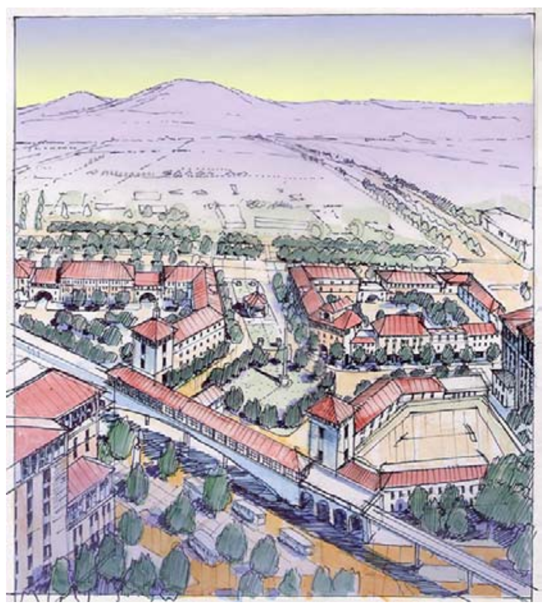
Crediting Low-Traffic Developments

Adjusting Site-Level Vehicle Trip Generation Using URBEMIS



Nelson\Nygaard Consulting Associates
785 Market Street, Suite 1300
San Francisco, CA 94103

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Introduction

Traffic studies are at the heart of many fundamental decisions on land use, street design and urban form. By analyzing the number of trips expected from a new development, and the consequent impact on traffic congestion at neighboring intersections, the traffic study is a driving force behind roadway widths, street and intersection design, and the level of fees that a developer must pay to upgrade the transportation infrastructure. In many cases, the traffic study determines the intensity of development and the type of uses that are possible on a given site, through establishing the constraints of the roadway network to move more vehicles.

The Institute for Traffic Engineers' (ITE's) *Trip Generation* report and the companion *Trip Generation Handbook* are the most definitive available sources for estimating the automobile traffic that different land uses will generate. Now in its seventh edition, *Trip Generation* provides a wealth of data on the average number of vehicle trips generated at different times of day by hundreds of land uses, from office buildings to funeral parlors.

Trip Generation is an invaluable reference for traffic studies and environmental assessments, as it is by far the most comprehensive source of empirical data on the traffic impacts of different land uses. However, the information is most useful for auto-oriented, stand-alone suburban sites, from where the vast majority of data were collected. For downtowns or areas with good public transportation, ITE advises that traffic engineers should collect local data, or adjust the ITE average trip generation rate to account for reduced auto use.

All too often, however, ITE's warnings are ignored and standard trip generation rates are applied in inappropriate locations – with serious impacts on the character and financial feasibility of urban development. Part of the reason is that, until now, there has been no standardized tool to allow these adjustments to trip generation rates to be made. In order to address this problem, the air quality management districts of California, along with the California State Department of Transportation, worked together in 2004 to examine all of the data that influence automobile trip generation. They were able to quantify the trip generation impact of key locational and programmatic factors, and inserted these formulas into URBEMIS, a national model for calculating air quality impacts of projects.

The URBEMIS mitigation component is a simple yet powerful tool; it employs standard traffic engineering methodologies, but provides the opportunity to adjust ITE rates to quantify the impact of a development's location, physical characteristics and any demand management programs. In this way, it provides an opportunity to "reward" developments that minimize their transportation impact, for example, through locating close to transit or providing high densities and a mix of uses. Figure 1 provides a summary of the specific trip reduction credits that are granted by URBEMIS.

The URBEMIS mitigation component was developed by Nelson\Nygaard, in association with Jones & Stokes, for the San Joaquin Valley Air Pollution Control District. It has been peer reviewed by Dr. Richard Lee of Fehr & Peers Associate and John Holtzclaw of the Sierra Club, and overseen by the URBEMIS Working Group. This work updates and extends the earlier mitigation component, which was developed by Dave Mitchell and Terry Parker.

The mitigation component forms part of the URBEMIS model, which was developed for California air pollution control districts to calculate the expected air quality impact of development proposals. The model is in widespread use by air quality, transportation and planning agencies in California and beyond. For details, see www.aqmd.gov/ceqa/urbemis.html or www.urbemis.com.

Figure 1 Summary of Trip Reduction Credits

	Residential (1)	Non-Residential
Physical Measures		
Net Residential Density	Up to 55%	N/A
Mix of Uses	Up to 9%	Up to 9%
Local-Serving Retail	2%	2%
Transit Service	Up to 15%	Up to 15%
Pedestrian/Bicycle Friendliness	Up to 9%	Up to 9%
Physical Measures subtotal	*Up to 90%*	*Up to 35%*
Demand Management and Similar Measures		
Affordable Housing	Up to 4%	N/A
Parking Supply (2)	N/A	No limit
Parking Pricing/Cash Out	N/A	Up to 25%
Free Transit Passes	25% * reduction for transit service	25% * reduction for transit service
Telecommuting (3)	N/A	No limit
Other TDM Programs	N/A	Up to 2%, plus 10% of the credit for transit and ped/bike friendliness
Demand Management subtotal (4)	*Up to 7.75%*	*Up to 31.65%*

Notes:

(1) For residential uses, the percentage reductions shown apply to the ITE average trip generation rate for single-family detached housing. For other residential land use types, some level of these mitigation measures is implicit in ITE average trip generation rates, and the percentage reduction will be lower.

(2) Only if greater than sum of other trip reduction measures.

(3) Not additive with other trip reduction measures.

(4) Excluding credits for parking supply and telecommuting, which have no limit.

Assessing Trip Generation

The methodology for conducting traffic studies is well established in the traffic engineering profession. The first step – which is the only element considered in this paper – is to calculate the number of vehicle trips that will be generated by each land use. Subsequently, these trips are assigned to the roadway network and the impact on vehicle level of service is calculated.

Typically, the analyst uses the following procedure to calculate trip generation:

- Determine the land-use type(s) (e.g. "High-Rise Residential Condominium/Townhouse") in the development
- Determine the trip generation rate for each land-use type using *Trip Generation* or similar references. These publications provide average trip generation rates per unit of land use (e.g., per residential unit, per employee, per 1,000 square feet of gross floor area, or per theatre seat)
- Multiply the average trip generation rate by the number of units of development for each type of land use included in the project, and sum the different land-use components
- The total number of trips can be reduced to account for (i) "internal capture" (i.e., trips between different components of a mixed-use project such as a restaurant and cinema); and (ii) "pass-by trips" (such as a commuter stopping to buy groceries on the way home from work)

An important advantage of this simple approach is that very little information about a project is needed to predict trip generation, and trip generation calculations are simple. There are, however, several limitations of such two-variable formulas. Most importantly, they do not take into account the multitude of other variables, such as parking price, transit service, and the quality of the pedestrian environment, that transportation research has shown to strongly affect trip generation.

This means that the variation in trip rates *within* each land use category is frequently very high, indicating that quantity of development (e.g. number of units or gross floor area) is not sufficient to predict trip generation with any accuracy. For example, the highest-density residential developments in the San Francisco Bay Area generate 82% fewer trips than the lowest-density developments. For some land uses, such as office supply superstores and fast-food restaurants, *Trip Generation* finds no statistically significant correlation between the quantity of development and trip generation rates, or finds that the correlation is in the "wrong" direction (i.e., there is an inverse correlation).[1] Indeed, ITE frequently advises caution and the use of engineering judgment when determining the appropriate trip generation rates.

[1] For an in-depth review of the development of trip generation rates, see Shoup (2003).

Even where there is a strong correlation between the amount of development and trip generation rates, there is still considerable variation in the rates observed in different surveys. For the land use type "Single Family Detached Housing", for example, ITE reported rates ranged from a low of 4.31 daily trips per dwelling unit, to a high of 21.85 daily trips. The *Trip Generation* manual reports that, "This land use included data from a wide variety of units with different sizes, price ranges, locations and ages. Consequently, there was a wide variation in trips generated within this category."

Recognizing these points, the *Trip Generation Handbook* includes a detailed appendix on the effects of TDM and transit. *Trip Generation* advises the reader:

> The average trip generation rates in this report represent weighted averages from studies conducted throughout the United States and Canada since the 1960s. Data were primarily collected at suburban locations having little or no transit service, nearby pedestrian amenities, or travel demand management (TDM) programs. At specific sites, the user may wish to modify trip generation rates presented in this document to reflect the presence of public transportation service, ridesharing or other TDM measures, enhanced pedestrian and bicycle trip-making opportunities, or other special characteristics of the site or surrounding area.

Modifying the trip generation rates in this way is essential for transit-oriented, mixed-use and other projects that can expect lower rates of auto use. Otherwise, they will be disadvantaged by the traffic study, which in effect assumes a "worst case scenario" in terms of car use. The development may be asked to pay higher fees or fund infrastructure widenings that may not be necessary – measures which often damage the quality of the pedestrian environment, not to mention affecting development feasibility.

These limitations have been well documented by ITE and other analysts. What has been missing until now, however, is an alternative, established tool to modify the average trip generation rates. This is the purpose of the URBEMIS mitigation component described in this paper. **At its heart, therefore, the URBEMIS mitigation component is a tool for adjusting the average trip generation rates reported in the Institute for Transportation Engineers' *Trip Generation* manual to more fairly reflect the particular characteristics of a proposed development.** It can be seen as a "plug in" to the standard traffic study methodology.

It should be noted that many agencies do provide credits for individual developments that implement trip reduction measures, for example when assessing impact fees or conducting traffic studies. Some California examples include C/CAG in San Mateo County and VTA in Santa Clara County. In general, however, these credit programs are only loosely based on the latest travel research, and it could be argued that they function more at a policy level, in providing incentives for developers to locate on transit corridors and implement demand management programs.

The URBEMIS Approach

The URBEMIS mitigation component (referred to simply as "URBEMIS" in the remainder of this paper) provides a simple method of estimating the percentage reduction in vehicle trips generated by a proposed development, compared to the baseline that would be obtained through the use of ITE average trip generation rates. It quantifies the trip reduction "credits" that can be gained through implementation of a range of mitigation measures.

In some cases, credits are obtained through simply locating a development in the right place – for example, close to transit, or in a place where it will optimize the jobs-housing balance. In some cases, the credits are assessed based on the physical characteristics of the development, such as density and provision of sidewalks. Other credits are granted based on commitments from the developer to implement demand management programs such as parking pricing, or provide deed-restricted affordable housing. Figure 1 summarizes the specific credits that are granted by URBEMIS. The sections below discuss each credit in turn and the rationale for the level of trip reduction.

It must be stressed that the trip reductions recommended here are subject to considerable uncertainty. They should be interpreted as the mid-point of a range, rather than as a single, precise value. Travel behavior is complex and difficult to predict, and the approach described here will need to be refined in future years, as more data become available.

However, although the methodological dangers are obvious, there is generally no question about the *direction* of the relationship between trip generation and a given mitigation measure, only the size of the relationship and the appropriate variable to use as a model input. Some adjustment is better than none at all – which is what most conventional trip generation methodologies provide (Ewing & Cervero, 2001). In addition, existing project-level trip generation methodologies, even though well-accepted within the transportation planning and engineering profession, are themselves subject to considerable uncertainty, and results are reported with unwarranted precision (Shoup, 2003).

Data Requirements

Figure 2 shows the inputs that are required to complete the URBEMIS mitigation component in full, along with suggested data sources. Note, however, that the mitigation component can still be run, even if some of these inputs are missing. While no reduction would be granted for the particular mitigation measure for which the input was required, credits are still granted for other trip reduction measures.

The number of trips generated by a development depends not only on the characteristics of the project itself, but also on the surrounding area. High-density housing in an urban area, for example, will generate fewer trips than the same housing located close to a freeway interchange and surrounded by low-density subdivisions. For this reason, URBEMIS requires data for the area within approximately a half-mile radius from the center of the project, or for the entire project area, whichever is larger. In effect, the smaller the development, the more important the development's context.

Even though URBEMIS is designed to use inputs that are readily available, small projects may still face a disproportionate burden in gathering the data to document their likely trip reduction. For this reason, URBEMIS allows small developments (generating 50 or fewer daily vehicle trips before mitigations) in an established urban area to adjust their trip generation rates based on the average mode share in that census tract. The analyst needs to certify that the project is similar in character to the existing development in the neighborhood.

Figure 2 Data Requirements and Suggested Sources

Required Input	Suggested Source	
	Project	Surrounding Development
Net residential density (1)	Project plans	Block-level census data
Number of housing units	Project plans	Block-level census data
Number of jobs	Project plans (2)	Census Transportation Planning Package. Local jurisdiction may provide more current or fine-grained data
Local serving retail	Project plans	Site observations
Below-market-rate units	Project plans	N/A
Parking supply	Project plans	N/A
Transit service	Transit agency maps/schedules	
Intersection density (3)	Project plans	Street plans
Sidewalk completeness (3)	Project plans	Site observations
Bike lane completeness (3)	Project plans	Site observations
Parking pricing	Development agreement or similar	Site observations (if applicable)
Free transit pass provision	Development agreement or similar	N/A
Telecommuting/flexible work schedules	Development agreement or similar	N/A
Other TDM programs	Development agreement or similar	N/A

Notes:
(1) Net residential data excludes land not devoted to residential uses.
(2) US Department of Energy figures can be used to calculate the number of employees when only development square footage is known. See, for example, http://www.eia.doe.gov/emeu/consumptionbriefs/cbecs/pbawebsite/summarytable.htm.
(3) These inputs can be calculated manually, or automatically if the plans and data are available in a GIS system

Relationship to ITE Residential Trip Generation Rates

It should be noted that, to some extent, ITE average trip generation rates for residential uses implicitly account for the level of transit service, density and other factors that influence trip generation. This is because ITE publishes average trip generation rates for several types of residential development, which vary considerably. A single-family detached house generates more than twice as many trips as a high-rise apartment unit, according to *Trip Generation*. Rather than being a function of the inherent characteristics of the different types of housing, this is largely due to the different types of environments in which the housing types are found; high-rise apartments, for example, are often located in dense neighborhoods with good transit.[2]

In order to avoid double counting, URBEMIS therefore assumes various default values for mitigation measures such as residential density, mix of uses and transit service. These defaults are set so that results from URBEMIS are consistent with ITE average trip generation rates.[3] In other words, the same trip generation result will be generated by URBEMIS regardless of the type of residential use selected (such as low- or high-rise apartment buildings), assuming that the mitigation measures are the same. The type of residential use *does* affect the *default* values for mitigation measures such as transit service, but these can be modified by the user.

For single-family detached housing, for example, the default values include a residential density of three units per residential acre, a transit service index score of 0 (representing no transit service within one-quarter mile of the site), and an intersection density of 250 intersections per square mile (typical of post-war cul-de-sac residential subdivisions). Figure 3 shows the default values for each land use type. Full details of each mitigation measure are provided in the following sections.

[2] ITE's *Trip Generation* manual states that data are collected primarily from suburban locations having little or no transit service, nearby pedestrian amenities, or travel demand management (TDM) programs. While little information is available about the precise characteristics of individual study sites, it appears from the sources referenced that this is not the case for some land uses, particularly higher density residential land uses. For the "High-Rise Residential Condominium/Townhouse", for example, the manual's text shows that sites were surveyed in such cities as Vancouver, Canada: a city where it is difficult to find high-density condominiums that lack sidewalks, transit service, and a mix of uses nearby.

[3] These default values were estimated using two methods. First, Nelson\Nygaard reviewed the literature and held discussions with professionals in the fields of architecture and town planning, to ascertain typical ranges for density and other characteristics of each land use type (for useful summaries, see Calthorpe, 1993, and Local Government Commission, 2002). Second, these ranges of values were plugged into the formulas for the mitigation measures, and adjusted until the baseline values for each characteristic equaled the average ITE trip generation rates for each land use.

Figure 3 Default Mitigation Values for Residential Uses

Land Use Code	Land Use Type	Default Mitigation Value (1)									ITE Trip Rate		
		Residential Density	Housing Units	Employees	Retail?	Transit Service	Intersection Density	Sidewalks	Bike Lanes	Ped factor	Low	Average	High
210	Single-Family Detached Housing	3	100	17	no	0.00	250	0	0	0.06	4.31	9.57	21.85
221	Low-Rise Apartment	16	100	26	no	0.06	250	0.5	0	0.23	5.1	6.59	9.24
230	Residential Condominium/Townhouse	16	100	60	yes	0.10	400	1	0	0.44	1.83	5.86	11.79
223	Mid-Rise Apartment (2)	38	100	60	yes	0.14	400	1	0	0.44	NA	4.68	NA
222	High-Rise Apartment	62	100	60	yes	0.14	400	1	0	0.44	3	4.2	6.45
232	High-Rise Residential Condo./Townhouse	64	100	60	yes	0.14	400	1	0	0.44	3.91	4.18	4.93

Notes:

(1) See text for description of units for each mitigation value.

(2) Since the *Trip Generation* manual provides no daily trip generation rate for the "Mid-Rise Apartment" land use, we estimated a rate by extrapolating from the daily trip rate for the "High-Rise Apartment" land use type. The PM peak hour trip rate of 0.39 trips per unit for mid-rise apartments is 11.4% higher than the PM peak hour rate for high-rise apartments (0.35 trips/unit). Therefore, the daily trip rate for the "Mid-Rise Apartment" land use was estimated to be 4.68 trips per unit, or 11.4% higher than the daily trip for high-rise apartments (4.2 trips/unit).

Mitigation Measures Included in URBEMIS

This section discusses each of the mitigation measures included in URBEMIS in turn. It provides a brief discussion of the rationale for the inclusion of that measure, and the method of calculation. Most mitigation measures apply to both residential and non-residential uses. The exceptions are density and affordable housing (which apply to residential uses only), and parking supply, parking pricing, telecommuting and other TDM programs (which apply to non-residential uses only).

Density

Residential density provides one of the strongest correlations of any variable with automobile use (Figure 4). However, care needs to be taken when calculating the impact of density on trip generation, since only some of this effect is due to the inherent effects of density, as opposed to factors for which density serves as a proxy, such as parking price, local retail, transit service frequency and pedestrian friendliness.[4] URBEMIS therefore uses the nonlinear equation developed by Holtzclaw *et. al*. (shown in Figure 4), but reduces the credit by 40% to avoid double counting with transit service, mix of uses and bicycle and pedestrian facilities, all of which correlate with density.

The input required is *net residential density*, which excludes the area devoted to arterials, open space and other land uses, but includes local streets. The baseline net residential density is three units per acre: URBEMIS provides trip reductions for higher density, and also increases trip generation rates for lower densities (e.g. large-lot housing). The formula is as follows:

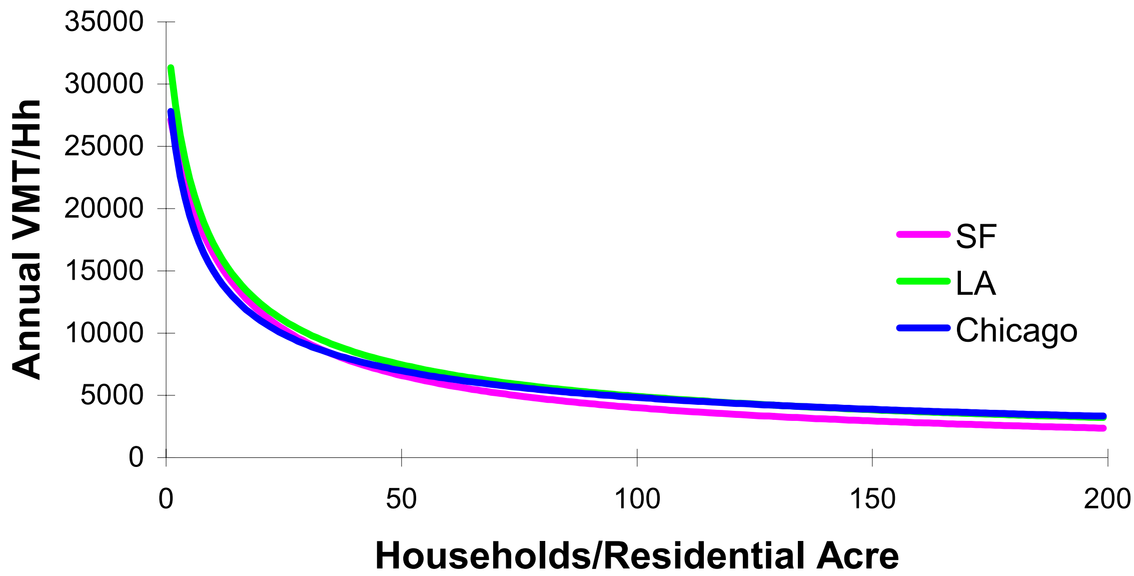
Trip reduction
$= 0.6*(1-(19749*((4.814+ \text{households per residential acre})/(4.814+7.14))^{-0.639})/25914)$

An apartment development of 16 units per residential acre, for example, would be estimated to generate 28% fewer trips than a three unit per acre project. The maximum reduction using this formula is 60%, although this is only obtained with extreme residential densities.[5]

Trip generation at the non-residential end is also influenced by density, but to a much lesser degree (Cervero, 1989, cited in Kuzmyak et. al, 2003). There are also far fewer studies investigating this relationship, and there is no comparable dataset to that for residential density. No credit is provided by URBEMIS for higher non-residential densities.

[4] For summaries, see Kuzmyak et. al. (2003); Boarnet & Crane (2001); Criterion and Fehr & Peers (2001); Cervero & Ewing (2001).
[5] This is because the formula uses a nonlinear equation, with an asymptote of 60%.

Figure 4 Residential Density Vs. Vehicle Travel



Source: Holtzclaw et. al. (2002).

Mix of Uses

Many references point to the impact of "diversity" or mix of uses on travel behavior. This is true both at the macro-scale, e.g. jobs-housing balance, and the micro-scale, e.g. the availability of services within walking distance.[6] The analysis is complicated by the fact that some of the most beneficial developments from this perspective may be single-use, in an area where another use is predominant (e.g. residential in an employment area). For this reason, the mix of uses in the wider neighborhood (within one-half mile of the project center) is considered, where this area is larger than the project area itself. URBEMIS uses the following formula (adapted from Criteron and Fehr & Peers, 2001):

Trip reduction = (1- (ABS (1.5 * h – e) / (1.5 * h + e)) – 0.25) / 0.25 * 0.03

Where: h = study area households (or housing units)
e = study area employment

Negative trip reductions of up to 3% can result, and are included by URBEMIS

This formula assumes an "ideal" housing balance of 1.5 jobs per household, based on Messenger & Ewing (1996, cited in Kuzmyak et. al., 2003), and a baseline diversity of 0.25. The maximum possible credit is 9%.

[6] See, for example, Criterion and Fehr & Peers (2001); Ewing & Cervero (2001); Kuzmyak et. al. (2003).

This reduction takes into account overall jobs-population balance. The presence of local serving *retail* can be expected to bring further trip reduction benefits, and URBEMIS provides an additional credit of 2%. This is towards the lower end of the range given in published research,[7] in order to avoid double counting with the jobs-housing balance mitigation measure.

Transit

Any index of transit service needs to consider two fundamental issues: the amount of service (i.e., frequency and service span), and quality (particularly speed), which have a strong relationship with ridership.[8] The index used by URBEMIS therefore places the emphasis on frequency, but gives greater weight to rail service (in view of greater speed and comfort) and dedicated shuttles (which will be targeted to the needs of the specific development). It considers the quantity of bus service within one-quarter mile, and rail service within one-half mile.[9] The index is determined as follows:

- Number of average daily weekday buses stopping within 1/4 mile of the site; plus
- *Twice* the number of daily rail or bus rapid transit trips stopping within 1/2 mile of the site
- *Twice* the number of dedicated daily shuttle trips
- Divided by 900, the point at which the maximum benefits are assumed. (This equates to a BART station on a single line, plus four bus lines at 15-minute headways.)
- Developments that are larger than 0.5 miles across in any direction must be broken into smaller units for purposes of determining the transit service index. The average of all units is then used.

In order to account for non-motorized access to transit, half the reduction is dependent on the pedestrian/bicycle friendliness credit (described in the following section). As well as existing service, planned and funded transit service should be included in the calculation. Purely demand responsive service may not be included. URBEMIS provides a maximum credit of 15%,[10] calculated as follows:

Trip reduction = t * 0.075 + t * ped/bike score * 0.075

Where t = transit service index

[7] E.g. Parsons Brinkerhoff (1996); and NTI (2000), both cited in Kuzmyak et. al. (2003).

[8] See, for example Kittselson & Associates et. al, (2003); Holtzclaw et. al. (2002) Pratt et. al. (2003); Nelson\Nygaard (2002).

[9] See Lund et. al. (2004) for a discussion of walking distances to transit.

[10] This ceiling is based on the previous version of URBEMIS, which is turn was based on the 1994 rail studies by Robert Cervero.

Bicycle and Pedestrian

Research for the Florida Department of Transportation, FHWA and other organizations has shown that there are numerous statistically significant factors that can assess the quality of the bicycle and pedestrian environment. These include motor vehicle volumes and speeds, truck volumes, roadway widths, urban design, and lateral separation between pedestrians and motor vehicles.[11] However, many of the data inputs required for these indices are highly complex to gather, particularly prior to occupancy. For this reason, URBEMIS uses three of the most important variables that are identified in the literature[12] to calculate the quality of the bicycle and pedestrian environment, as follows:

- Intersection density, which measures street connectivity. A well-connected grid (high intersection density) provides better opportunities for pedestrian travel than cul-de-sacs and "loops and lollipops" (low intersection density)
- Sidewalk completeness
- Bike network completeness

Since both bicycle and pedestrian use depend on similar neighborhood characteristics, such as a fine-grained street grid, a single factor is used to account for both modes.

URBEMIS assumes an "ideal" intersection density of 1,300 legs per square mile. This roughly equates to a dense grid with four-way intersections every 300 feet, per the recommendation of Ewing (1999). URBEMIS grants a maximum trip reduction of 9%, using the following formula:

Trip reduction =
9% * (intersection density + sidewalk completeness + bike lane completeness) / 3

Where:
Intersection density = intersection legs per square mile[13] / 1300 (or 1.0, whichever is less)

Sidewalk completeness =
% streets with sidewalks on both sides + 0.5 * % streets with sidewalk on one side

Bike lane completeness =
% arterials and collectors with bicycle lanes, or where suitable, direct parallel routes exist

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[11] For example, FHWA (1998); Landis et. al. (2001).

[12] See, for example, Dill (2003); Parsons Brinkerhoff (1993); Kuzmyak et. al, (2003); Ewing & Cervero (2001); and Ewing (1999). Note that network density is inversely related to block size, which is sometimes considered in the research.

[13] Intersections with dedicated routes for pedestrians and/or bicyclists should be included in this calculation. In most GIS applications, intersections are counted based on the number of line segment terminations, or each "valence." Intersections have a valence of 3 or higher – a valence of 3 is a "T" intersection, 4 is a four-way intersection, and so on. (Georgia Institute of Technology, 2002). Therefore, if intersections are counted manually on a map or project plan, care needs to be taken to distinguish between 3-, 4- and 5-way intersections, and factor them up accordingly.

No reduction is allowed if the entire area within a half-mile walk of the project center consists of a single use. However, the pedestrian/bicycle factor can still be used to calculate pedestrian access to transit, as part of the transit mitigation measure.

Affordable and Senior Housing

A significant amount of evidence points to the fact that lower-income households and senior citizens own fewer vehicles and drive less.[14] Obviously, it is difficult if not impossible to account for the exact incomes of residents in URBEMIS, because the occupants are not known at the pre-development stage. However, the percentage of deed-restricted below-market-rate (BMR) housing does offer a way to incorporate this effect.

URBEMIS provides a 4% reduction in vehicle trips for each deed-restricted BMR unit.[15] Thus, the total reduction is as follows:

Trip reduction = % units that are BMR * 0.04

A development with 20% BMR units would thus gain a 0.8% reduction. A development with 100% BMR units would gain a 4% reduction.

Parking Supply

There is a significant correlation between the quantity of parking provided and employee mode split.[16] In addition, incorporating data on parking supply can capture the effects of a range of mitigation measures that are not included in URBEMIS.

Theoretically, it is possible to reduce parking provision to below the level of actual demand, should drivers park in neighboring lots or on-street in surrounding areas. However, the development approval process and market realities will generally prevent this from occurring, A credit is only granted if measures to control overspill are in place, such as Residential Permit Parking programs, time limits or meters.

URBEMIS uses the Institute of Transportation Engineers' *Parking Generation* handbook as the baseline figure for parking supply. This is assumed to equate to unconstrained demand. The *Parking Generation* handbook covers most common land uses. For some land uses, however, no parking generation rates are available: in these cases, this particular mitigation measure may not be used. For land uses

[14] See, for example, Russo (2001); Holtzclaw et. al., 2002.
[15] Calculated from Holtzclaw et. al. (2002), assuming 12,000 average annual VMT per vehicle, median per capita income of $33,000 (2002 figures per California State Department of Finance), and an average income in BMR units 25% below median. Holtzclaw calculate the coefficient of -0.0565. Therefore, expected VMT reduction can be calculated as 0.0565 * 33,000 * 0.25 / 12,000 = 4%
[16] See, for example, Morrall & Bolger, 1996, cited in Kuzmyak et. al., 2003b; Lund et. al., (2004).

with rates for both weekday and weekend, URBEMIS will use whichever rate is higher.

If the percentage reduction from all other non-residential trip reduction measures is equal to or greater than the parking supply reduction, no additional credit is granted (in order to avoid double counting). In other cases, URBEMIS grants an additional credit of 50% of the difference between actual parking supply and values reported in *Parking Generation*.

The trip reduction is calculated as follows:

Trip reduction = Actual parking provision / ITE Parking Generation rate * 0.5

For example, if parking supply is reduced 25% from ITE levels, and transit, mixed use and pedestrian/bicycle credits amount to 15%, the total reduction would be:

15 + 0.5 * (25-15) = 20%.

Transportation Demand Management

Transportation Demand Management (TDM) programs have been shown to reduce employee vehicle trips by up to 38%, with the largest reductions achieved through parking pricing.[17] URBEMIS provides credits for a range of TDM program elements, provided that they form part of a legally enforceable agreement (for example, a development agreement with a city) that guarantees that the mitigation measures will be implemented. URBEMIS provides the most credit for the three TDM elements that have the greatest impact on travel behavior:

- Parking pricing – up to 25% trip reduction, which is attained with a $6 daily charge.[18] Parking cash-out programs are granted 50% of the reduction for direct parking charges, in recognition of the fact that their impacts tend to be significantly lower (Pratt, 2000).
- Free transit passes – up to 25% of the trip reduction granted for transit service availability.[19] Thus, the credit is more valuable in places that have good transit service.
- Telecommuting and compressed work schedules – employee vehicle trips are reduced by the percentage of employees that telecommute, or have a 'free' day gained through a compressed schedule, on an average day.

Other TDM program elements, that do not include financial incentives, tend to have a smaller impact on travel behavior. Reductions are based on the number of the following elements incorporated into the program, per Figure 5:

[17] Shoup & Willson (1980); Comsis (1993); Valk & Wasch (1998); Pratt (2000).
[18] The 25% reduction is based on the approximate midpoint of observed reductions, which range from 15% to 38% (Shoup & Willson, 1990; Comsis, 1993; Pratt, 2000).
[19] Free transit pass programs have been shown to increase transit ridership by 50-79% (City of Boulder, undated; Caltrans, 2002), and reduce vehicle trips by 19% (Shoup, 1999).

- Secure bicycle parking (at least one space per 20 vehicle parking spaces)
- Showers/changing facilities
- Guaranteed Ride Home
- Car-sharing services
- Information on transportation alternatives, such as bus schedules and bike maps
- Dedicated employee transportation coordinator
- Carpool matching programs
- Preferential carpool/vanpool parking

The impact of a TDM program will also depend on the travel alternatives available. A program will have more impact if the site is served by frequent transit, for example (although note that a TDM program can do much to promote carpooling even in other locations). For this reason, URBEMIS uses part of the TDM credit to adjust the credits granted for transit service and pedestrian/bicycle friendliness (see Figure 5).

Credits for all TDM program elements are applied only to the types of trips that the TDM program seeks to influence. For example, if only employees, and not visitors, are subject to parking charges, the credit is applied only to employee vehicle trips.

Figure 5 TDM Program Reductions

Level	Number of Elements	Recommended Reduction
Major	At least 5 elements	2%, plus 10% of the credit for transit and pedestrian/bike friendliness
Minor	At least 3 elements	1%, plus 5% of the credit of transit and pedestrian/bike friendliness
No program	None	None

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