Memorandum

To: David Schonbrunn, TRANSDEF
From: Norm Marshall
Subject: California High-speed Rail Model Coefficients Review
Date: April 26, 2010

I have reviewed the "final coefficients and constants in the HSR Ridership & Revenue Model" attached to the memorandum from George Mazur of Cambridge Systematics to Nick Brand dated January 29, 2010, plus March 2010 memos from Mazur and from the California High-Speed Rail Authority, and Bay Area/California High-Speed Rail Ridership and Revenue Study reports from the period 2005-2007.

As described in the March 2010 memo from the California High-Speed Rail Authority, a travel demand model was used to develop ridership and revenue forecasts:

> A travel demand model is a tool for making predictions about people's travel patterns. A model consists of a series of mathematical equations that produce forecasts of the number, origin and destination, travel mode, and travel route for trips as a function of variables such as population and employment, travel time and cost, fuel costs, rail and airline schedules, and a number of other variables. The mathematical equations in the model include coefficients and constants that describe the importance of each input variable in a traveler's decisions regarding the number of trips, destination, travel mode, and travel route. Typically, the mathematical equations, including the constants and coefficients, reside in computer software files that are used to apply the model. In applying the model, assumed values for the variables are input to the model, and the computer software applies the mathematical equations to these assumed values in order to make travel predictions. In the following [comments], the word "model" specifically refers to the mathematical equations, including the coefficients and constants, and does not include the assumed values that are input to the model.[1]

Based on my expertise and experience as documented in the attached C.V., I find:

1) The model coefficients used in developing the ridership and revenue forecasts are different than those disclosed to the public during the 2007 environmental review period.

2) The final frequency (headway) coefficients used in developing the ridership and revenue forecasts are invalid.

3) The use of these invalid frequency (headway) coefficients biases the alternatives analyses in favor of the Pacheco Alignment (P1) as compared to the Altamont alignment (A1).

4) Mode-specific constants were misrepresented during the public review process.

5) The mode-specific constants in the final model that were used to forecast ridership and revenue are invalid.

I provide support for these findings in the sections below.

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[1] Memorandum from George Mazur to Mehdi Morshed, Executive Director of the California High-Speed Rail Authority regarding "tHigh-Speed Rail Ridership and Revenue Model, p. 1, March 3, 2010.

High-speed Rail Model Misrepresented to Public during the Environmental Review Process

The California High-Speed Rail ridership and revenue forecasts are derived directly from a set of computer models. Information about these models was presented to the public in a series of project publications published between 2005 and 2007.[2] In 2010, it was disclosed that the final project reports misrepresented the model that was used to develop the ridership and revenue forecasts. Many model coefficients were different between the published model and the model that was applied, but I focus on two set of coefficients that are particularly significant – 1) coefficients related to train service frequency, and 2) mode-specific constants that capture any bias between the attractiveness of different travel modes (auto, high-speed rail, conventional rail and air) that is not captured in other model variables.

An important attribute of high-speed rail service is the frequency of service. If all other things are equal, higher frequency (trains more often) will attract higher ridership. The critical modeling question is: how much higher ridership? Answering this question was a focus of the survey and model development process. When urban transit service is frequent, e.g. every 10 minutes, modelers assume that travelers will arrive randomly without attention to the schedule. With 10-minute frequency, also referred to as a 10-minute headway, modelers assume an average wait time of one half the headway, or 5 minutes. With less frequent scheduled service, and particularly with service where advance ticket purchase is likely or even required (including air travel), travelers do not arrive randomly between departures. The summary of the second (and final) peer review meeting in June 2006 states:

> Frequency is included in the mode choice models directly rather than the traditional wait times, calculated as half the headway, because frequency has a different impact on interregional travel than it does on urban travel. Wait times were estimated separately based [on] direction from the peer review panel:[3]

As a result, the magnitude of the frequency effect was estimated from an extensive traveler survey. In March 2010, the California High-Speed Rail Authority reiterated the importance of the survey work, stating:

> Model development was supported by new transportation survey data and existing data from regional transportation agencies, the census, and other sources. The new survey effort included over 10,000 "stated-preference choice exercises" that allow the resulting model to predict travel demand for the new high-speed rail travel option. All aspects of this survey effort, including the sampling plan, followed state-of-the-practice guidelines and were vetted through peer review. The new transportation surveys are discussed in High-Speed Rail Study Survey Documentation (December 2005).[4]

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[2] I have reviewed several of these reports including: *Findings from Second Peer Review Panel Meeting: Final Report* (July 2006), *Interregional Model System Development: Final Report* (August 2006), *Statewide Model Validation Final Report* (July 2007), *Ridership and Revenue Forecasts: Final Report* (July 2007), and *Findings from First [sic] Peer Review Panel Meeting* (actually third peer review report with no meeting, September 2007).

[3] Cambridge Systematics, Inc. with Mark Bradley Research and consulting and SYSTRA Consulting, Inc. Bay Area/California High-Speed Rail Ridership and Revenue Forecasting Study: *Findings from Second Peer Review Panel Meeting: Final Report*, p. 4-14, July 2006.

[4] Morshed 2010, p. 2.

The frequency (headway) coefficients estimated from the survey data indicate that:

> "The value of frequency (headway) is significant for all segments, but is only about 20 percent as large as the in-vehicle time coefficient." (Final model development report [also called "Task 5a report"], August 2006).[5]

This same exact sentence is replicated in the project final report and in a recent peer-reviewed journal article about the modeling.

> "The value of frequency (headway) is significant for all segments, but is only about 20 percent as large as the in-vehicle time coefficient." (Final project report, July 2007)[6]

> "The value of frequency (headway) is significant for all segments, but is only about 20 percent as large as the in-vehicle time coefficient." (Peer-reviewed journal article published in March 2010)[7]

This 20 percent value is reasonable. It implies that adding an additional one hour between train departures will have the same effect on ridership as increasing the travel time on the train by 12 minutes. The question as to what values are reasonable will be discussed in greater depth in the "High-Speed Rail Model Coefficients are Invalid" section below.

Details in the August 2006 final model report provide detailed model coefficients, and indicate for long distance trips, the ratio of the frequency coefficient to the in-vehicle time coefficient is 0.21 for work trips and 0.24 for other trips. (Table 3-15, p. 3-37) These numbers are a more precise presentation of the information provided in the July 2007 project final report as "about 20 percent."

The first instance where any information was provided to the public that was different than "about 20 percent" was in a January 29, 2010 memo.[8] Attached to this memo were model coefficients that were very different from those presented earlier, and also inconsistent with the model description in the July 2007 final project report. The January 2010 information does not state so explicitly, but it can be inferred that instead of basing the frequency coefficients on the survey data, it instead was assumed that the ratio between frequency and in-vehicle time was 100%, or about 5 times as much as indicated by the survey data.[9] The memo also states that: "The client, MTC, elected not to update the Task 5a report nor to include the final coefficients and constants in the final project report."

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[5] Cambridge Systematics, Inc. with Mark Bradley Research and Consulting, Bay Area/California High-Speed Rail Ridership and Revenue Forecasting Study: *Interregional Model System Development: Final Report*, p. 3-36, August 2006.

[6] Cambridge Systematics, Inc. with Corey, Canapary & Glanis, Mark Bradley Research and Consulting, HLB Decision Economics, Inc., SYSTRA Consulting, Inc., and Citilabs. Bay Area/California High-Speed Rail Ridership and Revenue Forecasting Study: Final Report, p. 5-7, July 2007.

[7] Outwater, Maren, Kevin Tierney, Mark Bradley, Elizabeth Sall, Arun Duppam and Vamsee Modugula. "California Statewide Model for High-Speed Rail", p. 74, Journal of Choice Modelling, March 2010, 3(1) pp. 58-83.

[8] Memo, George Mazur of Cambridge Systematics to Nick Brand re "Final Coefficients and Constants in HSR Ridership and Revenue Model, January 29, 2010

[9] The coefficients attached to the January 29, 2010 Mazur memo included one case where the ratio was 1000%, but the California High-Speed Rail Authority later indicated that was a typographical error.

In the March 2010 California High-Speed Rail Authority memo cited earlier, Morshed makes an unsupported assertion that the information was somehow available to the public earlier.

> While the final constants and coefficients had not been compiled into summary table format prior to the January 29, 2010 memorandum, the information contained in the tables has been publicly available in a different form since 2007.

One can only speculate as to what is intended by this statement, but it appears to be a reference to the model itself; i.e. if the public suspected that the model was inconsistent with the published reports, that the model could have been requested and examined. Even in this scenario, discovering the discrepancies would have been a significant undertaking for the public. As the California High-Speed Rail Authority itself stated when transmitting the January 2010 memo and correct coefficients:

> "… this material as presented did not previously exist and significant amounts of sub-consultant staff time went into preparing it."[10]

In reality, the correct model information simply was not available to the public until 2010. There clearly was ample time within the environmental review process to properly disclose the model information. The March 2010 California High-Speed Rail Authority memo states that there were no changes to model coefficients after February 7, 2007.[11] Nevertheless, the July 2007 project final report restates the 20 percent ratio. There also are no mentions of any coefficient changes in the September 2007 third peer review report.[12] This suggests that even the peer reviewers were not informed about the changes. Table 1 summarizes the entire chronology.

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[10] Morshed 2010, p. 2-3.

[11] Morshed 2010, p. 2

[12] Cambridge Systematics, Inc.. Bay Area/California High-Speed Rail Ridership and Revenue Forecasting Study: *Findings from First [sic] Peer Review Panel Meeting*, September 2007.

Table 1: Chronology of Disclosure of Frequency Coefficient Information

Date	Document	Frequency/in-vehicle time ratio info
July 2006	2nd Peer Review meeting report	Estimate frequency coefficient rather than using half the headway
August 2006	Interregional Model System Development Final Report	"about 20 percent as large as the in-vehicle time coefficient" and ratios of 0.21 for long work trips and 0.24 for long other trips
February 2007	Morshed 2010, p. 2	Date when Cambridge Systematics and California High-speed Rail Authority state that coefficients were finalized
July 2007	Overall Final Report	"about 20 percent as large as the in-vehicle time coefficient"
September 2007	3rd Peer Review report (no meeting)	No mention of issue
March 2008	Journal article submitted	Presumably includes text and table numbers same as in March 2010 published version
December 2008	Journal article revisions submitted	Presumably includes text and table numbers same as in March 2010 published version
January 29, 2010	Cambridge Systematics memo	Discloses coefficients showing headway/in-vehicle time ratios of 1.0 and 10.0
March 2010	Journal article published	"about 20 percent as large as the in-vehicle time coefficient" and table with 0.21 and 0.24
March 3, 2010	Cambridge Systematics memo	Highlights typographical error in January 29 memo
March 3, 2010	California High-speed Rail Authority memo	States that "procedures, coefficients, and constants have remained unchanged since February 7, 2007"

Prior to 2010, the mathematical underpinnings of the HSR ridership and revenue forecasts were never disclosed to the public or to regulatory authorities, creating the false presumption that the previously documented coefficients and constants had been used to develop the forecasts.

High-speed Rail Model Coefficients are Invalid

As discussed above, the report from the second peer review meeting described estimating the frequency coefficients from the survey data, independent of headway/wait time. This June 2006 meeting was attended by nine peer review members:

- Ayalew Adamu (California Department of Transportation (Caltrans) Headquarters);
- Jean-Pierre Arduin (independent consultant);
- Chris Brittle (independent consultant representing MTC);
- Billy Charlton (San Francisco County Transportation Authority (SFCTA));
- Kostas Goulias (University of California at Santa Barbara);
- Keith Killough (Southern California Association of Governments (SCAG));
- Frank Koppelman (Northwestern University);
- Chausie Chu (Los Angeles County Metropolitan Transportation Authority (Metro)); and
- Kazem Oryani (URS Corporation).[13]

Especially notable in this group is Frank Koppelman who is a leading expert in mode choice modeling from stated preference data. Koppelman and Bhat have authored a guide to model estimation from which two short excerpts are reprinted below. The first excerpt discusses the use of ratios in model testing.

> The ratio of the estimated travel time and travel cost parameters provides an estimate of the value of time implied by the model; this can serve as another important informal test for evaluating the reasonableness of the model… Similar ratios may be used to assess the reasonableness of the relative magnitudes of other pairs of parameters. These include out of vehicle time relative to in vehicle time, travel time reliability (if available) relative to average travel time, etc.[14]

The focus on the ratio between frequency (headway) and in-vehicle time is a typical use of this type of reasonableness testing. If the ratio is reasonable, this adds confidence concerning the validity of the model. The second excerpt discusses "constraining" coefficients.

> Two approaches are commonly taken to identify a specification which is not statistically rejected by other models and has good behavioral relationships among variables. The first is to examine a range of different specifications in an attempt to find one which is both behaviorally sound and statistically supported. The other is to constrain the relationships between or among parameter values to ratios which we are considered reasonable. The formulation of these constraints is based on the judgment and prior empirical experience of the analyst. Therefore, the use of such constraints imposes a responsibility on the analyst to provide a sound basis for his/her decision. The advice of other more experienced analysts is often enlisted to expand and/or support these judgments.[15]

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[13] Cambridge Systematics et. al. July 2007, p. ES1 – ES2.

[14] Koppelman, Frank S. and Chandra Bhat. A Self Instructing Course in Mode Choice Modeling: Multinomial and Nested Logit Models, p. 78-79. Prepared for U.S. Department of Transportation, Federal Transit Administration 2006.

[15] Koppelman and Bhat 2006, p. 112.

In the original model, the estimated frequency (headway) coefficients were all highly statistically significant[16], so lack of statistical fit was not a basis for constraining the coefficients. Nevertheless, in the final California High-Speed Rail model, the frequency (headway) coefficients were constrained to 100 percent of the in-vehicle time coefficient. This implies that the effect of an additional hour between train departures on ridership is just as great as an additional hour on the train. This is contrary to common sense, and if true, would cancel out much of the rationale of high-speed train service. Instead, it likely would be cheaper just to add more frequent conventional train service. If the survey data resulted in this 100 percent ratio, it would be necessary to give it some credence, but as discussed above, the survey data indicate the ratio to be about 20 percent, or one fifth as great. As in the Koppelman and Bhat excerpt, constraining a coefficient rather than estimating it " imposes a responsibility on the analyst to provide a sound basis for his/her decision." No such "sound basis" has been provided anywhere, even to this day.

In the journal article published in 2010, a sentence was added that did not appear in an earlier draft or in similar paragraphs in earlier project reports. After the sentence about the 20 percent ratio, it states:

> This coefficient was constrained to match in-vehicle time based on comments from the peer review panel.[17] (p. 74)

This statement cannot be reconciled with the timeline presented in Table 1. The second peer review meeting was in June 2006, and no such comments are included there. There were no further peer review meetings. Only three of the nine who attended the June 2006 meeting participated in email communications summarized in the third peer review report, and Koppelman was not one of those who participated. The third peer review report contains nothing concerning this issue.

To summarize this section:

1) The final model includes an assumption that the time between trains is just as important as the time on the train in determining ridership.
2) There is no documentation for this assumption and no basis provided for it.
3) The assumption is contrary to the empirical results obtained from a large survey conducted at great cost for this project.
4) The assumption violates both common modeling practice and common sense.
5) The technical authors continued to publish the original coefficients in a refereed journal article[18] after the model had been changed.
6) The final coefficients used in developing the ridership and revenue forecasts are invalid.

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[16] Cambridge Systematics, Inc. with Mark Bradley Research and Consulting, August 2006, Table 3-15, p. 3-37.

[17] Outwater et. al. 2010, p. 74.

[18] Outwater et. al. 2010, p. 75, Table 5 and Footnote 3.

Invalid High-Speed Rail Model Coefficients Biased Comparison of Alternatives

The Altamont alternative (A1) was modeled with trains divided between San Jose and San Francisco destinations. Therefore, this alternative has lower frequency (higher headways) on the northern end than the Pacheco alternative (P1). The ridership and revenue study identified this factor as a primary cause for the lower ridership forecast for the Altamont Alternative as compared to the Pacheco alternative.

> The annual boardings forecast for the Altamont and Pacheco baseline HST alternatives are presented in Table 2.1. Overall the Pacheco alternative (P1) has higher projected ridership with over 93 million expected annual boardings compared to 87.9 million for the Altamont alternative (A1). The preference of the P1 alternative is most pronounced in the Bay Area and Southern California due to quicker travel times between these two regions. The Altamont alternative suffers from the division of service between San Jose and San Francisco termini once trains enter the Bay Area. The split effectively doubles the average train headways into and out of the Bay Area for individual stations resulting in decreased ridership. The Altamont Alternative produces more boardings in the Sacramento and Stockton area due to shorter travel time to the Bay Area compared to the Pacheco Alternative.[19]

As discussed above, the frequency (headway) effect in the final model is five times as great as indicated by the survey data or in the model information presented to the public during the environmental review process. This results in underestimated ridership for the Altamont alternative (A1) relative to the Pacheco alternative (P1). These biased ridership and revenue numbers contributed to the selection of the P1 alternative over the A1 alternative.

Mode-Specific Constants Were Misrepresented during the Public Review Process

The mode choice model determines how passengers travel based on the relative attractiveness of each alternative mode: auto, conventional rail, high-speed rail and air travel. Ideally, all of the differences between modes can be expressed as a function of service attributes including travel time and travel cost. In practice, there always are some residual effects between modes that are not captured in the service attributes. These residual effects are incorporated into the model as mode-specific constants. It is preferable that the constants do not dominate the model. This can be tested by dividing the mode-specific constant by the in-vehicle time coefficient to calculate an equivalent number of minutes. For example, if a mode-specific constant is 60 times the in-vehicle time coefficient (in minutes), it is equivalent to one hour of additional in-vehicle time (abbreviated as IVT equiv.).

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[19] Cambridge Systematics, Inc.. Bay Area/California High-Speed Rail Ridership and Revenue Forecasting Study: *Ridership and Revenue Forecasts: Final Report*, p. 2-1 -2.2, July 2007.

There are three sets of published mode-specific constants for the California high-speed rail modeling: 1) model development constants (August 2006), 2) validation report constants (July 2007) and 3) the final constants disclosed in January, 2010.

Table 2 presents the mode-specific constants given in the model development report for long commute/business and long recreation/other trips. Table 3 presents the mode-specific constants given in the *Statewide Model Validation* report for these same trip categories. Both tables convert these numbers into the equivalent number of travel minutes. Although there are no firm rules, the magnitude of the Table 3 constants in IVT equivalent minutes appear high relative to that which is desirable, and there is a danger that they may be dominating the service characteristics effects. The magnitude in IVT equivalent minutes is much high in Table 3 than in Table 2. For example, in the case of high speed rail for long-distance business trips, the model penalty relative to auto changed from 22 minutes in model development to 326 minutes in the Model Validation report.

Table 2: Mode-Specific Constants for Long Trips Reported in Model Development Report[20]

	Business/Commute		Recreation/Other	
	constant	IVT equiv. (min.)	constant	IVT equiv. (min.)
Auto (constant 0 by convention)	0	0	0	0
Air	-1.645	103	0.6898	-63
Conventional Rail	-0.387	24	0.6149	-56
High-Speed Rail	-0.3503	22	1.434	-130
Note: in-vehicle time coefficient (minutes)		-0.016		-0.011

Table 3: Mode-Specific Constants for Long Trips Reported in Validation Report[21]

	Business/Commute		Recreation/Other	
	constant	IVT equiv. (min.)	constant	IVT equiv. (min.)
Auto (constant 0 by convention)	0	0	0	0
Air	-7.5062	417	-3.0858	281
Conventional Rail	-3.9738	221	1.6557	-151
High-Speed Rail	-5.8600	326	-0.1807	16
Note: in-vehicle time coefficient (minutes)		-0.018		-0.011

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[20] Cambridge Systematics, Inc. with Mark Bradley Research and Consulting, August 2006, Table 3-15, p. 3-37.

[21] Cambridge Systematics, Inc. and Mark Bradley Research and Consulting, August 2006, Table 3.15 p. 3-37.

The final set of mode-specific coefficients for long trips disclosed in January 2010 shown below in Table 4 are very different from those in the July 2007 *Statewide Model Validation* report. According to the California High-Speed Rail Authority, there were no changes to model coefficients and constants after February 2007.[22] Therefore there is no justification for the discrepancy between the validation report and the final coefficients. Note the dramatic changes in the IVT equivalents for the air constants, while the rail alternatives changed only slightly. Also, there were significant changes in the Recreation/Other column for High-Speed Rail.

Table 4: Mode-Specific Constants for Long Trips Disclosed in January 2010[23]

	Business/Commute		Recreation/Other	
	constant	IVT equiv. (min.)	constant	IVT equiv. (min.)
Auto (constant 0 by convention)	0	0	0	0
Air				
High income most* air travel	-4.089	227	0.317	-29
Low income most* air travel	-5.269	293	0.317	-29
Conventional Rail				
High income	-4.007	223	2.010	-183
Low income	-4.620	257	1.272	-116
High-Speed Rail				
High income	-5.610	312	-0.713	65
Low income	-6.757	375	-0.713	65
Note: in-vehicle time coefficient (minutes)		-0.018		-0.011
*99% of modeled air travel uses these or higher mode-specific constants				

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[22] Morshed 2010, p. 2.

[23] Mazur 2010.

Unlike the constants in Tables 2 and 3, the constants in Table 4 are different for low-income and high-income travelers. These differences are relatively small. However, there also are larger underlying differences that are too complicated to be illustrated in Table 4. These involve 48 different "dummy variable" adjustment factors for airport pairs (Figure 1).

Figure 1: Airport-to-Airport Dummy Variables in Final Model Coefficients[24]

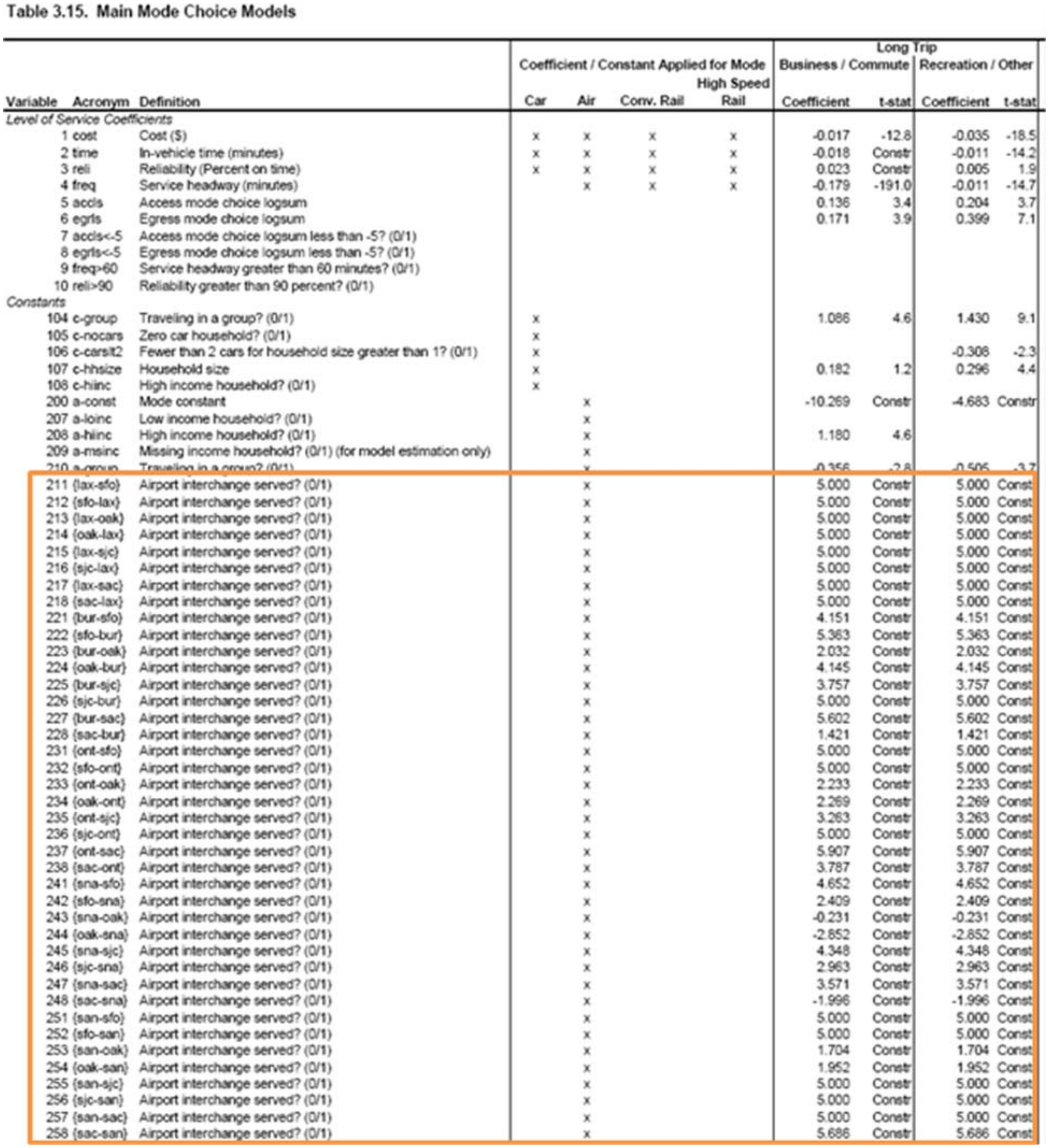

Table 3.15. Main Mode Choice Models

			Coefficient / Constant Applied for Mode				Long Trip			
							Business / Commute		Recreation / Other	
Variable	Acronym	Definition	Car	Air	Conv. Rail	High Speed Rail	Coefficient	t-stat	Coefficient	t-stat
Level of Service Coefficients										
1	cost	Cost ($)	x	x	x	x	-0.017	-12.8	-0.035	-18.5
2	time	In-vehicle time (minutes)	x	x	x	x	-0.018	Constr	-0.011	-14.2
3	reli	Reliability (Percent on time)	x	x	x	x	0.023	Constr	0.005	1.9
4	freq	Service headway (minutes)		x	x	x	-0.179	-191.0	-0.011	-14.7
5	accls	Access mode choice logsum					0.136	3.4	0.204	3.7
6	egrls	Egress mode choice logsum					0.171	3.9	0.399	7.1
7	accls<-5	Access mode choice logsum less than -5? (0/1)								
8	egrls<-5	Egress mode choice logsum less than -5? (0/1)								
9	freq>60	Service headway greater than 60 minutes? (0/1)								
10	reli>90	Reliability greater than 90 percent? (0/1)								
Constants										
104	c-group	Traveling in a group? (0/1)	x				1.086	4.6	1.430	9.1
105	c-nocars	Zero car household? (0/1)	x							
106	c-carslt2	Fewer than 2 cars for household size greater than 1? (0/1)	x						-0.308	-2.3
107	c-hhsize	Household size	x				0.182	1.2	0.296	4.4
108	c-hiinc	High income household? (0/1)	x							
200	a-const	Mode constant		x			-10.269	Constr	-4.683	Constr
207	a-loinc	Low income household? (0/1)		x						
208	a-hiinc	High income household? (0/1)		x			1.180	4.6		
209	a-msinc	Missing income household? (0/1) (for model estimation only)		x						
210	a-group	Traveling in a group? (0/1)		x			-0.356	-2.8	-0.505	-3.7
211	{lax-sfo}	Airport interchange served? (0/1)		x			5.000	Constr	5.000	Const
212	{sfo-lax}	Airport interchange served? (0/1)		x			5.000	Constr	5.000	Const
213	{lax-oak}	Airport interchange served? (0/1)		x			5.000	Constr	5.000	Const
214	{oak-lax}	Airport interchange served? (0/1)		x			5.000	Constr	5.000	Const
215	{lax-sjc}	Airport interchange served? (0/1)		x			5.000	Constr	5.000	Const
216	{sjc-lax}	Airport interchange served? (0/1)		x			5.000	Constr	5.000	Const
217	{lax-sac}	Airport interchange served? (0/1)		x			5.000	Constr	5.000	Const
218	{sac-lax}	Airport interchange served? (0/1)		x			5.000	Constr	5.000	Const
221	{bur-sfo}	Airport interchange served? (0/1)		x			4.151	Constr	4.151	Const
222	{sfo-bur}	Airport interchange served? (0/1)		x			5.363	Constr	5.363	Const
223	{bur-oak}	Airport interchange served? (0/1)		x			2.032	Constr	2.032	Const
224	{oak-bur}	Airport interchange served? (0/1)		x			4.145	Constr	4.145	Const
225	{bur-sjc}	Airport interchange served? (0/1)		x			3.757	Constr	3.757	Const
226	{sjc-bur}	Airport interchange served? (0/1)		x			5.000	Constr	5.000	Const
227	{bur-sac}	Airport interchange served? (0/1)		x			5.602	Constr	5.602	Const
228	{sac-bur}	Airport interchange served? (0/1)		x			1.421	Constr	1.421	Const
231	{ont-sfo}	Airport interchange served? (0/1)		x			5.000	Constr	5.000	Const
232	{sfo-ont}	Airport interchange served? (0/1)		x			5.000	Constr	5.000	Const
233	{ont-oak}	Airport interchange served? (0/1)		x			2.233	Constr	2.233	Const
234	{oak-ont}	Airport interchange served? (0/1)		x			2.269	Constr	2.269	Const
235	{ont-sjc}	Airport interchange served? (0/1)		x			3.263	Constr	3.263	Const
236	{sjc-ont}	Airport interchange served? (0/1)		x			5.000	Constr	5.000	Const
237	{ont-sac}	Airport interchange served? (0/1)		x			5.907	Constr	5.907	Const
238	{sac-ont}	Airport interchange served? (0/1)		x			3.787	Constr	3.787	Const
241	{sna-sfo}	Airport interchange served? (0/1)		x			4.652	Constr	4.652	Const
242	{sfo-sna}	Airport interchange served? (0/1)		x			2.409	Constr	2.409	Const
243	{sna-oak}	Airport interchange served? (0/1)		x			-0.231	Constr	-0.231	Const
244	{oak-sna}	Airport interchange served? (0/1)		x			-2.852	Constr	-2.852	Const
245	{sna-sjc}	Airport interchange served? (0/1)		x			4.348	Constr	4.348	Const
246	{sjc-sna}	Airport interchange served? (0/1)		x			2.963	Constr	2.963	Const
247	{sna-sac}	Airport interchange served? (0/1)		x			3.571	Constr	3.571	Const
248	{sac-sna}	Airport interchange served? (0/1)		x			-1.996	Constr	-1.996	Const
251	{san-sfo}	Airport interchange served? (0/1)		x			5.000	Constr	5.000	Const
252	{sfo-san}	Airport interchange served? (0/1)		x			5.000	Constr	5.000	Const
253	{san-oak}	Airport interchange served? (0/1)		x			1.704	Constr	1.704	Const
254	{oak-san}	Airport interchange served? (0/1)		x			1.952	Constr	1.952	Const
255	{san-sjc}	Airport interchange served? (0/1)		x			5.000	Constr	5.000	Const
256	{sjc-san}	Airport interchange served? (0/1)		x			5.000	Constr	5.000	Const
257	{san-sac}	Airport interchange served? (0/1)		x			5.000	Constr	5.000	Const
258	{sac-san}	Airport interchange served? (0/1)		x			5.686	Constr	5.686	Const

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[24] Mazur 2010.

For the less popular air markets, the dummy variable structure suppresses the air share of travel to very small numbers. [25] The inclusion of these widely-variable “fudge factors” calls model validity into question as the model should handle both long and short trips without these adjustments. Would unknown adjustments be needed to match high-speed rail shares?

The *Statewide Model Validation* report states that the model is able to match observed air boardings closely: “The three largest markets match boardings with observed boardings within +/- 2 percent and the overall total air trips match observed boardings within +/- 1 percent.”[26] Serious questions are raised about this statement given the revelation that the final mode-specific constants do not match those reported in this report, and that the final mode-specific constants include airport-to-airport adjustment factors. The use of such factors would make achieving a good model fit a trivial exercise, and therefore such a statement would not engender the level of confidence that it otherwise would. Questions include:

- Were the mode-specific constants in the *Statewide Model Validation* report used to produce the base year travel estimates in the *Statewide Model Validation* report?
- If the reported constants were used and were validated, why were they later changed?
- Have the final model constants been validated?
- If the final constants reported in January 2010 were used in the validation effort, then why weren’t they reported accurately and why wasn’t the use of airport-to-airport adjustment factors disclosed in 2007?

No matter what the answers to these questions are, it is clear that the model constants were not properly disclosed to the public during the environmental review process.

Final Mode-Specific Constants Are Invalid for Forecasting

The final mode-specific constants in Table 4 show high-speed rail as less attractive than either air or conventional rail for both business and non-business travel. Furthermore, the differences are large. For business travelers, the preference for air over high-speed rail is equivalent to 83-85 minutes of travel[27] (depending on income). More inexplicably, the preference for conventional rail over high-speed rail is equivalent to 89-119 minutes. For non-business travelers the preference for air over high-speed rail is 94 minutes, and the preference for conventional rail over high-speed rail is 180-248 minutes. If all three non-auto modes are available (air, conventional rail and high-speed rail), and service characteristics are identical (in-vehicle time, out-of-vehicle time, cost, frequency, etc.), high-speed rail will have the smallest mode share of the three modes modeled.

These numbers make absolutely no sense and cannot be justified by the model development process. The original mode-specific constants (Table 2) showed no such bias against high-speed rail. In the constants estimated from the stated preference data, high-speed rail is <u>more</u> attractive than either conventional rail

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[25] The final model includes a high negative base constant for air that is partially offset by large positive constants for the most popular air markets. These factors vary widely, but the net airport-to-airport air constants in the final model (after adding the base constant to the airport-to-airport dummy) are equal to or higher than the values shown in Table 4 for 99 percent of the modeled air boardings (for all major long distance airport pairs). Most of these interchanges include a dummy adjustment of + 5.0

[26] Cambridge Systematics, Inc. with Mark Bradley Research and Consulting, July 2007, p. 6-3.

[27] Subtract one IVT equivalent from another to see the preference.

or air travel. Compared to conventional rail, the preference for high-speed rail is equivalent to 3 minutes for business travelers and 74 minutes for non-business travelers. Compared to air, the preferences are equivalent to 72 minutes (business) and 67 minutes (non-business).

It is common to adjust mode-specific constants to make models better match base ridership data. Therefore, it was appropriate to adjust the constants for air and conventional rail to match observed mode shares. If those adjustments were significant, it would also have been necessary to adjust the high-speed rail constants as well, but these adjustments need to be consistent across modes. There is no justification for switching high-speed rail from being the most attractive non-auto mode to being the least attractive. It is especially absurd that high-speed rail could be modeled as less attractive than conventional rail if service characteristics were identical. The final model constants are invalid for forecasting.

Conclusions

The California high-speed rail ridership and revenue forecasts used in the selection of a preferred alignment were based on modeling that was misrepresented and that was invalid. Specifically:

1) The model coefficients used in developing the ridership and revenue forecasts are different than those disclosed to the public during the environmental review period.

2) The final frequency (headway) coefficients used in developing the ridership and revenue forecasts are invalid.

3) The use of these invalid frequency (headway) coefficients biases the alternatives analyses in favor of the Pacheco Alignment (P1) as compared to the Altamont alignment (A1).

4) Mode-specific constants were misrepresented during the public review process.

5) The mode-specific constants in the final model that were used to forecast ridership and revenue are invalid.

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EDUCATION:

Master of Science in Engineering Sciences, Dartmouth College, Hanover, NH, 1982
Bachelor of Science in Mathematics, Worcester Polytechnic Institute, Worcester, MA, 1977

PROFESSIONAL EXPERIENCE:

Norm Marshall helped found Smart Mobility, Inc. in 2001. Prior to this, he was at Resource Systems Group, Inc. for 14 years where he developed a national practice in travel demand modeling. He specializes in analyzing the relationships between the built environment and travel behavior, and doing planning that coordinates multi-modal transportation with land use and community needs.

Regional Land Use/Transportation Scenario Planning

Chicago Metropolis Plan and Chicago Metropolis Freight Plan (6-county region)— developed alternative transportation scenarios, made enhancements in the regional travel demand model, and used the enhanced model to evaluate alternative scenarios including development of alternative regional transit concepts. Developed multi-class assignment model and used it to analyze freight alternatives including congestion pricing and other peak shifting strategies. Chicago Metropolis 2020 was awarded the Daniel Burnham Award for regional planning in 2004 by the American Planning Association, based in part on this work.

Envision Central Texas Vision (5-countyregion)—implemented many enhancements in regional model including multiple time periods, feedback from congestion to trip distribution and mode choice, new life style trip production rates, auto availability model sensitive to urban design variables, non-motorized trip model sensitive to urban design variables, and mode choice model sensitive to urban design variables and with higher values of time (more accurate for "choice" riders). Analyzed set land use/transportation scenarios including developing transit concepts to match the different land use scenarios.

Mid-Ohio Regional Planning Commission Regional Growth Strategy (7-county Columbus region)—developed alternative future land use scenarios and calculated performance measures for use in a large public regional visioning project.

Baltimore Vision 2030—working with the Baltimore Metropolitan Council and the Baltimore Regional Partnership, increased regional travel demand model's sensitivity to land use and transportation infrastructure. Enhanced model was used to test alternative land use and transportation scenarios including different levels of public transit.

Chittenden County (2060 Land use and Transportation Vision Burlington Vermont region) – leading extensive public visioning project as part of MPO's long-range transportation plan update.

Burlington (Vermont) Transportation Plan – Leading team developing Transportation Plan focused on supporting increased population and employment without increases in traffic by focusing investments and policies on transit, walking, biking and Transportation Demand Management.

Transit Planning

Regional Transportation Authority (Chicago) and Chicago Metropolis 2020 – evaluating alternative 2020 and 2030 system-wide transit scenarios including deterioration and enhance/expand under alternative land use and energy pricing assumptions in support of initiatives for increased public funding.

Capital Metropolitan Transportation Authority (Austin, TX) Transit Vision – analyzed the regional effects of implementing the transit vision in concert with an aggressive transit-oriented development plan developed by Calthorpe Associates. Transit vision includes commuter rail and BRT.

Bus Rapid Transit for Northern Virginia HOT Lanes (Breakthrough Technologies, Inc and Environmental Defense.) – analyzed alternative Bus Rapid Transit (BRT) strategies for proposed privately-developing High Occupancy Toll lanes on I-95 and I-495 (Capital Beltway) including different service alternatives (point-to-point services, trunk lines intersecting connecting routes at in-line stations, and hybrid).

Central Ohio Transportation Authority (Columbus) – analyzed the regional effects of implementing a rail vision plan on transit-oriented development potential and possible regional benefits that would result.

Essex (VT) Commuter Rail Environmental Assessment (Vermont Agency of Transportation and Chittenden County Metropolitan Planning Organization)—estimated transit ridership for commuter rail and enhanced bus scenarios, as well as traffic volumes.

Georgia Intercity Rail Plan (Georgia DOT)—developed statewide travel demand model for the Georgia Department of Transportation including auto, air, bus and rail modes. Work included estimating travel demand and mode split models, and building the Departments ARC/INFO database for a model running with a GIS user interface.

Roadway Corridor Planning

Hudson River Crossing Study (Capital District Transportation Committee and NYSDOT) – Analyzing long term capacity needs for Hudson River bridges which a special focus on the I-90 Patroon Island Bridge where a microsimulation VISSIM model was developed and applied.

State Routes 5 & 92 Scoping Phase (NYSDOT) —evaluated TSM, TDM, transit and highway widening alternatives for the New York State Department of Transportation using local and national data, and a linkage between a regional network model and a detailed subarea CORSIM model.

Twin Cities Minnesota Area and Corridor Studies (MinnDOT)—improved regional demand model to better match observed traffic volumes, particularly in suburban growth areas. Applied enhanced model in a series of subarea and corridor studies.

Developing Regional Transportation Model

Pease Area Transportation and Air Quality Planning (New Hampshire DOT)—developed an integrated land use allocation, transportation, and air quality model for a three-county New Hampshire and Maine seacoast region that covers two New Hampshire MPOs, the Seacoast MPO and the Salem-Plaistow MPO.

Syracuse Intermodal Model (Syracuse Metropolitan Transportation Council)—developed custom trip generation, trip distribution, and mode split models for the Syracuse Metropolitan Transportation Council. All of the new models were developed on a person-trip basis, with the trip distribution model and mode split models based on one estimated logit model formulation.

Portland Area Comprehensive Travel Study (Portland Area Comprehensive Transportation Study)—Travel Demand Model Upgrade—enhanced the Portland Maine regional model (TRIPS software). Estimated person-based trip generation and distribution, and a mode split model including drive alone, shared ride, bus, and walk/bike modes.

Chittenden County ISTEA Planning (Chittenden County Metropolitan Planning Organization)—developed a land use allocation model and a set of performance measures for Chittenden County (Burlington) Vermont for use in transportation planning studies required by the Intermodal Surface Transportation Efficiency Act (ISTEA).

Research

Obesity and the Built Environment (National Institutes of Health and Robert Wood Johnston Foundation) – Working with the Dartmouth Medical School to study the influence of local land use on middle school students in Vermont and New Hampshire, with a focus on physical activity and obesity.

The Future of Transportation Modeling (New Jersey DOT)—Member of Advisory Board on project for State of New Jersey researching trends and directions and making recommendations for future practice.

Trip Generation Characteristics of Multi-Use Development (Florida DOT)—estimated internal vehicle trips, internal pedestrian trips, and trip-making characteristics of residents at large multi-use developments in Fort Lauderdale, Florida.

Improved Transportation Models for the Future—assisted Sandia National Laboratories in developing a prototype model of the future linking ARC/INFO to the EMME/2 Albuquerque model and adding a land use allocation model and auto ownership model including alternative vehicle types.

Critiques

C-470 (Denver region) – Reviewed express toll lane proposal for Douglas County, Colorado and prepared reports on operations, safety, finances, and alternatives.

Intercounty Connector (Maryland) – Reviewed proposed toll road and modeled alternatives with different combinations of roadway capacity, transit capacity (both on and off Intercounty Connector) and pricing.

Foothills South Toll Road (Orange County, CA) – Reviewed modeling of proposed toll road.

I-93 Widening (New Hampshire) – Reviewed Environment Impact Statement and modeling, with a particular focus on induced travel and secondary impacts, and also a detailed look at transit potential in the corridor.

Stillwater Bridge – Participated in 4-person expert panel assembled by Minnesota DOT to review modeling of proposed replacement bridge in Stillwater, with special attention to land use, induced travel, pricing, and transit use.

Ohio River Bridges Projects– Reviewed Environmental Impact Statement for proposed new freeway bridge east of Louisville Kentucky for River Fields, a local land trust and historic preservation not-for-profit organization.

PUBLICATIONS AND PRESENTATIONS (partial list)

Understanding the Transportation Models and Asking the Right Questions. Lead presenter on national Webinar put on by the Surface Policy Planning Partnership (STTP) and the Center for Neighborhood Technologies (CNT) with partial funding by the Federal Transit Administration, 2007.

Sketch Transit Modeling Based on 2000 Census Data with Brian Grady. Presented at the Annual Meeting of the Transportation Research Board, Washington DC, January 2006, and *Transportation Research Record*, No. 1986, "Transit Management, Maintenance, Technology and Planning", p. 182-189, 2006.

Travel Demand Modeling for Regional Visioning and Scenario Analysis with Brian Grady. Presented at the Annual Meeting of the Transportation Research Board, Washington DC, January 2005, and *Transportation Research Record*, No. 1921, "Travel Demand 2005", p. 55-63, 2006.

Chicago Metropolis 2020: the Business Community Develops an Integrated Land Use/Transportation Plan with Brian Grady, Frank Beal and John Fregonese, presented at the Transportation Research Board's Conference on Planning Applications, Baton Rouge LA, April 2003.

Chicago Metropolis 2020: the Business Community Develops an Integrated Land Use/Transportation Plan with Lucinda Gibson, P.E., Frank Beal and John Fregonese, presented at the Institute of Transportation Engineers Technical Conference on Transportation's Role in Successful Communities, Fort Lauderdale FL, March 2003.

Evidence of Induced Travel with Bill Cowart, presented in association with the Ninth Session of the Commission on Sustainable Development, United Nations, New York City, April 2001.

Induced Demand at the Metropolitan Level – Regulatory Disputes in Conformity Determinations and Environmental Impact Statement Approvals, Transportation Research Forum, Annapolis MD, November 2000.

Evidence of Induced Demand in the Texas Transportation Institute's Urban Roadway Congestion Study Data Set, Transportation Research Board Annual Meeting, Washington DC: January 2000.

Subarea Modeling with a Regional Model and CORSIM" with K. Kaliski, presented at Seventh National Transportation Research Board Conference on the Application of Transportation Planning Methods, Boston MA, May 1999.

New Distribution and Mode Choice Models for Chicago with K. Ballard, Transportation Research Board Annual Meeting, Washington DC: January 1998.

"Land Use Allocation Modeling in Uni-Centric and Multi-Centric Regions" with S. Lawe, Transportation Research Board Annual Meeting, Washington DC: January 1996.

Multimodal Statewide Travel Demand Modeling Within a GIS with S. Lawe, Transportation Research Board Annual Meeting, Washington DC: January 1996.

Linking a GIS and a Statewide Transportation Planning Model, with L. Barbour and Judith LaFavor, Urban and Regional Information Systems Association (URISA) Annual Conference, San Antonio, TX, July 1995.

Land Use, Transportation, and Air Quality Models Linked With ARC/INFO. with C. Hanley, C. Blewitt, and M. Lewis, Urban and Regional Information Systems Association (URISA) Annual Conference,: San Antonio, TX, July 1995.

Forecasting Land Use Changes for Transportation Alternative with S. Lawe, Fifth National Conference on the Application of Transportation Planning Methods, Seattle WA, April 1995.

Forecasting Land Use Changes for Transportation Alternatives, with S. Lawe, Fifth National Conference on the Application of Transportation Planning Methods (Transportation Research Board),: Seattle WA, April 1995.

Integrated Transportation, Land Use, and Air Quality Modeling Environment with C. Hanley and M. Lewis Fifth National Conference on the Application of Transportation Planning Methods (Transportation Research Board), Seattle WA, April 1995.

MEMBERSHIPS/AFFILIATIONS

Member, Institute of Transportation Engineers
Individual Affiliate, Transportation Research Board
Member, American Planning Association
Member, Congress for the New Urbanism