelling units, employment, or a combination of both. The investigators used criteria similar to the California research to designate TAZs in the San Francisco Bay Area as general urban/urban center. As shown in the following, to set the upper limit of general urban/urban center density, the team used the lower limit of density in known urban cores.

Lower limit of urban core density = upper limit of general urban/urban center density:

Employees/gross acres greater than 70 and/or households/gross acres greater than 40

In this example, the team used the known urban cores of San Francisco's and Oakland's central business districts. Year-2000 census data were used to determine residential density and MTC's year-2000 employment database (used in travel demand forecasting) was used to determine employment density.

The lower limit of general urban/urban center was set as the upper limit of the Bay Area's suburban density. Suburban densities range greatly, so the investigators considered MTC's and Florida Department of Transportation's quantitative criteria for suburban areas and the criteria documented in *Trip-Generation Rates for Urban Infill Land Uses in California, Phase 2: Data Collection, Final Report* to establish the lower limit of general urban/urban center. The following summarizes these thresholds:

Upper limit of suburban density = lower limit of general urban/urban center density:

Employees/gross acres less than 35 and/or households/gross acres less than 10

These thresholds, individually and in combination, were used to isolate the Bay Area's TAZs that meet either or both criteria. This resulted in a relatively small number of TAZs

(176) out of the 1,454 in the Bay Area. About 32,800 individual trip records have either an origin or destination in these 176 TAZs. These zones were the initial pool for a series of steps that incrementally reduced the pool and the eventual size of the sample trip records. The sequence of steps of querying and isolating trip records is:

1. Use trip purpose at origin and destination to isolate trips by the four proposed study land uses (residential, restaurant, retail, and office);
2. Identify TAZs within ½-mile walk of rail/ferry or ¼ mile of high-frequency bus routes, and isolate trip records within these zones;
3. Isolate weekday trip records from weekend trip records;
4. Isolate a.m. and p.m. peak periods from daily trip records; and
5. Isolate inbound and outbound trip records.

The sequence of the key steps is briefly described in the following sections. Detailed discussion on isolation and a summary of data by key variables are not included.

4.2.1 Variables Representing Study Land Use Categories

The four land use categories proposed for initial development of adjustment are residential, restaurant, retail, and office. Because the available data are activity-based and not place-based, the type of land use at the origin or destination of the trip needs to be inferred from the trip records. The linked-trip data contain a variable for the activity purpose at both ends of the linked trip. While not in great detail, the activity variable has 17 activities the participant can choose from. From these the investigators selected those activities that best represent an activity at a specific land use. Clearly missing from household travel survey data are trips made by delivery or service people, with the exception of survey participants who are employed in these fields. This is a potential source of error in estimating actual trips but not a significant error in calculating mode split or vehicle occupancy. The activities used to determine land uses associated with trips are discussed in the following paragraphs.

Residential-related trips were selected from the trip records with an origin purpose or a destination purpose classified as "home." It appears that the majority of the trip records are from the residents themselves and do not capture non–resident-related trips.

Restaurant-related trips were selected from the trip records with an origin purpose or a destination purpose classified as "meals." The "meal" activity encompasses "at home, take-out, restaurant, coffee, and snack." Based on this definition, it is not possible to eliminate the meals eaten at the home that do not generate an external trip from the home. The trip records include both employee and patron trips.

Retail or shopping-center–related trips were selected from the trip records with an origin purpose or a destination purpose classified as "shopping away from the home" or "personal services/bank/government." The "personal services/bank/government" purpose includes barber, beauty shop, dry cleaning, banking, and government services. The trip records include only patron trips.

Office-building–related trips were selected from the trip records with an origin purpose or a destination purpose classified as "work or work related." These trip records include all work trips and do not classify the origin or destination as office. Under the MTC variables, there is no reasonable way to separate work trips from those specific as to an office building except by reviewing the participant's comments. However, on review, this was not deemed to be an impractical way to isolate office building related trips. While this is a potential source of error and inaccuracy, it was used because the resulting mode split and vehicle occupancy represent work-related trips for all land uses, including office buildings. Further, a comparison of the resulting mode splits and vehicle occupancies does not look unreasonable compared to generalized work mode splits for the entire region or within ½ mile of rail stations as published by MTC. Therefore, while use of the "work or work-related" trip purpose captures trip records to non-office locations, the data appear to reasonably represent work trips to office land uses.

The inability to distinguish between different workplaces for work-related trips may not be a universal problem with household travel survey data. An examination of the 2007 Chicago area household travel survey includes a variable identifying the origin or destination as a restaurant but does not specifically include office buildings. This issue will require further exploration to determine its extent and whether the issue results in significant error.

4.2.2 Transit Proximity

For the 2000 BATS data set, only the general urban and urban center land uses within ½ mile of a rail (or ferry) station and within ¼ mile of a high-frequency (maximum 15-min headways for 6 or more hours of the day) bus route were considered infill development. Mode split and vehicle occupancy adjustment factors are, therefore, determined from TAZs that meet these proximity criteria. For the San Francisco Bay Area example, GIS was used to map rail and ferry stations and to identify a ½-mile buffer around the station. A similar analysis was prepared for high-frequency bus lines.

4.2.3 Determining TAZ Proximity to Transit

A TAZ was considered to be in proximity to the transit facility if the TAZ was entirely within the buffer ring or if the edge of the buffer ring covered more the ⅓ of the TAZs area. In metropolitan areas where GIS layers of transit routes and stops are not available, the exercise of selecting transit proximate TAZs is performed manually. This exercise demonstrated that it is impractical to use very close proximities to transit (i.e., 400–600 ft) if the typical size of a TAZ is greater than ¼ mile. Although the resolution of transit proximity could be improved using census blocks (or geo-coded origins and destinations), the significant reduction in trip records (or the likelihood of blocks without any trip records) may offset the benefit of increased resolution. When acquiring transit system data, it is important that the transit route, stop, and frequency information match the year of the household survey data or that it be demonstrated that the transit system has not undergone change since the survey was conducted.

4.3 Weighting and Expansion of Survey Data

Household survey data are typically adjusted through a process of weighting and expansion. According to the MTC:[4]

> Sample weighting is a technical necessity to account and correct for geographic and demographic biases in a survey. Sample expansion, on the other hand, is the process used to factor up survey records to represent aggregate demographic and travel characteristics. The weighting factors used in this analysis [the 2000 BATS] are essentially combined weighting and expansion factors.

The objective of applying weighting factors to samples is to draw valid conclusions about the entire study population based on the survey results of a relatively small sample. Weighting is determined by comparing the sample variables to the actual values from a known credible source like the census.

4.3.1 Weighting and Expansion Method Used in San Francisco Bay Area Example

The 2000 BATS data were weighted and expanded based on Census 2000 data. Weighting and expansion factors for each trip record are based on the PUMA of household characteristics, including household size, vehicles available, tenure, and race/ethnicity. The system of PUMAs in the San Francisco Bay Area makes up 54 districts encompassing the region's 1,454 TAZs.

For this proposed methodology, weighting and expansion factors may be applied to trip records in this method so that the resulting mode splits and vehicle occupancies are more representative of the areas where the data were collected. This can be particularly important in study areas that are rich in the types of household demographics that influence transit use.

4.3.2 Creating New Weighting and Expansion Factors

Since the trip records used to derive mode split and vehicle occupancy in the example used in this methodology are from a subset of the San Francisco Bay Area (e.g., general urban and urban center in proximity to rail stations and high-frequency bus routes), the weighting and expansion factors developed for the entire region in the 2000 BATS survey are not representative of the geographical subset. New weighting and expansion factors would need to be developed using the same weighting and expansion procedure used by MTC. Validating the new factors requires comparing the subset demographic and mode share data to 2000 census data for the selected general urban and urban center areas before and after weighting and expansion. Weighting districts for the revised factors may continue to be done using PUMA districts since smaller scales of district (e.g., TAZs or census tracts) may prove to be too small.

The need to develop new weighting and expansion factors is a challenging aspect of this methodology. It is a complex analytical effort with the potential for error by practitioners unfamiliar with the procedure. In applying the household travel survey method, the practitioner should carefully review documented procedures and analysis of the weighting and expansion method the MPO applied to the HTS sampled data. Reviewing the procedures and comparing the survey's sampled data to the weighted and expanded data can inform the practitioner of the expected change if the procedure were applied to the TAZs being used to extract adjustment factors.

4.3.3 Comparison of Data by Level of Disaggregation

As stated previously, the number of usable trip records decreases as the records representing the total population are disaggregated into finer resolution to distinguish and isolate trips by (1) context, (2) land use, (3) day of week, (4) proximity to transit, (5) peak period, and (6) directionality. In general, a decrease in the number of trip records corresponds to a decrease in the precision of the survey findings.

The 2000 BATS data provide over 236,000 total linked-trip records representing the total population. At each successive disaggregation, the number of records can diminish substantially. For example, by isolating the trip records to those within general urban/urban center contexts, the trip records decrease by 85% to about 33,000. The smallest number of trips in any of the distillations is less than 50 records for one direction of 1 peak hour for the retail land use category. The average number of peak hour trip records for a given land use and transit proximity scenario is about 1,750. Figure 4.1 graphs the number of trip records that result from disaggre-

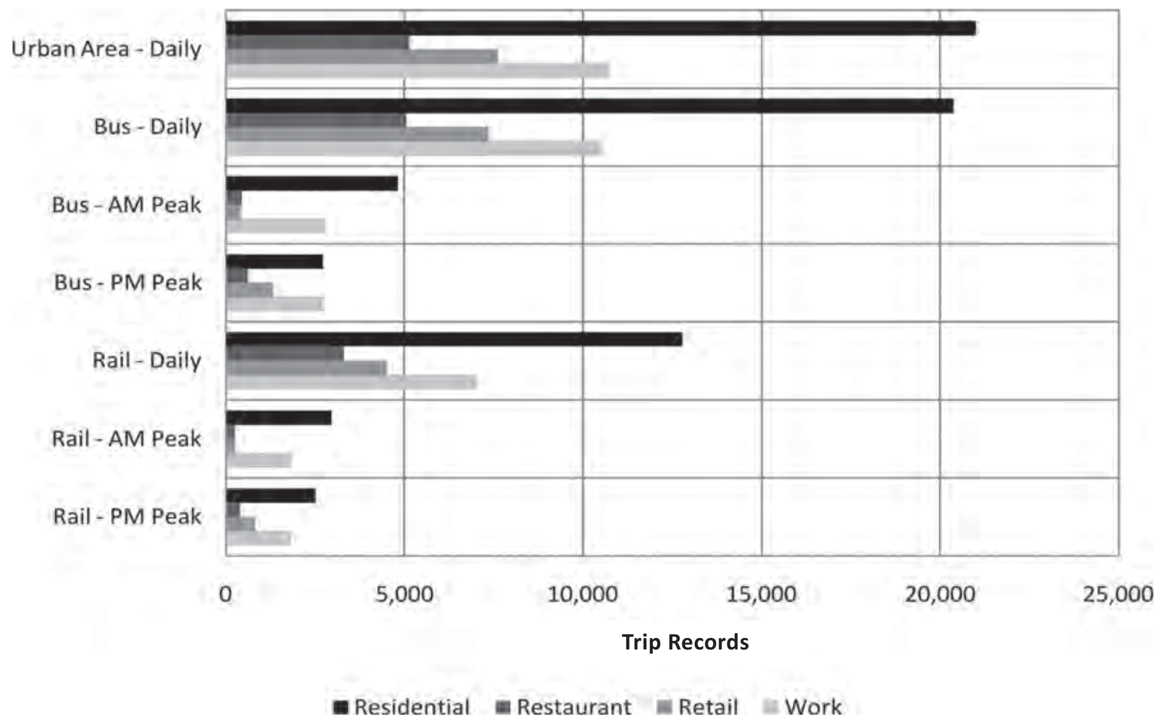


Figure 4.1. Trip records by time period, proximity to transit, and land use.

gating the data to represent context, land use type, weekday peak time periods, and proximity to transit.

4.4 Estimated Mode Share by Land Use

The trip records for each land use category were aggregated by mode to determine mode share percentages for bike, walk, bus, rail, car, and other. The percentages in the last two columns of Table 4.1 are the factors included in the trip generation conversions.

4.5 Estimated Vehicle Occupancy by Land Use

Table 4.2 presents an example (p.m. peak hour) summary of average vehicle occupancy adjustment factors by land use category. Occupancies based on the survey data are used to

Table 4.1. Example mode share adjustment factors for San Francisco Bay Area (p.m. peak period).

Land Use	Context Criteria	Type of Transit (Maximum 15-min Headway)	Proximity	Mode Share (All Trips)	
				Transit	Walk/Bike
Residential	**General urban/ urban center** (30–70 emp/gross acre) (10–40 DUs/gross acre)	Bus	Rail: ½-mile Bus: ¼-mile	17.5%	13.3%
		Rail		16.2%	13.7%
Restaurant		Bus		14.3%	16.6%
		Rail		15.5%	19.8%
Retail		Bus		10.7%	15.3%
		Rail		11.7%	16.3%
Office/work		Bus		22.4%	8.6%
		Rail		20.6%	9.4%

Notes: DUs = dwelling units.
Based on 2000 BATS data from 93 TAZs around rail stations and 170 TAZs around high-frequency bus stops.
Rail and bus modes must have 15-min headways or shorter for at least 6 hours of the day to meet transit proximity criteria.

Table 4.2. Example vehicle occupancy adjustment factors for San Francisco Bay Area (p.m. peak period).

Land Use	Context	Vehicle Occupancy
Residential	**General urban/ urban center** (30–70 emp/gross acre) (10–40 DUs/gross acre)	1.62
Restaurant		2.11
Retail		1.50
Office/work		1.27

convert between person trips and vehicle trips in the proposed methodology. Appendix B of this technical report displays the mode splits and vehicle occupancy by land use for (1) the entire Bay Area, (2) weekday trips in areas designated as general urban/urban center, (3) a.m. and p.m. peak hour trips by proximity to high-frequency bus service, and (4) a.m. and p.m. peak hour trips by proximity to rail service. Appendix C of this technical report presents the mode share and average vehicle occupancy adjustment factors by land use for daily, a.m. peak, and p.m. peak hours.

4.6 Use of Local Travel Demand Model to Derive Adjustment Factors

If a regional or local travel demand forecasting model is available to the practitioner, and the model has a mode split submodel, data from the model can be used to derive mode share adjustment factors reflecting the existing or future planning horizon of the study area. The model-projected adjustment factors can only be used to estimate traffic generation of the forecast year of the model.

The *A* columns of Table 4.3 are predetermined using household travel survey data and represent the percentage of total person trips by each trip purpose. The *B* and *C* columns, completed by the practitioner, contain transit and nonmotorized trip purpose data for the study area TAZs and analysis year as output from a regional or local travel demand model. If the model being used does not provide mode share for walk or bike, then the method described can be used to obtain those mode splits.

The *D* columns, the mode share adjustment factors, are calculated by multiplying the percent of trips by purpose (*A*) times the corresponding mode share percentages (*B* or *C*) and summing the totals into the corresponding cell of the *D* column.

Table 4.3. Template for determining mode share adjustment factors using local travel demand model forecasts by TAZ, San Francisco Bay Area (p.m. peak hour in general urban/urban center contexts).

Land Use	A			B			C			D	
	Typical Percent of Total Trips			Analysis Year TAZ Projected Percent of Trips By Transit			Analysis Year TAZ Projected Percent By Nonmotorized Modes			Estimated Analysis Year Mode Share (%)	
	HBW [1]	HBO [2]	NHB [3]	HBW [1]	HBO [2]	NHB [3]	HBW [1]	HBO [2]	NHB [3]	Transit [1]	Walk/Bike [2]
Residential	46.2%	53.8%	0%	___%	___%	___%	___%	___%	___%		
Restaurant	0%	40.8%	59.2%								
Retail	0%	44.1%	55.9%								
Office/work	68.5%	0%	31.5%								

Example equations for determining mode share by land use type:

Transit mode share (from row with desired land use) = Σ(cells A[1]*B[1] + A[2]*B[2] + A[3]*B[3]) = D[1]

Walk/bike mode share (from row with desired land use) = Σ(cells A[1]*C[1] + A[2]*C[2] + A[3]*C[3]) = D[2]

CHAPTER 5

Selection of a Household Travel Survey as a Case Study

This chapter summarizes the development of a case study to extract adjustment factor data from a household travel survey. This information was originally submitted to NCHRP in a technical memorandum[5] for this study. As suggested by the research panel, the following metropolitan areas were the focus of this evaluation:

- Atlanta, GA.
- Dallas, TX.
- Salt Lake City, UT.
- Denver, CO.
- Washington, D.C.

5.1 Criteria for Selecting a Metropolitan Area with a Suitable Household Travel Survey

The research team contacted staff responsible for coordinating transportation activities at the selected MPOs to assess the availability and usability of data necessary to meet the requirements of the case study. The research team interviewed MPO staff regarding their most recent household surveys and data included in their geographic information systems (GISs). In addition to the resulting interview findings, the project team reviewed other important characteristics to determine the suitability of the candidate metropolitan areas for the case study, including confirmation of the following criteria:

- Existence of urban light or heavy rail transit serving general urban and/or urban core areas;
- A metropolitan household travel survey was conducted when the rail system was in operation and contains the minimum required data variables, as described in previous submissions;
- Metropolitan household travel survey data would be available from the MPO for analysis by the research team, and MPO staff were available for questions and clarifications;
- MPO or another agency would make available to the research team GIS data files with sufficient land use data to determine current household and employment data by TAZ, and the availability of current rail and bus transit route, stop, and schedules (preferably in a GIS); and
- Metropolitan area contains a quantity of infill developments in close proximity to qualifying rail stations or bus stops that can be successfully isolated for an accurate modal person-trip cordon count.

5.2 Selection of a Metropolitan Area

Based on information provided by MPO staff, the previously mentioned criteria, project requirements, and data collection considerations, the research team selected Washington, D.C. (the Metropolitan Washington Council of Governments) as the source of data for the case study. One of the principal reasons for selecting Washington, D.C., was the age of its household survey (completed in 2008). This is an important consideration given that the validation process would have to rely on 2011 traffic count data. Older data would be difficult to substantiate given the difficulty of verifying that land uses and the location/availability of transit (or other variables strongly correlated to trip generation) have remained constant over extended periods of time.

The research team also ranked Denver a strong candidate because its ongoing household travel survey is expected to have more records than Washington, D.C.; however, complete data would not have been available in time. The research team eliminated the remaining possible metro areas (Atlanta, Dallas, and Salt Lake City) from further consideration because the available data were dated or the survey's dataset contained a small number of records. Summary findings for each of the candidate metropolitan areas are provided in Appendix A of this technical report.

The research team identified Washington, D.C., as one of the most viable candidates because it has an established transit system that operates within urban and suburban areas, and local governments promote infill and transit-oriented developments around transit stations. The Washington Metropolitan Area Transit Authority operates and maintains Metrorail and Metrobus, the major rail and bus transit systems in the area.

5.3 Sufficiency of the Dataset

One potential challenge with the Washington, D.C., data was whether there would be sufficient records at the level of detail required by the methodology. Although the research team did not expect that this would negate Washington, D.C., as a candidate, it was not possible to make a final assessment until the required linked-trip records were extracted from the total dataset. The linked-trip records were required to meet multiple criteria, including the provision of trip purpose, primary mode share, geographic identifiers, and the ability to discern origin and destination land use type (i.e., single family, multifamily, office, retail, and restaurant). The most recent survey for Washington, D.C., was completed in 2008 and includes 11,000 households (approximately 88,000 trips).

Following is a summary of the Washington, D.C., household travel survey data received. For reference, the number of trips from the initial demonstration project that used the 2000 BATS is provided in parentheses:

- 87,926 (236,573 in 2000 BATS dataset) total trips.
- 63,107 (176,083) trips with origin purpose or destination purpose of “home.”
- 27,210 (72,275) trips with origin purpose or destination purpose of “work.”
- 31,462 (67,295) trips with origin purpose or destination purpose of “shop.”
- 8,088 (36,827) trips with origin activity or destination activity of “eat a meal outside of home or work.”

5.4 Next Steps in the Process

The next three steps in the process were to extract the data outlined in the following. Details of the extraction processes undertaken are provided in Chapter 6.

- The research team requested detailed GIS information for the Washington, D.C., metropolitan area aggregated at the TAZ level to analyze and identify zones that meet the general urban/urban center criteria. Once the GIS data were obtained and analyzed, the research team developed a map of the zones classified as general urban/urban center. Subsequently, the research team extracted the appropriate records from the dataset and assessed the viability of the resulting data for use in the proposed methodology.
- Viable data were used to produce a series of mode share matrices by land use type, time of day, and direction of travel. These matrices were used to populate the variables in the proposed methodology’s equations. The research team then documented the viability assessment in a brief report that also documents limitations and potential sources of error in the data.
- Once the research team confirmed the viability of the data, they systematically sought sites within the Washington, D.C., metropolitan area for use in the validation case study. The search process used GIS data, Google Maps, and the knowledge of the research team’s staff (Kimley-Horn and Associates in Northern Virginia). The research team then prepared a validation site-selection work plan documenting selection criteria and data collection procedures.

CHAPTER 6

Analysis of Household Travel Survey Data

This chapter describes how the research team distilled household travel survey data for the Washington, D.C., case study selected in Chapter 5 to segregate trips and mode share to and from TAZs that met the criteria for the four primary land use categories being studied (residential, restaurant, retail, and office). Further, this chapter describes the process used to identify candidate sites within these TAZs that could be used to collect cordon traffic counts to validate the methodology proposed in this research project.

6.1 GIS Analysis

The research team obtained GIS information from several sources for the purpose of identifying TAZs that met the criteria described in the previous section. Following are the primary GIS layers used during the analysis, as well as the source of the data:

- Traffic analysis zones – 3,669 records were included in the database provided by the Metropolitan Washington Council of Governments.
- Metro lines – Five records were included in the database obtained from the website http://data.dc.gov/.
- Metro stations – 86 records were included in the database obtained from the website http://data.dc.gov/.
- Bus lines – 178 records were included in the database obtained from the website http://data.dc.gov/.
- Bus stops – 12,091 records were included in the database obtained from the website http://data.dc.gov/.

Using information provided in the TAZ layer, the research team first identified TAZs that met the general urban/urban center criteria detailed in Chapter 4. Accordingly, the TAZ was required to have employment per gross acre exceeding 70 or households per gross acre exceeding 40 to be identified as general urban/urban center. The Metro station GIS layer was used to identify TAZs in which transit service covers greater than 33% of the TAZs physical area based on a ½-mile service radius extending out from each of the stations.

As described in Chapter 4, "high-frequency bus stops" are defined as being stops served by lines with 15-min headways that are maintained for at least 6 hours of each weekday or are located within transit corridors with multiple lines traveling in the same direction that effectively meet the 15-min headway criterion. During the next step, the research team identified TAZs in which greater than 33% of the zone's area was accessible based on a ¼-mile service radius extending out from high-frequency bus stops.

The research team's analysis of the San Francisco Bay Area travel survey data was comparatively simple given that MTC provides GIS data including bus transit headways and schedules by stop. Based on a review of available GIS files from the candidate metropolitan areas, recent bus transit headway data in GIS format may not typically be available. As a result, these data had to be obtained and coded into GIS separately. Figure 6.1 demonstrates how the GIS analysis was carried out.

6.2 Household Travel Survey Analysis

The investigators then reviewed the linked-trip data of the individual TAZs meeting both the general urban/urban center and rail transit proximity criteria described earlier. Subsequently, the data contained in the linked-trip records were further disaggregated by applying the following screens:

- Trip purpose or activity at origin and destination to isolate trips representing each of the four proposed study land uses (residential, restaurant, retail, and office).
- a.m. and p.m. peak periods.
- Inbound and outbound records for origin and destination.
- Vehicle occupancy for trips by automobile mode.

This same process was applied to the general urban/urban center TAZs that met the high-frequency bus stop criteria.

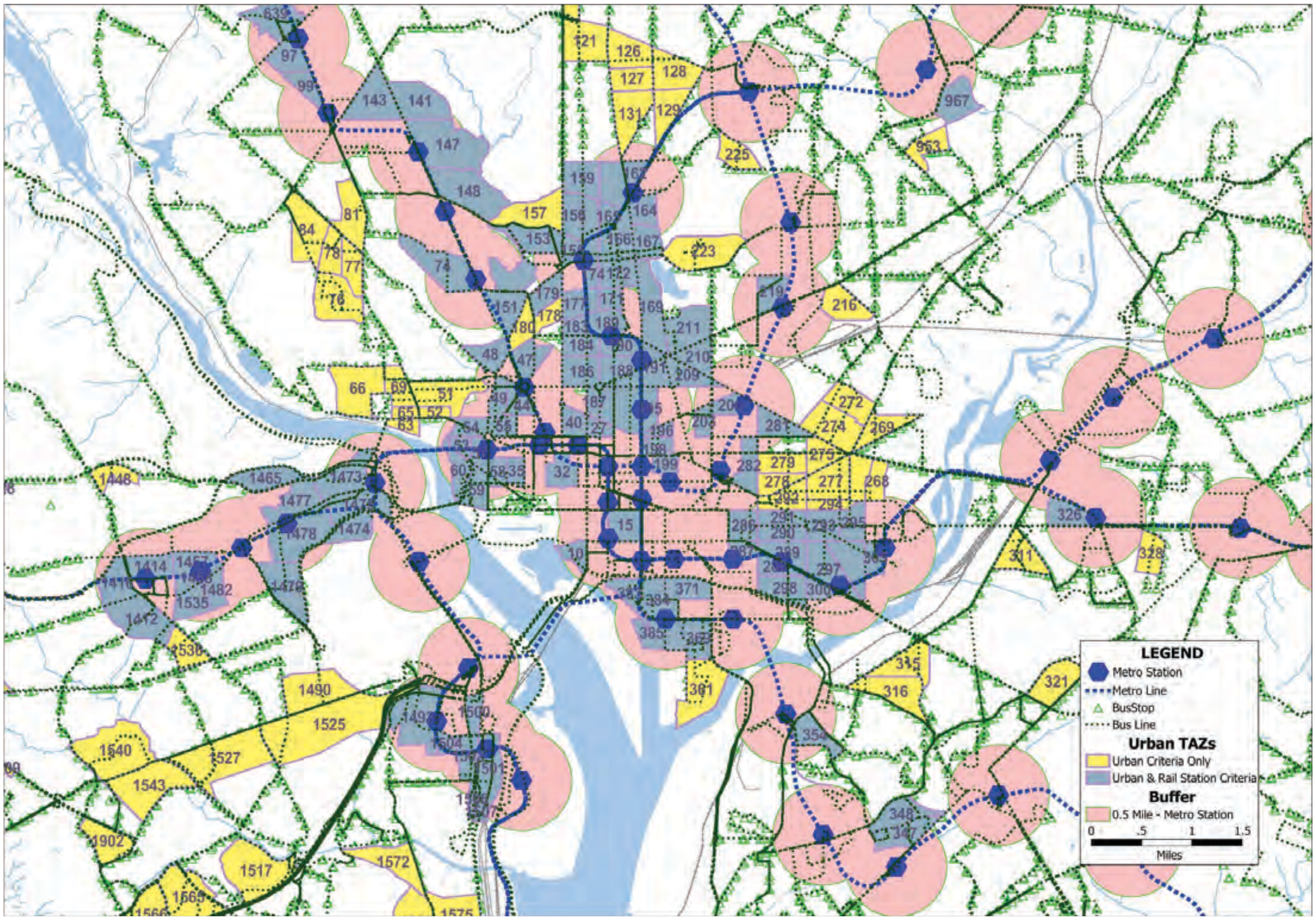


Figure 6.1. Example GIS analysis of TAZs.

The Washington, D.C., HTS is activity-based and not place-based, so the type of land use at the origin or destination of the trip needs to be inferred from the trip purpose description provided in the trip records. Survey participants selected from 13 different predetermined trip purposes (or activities). From these, the investigators chose those activities that best represented the activity for a specific land use. Given the manner in which the household travel survey was conducted, trips made by delivery or service people (with the exception of survey participants who are employed in these fields) were not captured. This is a potential source of undercounting in estimating actual trips for each of the study's land uses.

The following is a brief overview regarding trip purposes and potential sources of error for each of the study's four land uses, as also documented in the application of the methodology to the 2000 BATS:

- Residential trips are identified as those with an origin trip purpose or a destination trip purpose classified as "home." As one would expect, the vast majority of the trip records are reported by residents, and nonresident trips are not well represented. As such, the records likely under-report trips related to deliveries, services, and guest trips unless recorded as an activity by another survey participant.
- Restaurant trips are identified as those with an origin activity or a destination activity classified as "eat a meal outside of home or work." The trip records only include patron trips and do not capture employee, delivery, or service trips unless recorded by another survey participant. This may affect calculation of the mode split or vehicle occupancy since restaurant patrons may have significantly different travel characteristics to and from restaurants than employees of the restaurant. Employee-related trips are captured in the "work" trip purpose.
- Retail or shopping center trips are identified as those with an origin trip purpose or a destination trip purpose classified as "shop." Like restaurants, the trip records for shopping only include patron trips and do not capture employee, delivery, or service trips unless recorded by another survey participant. This may affect calculation of the mode split

and vehicle occupancy. Employee-related trips are captured in the "work" trip purpose.

- Office building trips are identified as those with an origin trip purpose or a destination trip purpose classified as "work." Based on this descriptor, it is not possible to positively determine whether a work trip has an origin or destination that is an office building. During the Phase 1 assessment of the 2000 BATS data, it was determined that this potential source of error may be acceptable because the MTC's detailed documentation of the household survey data suggested that mode split and vehicle occupancy for office trips were similar to those of aggregated non-office work trips. The investigators are not certain this finding is applicable to other metropolitan areas and are attempting to find sources that will validate the premise in the Washington, D.C., area.

6.2.1 Extracting Mode Split and Vehicle Occupancy from Household Travel Survey Data

The linked-trip records for each land use category were disaggregated by mode to determine mode split percentages for transit, auto (driver and passenger), walk, bike, and other. This resulted in the derivation of adjustment factors by land use in proximity to rail stations and high-frequency bus routes for daily, a.m. peak, and p.m. peak hours. Detailed mode share tables are included in Appendix D of this technical report. This information was then used to populate the mode split adjustment and vehicle occupancy tables, shown in Appendix E of this technical report. The tables in the appendix also include the vehicle occupancy adjustments.

Using the proposed methodology, mode split data were used to determine the share of person trips generated by a land use category with travel by automobile, and the vehicle occupancy derived from the survey data was used to convert "person vehicle trips" to "vehicle trips." It should be noted that vehicle occupancy data from the household travel survey could only be obtained when the participant was the driver of the vehicle. Vehicle occupancy when the participant was a passenger was not collected as part of this HTS. The mode split linked-trip records were disaggregated to inbound and outbound trips for the four land use categories that met the rail criteria. This same process was conducted on the trip records that met the high-frequency bus stop criteria.

CHAPTER 7

Selection of Candidate Sites for Cordon Counts

This chapter describes the process for collecting the empirical data for validating the Washington, D.C., case study. The process of selecting the candidate sites is summarized in the following:

- **Finalize cordon count procedures.** The research team finalized data collection procedures initially developed earlier in the study. The procedures were designed to collect peak-hour automobile trip data for establishing trip generation rates, and secondarily to collect person-trip data for establishing mode share.
- **Conduct cordon counts at urban infill sites and suburban control sites.** Assess candidate sites against meeting the selection criteria, and assess suburban sites selected for use as control sites. Data were collected for representative sites making up the four primary land use categories (residential, restaurant, retail, and office) identified for study.
- **Review and compare cordon count data.** Check the count data for errors or unreasonable results. Compare the vehicle cordon counts to an estimate of site traffic calculated using ITE data for similar land uses. Use the cordon counts and the site's independent variable (e.g., square feet of floor area, dwelling units) to derive a trip generation rate for the validation site and compare the validation site's trip generation rates with the trip generation rates published in the ITE *Trip Generation Manual* for the same land use classification.

7.1 Selecting Urban Infill Sites for Cordon Counts

The research team identified the TAZs in the Washington, D.C., metropolitan area that met the criteria established for defining general urban/urban center contexts. Candidate sites within these TAZs were screened based on their proximity to "high-frequency bus stops" or rail stations. The sites remaining after screening for context and transit proximity were further evaluated using aerial photography and subsequent field investigations to confirm that they possessed the required qualitative characteristics and that the sites could be cost-effectively surveyed. Field investigations recorded observable information regarding land uses, data collection requirements and challenges, and other local conditions. Finally, the research team reviewed the details of each site and prioritized the candidate locations based on:

- The ability of the site to meet site-selection criteria.
- That the surrounding context met the definition of general urban/urban center.
- That the site met the criteria for proximity to transit, and the transit system met the criteria for quality of service.
- That the necessary data could be collected from the site cost-effectively.

Using the approach described, the research team identified 30 candidate sites but determined that further information was needed before expending limited resources on collecting data—information that could only be confirmed visually in the field. Senior members of the research team experienced in data collection visited the candidate sites on weekdays during the month of November 2011. Site-specific data collection plans were prepared for the high-priority locations that satisfied the scrutiny of the team's engineers in the field. As a result of the site visits, the research team rejected five of the candidate sites primarily related to the practicality of collecting data (three residential, one office, and one restaurant). The research team replaced the five rejected candidate sites with new residential, office, and retail sites (one residential, two office, and two retail sites). The replacement sites were subjected to the selection criteria and field investigations to determine their viability as candidates for use in validation.

The final step before collecting data required by the research team was to contact each site's owner or its representative to confirm its participation in the study and to determine required land use attributes and independent variables. Owner inquiries were, as required, supplemented with public database searches to determine required land use attributes (i.e., gross square feet, number of employees, residential units).

7.1.1 Selecting Suburban Control Sites for Cordon Counts

In addition to the urban infill sites selected for data collection, a representative suburban site was identified for each of the four land uses to serve as the control population (to be compared with ITE trip generation data, which are primarily based on suburban locations). The suburban sites were also subject to meeting selection criteria, field investigations, and preparation of site-specific data collection plans.

7.1.2 Final Validation Sites

Based on the research panel's input, 14 sites were ultimately selected from the candidate pool. Ten of the 14 locations represented urban infill developments (four residential, three office, two retail, and one restaurant site). The remaining four sites represented developments in suburban contexts for use as control sites. Appendix F of this technical report includes a summary of candidate sites and their relative prioritization.

7.2 Summary of the Data Collection Procedures

7.2.1 Data Collection Dates and Time Periods

The cordon counts of automobiles entering and exiting the sites were manually conducted during peak periods at each of the 14 study sites. For the purposes of this research study, a.m. and p.m. peak periods for the residential, office, and retail sites were identified as occurring between 7 a.m. and 9 a.m. and 4 p.m. and 6 p.m., respectively. These time periods contain the typical morning and afternoon hour representing the "peak hour of the adjacent street"—a common time period used in traffic impact analyses for the aforementioned land uses. As the restaurant location generated an insignificant level of traffic during the traditional morning peak hour, counts were conducted during the lunch peak period (11:30 a.m. to 1:30 p.m.) as well as the traditional afternoon peak period (4:00 p.m. to 6:00 p.m.). The counts were conducted mid-week (Tuesday, Wednesday, and Thursday) between November 8, 2011, and November 10, 2011, or between November 15, 2011, and November 17, 2011.

7.2.2 Data Collection Methodology

Research team personnel stationed at each of the study site's parking lot or garage access driveways recorded inbound and outbound vehicle trips and vehicle occupancy during the peak periods in 15-min increments. Since the intent of the cordon counts is to capture all of the vehicle trips generated by the site, the survey personnel recorded vehicle trips that were observed parking off-site (e.g., the adjacent street) and for which occupants subsequently entered/exited the study site. The selection process attempted to avoid sites where visitors to the site chose to park on-street even when there was available and free off-street parking at the site itself. During the preliminary site investigation visits, candidate sites that were observed to have a significant number of trips originating from vehicles parked on-street were not selected for the data collection phase. Further, potential study sites were excluded from consideration if attractive or viable off-site parking options, such as nearby parking garages or lots, were available within reasonable proximity to the site. Off-site parking potentially introduces errors into the accuracy of the cordon counts.

7.2.3 Additional Data Collection

In addition to the vehicle trips, survey personnel recorded other trip information that could be used as either local data in the proposed trip generation methodology or could be useful in validating the methodology. These data include:

- **Person trips.** Survey personnel recorded the number of people entering and exiting the site's building(s) regardless of their mode of access. This information was recorded only if all of the building access points were visible to survey personnel and recording these trips did not interfere with the accuracy of the vehicle counts.
- **Mode of access.** Survey personnel recorded the mode of travel for each of the persons observed entering the site's building when recording person trips. Mode of access (vehicle, walk, bike, or transit) was recorded only if the recorded person's mode of transportation was clearly observed by the survey personnel.
- **General observations of site conditions.** Survey personnel observed and recorded the level of bicycle and transit activity in the streets surrounding the site, the surveyor's judgment of the walkability of the adjacent streets (in terms of comfort, safety, and directness), and other conditions unique to each site that might influence the site's trip generation characteristics.

Based on the general observations recorded by both the survey personnel and supervising research team members during the course of the data collection, there was general agreement that there was a greater use of more nonmotorized modes of travel in the vicinity of the selected urban infill sites than the selected suburban control sites (primarily pedestrian and bike). Pedestrians were frequently observed walking to and from the general direction of Metro stations, while suburban sites, in contrast, were observed to have little or no pedestrian and bicycle activity. Appendix G of this technical report includes a sample of the results of the data collection surveys.

SUPPLEMENTAL TECHNICAL REPORT
APPENDIX A

Overview of Household Travel Surveys Assessed for Case Study

Atlanta (Atlanta Regional Commission)

- Most recent survey completed in 2002.
- Dataset includes approximately 8,000 households and 151,000 trips.
- Survey data are not geo-coded, and transit information is not readily available in GIS.
- TAZ information is available in GIS.
- Currently in the process of preparing a new household survey, anticipate completion in 2012.
- Candidate metro area not recommended based on age of data and limited number of records. In addition, lack of GIS coded data would increase challenges.

Dallas (North Central Texas Council of Governments)

- Most recent survey completed in 2009 as part of the NHTS.
- Dataset includes approximately 5,900 households and 49,000 trips.
- TAZ and transit information in GIS, including bus routes.
- It is unknown when household travel survey will be updated.
- Candidate metro area not recommended based on expectation that the number of records available would not meet needs of the methodology.

Denver (Denver Regional Council of Governments)

- Survey conducted in 2010, and currently in process of developing weighting and expansion factors, which should be complete by October 2011.
- Dataset includes approximately 12,000 households, 100,000 trips.
- TAZ and transit information in GIS, including bus routes.
- Public use files not yet available; however, may be able to obtain trip data without personal information—discussed with MPO.
- Candidate metro area not recommended based on unavailability of weighting and expansion factors. However, if there are insufficient trip records from the Washington, D.C., survey, Denver could be substituted as the case study metro area.

Salt Lake City (Wasatch Front Regional Council)

- Last survey conducted in 1993.
- Research team waited for response on size of dataset and number of trip records.
- MPO in the process of selecting consultant to conduct statewide household travel survey with anticipated completion in 2012 or 2013.
- Candidate metro area not recommended based on age of survey data.

Washington, D.C. (Metropolitan Washington Council of Governments)

- Most recent survey completed in 2008.
- Dataset includes approximately 11,000 households and 88,000 trips.
- TAZ and transit information in GIS, including bus routes.
- Candidate metro area selected by research team based on availability of recent data, immediate availability of public use files, and available GIS information.

SUPPLEMENTAL TECHNICAL REPORT
APPENDIX B

Detailed Mode Share Tables for San Francisco Bay Area Example

Entire Bay Area

Bay Area - Residential

Bike	2,636	1.5%
Walk	13,312	7.6%
Bus	4,055	2.3%
Rail/Ferry	4,431	2.5%
Car	150,677	85.6%
Other	972	0.6%
Records	176,083	
Veh.Occ.	1.84	

Bay Area - Restaurant

Bike	340	0.9%
Walk	4,942	13.4%
Bus	429	1.2%
Rail/Ferry	631	1.7%
Car	30,338	82.4%
Other	147	0.4%
Records	36,827	
Veh.Occ.	2.12	

Bay Area - Retail

Bike	618	0.9%
Walk	4,363	6.5%
Bus	652	1.0%
Rail/Ferry	568	0.8%
Car	60,822	90.4%
Other	272	0.4%
Records	67,295	
Veh.Occ.	1.72	

Bay Area - Work

Bike	955	1.3%
Walk	4,621	6.4%
Bus	1,845	2.6%
Rail/Ferry	3,548	4.9%
Car	60,945	84.3%
Other	361	0.5%
Records	72,275	
Veh.Occ.	1.27	

Urban Area — Weekday Trips

Urban Area - Residential Weekday

Bike	593	2.8%
Walk	2,841	13.5%
Bus	1,303	6.2%
Rail/Ferry	1,446	6.9%
Car	14,628	69.7%
Other	172	0.8%
Records	20,983	
Veh.Occ.	1.66	

Urban Area - Restaurant Weekday

Bike	107	2.1%
Walk	1,298	25.2%
Bus	163	3.2%
Rail/Ferry	253	4.9%
Car	3,293	64.0%
Other	29	0.6%
Records	5,143	
Veh.Occ.	1.91	

Urban Area - Retail Weekday

Bike	178	2.3%
Walk	1,250	16.4%
Bus	267	3.5%
Rail/Ferry	175	2.3%
Car	5,691	74.8%
Other	44	0.6%
Records	7,605	
Veh.Occ.	1.56	

Urban Area - Work Weekday

Bike	299	2.8%
Walk	1,110	10.3%
Bus	727	6.8%
Rail/Ferry	1,049	9.8%
Car	7,509	69.8%
Other	61	0.6%
Records	10,755	
Veh.Occ.	1.31	

Proximity to Bus Station — Weekday Trips

Bus - Residential Weekday

Bike	579	2.8%
Walk	2,814	13.8%
Bus	1,273	6.2%
Rail/Ferry	1,436	7.0%
Car	14,098	69.2%
Other	172	0.8%
Records	20,372	
Veh.Occ.	1.65	

Bus - Restaurant Weekday

	Bike	106	2.1%
16.7%	Walk	1,292	25.6%
	Bus	161	3.2%
13.3%	Rail/Ferry	253	5.0%
	Car	3,203	63.5%
	Other	29	0.6%
	Records	5,044	
	Veh.Occ.	1.90	

Bus - Retail Weekday

	Bike	175	2.4%
27.7%	Walk	1,231	16.7%
	Bus	266	3.6%
8.2%	Rail/Ferry	174	2.4%
	Car	5,464	74.3%
	Other	44	0.6%
	Records	7,354	
	Veh.Occ.	1.55	

Bus - Work Weekday

	Bike	297	2.8%
19.1%	Walk	1,108	10.5%
	Bus	705	6.7%
6.0%	Rail/Ferry	1,047	10.0%
	Car	7,301	69.4%
	Other	61	0.6%
	Records	10,519	
	Veh.Occ.	1.31	

Proximity to Bus Station — Weekday AM Peak Trips

Bus - Residential Weekday - AM Peak

Bike	118	2.5%
Walk	524	10.9%
Bus	427	8.9%
Rail/Ferry	544	11.3%
Car	3,158	65.8%
Other	31	0.6%
Records	4,802	
Veh.Occ.	1.61	

Bus - Restaurant Weekday - AM Peak

	Bike	11	2.5%
13.4%	Walk	81	18.3%
	Bus	44	10.0%
20.2%	Rail/Ferry	74	16.7%
	Car	231	52.3%
	Other	1	0.2%
	Records	442	
	Veh.Occ.	1.37	

Bus - Retail Weekday - AM Peak

	Bike	11	2.7%
20.8%	Walk	36	8.8%
	Bus	29	7.1%
26.7%	Rail/Ferry	23	5.6%
	Car	309	75.2%
	Other	3	0.7%
	Records	411	
	Veh.Occ.	1.50	

Bus - Work Weekday - AM Peak

	Bike	63	2.3%
11.4%	Walk	171	6.1%
	Bus	259	9.3%
12.7%	Rail/Ferry	400	14.3%
	Car	1,894	67.6%
	Other	13	0.5%
	Records	2,800	
	Veh.Occ.	1.36	

Proximity to Bus Station — Weekday PM Peak Trips

Bus - Residential Weekday - PM Peak

Bike	106	2.7%
Walk	422	10.6%
Bus	319	8.0%
Rail/Ferry	377	9.5%
Car	2,716	68.3%
Other	35	0.9%
Records	3,975	
Veh.Occ.	1.60	

Bus - Restaurant Weekday - PM Peak

	Bike	19	3.1%
13.3%	Walk	83	13.5%
	Bus	41	6.7%
17.5%	Rail/Ferry	47	7.6%
	Car	424	68.8%
	Other	2	0.3%
	Records	616	
	Veh.Occ.	2.07	

Bus - Retail Weekday - PM Peak

	Bike	31	2.4%
16.6%	Walk	170	12.9%
	Bus	69	5.2%
14.3%	Rail/Ferry	72	5.5%
	Car	973	73.8%
	Other	3	0.2%
	Records	1,318	
	Veh.Occ.	1.49	

Bus - Work Weekday - PM Peak

	Bike	67	2.5%
15.3%	Walk	167	6.2%
	Bus	239	8.8%
10.7%	Rail/Ferry	367	13.6%
	Car	1,856	68.5%
	Other	12	0.4%
	Records	2,708	
	Veh.Occ.	1.27	

Proximity to Rail Station — Weekday Trips

Rail - Residential Weekday

Bike	432	3.4%
Walk	1,760	13.8%
Bus	628	4.9%
Rail/Ferry	1,033	8.1%
Car	8,834	69.1%
Other	100	0.8%
Records	12,787	
Veh.Occ.	1.67	

Rail - Restaurant Weekday

	Bike	86	2.6%
17.1%	Walk	894	27.1%
	Bus	89	2.7%
13.0%	Rail/Ferry	181	5.5%
	Car	2,035	61.6%
	Other	18	0.5%
	Records	3,303	
	Veh.Occ.	1.92	

Rail - Retail Weekday

	Bike	134	3.0%
29.7%	Walk	760	16.9%
	Bus	156	3.5%
8.2%	Rail/Ferry	131	2.9%
	Car	3,293	73.2%
	Other	27	0.6%
	Records	4,501	
	Veh.Occ.	1.60	

Rail - Work Weekday

	Bike	217	3.1%
19.9%	Walk	805	11.5%
	Bus	325	4.6%
6.4%	Rail/Ferry	744	10.6%
	Car	4,877	69.6%
	Other	39	0.6%
	Records	7,007	
	Veh.Occ.	1.31	

Proximity to Rail Station — Weekday AM Peak Trips

Rail - Residential Weekday - AM Peak

Bike	79	2.7%
Walk	311	10.5%
Bus	202	6.8%
Rail/Ferry	369	12.5%
Car	1,981	66.9%
Other	20	0.7%
Records	2,962	
Veh.Occ.	1.58	

Rail - Restaurant Weekday - AM Peak

	Bike	10	3.9%
13.2%	Walk	43	16.7%
	Bus	22	8.6%
19.3%	Rail/Ferry	43	16.7%
	Car	138	53.7%
	Other	1	0.4%
	Records	257	
	Veh.Occ.	1.44	

Rail - Retail Weekday - AM Peak

	Bike	9	3.5%
20.6%	Walk	23	8.8%
	Bus	13	5.0%
25.3%	Rail/Ferry	21	8.1%
	Car	191	73.5%
	Other	3	1.2%
	Records	260	
	Veh.Occ.	1.55	

Rail - Work Weekday - AM Peak

	Bike	40	2.2%
12.3%	Walk	124	6.9%
	Bus	102	5.6%
13.1%	Rail/Ferry	271	15.0%
	Car	1,263	69.9%
	Other	6	0.3%
	Records	1,806	
	Veh.Occ.	1.35	

Proximity to Rail Station — Weekday PM Peak Trips

Rail - Residential Weekday - PM Peak

Bike	79	3.2%
Walk	265	10.6%
Bus	139	5.5%
Rail/Ferry	267	10.7%
Car	1,734	69.2%
Other	22	0.9%
Records	2,506	
Veh.Occ.	1.61	

Rail - Restaurant Weekday - PM Peak

	Bike	15	3.8%
13.7%	Walk	63	16.0%
	Bus	25	6.3%
16.2%	Rail/Ferry	36	9.1%
	Car	255	64.7%
	Other	0	0.0%
	Records	394	
	Veh.Occ.	2.13	

Rail - Retail Weekday - PM Peak

	Bike	27	3.4%
19.8%	Walk	104	13.0%
	Bus	42	5.2%
15.5%	Rail/Ferry	52	6.5%
	Car	576	71.7%
	Other	2	0.2%
	Records	803	
	Veh.Occ.	1.53	

Rail - Work Weekday - PM Peak

	Bike	48	2.7%
16.3%	Walk	120	6.7%
	Bus	105	5.9%
11.7%	Rail/Ferry	264	14.7%
	Car	1,248	69.6%
	Other	8	0.4%
	Records	1,793	
	Veh.Occ.	1.27	

SUPPLEMENTAL TECHNICAL REPORT
APPENDIX C

Example Output Tables for San Francisco Bay Area Infill Area Mode Share and Vehicle Occupancy Adjustment Factors

Example Daily Output Tables for San Francisco Bay Area Infill Area Mode Split and Vehicle Occupancy Adjustments to ITE Trip Generation Rates/Equations

Table A. Example summary of mode share adjustment factors by land use and proximity to transit for the San Francisco Bay Area (daily).

Land Use	Context Criteria	Type of Transit (Max 15-min Headway)	Proximity	Mode Share (All Trips)	
				Transit	Walk/Bike
Residential	**General urban/ urban center** (30–70 emp/gross acre) (10–40 DUs/gross acre)	Bus	Rail: ½-mile Bus: ¼-mile	13.3%	16.7%
		Rail		13.0%	17.1%
Restaurant		Bus		8.2%	27.7%
		Rail		8.2%	29.7%
Retail		Bus		6.0%	19.1%
		Rail		6.4%	19.9%
Office/work		Bus		16.7%	13.4%
		Rail		15.3%	14.6%

Based on 2000 BATS data from 93 TAZs around rail stations and 170 TAZs around high-frequency bus stops.
Rail and bus modes must have 15-min headways or shorter for at least 6 hours of the day to meet transit proximity criteria.

Table B. Example summary of average vehicle occupancy adjustment factors by land use for the San Francisco Bay Area (daily).

Land Use	Context	Average Vehicle Occupancy
Residential	**General urban/urban center** (30–70 emp/gross acre) (10–40 DUs/gross acre)	1.66
Restaurant		1.91
Retail		1.56
Office/work		1.31

Example a.m. Peak Hour Output Tables for San Francisco Bay Area Infill Area Mode Share and Vehicle Occupancy Adjustments to ITE Trip Generation Rates/Equations

Table A. Example summary of mode share adjustment factors by land use and proximity to transit for the San Francisco Bay Area (a.m. peak hour).

Land Use	Context Criteria	Type of Transit (Max 15-min Headway)	Proximity	Mode Share (All Trips)	
				Transit	Walk/Bike
Residential	**General urban/ urban center** (30–70 emp/gross acre) (10–40 DUs/gross acre)	Bus	Rail: ½ mile Bus: ¼ mile	20.2%	13.4%
		Rail		19.3%	13.2%
Restaurant		Bus		26.7%	20.8%
		Rail		25.3%	20.6%
Retail		Bus		12.7%	11.4%
		Rail		13.1%	12.3%
Office/work		Bus		23.5%	8.4%
		Rail		20.2%	13.4%

Based on 2000 BATS data from 93 TAZs around rail stations and 170 TAZs around high-frequency bus stops.
Rail and bus modes must have 15-min headways or shorter for at least 6 hours of the day to meet transit proximity criteria.

Table B. Example summary of average vehicle occupancy adjustment factors by land use for the San Francisco Bay Area (a.m. peak hour).

Land Use	Context	Average Vehicle Occupancy
Residential	**General urban/ urban center** (30–70 emp/gross acre) (10–40 DUs/gross acre)	1.62
Restaurant		1.37
Retail		1.49
Office/work		1.36

Example p.m. Peak Hour Output Tables for San Francisco Bay Area Infill Area Mode Share and Vehicle Occupancy Adjustments to ITE Trip Generation Rates/Equations

Table A. Example summary of mode share adjustment factors by land use and proximity to transit for the San Francisco Bay Area (p.m. peak hour).

Land Use	Context Criteria	Type of Transit (Max 15-min Headway)	Proximity	Mode Share (All Trips)	
				Transit	Walk/Bike
Residential	**General urban/ urban center** (30–70 emp/gross acre) (10–40 DUs/gross acre)	Bus	Rail: ½-mile Bus: ¼-mile	17.5%	13.3%
		Rail		16.2%	13.7%
Restaurant		Bus		14.3%	16.6%
		Rail		15.5%	19.8%
Retail		Bus		10.7%	15.3%
		Rail		11.7%	16.3%
Office/work		Bus		22.4%	8.6%
		Rail		17.5%	13.3%

Based on 2000 BATS data from 93 TAZs around rail stations and 170 TAZs around high-frequency bus stops.
Rail and bus modes must have 15-min headways or shorter for at least 6 hours of the day to meet transit proximity criteria.

Table B. Example summary of average vehicle occupancy adjustment factors by land use for the San Francisco Bay Area (p.m. peak hour).

Land Use	Context	Average Vehicle Occupancy
Residential	**General urban/ urban center** (30–70 emp/gross acre) (10–40 DUs/gross acre)	1.62
Restaurant		2.11
Retail		1.50
Office/work		1.27

SUPPLEMENTAL TECHNICAL REPORT
APPENDIX D

Detailed Mode Share Tables for the Washington, D.C., Case Study

Household Travel Survey Linked Trip Analysis

Mode Split Summary by Scenario

Washington DC Area

DC Area - Eat Out		
Transit	250	3.1%
Auto - Driver	3970	49.3%
Auto - Passenger	2242	27.9%
Walk	1464	18.2%
Bike	38	0.5%
Other	83	1.0%
Total Trip Records	**8047**	
Vehicle Occupancy	1.66	

DC Area - Residential		
Transit	4438	7.0%
Auto - Driver	38514	61.0%
Auto - Passenger	13003	20.6%
Walk	4078	6.5%
Bike	382	0.6%
Other	2692	4.3%
Total Trip Records	**63107**	
Vehicle Occupancy	1.35	

DC Area - Shopping		
Transit	844	3.0%
Auto - Driver	17684	62.6%
Auto - Passenger	6068	21.5%
Walk	3434	12.2%
Bike	92	0.3%
Other	141	0.5%
Total Trip Records	**28263**	
Vehicle Occupancy	1.40	

DC Area - Work		
Transit	3665	13.7%
Auto - Driver	18553	69.4%
Auto - Passenger	1352	5.1%
Walk	2634	9.8%
Bike	216	0.8%
Other	322	1.2%
Total Trip Records	**26742**	
Vehicle Occupancy	1.13	

Proximity to Rail Station
General Urban - Daily

Urban - Rail - Eat Out		
Transit	120	8.8%
Auto - Driver	391	28.6%
Auto - Passenger	218	16.0%
Walk	584	42.8%
Bike	15	1.1%
Other	37	2.7%
Total Trip Records	**1365**	
Vehicle Occupancy	1.66	

Urban - Rail - Residential		
Transit	1856	22.5%
Auto - Driver	3735	45.4%
Auto - Passenger	1068	13.0%
Walk	1290	15.7%
Bike	137	1.7%
Other	146	1.8%
Total Trip Records	**8232**	
Vehicle Occupancy	1.30	

Urban - Rail - Shopping		
Transit	372	9.7%
Auto - Driver	1571	40.8%
Auto - Passenger	458	11.9%
Walk	1364	35.4%
Bike	38	1.0%
Other	45	1.2%
Total Trip Records	**3848**	
Vehicle Occupancy	1.34	

Urban - Rail - Work		
Transit	1515	28.5%
Auto - Driver	2285	43.0%
Auto - Passenger	236	4.4%
Walk	1069	20.1%
Bike	98	1.8%
Other	108	2.0%
Total Trip Records	**5311**	
Vehicle Occupancy	1.15	

Proximity to Rail Station
General Urban - AM Peak

Urban - Rail - Eat Out		
Transit	6	12.2%
Auto - Driver	17	34.7%
Auto - Passenger	7	14.3%
Walk	19	38.8%
Bike	0	0.0%
Other	0	0.0%
Total Trip Records	**49**	
Vehicle Occupancy	1.35	

Urban - Rail - Residential		
Transit	653	32.5%
Auto - Driver	848	42.2%
Auto - Passenger	213	10.6%
Walk	219	10.9%
Bike	40	2.0%
Other	38	1.9%
Total Trip Records	**2011**	
Vehicle Occupancy	1.30	

Urban - Rail - Shopping		
Transit	44	19.7%
Auto - Driver	89	39.9%
Auto - Passenger	10	4.5%
Walk	78	35.0%
Bike	1	0.4%
Other	1	0.4%
Total Trip Records	**223**	
Vehicle Occupancy	1.16	

Urban - Rail - Work		
Transit	569	38.8%
Auto - Driver	641	43.7%
Auto - Passenger	59	4.0%
Walk	141	9.6%
Bike	34	2.3%
Other	22	1.5%
Total Trip Records	**1466**	
Vehicle Occupancy	1.15	

Proximity to Rail Station
General Urban - PM Peak

Urban - Rail - Eat Out		
Transit	23	16.1%
Auto - Driver	48	33.6%
Auto - Passenger	36	25.2%
Walk	32	22.4%
Bike	0	0.0%
Other	4	2.8%
Total Trip Records	**143**	
Vehicle Occupancy	1.69	

Urban - Rail - Residential		
Transit	506	27.7%
Auto - Driver	776	42.4%
Auto - Passenger	243	13.3%
Walk	257	14.0%
Bike	32	1.7%
Other	16	0.9%
Total Trip Records	**1830**	
Vehicle Occupancy	1.34	

Urban - Rail - Shopping		
Transit	107	16.5%
Auto - Driver	292	45.0%
Auto - Passenger	95	14.6%
Walk	142	21.9%
Bike	6	0.9%
Other	7	1.1%
Total Trip Records	**649**	
Vehicle Occupancy	1.36	

Urban - Rail - Work		
Transit	478	35.6%
Auto - Driver	610	45.4%
Auto - Passenger	67	5.0%
Walk	140	10.4%
Bike	28	2.1%
Other	21	1.6%
Total Trip Records	**1344**	
Vehicle Occupancy	1.17	

Prox to High Freq. Bus Stop
General Urban - Daily

Urban - Bus - Eat Out		
Transit	138	7.5%
Auto - Driver	646	34.9%
Auto - Passenger	337	18.2%
Walk	674	36.4%
Bike	17	0.9%
Other	40	2.2%
Total Trip Records	**1852**	
Vehicle Occupancy	1.62	

Urban - Bus - Residential		
Transit	2288	18.8%
Auto - Driver	6177	50.8%
Auto - Passenger	1620	13.3%
Walk	1634	13.4%
Bike	174	1.4%
Other	266	2.2%
Total Trip Records	**12159**	
Vehicle Occupancy	1.28	

Urban - Bus - Shopping		
Transit	441	8.1%
Auto - Driver	2591	47.5%
Auto - Passenger	720	13.2%
Walk	1605	29.4%
Bike	43	0.8%
Other	56	1.0%
Total Trip Records	**5456**	
Vehicle Occupancy	1.33	

Urban - Bus - Work		
Transit	1815	24.4%
Auto - Driver	3809	51.2%
Auto - Passenger	342	4.6%
Walk	1222	16.4%
Bike	125	1.7%
Other	128	1.7%
Total Trip Records	**7441**	
Vehicle Occupancy	1.13	

Prox to High Freq. Bus Stop
General Urban - AM Peak

Urban - Bus - Eat Out		
Transit	8	10.4%
Auto - Driver	33	42.9%
Auto - Passenger	13	16.9%
Walk	22	28.6%
Bike	1	1.3%
Other	0	0.0%
Total Trip Records	**77**	
Vehicle Occupancy	1.36	

Urban - Bus - Residential		
Transit	806	27.3%
Auto - Driver	1398	47.3%
Auto - Passenger	330	11.2%
Walk	282	9.5%
Bike	53	1.8%
Other	87	2.9%
Total Trip Records	**2956**	
Vehicle Occupancy	1.27	

Urban - Bus - Shopping		
Transit	50	15.4%
Auto - Driver	154	47.5%
Auto - Passenger	22	6.8%
Walk	94	29.0%
Bike	2	0.6%
Other	2	0.6%
Total Trip Records	**324**	
Vehicle Occupancy	1.20	

Urban - Bus - Work		
Transit	698	33.4%
Auto - Driver	1074	51.5%
Auto - Passenger	82	3.9%
Walk	161	7.7%
Bike	44	2.1%
Other	28	1.3%
Total Trip Records	**2087**	
Vehicle Occupancy	1.13	

Prox to High Freq. Bus Stop
General Urban - PM Peak

Urban - Bus - Eat Out		
Transit	29	13.8%
Auto - Driver	89	42.4%
Auto - Passenger	51	24.3%
Walk	37	17.6%
Bike	0	0.0%
Other	4	1.9%
Total Trip Records	**210**	
Vehicle Occupancy	1.71	

Urban - Bus - Residential		
Transit	631	24.0%
Auto - Driver	1255	47.8%
Auto - Passenger	358	13.6%
Walk	312	11.9%
Bike	40	1.5%
Other	32	1.2%
Total Trip Records	**2628**	
Vehicle Occupancy	1.32	

Urban - Bus - Shopping		
Transit	126	13.5%
Auto - Driver	481	51.4%
Auto - Passenger	142	15.2%
Walk	172	18.4%
Bike	6	0.6%
Other	8	0.9%
Total Trip Records	**935**	
Vehicle Occupancy	1.36	

Urban - Bus - Work		
Transit	585	31.0%
Auto - Driver	992	52.5%
Auto - Passenger	93	4.9%
Walk	161	8.5%
Bike	36	1.9%
Other	23	1.2%
Total Trip Records	**1890**	
Vehicle Occupancy	1.16	

SUPPLEMENTAL TECHNICAL REPORT
APPENDIX E

Output Tables for Washington, D.C., Infill Area Mode Share and Vehicle Occupancy Adjustment Factors

Washington, D.C., Household Travel Survey Linked-Trip Analysis

Output Tables for Infill Area Mode Split and Vehicle Occupancy Adjustments to ITE Trip Generation Rates/Equations

Table A. Summary of mode share adjustment factors by land use and proximity to transit for the Washington, D.C., case study area (daily).

Land Use	Context/Area Type	Transit Mode Available (<15-min Headway)	Transit Proximity	Mode Share	
				Percent by Transit	Percent by Nonmotorized
Residential	General urban/urban center	Bus	<¼ mile	18.8%	14.9%
		Rail	<½ mile	22.5%	17.3%
Restaurant		Bus	<¼ mile	7.5%	37.3%
		Rail	<½ mile	8.8%	43.9%
Retail		Bus	<¼ mile	8.1%	30.2%
		Rail	<½ mile	9.7%	36.4%
Office/work		Bus	<¼ mile	24.4%	18.1%
		Rail	<½ mile	28.5%	22.0%

Table B. Summary of average vehicle occupancy adjustment factors by land use for the Washington, D.C., case study area (daily).

Land Use	Context/Area Type	A (Bus)	A (Rail)
		Veh. Occ.	Veh. Occ.
Residential	General urban/urban center	1.28	1.30
Restaurant		1.62	1.66
Retail		1.33	1.34
Office/work		1.13	1.15

Washington, D.C., Household Travel Survey Linked-Trip Analysis

Output Tables for Infill Area Mode Split and Vehicle Occupancy Adjustments to ITE Trip Generation Rates/Equations

Table A. Summary of mode share adjustment factors by land use and proximity to transit for the Washington, D.C., case study area (a.m. peak hour).

Land Use	Context/Area Type	Transit Mode Available (<15-min Headway)	Transit Proximity	Mode Share	
				Percent by Transit	Percent by Nonmotorized
Residential	General urban/urban center	Bus	<¼ mile	27.3%	11.3%
		Rail	<½ mile	32.5%	12.9%
Restaurant		Bus	<¼ mile	10.4%	29.9%
		Rail	<½ mile	12.2%	38.8%
Retail		Bus	<¼ mile	15.4%	29.6%
		Rail	<½ mile	19.7%	35.4%
Office/work		Bus	<¼ mile	33.4%	9.8%
		Rail	<½ mile	38.8%	11.9%

Table B. Summary of average vehicle occupancy adjustment factors by land use for the Washington, D.C., case study area (a.m. peak hour).

Land Use	Context/Area Type	A (Bus)	A (Rail)
		Veh. Occ.	Veh. Occ.
Residential	General urban/urban center	1.27	1.30
Restaurant		1.36	1.35
Retail		1.20	1.16
Office/work		1.13	1.15

Washington, D.C., Household Travel Survey Linked-Trip Analysis

Output Tables for Infill Area Mode Split and Vehicle Occupancy Adjustments to ITE Trip Generation Rates/Equations

Table A. Summary of mode share adjustment factors by land use and proximity to transit for the Washington, D.C., case study area (a.m. peak hour).

Land Use	Context/Area Type	Transit Mode Available (<15-min Headway)	Transit Proximity	Mode Share	
				Percent by Transit	Percent by Nonmotorized
Residential	General urban/urban center	Bus	<¼ mile	24.0%	13.4%
		Rail	<½ mile	27.7%	15.8%
Restaurant		Bus	<¼ mile	13.8%	17.6%
		Rail	<½ mile	16.1%	22.4%
Retail		Bus	<¼ mile	13.5%	19.0%
		Rail	<½ mile	16.5%	22.8%
Office/work		Bus	<¼ mile	31.0%	10.4%
		Rail	<½ mile	35.6%	12.5%

Table B. Summary of average vehicle occupancy adjustment factors by land use for the Washington, D.C., case study area (p.m. peak hour).

Land Use	Context/Area Type	A (Bus)	A (Rail)
		Veh. Occ.	Veh. Occ.
Residential	General urban/urban center	1.32	1.34
Restaurant		1.71	1.69
Retail		1.36	1.36
Office/work		1.16	1.17

SUPPLEMENTAL TECHNICAL REPORT
APPENDIX F

Prioritization of Candidate Sites for Cordon Counts

Site Name	Location	Land Use	Proximity to Transit
PRIORITY 1 SITES: IDEAL CANDIDATES FOR STUDY (FEW APPARENT LOGISTICAL CHALLENGES FOR DATA COLLECTION)			
The Flats at Dupont Circle	2000 N Street Northwest	Multi-family Residential (Apartments)	<0.30 mi to Metro Rail Station
1315 Rhode Island Avenue	1315 - 1333 Rhode Island Avenue NE, Washington DC	Retail (Retail Strip Mall w/ Mix of Types)	<0.25 miles to High-Frequency Bus Service
Columbia Uptown	1375 Fairmont Street NW, Washington DC 20009	Multi-family Residential (Apartments and Corporate Housing)	<0.30 mi to Metro Rail Station
The Beauregard	2100 11th Street, NW	Multi-family Residential (Condominiums)	<0.25 mi to Metro Rail Station
Langston Lofts	1390 V Street, NW, Washington DC, 20009	Multi-family Residential (Condominiums)	<0.25 mi to Metro Rail Station
The Flats at Union Row	2125 14th Street NW, Washington DC 20009	Multi-family Residential (High Rise Condominiums)	<0.30 mi to Metro Rail Station
111 Massachusetts Avenue	111 Massachusetts Avenue, NW, Washington DC 20001	Office Building	<0.40 mi to Metro Rail Station
Jamaican Restaurant	1333 Rhode Island Avenue NE, Washington DC	High-Turnover (Sit-Down) Restaurant	<0.25 miles to High-Frequency Bus Service
Café & Restaurant	3740 12th Street NE, Washington DC	High-Turnover (Sit-Down) Restaurant	<0.30 mi to Metro Rail Station
PRIORITY 2 SITES: GOOD CANDIDATES FOR STUDY (SOME APPARENT LOGISTICAL CHALLENGES FOR DATA COLLECTION)			
Park Place Apartments	850 Quincy Street NW, Washington D.C. 20011	Multi-family Residential (Apartments)	<0.1 mi to Metro Rail Station
The Rhapsody	2120 Vermont Avenue NW, Washington D.C. 20001	Multi-family Residential (Condominiums)	<0.25 mi to Metro Rail Station
The Caravel Building	1601 Connecticut Avenue, Washington D.C. 20009	Office Building w/ Ground Floor Retail (separate access)	<0.25 mi to Metro Rail Station
Sibley Plaza	1140 N Capitol Street NW, Washington DC 20002	Multi-family Residential (Apartments)	<0.50 mi to Metro Rail Station
1920 N Street	1920 N Street NW, Washington D.C. 20036	Office Building	<0.30 mi to Metro Rail Station
1501 M Street	1501 M Street, NW, Washington, DC 20005	Office Building	<0.40 mi to Metro Rail Station
The Floridian	929 Floridia Avenue, NW, Washington DC 20001	Multi-family Residential (Condominiums)	<0.30 mi to Metro Rail Station
314 Wisconsin Ave	314 Wisconsin Ave, Washington DC	Multi-family Residential (apartment)	<0.25 miles to High-Frequency Bus Service
400 New York Avenue, NW	400 New York Avenue, NW, Washington DC 20001	Multi-family Residential	<0.40 mi to Metro Rail Station
Gelmarc Towers	1930 Columbia Road NW , Washington DC 20009	Multi-family Residential (High Rise Condominiums)	<0.25 miles to High-Frequency Bus Service
325 7th Street	325 7th Street, NW, Washingotn DC 20004	Office Building w/ Ground Floor Retail (Separate Access)	<0.1 mi to Metro Rail Station
600 13th Street	600 13th Street, NW Washington DC	Office w/ Ground Floor Retail	<0.25 mi to Metro Rail Station
1909 K Street / 1925 K Street	1909 K Street / 1925 K Street	Office Building	<0.40 miles to High-Frequency Bus Service
PRIORITY 3 SITES: POTENTIAL CANDIDATES FOR STUDY (CONSIDERABLE LOGISTICAL CHALLENGES FOR DATA COLLECTION)			
Logan Station - Logan Circle	1210 + 1224 R Street, NW Washington, DC 20009	Multi-family Residential (Condominiums)	<0.25 mi to Metro Rail Station
The Altamont	1901 Wyoming Avenue, NW Washington, DC 20009	Multi-family Residential (Condominiums)	<0.25 mi to Metro Rail Station
The Chesterfield	3315 Wisconsin Avenue , NW, Washingont DC 20016	Multi-family Residential (Apartments)	<0.25 miles to High-Frequency Bus Service
Gables City Vista	460 L Street, NW, Washingotn DC 20001	Multi-family Residential (High Rise Apartments)	<0.40 mi to Metro Rail Station
The L	440 L Street, NW, Washington DC 20001	Multi-family Residential (High Rise Condominiums)	<0.40 mi to Metro Rail Station
Park Triangle Apartments Loft and Flats	1375 Kenyon Street Northwest, Washington DC, 20010	Multi-family Residential (High Rise Apartments, Condominiums)	<0.25 mi to Metro Rail Station
Museum Square Apartments	401 K Street, NW, Washington DC. 20001	Multi-family Residential (Apartments)	<0.50 mi to Metro Rail Station
The Cambridge	1221 Massachusetts Ave., NW, Washington DC 20005	Multi Family Residential	<0.40 mi to Metro Rail Station
The Belvedere	1301 Massachusetts Ave., NW, Washington DC 20005	Multi Family Residential	<0.40 mi to Metro Rail Station
Park Monroe Apartments	3300 16th Street Northwest, Washington, DC 20010	Multi-family Residential (High Rise Apartments)	<0.25 miles to High-Frequency Bus Service

Total Preliminary Sites Identified: 32
Residential Sites Identified: 22
Retail Sites Identified: 1
Office Sites Identified: 7
Restaurant Sites Identified: 2

SUPPLEMENTAL TECHNICAL REPORT
APPENDIX G

Example Data Summaries for Candidate Sites

Kimley-Horn and Associates, Inc.

4/26/2012

SITE SUMMARY: Study Site #9

Site Name: Jamaican Restaurant

Site Location: 1333 Rhode Island Avenue NE, Washington DC

Land Use Type: High-Turnover (Sit-Down) Restaurant

Site Characteristics:

	Quantity	
Studios Units:	N/A	D.U
1 Bedroom Units:	N/A	D.U
2 Bedrooms Units:	N/A	D.U
3 + Bedrooms Units:	N/A	D.U
Total	N/A	D.U

Building Area: 2,400 Sq. Ft. (estimate based on aerial photography)

Occupancy: 100%

Number of on-site parking spaces: Unknown

Cost of Parking: Free

Number of spaces per 1,000 square feet: N/A

Site Description:

Meets Density Criteria: Yes

Proximity to Transit: <0.25 miles to Bus Stop (Routes: 81,82,83,84,86,B8,B9,T18)

Survey Date: November 8, 2011

ITE Land Use Codes: ITE 932 (High-Turnover) Sit-Down Restaurant

Independent Variable: 1,000 Sq Ft.

Trip Rate Comparison:

	Midday Peak Hour			PM Peak Hour		
	In	Out	Total	In	Out	Total
ITE Trip Rate*	7.04	6.49	13.53	6.58	4.57	11.15
Directional Distribution	52%	48%	100%	59%	41%	100%
Surveyed Trip Rate	2.08	1.67	3.75	2.08	1.25	3.33
Directional Distribution	56%	44%	100%	63%	38%	100%

*ITE trip rate for A.M. Peak Hour of Generator used to compare to observed trip generation data for midday peak hour.

Observed Vehicle Occupancy**: N/A persons/veh

**Based on 15-min spot surveys. Sample size not large enough to estimate occupancy.

Notes/Observations:
- Restaurant closed for AM Peak, Midday Peak Hour studied instead (11:30am - 1:30 pm)
- Restaurant weekday business hours: 11:00am - 10:00pm.

Kimley-Horn and Associates, Inc.

4/26/2012

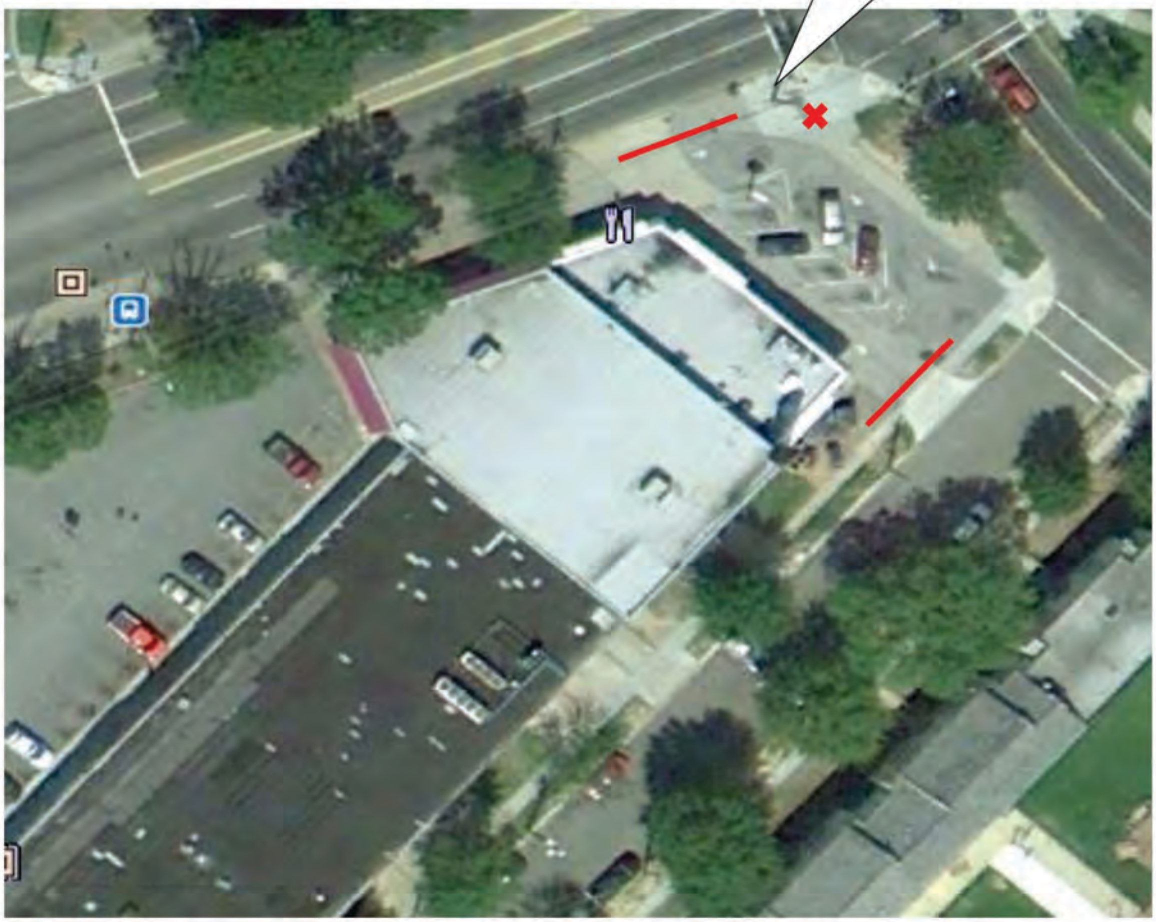
SITE SUMMARY: Study Site #9

Site Name: Caribbean Restaurant

Site Location: 1333 Rhode Island Avenue NE, Washington DC

Land Use Type: High-Turnover (Sit-Down) Restaurant

Count technician counts driveway trips and monitors any trips from on-street parking or adjacent parking lot.



Legend:

Garage/Parking Lot Driveway

Data Collection Staff Location

TRANSPORTATION RESEARCH BOARD
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Kimley-Horn and Associates, Inc.

SITE SUMMARY: Study Site #9

Site Name:Carribean Restaurant
Site Address: 1330 Rhode Island Ave NE, Washington D.C.
Survey Date: November 15, 2011 - Tuesday
Survey Period: Midday Peak (11:30am-1:30pm)
Count Location: Parking Lot Access

REQUIRED DATA

Parking Garage/Lot Driveway (veh trips)			Trips from Veh. Parked On-Street (veh trips)		15-Minute Spot Vehicle Occupancy Observations	
Time Period	In	Out	In	Out	Persons/Veh	Count
7:00am - 7:15am	1	0	0	0	1	0
7:15am - 7:30am	0	0	0	0	2	1
7:30am - 7:45am	0	1	0	0	3	1
7:45am - 8:00am	2	0	0	0	4	0
8:00am - 8:15am	1	0	0	1	5+	0
8:15am - 8:30am	0	2	0	0		
8:30am - 8:45am	1	1	1	0		
8:45am - 9:00am	1	1	0	0		

SUPPLEMENTARY DATA

Time Period	*Street-Level Building Entrance (person trips) In			Out		
	Walk	Bike	Transit	Walk	Bike	Transit
7:00am - 7:15am	2	0	0	3	0	0
7:15am - 7:30am	2	0	0	1	0	0
7:30am - 7:45am	5	0	0	1	0	0
7:45am - 8:00am	4	0	0	2	0	0
8:00am - 8:15am	1	0	0	0	0	0
8:15am - 8:30am	5	0	0	0	0	0
8:30am - 8:45am	2	0	0	1	0	0
8:45am - 9:00am	6	0	0	0	0	0

*Information is desired, but not required.

OBSERVATIONS:

Weather:	Clear ☑	Rain ☐	Snow ☐			
Bicycle Activity:	Low ☑	Moderate ☐	High ☐	Comments:		
Transit Activity:	Low ☑	Moderate ☐	High ☐	Comments:		

Other Comments:

Moderate-to-low income area. Moderate amount of pedestrians around the area. Bus stop close to the restaurant. Restaurant moderately busy.

Kimley-Horn and Associates, Inc.

4/26/2012

SITE SUMMARY: Study Site #14

Site Name: BBQ Restaurant

Site Location: 4150 Chain Bridge Road Fairfax Va

Land Use Type: High-Turnover (Sit-Down) Restaurant

Site Characteristics:

	Quantity	
Studios Units:	N/A	D.U
1 Bedroom Units:	N/A	D.U
2 Bedrooms Units:	N/A	D.U
3 + Bedrooms Units:	N/A	D.U
Total	N/A	D.U

Building Area: 3,104 Sq. Ft.

Occupancy: 100%

Number of on-site parking spaces: Unknown

Number of spaces per 1,000 square feet: N/A

Cost of Parking: Free

Site Description:

Meets Density Criteria: No (Suburban site)

Proximity to Transit: No qualifying transit services within vicinity of site.

Survey Date: November 17, 2011

ITE Land Use Codes: ITE 932 (High-Turnover) Sit-Down Restaurant

Independent Variable: 1,000 Sq Ft.

Trip Rate Comparison:

	Midday Peak Hour			PM Peak Hour		
	In	Out	Total	In	Out	Total
ITE Trip Rate*	7.04	6.49	13.53	6.58	4.57	11.15
Directional Distribution	52%	48%	100%	59%	41%	100%
Surveyed Trip Rate	10.31	8.70	19.01	11.28	3.22	14.50
Directional Distribution	54%	46%	100%	78%	22%	100%

*ITE trip rate for A.M. Peak Hour of Generator used to compare to observed trip generation data for midday peak hour.

Observed Vehicle Occupancy**: 1.4 persons/veh

**Note: Based on 15-min spot surveys.

Notes/Observations: • Observed midday peak (11:30am - 1:30am) period instead of AM Peak period

Kimley-Horn and Associates, Inc.

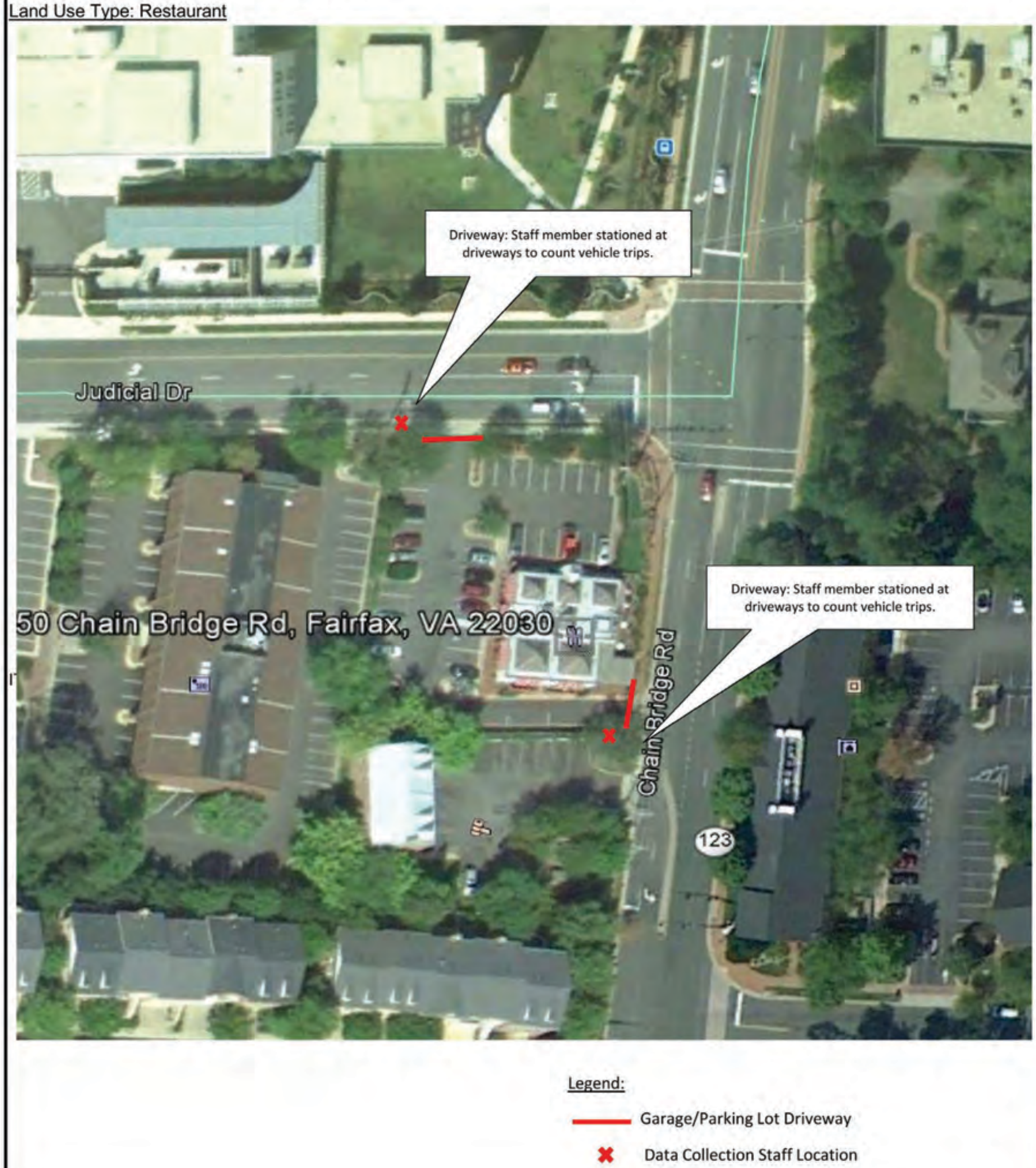
4/26/2012

SITE SUMMARY: Study Site #14

Site Name: BBQ Restaurant

Site Location: 4150 Chain Bridge Road Fairfax Va

Land Use Type: Restaurant



TRANSPORTATION RESEARCH BOARD
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Kimley-Horn and Associates, Inc.

SITE SUMMARY: Study Site #14

Site Name: BBQ Restaurant
Site Address: 4150 Chain Bridge Road, Fairfax, VA
Survey Date: November 17, 2011 - Thursday
Survey Period: PM Peak (4:00 - 6:00 PM)
Count Location: Driveway Access - Judicial Dr

REQUIRED DATA

Parking Garage/Lot Driveway (veh trips)			Trips from Veh. Parked On-Street (veh trips)		15-Minute Spot Vehicle Occupancy Observations	
Time Period	In	Out	In	Out	Persons/Veh	Count
4:00pm - 4:15pm	3	2			1	4
4:15pm - 4:30pm	3	2			2	0
4:30pm - 4:45pm	4	2			3	0
4:45pm - 5:00pm	1	1			4	0
5:00pm - 5:15pm	4	2			5+	0
5:15pm - 5:30pm	12	2				
5:30pm - 5:45pm	6	1				
5:45pm - 6:00pm	11	1				

SUPPLEMENTARY DATA

*Street-Level Building Entrance (person trips)					
In			Out		
Walk	Bike	Transit	Walk	Bike	Transit
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
1	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0

*Information is desired, but not required.

OBSERVATIONS:

Weather: Clear ☑ Rain ☐ Snow ☐
Bicycle Activity: Low ☑ Moderate ☐ High ☐
Transit Activity: Low ☑ Moderate ☐ High ☐

Comments: Little transit or bike activity
Comments:

Other Comments:

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

Kimley-Horn and Associates, Inc.

SITE SUMMARY: Study Site #14

Site Name: BBQ Restaurant

Site Address: 4150 Chain Bridge Road, Fairfax, VA

Survey Date: November 17, 2011 - Thursday

Survey Period: Midday Peak (11:30 - 1:30 PM)

Count Location: Driveway Access - Judicial Dr

REQUIRED DATA

Parking Garage/Lot Driveway (veh trips)			Trips from Veh. Parked On-Street (veh trips)		15-Minute Spot Vehicle Occupancy Observations	
Time Period	In	Out	In	Out	Persons/Veh	Count
11:30am - 11:45am	12	2			1	1
11:45am - 12:00pm	8	4			2	3
12:00pm - 12:15pm	6	5			3	0
12:15pm - 12:30pm	9	5			4	0
12:30pm - 12:45pm	7	4			5+	0
12:45pm - 1:00pm	7	2				
1:00pm - 1:15pm	7	5				
1:15pm - 1:30pm	7	9				

SUPPLEMENTARY DATA

*Street-Level Building Entrance (person trips)					
In			Out		
Walk	Bike	Transit	Walk	Bike	Transit
1	0	0	0	0	0
3	0	0	0	0	0
2	0	0	0	0	0
3	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0

*Information is desired, but not required.

OBSERVATIONS:

Weather: Clear ☑ Rain ☐ Snow ☐

Bicycle Activity: Low ☑ Moderate ☐ High ☐ Comments:

Transit Activity: Low ☑ Moderate ☐ High ☐ Comments:

Other Comments:

Notes and Citations to Supplemental Technical Report

1. Institute of Transportation Engineers. *Trip Generation Manual, An Informational Report*, 9th Edition. Institute of Transportation Engineers. Washington, D.C., 2012.
2. Tierney, K.; Decker, S.; Proussaloglou, K.; Rossi, T.; Ruiter, E.; McGuckin, N.; Tierney, K. (Editor), *Travel Survey Manual: How to Do a Survey*, U.S. Department of Transportation and U.S. Environmental Protection Agency, June 1996.
3. Kimley-Horn and Associates, Inc. *Trip-Generation Rates for Urban Infill Land Uses in California, Phase 2: Data Collection, Final Report*. California Department of Transportation. June 2009.
4. Metropolitan Planning Commission, *Sample Weighing and Expansion Working Paper 2 – 1990 MTC Travel Survey*, National Transportation Library, June 1993.
5. NCHRP Project 8-66: Revised Phase 2 Methodology Case Study Approach, National Cooperative Highway Research Program, May 5, 2011.

Abbreviations and acronyms used without definitions in TRB publications:

A4A	Airlines for America
AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation