Developing Dwelling Unit Equivalent (DUE) Rates Using an Activity Based Travel Demand Model

Institute of Transportation Engineers
ITE Western District Annual Meeting
Phoenix, Arizona
July 14-17, 2013

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Introduction and Background

As cities and urban areas grow adding new residential and commercial developments the need for services and infrastructure in-turn expand. Demand for schools, gas, electricity and other utilities grow, as do demands on our transportation systems as our urban areas expand. Many jurisdictions and agencies have adopted district based fee programs to help fund the additional capital improvement projects and services needed to accommodate growth. In transportation development fee programs (TDFs) and other utility fee programs, dwelling unit equivalent (DUE) rates are often estimated to allocate impacts on the transportation system to land uses. These allocations are compared to one standard single family dwelling unit, thus the name dwelling unit equivalent.

Over the decades, several methods and data sources have been used to estimate DUE rates for fee programs. Trip based DUE rates are one of the simplest to estimate and commonly based on peak hour or daily trip rates found in the Institute of Transportation Engineers Trip Generation Manual. Estimating DUE rates based on vehicle-miles-traveled (VMT) by combining trip generation rates with average trip distances more accurately captures impacts to the transportation system. Many current DUE estimates incorporate the use of "pass-by" and "link-diverted" trip reduction factors to correct for the over allocation of VMT to intermediate stops made by traffic already using the adjacent roadway.

Travel demand models have been also used to estimate DUE rates. With a travel demand model, DUE rates can be estimated for future year scenarios using future year travel patterns, future year levels of congestion and forecast the demand placed on the region's transportation from proposed housing and commercial developments that may not be built for a decade or more. Further, the travel demand model can forecast these demands and impacts on roadways which may not even be funded yet alone constructed and ready for use. Further, DUE rates estimate using a regional travel demand model are specific to a region, accounting for trip generation rates and trip lengths that differ from nationally published averages. However, developing DUE rates using a traditional 4-step travel demand model has its limitations like all estimation methods.

In previous efforts to produce DUE rates using travel demand models and data, DKS Associates noticed that retail and some other land use categories were attributed with unexpectedly high VMT rates. Upon investigation, it was found that this was an artifact of the 4-step travel demand model which models disjoint trip legs by trip purpose rather than modeling tours (or some other means of accounting for whole trips between primary purpose destinations). This means that a home-work trip with an intermediate stop, say to a gas station for gasoline or a cup of coffee, is modeled as two totally independent, unconnected or disjoint trip legs; one from home to the gas station (a home-shop trip), and a second individual and disconnected trip from the gas station to the office (an other-work trip). This means one-half of the home to gas station trip is attributed to the land use at the trip origin (home) and the other half of the trip is attributed to the destination land use (the gas station). Likewise, half of the gas station to office trip leg is attributed to the origin land use (gas station), with the other half to the destination land use (office). When summed up, the home is attributed with 25% of the trip, the gas station with 50% of the trip, and the office with 25% of the home-work trip. In reality, the home-work trip is about the same without the gas station stop. To summarize, intermediate stops on the home-work tour gets attributed with a

disproportionately large share of the home-work VMT. The same is true for any intermediate stops on the other trip purposes modeled (i.e., home-other, home-shop, other-work, other-other). Using a 4-step travel demand model, no known methods have been developed to link VMT to land uses that avoid this intermediate stop bias. Furthermore, there are no known means to develop correction (calibration) factors using a 4-step model.

In recent years, the travel demand modeling state of the art practice has moved from aggregate trip (leg) based forecasting methods toward disaggregate tour based methods. In a tour based model, the individual trip legs are not modeled as disjoint trip legs, rather they are modeled as subsets or sub-trips within a larger round-trip tour. For example, a "home to gas station (shop) to office (work) to restaurant (lunch) to office (work) to grocery store (shop) to home" tour would be modeled as one single round-trip tour with multiple stops. Additionally, the tour would have a primary origin (home) and a primary destination and purpose (office, work). These tour based models that replicate individual travel activities as tours are called activity based travel demand model, or simply - activity models.

The currently adopted SACOG MTP travel demand (SACSIM) model is one of these new activity models. SACSIM tracks information on complete tours, with primary trip origin, intermediate stops and primary trip destination. The tour's total length and proportion of travel for each stop can be correctly allocated to the tour's primary origin, primary destination and each intermediate stop.

Using the SACOG activity model, two different methods were developed for two TMF programs to overcome the limitations of the 4-step travel models the disjoint trip legs. In the first example, SACSIM was used to develop a set of DUE correction factors for the City of Roseville's TMF program. The correction factors are similar to ITE's "pass-by" reduction factors in that they adjust DUE rates to better account for the additional VMT associated with intermediate stops. In the second example, SACSIM was used to develop a unique set of DUE rates for each of the four fee districts in a sub-regional TMF program.

Calculating DUE Adjustment Factors for the City of Roseville

For the City of Roseville's Traffic Mitigation Fee (TMF) update, SACOG's activity-based travel demand simulation model (SACSIM) was used to develop a set DUE rates that do not inherit the VMT over-estimation attributed to intermediate stops on commutes and other trips. An activity-based model is a tour based model, where the individual trip components are not modeled as disjoint trip legs, rather they are modeled as subsets or sub-trips within a larger round-trip tour. Additionally, tours have a primary origin (home) and a primary destination and purpose (office, work). The "tours" database from the SACSIM model and the associated parcel-level land use database were used in a regression analysis to develop DUE correction factors for the City of Roseville California's traffic mitigation fee program that did not overtax retail and other land-uses that are typical intermediate stops on commutes. Table 1 shows the unadjusted PM Peak VMT factors by land use category derived from the Roseville 4-step travel demand model. For this correction, two sets of factors had to be estimated using the SACSIM "tours" database. The first set of factors estimated VMT attributable to "primary" stops (i.e., primary origins and primary destinations) by land use category (see Table 2).

Table 1: Roseville's Travel Demand Model PM Peak VMT Factors

Roseville TDM Land Use Category	VMT Parameter Estimate	Standard Error of Estimator	t value	Pr(>|t|)	Significance
Single Family Dwelling Unit	0.993	0.030	32.601	< 2e-16	***
Multi Family Dwelling Unit	0.652	0.043	15.184	< 2e-16	***
Age Restricted Dwelling Unit	0.348	0.069	5.063	6.02E-07	***
Retail	2.102	0.051	41.012	< 2e-16	***
Mall	1.858	0.054	34.104	< 2e-16	***
Office	1.929	0.049	39.054	< 2e-16	***
Industrial	0.874	0.030	29.100	< 2e-16	***
High Tech Industrial	1.486	0.037	40.146	< 2e-16	***
Medical Offices	1.680	0.055	30.673	< 2e-16	***
Hotel	1.041	0.117	8.915	< 2e-16	***
Public Quasi-Public	1.988	0.126	15.800	< 2e-16	***
School	0.040	0.016	2.461	1.42E-02	*
Golf	1.098	0.277	3.964	8.55E-05	***
*Significance Codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1*					

Table 2: SACSIM Future Year Primary and Secondary Trip-end Factors

Roseville TDM Land Use Category	Probability of Stop being "Primary" (in percent)	Probability of Stop being "Secondary" (in percent)	t value	Pr(>|t|)
Single Family Dwelling Unit	88%	12%	< 2e-16	***
Multi Family Dwelling Unit	88%	12%	< 2e-16	***
Age Restricted Dwelling Unit	88%	12%	< 2e-16	***
Retail	38%	62%	< 2e-16	***
Mall [1]	69%	31%	#N/A	#N/A
Office	59%	41%	< 2e-16	***
Industrial	62%	38%	< 2e-16	***
High Tech Industrial	62%	38%	< 2e-16	***
Medical Offices	43%	57%	< 2e-16	***
Hotel [1]	69%	31%	#N/A	#N/A
Public Quasi-Public	66%	34%	< 2e-16	***
School	96%	4%	< 2e-16	***
Golf [1]	69%	31%	#N/A	#N/A
*Significance Codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1*				
Note (1): Land use not represented in the model's land use database. Average primary vs. secondary trip proportion factors were applied.				

The second factor estimated the average additional tour distance associated with intermediate stops. On some tours, the intermediate stops added only nominal distances to the tour, while other intermediate stops added considerable distances to the round-trip tour. On average, each additional tour stop increases the tour distance by 40%.

The SACSIM estimated correction factors were applied to the original Roseville 2025 PM Peak model VMT factors. The final dwelling unit equivalence (DUE) rates are shown in Table 3 along with the previously estimated (or uncorrected) DUE rates.

Table 3: DUE Rates for Roseville's TMF Program

Land Use Category	4-step Model Estimated DUE Rates	Activity Model Corrected DUE Rates
Single Family Dwelling Unit	1.000	1.000
Multi Family Dwelling Unit	0.614	0.657
Age Restricted Dwelling Unit	0.267	0.350
Retail	1.740	1.427
Mall	1.610	1.639
Office	1.380	1.580
Industrial	0.910	0.730
High Tech Industrial	1.000	1.240
Medical Offices	2.890	3.001
Hotel	0.549	0.918
Public Quasi-Public	1.120	1.712
School	0.082	0.042
Golf	0.687	0.969

Developing Unique DUE Rates for Each TMF District in a Fee Program

The I-5 Sub-regional Mitigation Working Group developed a transportation improvement package and fee program focused on reducing future congestion on the State highway system in the "Performance Area". For this program, DKS Associates estimated dwelling unit equivalent (DUE) rates that reflected new development's contribution to congestion on the State highway system based on both development type and development location. This calculation captures the effects of both typical trip generation differences and travel patterns associated with a district level jobs/housing proportion.

Differing from other fee programs, the I-5 Sub-regional Mitigation DUE rates and associated fees for a new residential unit or commercial building varied by "fee district" as well as varying by land use category. The number of new vehicle trips traveling to or from each fee district, estimated by SACOG's regional travel forecasting model, was used to determine each district's responsibility to congestion on the performance area State highway system. Figure 1 shows the four designated fee districts for this sub-regional fee program.

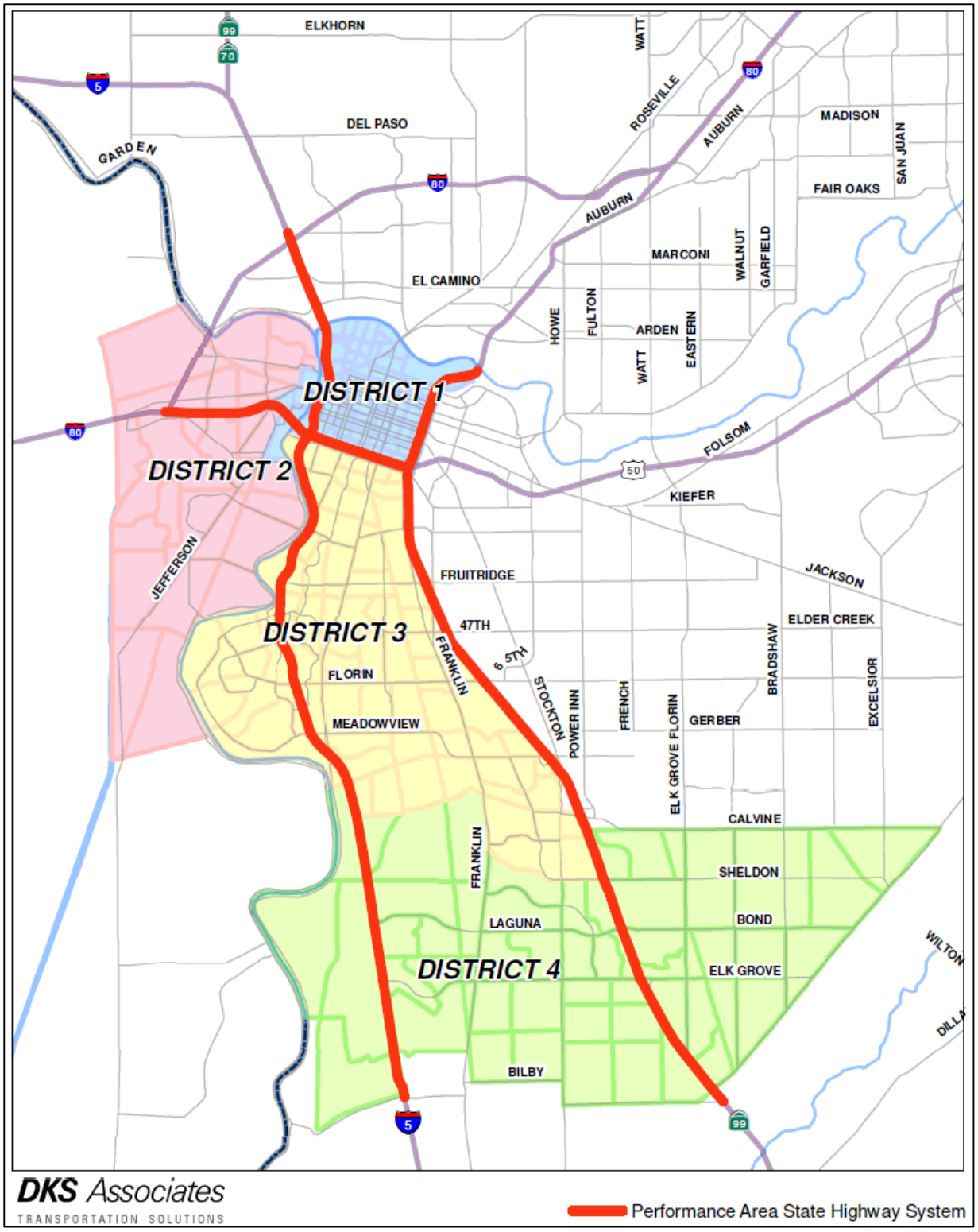

Figure 1: I-5 Sub-regional Mitigation Fee Districts

SACOG's activity-based travel forecasting model (SACSIM) was used to develop DUE rates because of the models ability to distinguish the primary trip origin and primary trip destination (by trip purpose) from intermediate stops within a trip.

SACSIM's "tours" database was used to track peak period vehicle hours of delay on the state highway system in the performance area for all trip origin-destination combinations. Vehicle delay was calculated using the SACSIM activity-based travel forecasting model using 2018 pseudo parcel land use data and an existing roadway and transit network as inputs. Existing year (2005) roadway and transit networks were used to capture the impacts from future growth on today's state highway system. This calculation then associates each primary trip origin and trip destination with a quantified measure of "impact" for each development type.

A "dwelling unit equivalent" or "DUE" rate is assigned to each type of development within each fee district. In this analysis, DUE rates can be thought of as a numerical measure of how the combination of development type and location contribute to peak period congestion on the performance area's State highway system.

The advantage of a delay calculation is its ability to quantify impacts based on trip length and trip direction. For example, an AM commute trip from Elk Grove to Downtown Sacramento would have a heavier impact to the state highway system than an AM commute trip from Downtown Sacramento to Elk Grove, yet both commute trips have approximately the same travel distance on the state highway system. The heavier impact is due to the freeway's congestion being a directional problem in the performance area. Hence each fee district's DUE rate implements the effects of a district being overly saturated with jobs or houses. Finally, the DUE rates were scaled such that a single family dwelling unit in the Elk Grove District (District 4) equaled 1.00. The DUE rates used to estimate the district based transportation mitigation fees are shown in Table 4.

Table 4: SACSIM Estimated DUE Rates by Fee District

		Rate per Dwelling Unit		Rate per 1,000 Square Feet		
	District	Single Family	Multi-Family	Retail	Office	Industrial / Other
1	Sacramento Central City / West Sacramento (Riverfront)	0.49	0.30	0.93	0.92	0.65
2	West Sacramento (North and Southport)	0.43	0.26	0.74	0.66	0.46
3	Land Park / So. Sacramento / Pocket	0.71	0.44	0.81	0.59	0.41
4	Elk Grove	1.00	0.62	0.34	0.23	0.16

The DUE rates shown in Table 4 differ from standard DUE rates in that there is a unique DUE rate for each of the four districts in the fee program. In most fee programs, one single

set of average DUE rates are estimated for the entire program's region, rather than a unique set of DUE rates for each District in the fee program. Comparing the DUE rate of 0.49 in District #1 (Sacramento's Central City) with the DUE rate of 1.00 in District #4 (Elk Grove) shows that SACSIM estimates that a single family residential unit in Elk Grove causes about twice the peak period congestion on state routes in the fee program's study area than a single family residential unit in Sacramento's downtown area. Conversely, building additional retail in Elk Grove will cause much less peak period congestion on state routes than additional retail in Sacramento's downtown area.

Development in the proposed Performance Area should pay a reasonable share of a selected set of improvements based on both the level of traffic congestion reduction and the performance area's share of growth on the selected State highway segments. For illustrative purposes, a $5,000 fee was assumed for a single family dwelling unit in Elk Grove, District 4. Table 5 shows the associated cost for each development type by fee district for the assumed $5,000/DUE fee.

Table 5: Illustrative Cost per DUE with District 4 Single-family = $5,000

District		Cost per Dwelling Unit		Cost per 1,000 Square Feet		
		Single Family	Multi-Family	Retail	Office	Industrial
1	Sacramento Central City / West Sacramento (Riverfront)	$2,439	$1,512	$4,668	$4,622	$3,235
2	West Sacramento (North and Southport)	$2,134	$1,323	$3,711	$3,302	$2,311
3	Land Park / So. Sacramento / Pocket	$3,560	$2,207	$4,044	$2,960	$2,072
4	Elk Grove	$5,000	$3,100	$1,679	$1,144	$801