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Post-construction evaluation of traffic forecast accuracy

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ABSTRACT

This research evaluates the accuracy of demand forecasts using a sample of recently-completed projects in Minnesota and identifies the factors influencing the inaccuracy in forecasts. Based on recent research on forecast accuracy, the inaccuracy of traffic forecasts is estimated as the difference between forecast traffic and actual traffic, standardized by the actual traffic. The analysis indicates a general trend of underestimation in roadway traffic forecasts with factors such as roadway type, functional classification and direction playing an influencing role. Roadways with higher volumes and higher functional classifications such as freeways are underestimated compared to lower volume roadways and lower functional classifications. The comparison of demographic forecasts shows a trend of overestimation while the comparison of travel behavior characteristics indicates a lack of incorporation of fundamental shifts and societal changes.

1. Introduction

Travel demand forecasts are routinely used to design transportation infrastructure. For example, demand forecasts help determine roadway capacities or the length of station platforms in transit projects and so on. The evaluation of proposed transportation projects and their subsequent performance depends on the demand forecasts made in support of these projects, ahead of project implementation. The high cost of transportation projects, limited availability of resources, irreversibility of such decisions and associated inefficiencies make it essential to focus on the (in)accuracy of transportation forecasts.

While research efforts have focused on improving technical aspects of a typical four-step transportation planning model, few studies have evaluated model accuracy by comparing forecasts to actual traffic counts (Horowitz and Emslie, 1978; Mackinder and Evans, 1981). The Minnesota Department of Transportation (MnDOT) conducted a forecast accuracy study in the 1980s to measure the accuracy of the long range traffic forecasts produced between 1961 and 1964 for the Twin Cities Seven County Metropolitan area with a horizon year of 1980 (Page et al., 1981). The objective of the study was to measure the historical accuracy of the long range traffic forecasts produced in the 1960s when computer based modeling was still in its infancy.

The accuracy was estimated by comparing the forecasts produced in the 1960s by the computer based forecasting model against the actual 1978 traffic counts collected. A total of 330 reports were used providing a database of 391 major roadway links of which 273 roadway links were used for direct comparison of traffic forecast to the traffic counts. This direct comparison indicated a mean absolute percentage error of 19.52% with a percentage error range of −59.9% to +56.9%. Further the analysis indicated that traffic forecasts on 61.5% of the links were underestimated compared to the actual traffic counts and the forecasts were more accurate for higher volume roadways.

There has been a recent revival of interest in evaluating the accuracy of project forecasts following project implementation, in part, due to recent books on large-scale infrastructure projects (Altshuler and Luberoff, 2003; Flyvbjerg et al., 2003). While both these studies looked at the role of various technical analyses in project development, the role of travel demand forecasting and the accuracy/inaccuracy of forecasts made in support of these projects have been of particular importance.

This research follows on the current research interest using data from the Minnesota Department of Transportation (Mn/DOT) to estimate (in)accuracies in roadway traffic forecasts and also analyze the reasons for the presence of inaccuracies. The rest of the paper is organized as follows. The next section provides a brief review of relevant literature followed by a description of the data used for analysis. The illustrative, quantitative and qualitative analyses conducted in this study to estimate inaccuracies are then described. This is followed by a discussion on identifying reasons for the presence of inaccuracies in traffic forecasts. The paper concludes with key findings from the study and provides recommendations to improve forecasts.

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2. Research synthesis

2.1. Error/uncertainty in model forecasts

Researchers have traditionally focused their efforts on identifying and developing methods to incorporate the errors/uncertainties present in the traditional four-step transportation planning model (Gilbert and Jessop, 1977; Ashley, 1980; Pell and Meyburg, 1985). Clarke et al. (1981) expanded previous work on error and uncertainty in forecasting and scenario analyses to focus on the error and uncertainty in travel surveys by comparing the differences in reported trip behavior of the residents in Oxfordshire town of Banbury in Great Britain from two different survey instruments, namely the conventional trip diary and an activity diary. The results confirmed their hypothesis with the activity diary providing significantly higher reported trip rates and travel times compared to the conventional trip diary.

Talvitie et al. (1982) conducted an analysis of the total prediction error in a disaggregate mode choice model for work trips by using measures of average absolute error and root mean square error using data from the following sources: pre-BART data set collected in 1972, post-BART data collected in 1975, Baltimore, Maryland data set collected in 1977 and the Twin Cities data set collected in 1970. The results indicated that the total prediction error in the mode choice models were rather large and varied between 25 and 65% of the predicted value with the Twin Cities data set showing the highest prediction error.

Few researchers have also proposed theoretical approaches to identify and incorporate uncertainty in urban transportation planning (Mahmassani, 1984; Niles and Nelson, 2001). Zhao and Kockelman (2002) investigated the stability of a traditional four-step travel demand model by simulating the propagation of uncertainty in a 25-zone network. The results indicated that the average uncertainty increases in the first three steps of the forecasting process—trip generation, trip distribution and mode choice while the final traffic assignment step decreases average uncertainty. The results also indicate that uncertainty is compounded over the four stages of the forecasting process. The final flow uncertainties produced at the end of the forecasting process are higher than the input uncertainty.

Hugosson (2005) developed a procedure to utilize the 'Bootstrap' method to estimate the sampling related uncertainty in a travel forecasting system. The Swedish National Travel Demand Forecasting System, also called SAMPERS, was used to estimate the standard errors and confidence intervals of the total demand in origin-destination matrices and on link flows. The results from the study indicated that the uncertainties are $\pm$10–15% in total demand on OD matrices and at a 5% risk level in demand on links and train flows. The uncertainty in the value of time was slightly higher at $\pm$16% for cars and $\pm$23% for other modes. Similar to Hugosson's work, de Jong et al. (2007) developed a method of quantifying uncertainty in traffic forecasts in The Netherlands using LMS, the Dutch national model system with a specific focus on the A16 motorway extension in the Rotterdam area.

2.2. Other factors influencing model forecasts

Some researchers have attempted to improve model forecasts by focusing on the impact of variations in the modeling process on performance. Daly and Ortuzar (1990) addressed the problem of the appropriate level of aggregation in a travel demand model by focusing on the mode choice and trip distribution procedures in the travel demand model. The authors designed an experiment to assess the importance of data disaggregation and mode-destination choice integration using data from recent studies in Santiago, Chile. The results indicated that data aggregation affected the quality of the mode choice routine in the forecasting process.

Johnston and Ceerla (1996) looked at the impact of feedback in the trip distribution step on model forecasts using the Sacramento Regional Travel Demand Model. The authors noted that the lack of feedback in the trip distribution procedure results in forecasts that are biased in favor of the build alternatives (capacity enhancements) due to underprojections of the trip lengths induced by the added capacity, which in turn resulted in biased cost and emissions estimates.

Chang et al. (2002) conducted a simulation study with eleven transportation analysis zone structures and two types of network structure to test the effect of spatial data aggregation on travel demand model performance using the Idaho Statewide travel demand model. The study found that models with smaller zonal structure generated shorter trip lengths, higher interzonal trips percentage, better estimated traffic volumes (V) to observed ground count ratios (A) and lower percentage root mean square error between V and A. The variation in network detail showed a negligible effect on the trip length or proportion of interzonal trips but impacted the percentage root mean square error between V and A.

Rodier (2004) applied the model validation procedure to the Sacramento, California regional travel demand model to test the model accuracy, model prediction capabilities and the model representation of induced travel. The study concluded that the model captured about half of the estimated induced travel trips, modestly overestimated vehicle miles traveled (VMT), vehicle hours traveled (VHT) by 5.7%, 4.2%, respectively, and significantly overestimated vehicle hours of delay (VHD) by 17.1%.

Another explanation for the underestimation seen in forecasts, specifically road forecasts, can be attributed to the non-incorporation of induced traffic into the model forecasting procedure. The theory of induced demand states that increases in highway capacity induces additional growth in traffic resulting in increased levels of vehicle traffic. From an economic perspective, the travel demand increases as the cost of travel decreases due to capacity improvements resulting in an elasticity of demand associated with travel (Noland and Lem, 2000; Noland, 2001).

Goodwin (1996) provided an average value for elasticity of traffic volume with respect to travel time of -0.5 in the short-term and upto -1.0 in the long-term based on a literature review of induced demand research. This is confirmed by a comparison of forecasted traffic and actual traffic counts taken a year after opening for 151 Department of Transport road projects in the United Kingdom. The actual traffic flows were on average 10.4% higher than forecast a year after opening. A similar comparison on 85 of the alternative or 'relieved' routes indicated that the observed flows were on average 16.4% higher than the traffic forecast. While this discrepancy between the traffic forecast and actual traffic counts can be attributed to the errors in forecasting process (other than non-inclusion of induced traffic), the underestimation in traffic flows on the alternative routes that the capacity enhancement were expected to relieve points to the induced traffic error.

2.3. Evaluation of model performance

Flyvbjerg (2005) and Flyvbjerg et al. (2005, 2006) conducted one of the most comprehensive studies on inaccuracy in demand forecasts. This statistical study compared the forecast demand with the actual demand for a list of 210 projects between 1969 and 1998. The project list, worth U.S $59 billion, was compiled from projects located in 14 countries, both developed and developing, and included both transit (rail) and highway projects.

The inaccuracy in travel forecasts was estimated as the difference between the actual forecast and the forecasted traffic standardized by the percentage of the forecasted traffic. Actual forecasts were usually counted from the first year of operations or opening year of the facility while the forecasted demand was obtained from the demand estimation produced at the time of decision to go ahead with the project.

The results from the estimation of inaccuracy indicated that forecasts produced for both rail and road projects were significantly misleading. The rail forecasts were highly inflated with passenger forecasts overestimated by two-thirds for 72% of all rail projects with an average overestimation of 106%. Inaccuracy in road projects were not as high or one-sided as rail forecasts but 50% of the road projects showed a $\pm 20\%$ difference between actual and forecasted traffic. Further the inaccuracies in rail and road forecasts did not improve over time with road forecasts showing greater inaccuracies towards the end of the 30-year study period.

Bain and Polakovic (2005) continued on their previous the toll-road study in 2005 expanding their data set from 87 projects to 104 international toll-road, bridge and tunnel case studies to estimate the ratio of actual to forecast traffic for periods beyond year-one. The preliminary analysis indicated that there was not a systematic improvement in traffic forecasting accuracy beyond year-one with the mean varying between 0.78 and 0.80 and the standard deviation, indicating forecasting error, varying between 0.22 and 0.25. Further disaggregation of the traffic forecasts by vehicle type indicated a high variability in truck forecasts which in turn contributed to the overall uncertainty.

Wachs (1992) provided some reasons for forecast inaccuracies by exploring the nature of ethical dilemmas in forecasting. Technical experts drawn from the ranks of social scientists, engineers and planners produce most forecasts used to justify investment decisions in transportation. However the complexity inherent in our government structure coupled with limited resources available to policy makers places a huge burden on forecaster to produce self-serving forecasts, while also attempting to maintain objectivity. Since the forecasting process is highly subjective producing consequences of great significance, it becomes rather easy to play with technical assumptions to produce self-serving forecasts.

Kain (1990) talks about the Dallas Area Rapid Transit's (DART) strategic misrepresentation of land-use and ridership forecasting in its campaign to get voters to support the planned 92-mile light rail transit system. This report confirms Wachs's take on the ethical dilemmas that forecasters face wherein decisions taken are not completely objective and are governed by the preferences of the policy makers. Similar to Kain's work in Dallas, Pickrell (1992) conducted a study assessing the accuracy of ridership forecasts and cost estimates for rail projects in eight US cities, namely, Washington, Atlanta, Baltimore, Miami, Buffalo, Pittsburgh and Sacramento. The comparison of costs indicated a uniform trend of gross overestimation of rail ridership forecasts along with an underestimation of the rail construction costs and operating expenses in all the eight cities considered in the analysis.

Richmond (2001) conducted a comparison of rail ridership forecasts to actual ridership as part of his study on evaluating urban transit investments using transit data from US cities and Canada (Ottawa). The analysis indicated that the impact of new rail projects on increasing total transit ridership was minimal and actual ridership in most of the cities considered fell far short of the ridership forecasts available to the decision-maker at the time of deciding to go ahead with the project.

The Federal Transit Administration (FTA) recently conducted a study to analyze predicted and actual impacts of 21 recently opened major transit projects funded under the New Starts program (Lewis-Workman et al., 2007). This study was an extension of two prior studies—the 1990 Urban Mass Transportation Administration study and a 2003 FTA study, looking at projects that opened for revenue service between 1990 and 2002. The ridership analysis conducted as part of this study compared the forecast and actual average weekday boardings and indicated that slightly less than half (8 of 18) of projects completed between 2003 and 2007 have either achieved or have a good chance of exceeding 80% of the initial planning level forecasts.

3. Data

The forecast traffic data relevant to this analysis was collected from the following Minnesota Department of Transportation (Mn/DOT) reports prepared in support of the various roadway projects.

- Transportation Analysis Reports (TAR),
- System Planning and Analysis Reports (SPAR),
- Environmental Impact Statement (EIS).

These reports, with a horizon forecast year of 2010 or earlier, focused on the Twin Cities metro area and were collected from various locations, namely, Mn/DOT Central Library, the Collection Department of the State Archives at the Minnesota Historical Society, MnDOT Office of Traffic Forecasting & Analysis and the MnDOT Metro District Office (Roseville).

Typically, any description of the roadway networks, socio-economic inputs and other assumptions that went into creating the forecasts were brief. In most cases the assumptions were not provided at all. Further the reports lacked any clear description of the actual roadway project or any explanation as to the need for the report. In general, the forecasts provided in the reports were apparently based on outputs from the Twin Cities regional model altered by ground counts and turning movements taken in the study area.

The actual traffic data used to estimate the inaccuracy in traffic forecasts was obtained from the traffic count database maintained by the Office of Traffic Forecasting & Analysis Section at Mn/DOT. The data collection efforts for this research project was a intensive and time consuming effort due to lack of proper documentation and proper record keeping procedures. The final database consisted of 108 project reports resulting in a total of 5158 roadway segments in the database and the actual traffic information was obtained for 2984 of the 5158 roadway segments. Fig. 1 shows the geographical locations of the various projects considered in this analysis.

4. Analysis

4.1. Illustrative analysis

A scatterplot analysis of all the roadway segments in the database comparing actual traffic data to forecast traffic, is provided in Fig. 2. The target line in the scatterplot shows the ideal condition where the actual traffic data exactly matches the forecast traffic data. From a modeling perspective, it is ideal to have the points in the scatterplot as close to and evenly spread out from the target line as possible. In Fig. 2, the majority of the data points in the scatterplot lie above the target line indicating a significant underestimation trend, meaning forecasted traffic numbers often fall short of actual traffic numbers , especially for higher volumes.

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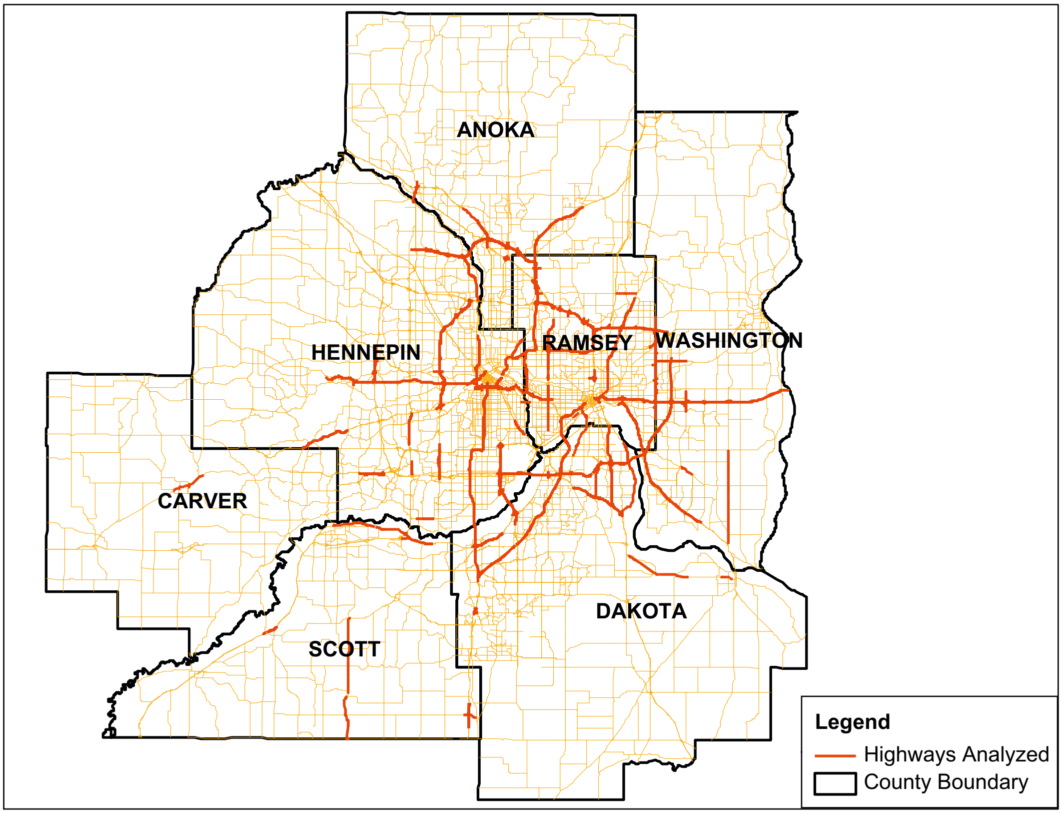

Fig. 1. Geographical location of roadways analyzed.

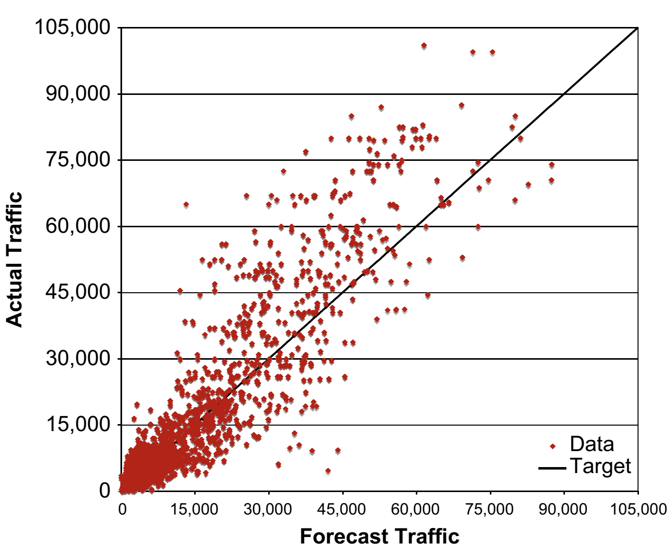

Fig. 2. Scatterplot of actual traffic to forecast traffic.

The inaccuracy in traffic forecasts was estimated as

$$I = (F/A) - 1 \tag{1}$$

where I is the estimated inaccuracy in traffic forecasts, F the forecast traffic, A the actual/observed traffic.

A positive inaccuracy value indicates overestimation in the traffic forecasts while a negative value indicates underestimation in traffic forecasts. A value of zero indicates an accurate forecast.

The estimated average inaccuracy by project is presented in Fig. 3. The inaccuracy was estimated for each of the data points in the database with both forecast traffic and actual traffic information and then averaged by project to obtain the average inaccuracy. Table A1 in the Appendix compiles the projects analyzed and the estimated average inaccuracies for each project. The estimation of average inaccuracy shows that the average inaccuracy is less than zero in 47% of the projects and the average inaccuracy is greater than zero in 49% of the projects. The estimated average inaccuracy equals zero in 4% of the projects (within $\pm 0.5\%$).

The average inaccuracy was estimated by different categories to better understand the data and underlying trends. The inaccuracy on critical links, defined here as links with the highest actual traffic, is presented in Fig. 4. This analysis was done to see if these critical links had greater accuracy compared to the other roadways in the project area. The results show a very clear trend of underestimation in the forecasts with 65% of the critical links showing underestimated traffic forecasts. 27% of the critical links have overestimated forecast traffic and only 8% of the critical links have forecast that match the actual counts (within $\pm 5\%$).

The frequency distribution plot of the inaccuracies estimated for the various roadway data points in the database is presented in Fig. 5, and indicates a trend of underestimation. 56% of the total roadway points in the database are underestimated with inaccuracy less than zero and 44% of the total roadway points are overestimated with an inaccuracy greater than zero. The highest frequency of 46% is seen between the ranges of -0.5–0.0.

The average inaccuracy by roadway functional classification is presented in Fig. 6. The roadway segments in the database with forecast traffic and actual traffic data were classified into one of five categories provided below. These classifications were based on the roadway functional classification used in the Year 2000 Twin Cities Regional Travel Demand Model.

- Freeways,
- Undivided Arterials,

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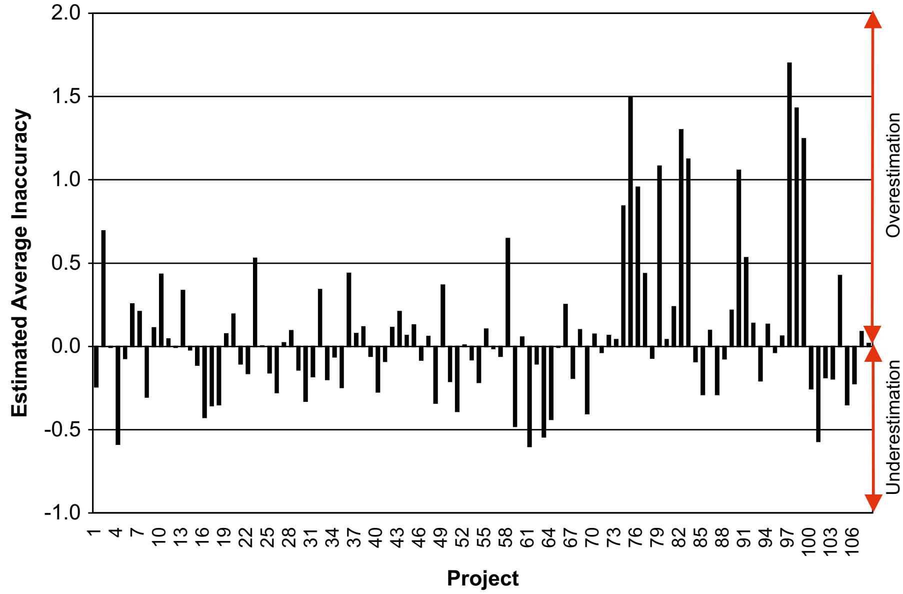

Fig. 3. Estimated average inaccuracy by project.

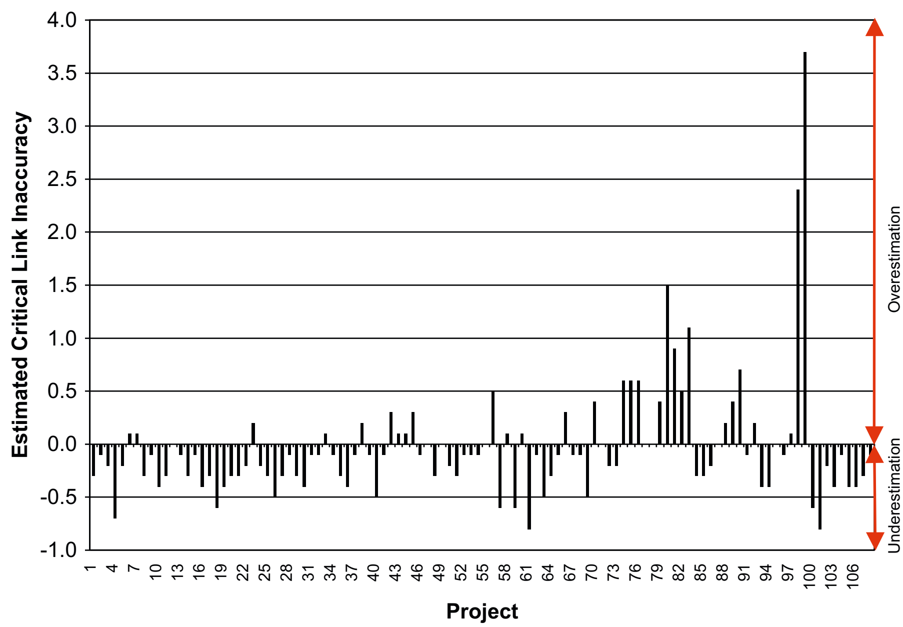

Fig. 4. Estimated inaccuracy on critical links by project.

- Divided Arterials,
- Expressways,
- Collectors.

The inaccuracy was estimated for each data point and then averaged by functional classification to obtain the inaccuracy by functional classification. Fig. 6 indicates that freeways, with an inaccuracy less than zero, are underestimated in traffic forecasts compared to the other roadways functional classifications, which are overestimated.

Fig. 7 represents the average inaccuracy stratified by the count range. This stratification indicates that the higher volume roadways are subject to the problem of underestimation compared to overestimated lower volume roads. Roadways with volumes of 20,000 or less have positive inaccuracy while higher count ranges have negative inaccuracy. This result is in line with the inaccuracy by functional classification since freeways typically carry higher volumes of traffic compared to the other roadways.

Finally the average inaccuracy was estimated for new and existing facilities in the database. This classification is based on the existence/non-existence of the concerned roadway at the time of report preparation, using information from the MnDOT construction project logs and consultations with MnDOT staff. The average inaccuracy for all existing roadway facilities, comprising of 77% of the projects in the database, was estimated to be 0.20 with the minimum and maximum inaccuracy varying between −0.99 and 7.94. The average inaccuracy for the new roadway facilities, comprising of 23% of the projects, was −0.05 with the maximum and minimum inaccuracy varying between −0.84 and 4.00. This indicates that forecasts on existing

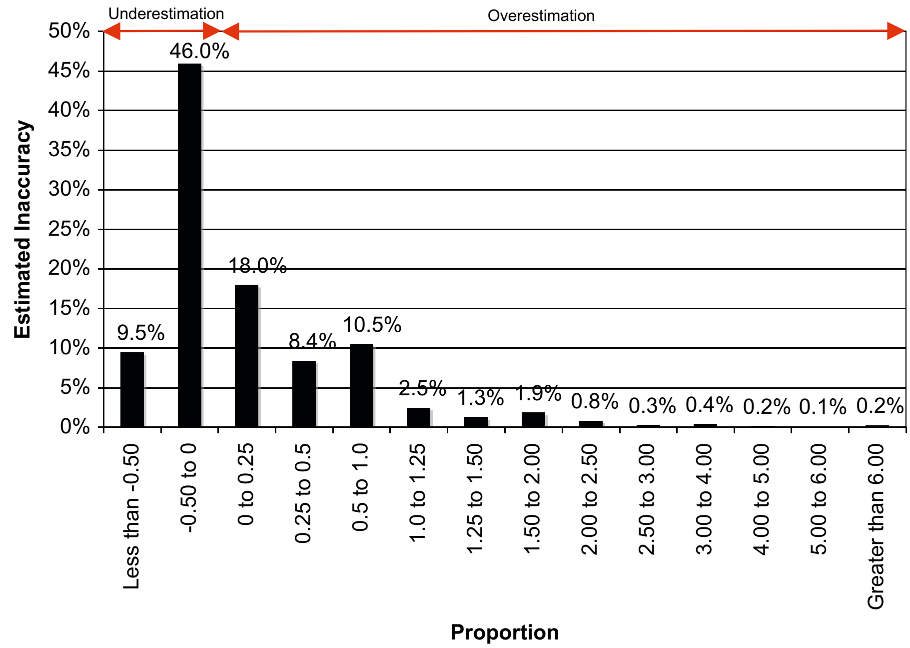

Fig. 5. Frequency distribution plot of estimated average inaccuracy.

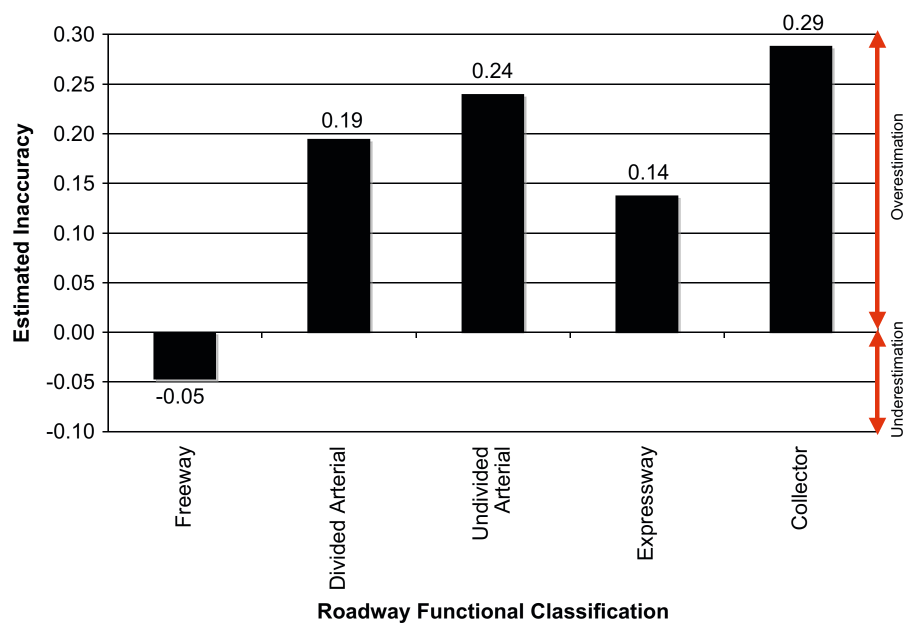

Fig. 6. Estimated average inaccuracy by roadway functional classification.

facilities in the Twin Cities are overestimated compared to new facilities.

The illustrative analysis was conducted to provide a macro level understanding of the database. The results indicate a trend of underestimation in roadway forecasts particularly in roadways of higher volumes and higher functional classifications. The next section on the quantitative analysis will look at the factors that contribute to inaccuracies in traffic forecasts.

4.2. Quantitative analysis

As part of the quantitative analysis, a model was developed formulating the inaccuracy in roadway forecasts as a function of certain relevant independent variables. The quantitative analysis used the same data as the illustrative analysis except that it focused only on the main roadway in each project. The analysis did not consider the side streets or other roadways in the project for which forecasts had been provided. The following additional information was collected for each of the main roadway segments in the database with both forecast traffic data and actual traffic data.

- Number of years between the year in which the report was prepared and the forecast year,
- forecast vehicle kilometers traveled (VKT) by project,
- roadway type,
- roadway functional classification,
- roadway segment direction,
- decade of report preparation,

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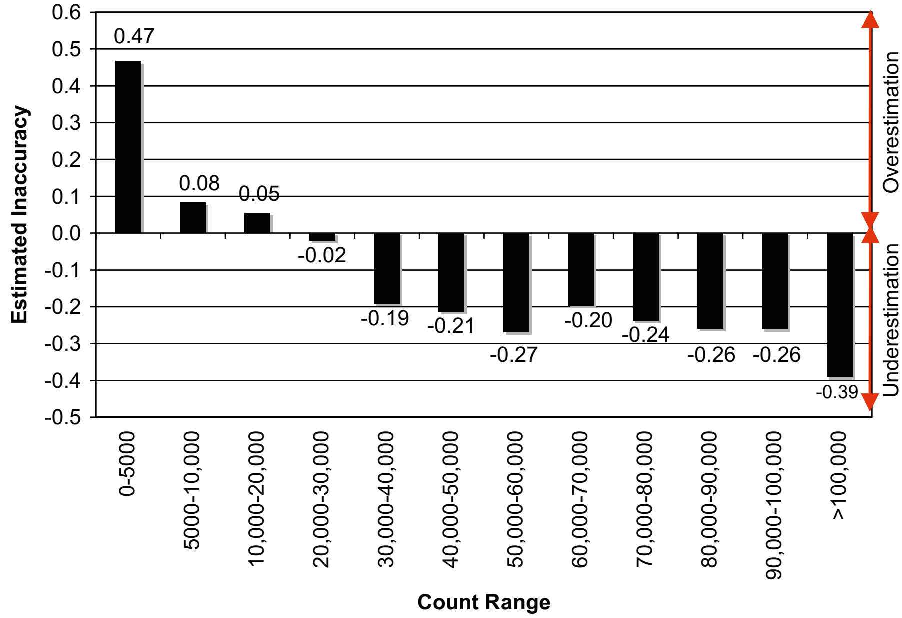

Fig. 7. Estimated average inaccuracy by counts.

- project status (existing/new facility) at the time of report preparation.

The forecast traffic provided on each main roadway segment was multiplied with the segment length, measured as part of this analysis. This estimated forecast VKT on each main roadway segment was then summed up by project to obtain a measure of project size. The main roadways were separated into two roadway types: radial and lateral. Roadways that radiate directly from downtown Minneapolis or St. Paul that could be used as a way to get direct access to the downtowns were classified as radial roadways. The other roadways that do not provide a direct access to the downtown were classified as laterals. For example, in the Twin Cities region, highways such as I-394, I-94, I-35W, I-35E were classified as radial roadways and roadways such as TH 100, TH 169, TH 51 were classified as lateral roadways.

The roadway functional classification is the same as the one used in the illustrative analysis and is described above in detail. The segment direction was based on the roadway direction with respect to the central cities of Minneapolis and St. Paul. The following segment direction classification was used in this analysis:

- east,
- middle,
- middle north,
- middle south,
- north,
- northeast,
- northwest,
- south,
- southeast,
- southwest,
- west.

In addition, each project was classified into one of the following four time categories based on the year in which the report was prepared.

- 1960–1970—refers to reports prepared between 1961 and 1970,
- 1970–1980—refers to reports prepared between 1971 and 1980,
- 1980–1990—refers to reports prepared between 1981 and 1990,
- After 1990—refers to reports prepared after 1990.

The main roadways in the database were categorized into existing or new facilities as described previously in the illustrative analysis.

The basic functional form of the regression model estimated is

$$I = f(N,H,F,V,D,T,S) \tag{2}$$

where I is the Inaccuracy ratio estimated as the difference between the forecast and actual traffic, standardized by the actual traffic, N the Number of years between report year and forecast year, H the Roadway type, F the Functional Classification (used in Model 1 alone), V the Project size measured in VKT, D the Segment direction, T the Time variable representing decade of report preparation, S the Roadway status.

A simple ordinary least squares (OLS) regression model was estimated using the roadway segments that had complete information for all the variables considered in the analysis. In addition to this simple OLS model, also referred to as the basic model, three separate regression models were estimated based on the roadway functional classification. The models thus estimated are:

- Model 1—Entire dataset,
- Model 2—Freeways,
- Model 3—Undivided arterials,
- Model 4—Other, consisting of,
  Expressways.
  Divided Arterials.
  Collectors.

The stratification and analysis of the dataset by functional classification in addition to the basic model, was to obtain a better understanding of the causal factors and the variation of their influences by roadway type. The grouping of the expressway, divided arterials and collectors into the other category in the final

Table 1
Results from OLS regression.

Variable	Model 1-Entire dataset			Model 2-Freeways			Model 3-Undivided Arterials			Model 4-Other		
	Coefficient	t	Sig	Coefficient	t	Sig	Coefficient	t	Sig	Coefficient	t	Sig
Dependent variable: inaccuracy in roadway forecasts												
Number of years	−3.39E−02	−9.56	***	−2.57E−02	−6.95	***	−5.72E−02	−3.92	***	−7.30E−02	−8.35	***
Project VKT	−7.47E−09	−1.43		−5.54E−09	−0.23		−1.30E−08	−0.02		−1.22E−08	−2.25	*
Radial highway type	−1.08E−01	−3.33	**	−2.10E−01	−5.07	***	4.57E−01	2.88	**	−8.23E−02	−1.16	
Collector	−1.12E−01	−0.50										
Divided arterial	4.69E−02	0.83										
Expressway	9.70E−02	2.27	*									
Undivided arterial	3.11E−02	0.64										
East	2.64E−01	3.23	**	3.47E−01	4.01	***	2.19E−01	0.12		2.77E−01	1.70	+
Middle north	−3.61E−02	−0.49		1.51E−01	1.76	+	3.19E−01	0.78		−4.79E−02	−0.43	
Middle south	−3.48E−01	−3.32	**	4.44E−02	0.37		−9.54E−01	−3.09	**	−8.12E−01	−2.29	*
North	−1.13E−01	−1.56		1.53E−01	1.90	+	1.21E+00	3.15	**	−5.13E−01	−3.73	***
Northeast	5.52E−01	7.20	***	3.68E−01	2.73	**	6.57E−01	2.41	*	7.23E−01	6.06	***
Northwest	−1.93E−01	−2.22	*	−5.36E−03	−0.06		1.32E+00	3.19	**	−6.78E−01	−4.08	***
South	−5.58E−02	−0.78		1.86E−01	2.24	*	4.80E−01	2.07	*	−4.06E−01	−2.56	*
Southeast	3.58E−01	5.14	***	8.47E−01	8.18	***	1.63E−01	0.80		3.27E−01	3.11	**
Southwest	−1.62E−01	−2.05	*	1.41E−01	1.37		3.51E−01	1.15		−3.05E−01	−2.56	*
West	−1.54E−01	−1.86	+	4.92E−02	0.55					1.26E−02	0.07	
Report year between 1970 and 1980	1.11E−01	2.61	**	−1.04E−01	−1.87	+	1.15E+00	6.02	***	1.16E−01	1.44	
Report year between 1980 and 1990	6.38E−02	1.35		−2.12E−01	−3.32	**	−2.37E−02	−0.16		3.54E−01	3.60	***
Report year after 1990	2.78E−01	1.26					9.54E−01	0.52				
New facilities	−1.25E−01	−3.22	**	−1.18E−01	−3.11	**	−5.27E−01	−0.30		−2.38E−01	−2.10	*
Constant	1.64E+00	18.63	***	5.35E−01	5.17	***	3.28E−01	0.95		1.41E+00	8.16	***
Number of observations	1275			745			185			345		
$F(x,x)$	19.96			24.13			6.01			11.91		
Prob > F	0.0000			0.0000			0.0000			0.0000		
Adj. R-squared	0.2381			0.3322			0.3034			0.3366		

Note: Other includes Expressways, Divided Arterials & Collectors.
$^{+}p<0.10$, $^{*}p<0.05$, $^{**}p<0.01$, $^{***}p<0.00$.

regression model (model 4) was to ensure adequacy in sample size.

The results of all the four analyses are provided in Table 1 and identify the factors that influence the inaccuracies in roadway forecasts. A variable which is positive and significant increases the inaccuracy indicating overestimation, while a variable that is negative and significant decreases the inaccuracy ratio resulting in underestimation. The variables that have a significant influence (positive or negative) are identified in Table 1.

The stratification of the data by functional classification did not show major differences in the patterns of influence but indicates significant minor distinctions. The results of the basic model (model 1) alone will be presented here for brevity. We can see that the increase in the number of years between the report year and forecast year results in underestimation of traffic forecasts. Radial roadways are more underestimated compared to lateral roadways in the region. The functional classification of the roadway does not play an influencing role except for expressways which are subject to overestimation with respect to freeways.

Compared to roadways located between the cities of Minneapolis or St. Paul, roadways located in the middle south (between Minneapolis and St. Paul), southwest, northwest and west direction show a trend of underestimation while roadways in the east, northeast and southeast directions show overestimation in traffic forecasts.

The reports prepared in the decade between 1970 and 1980 produced overestimated forecasts compared to the base decade of 1960–1970 but the other time categories do not play an influencing role on forecast inaccuracy. The roadway status (existing/new) at the time of report preparation influences the inaccuracy in forecasts with new facilities underestimated in traffic forecasts compared to the existing roadway facilities. The size of the roadway project does not influence the inaccuracy in forecasts.

The quantitative analysis was conducted to go beyond the illustrative analysis and identify factors that contribute to the underestimation or overestimation in traffic forecasts. While the estimated model was a simple OLS model, the results confirm that the inaccuracy in traffic forecasts is influenced by many factors and also shows the type of influence that each of the variables have on forecast inaccuracy. Both the illustrative analysis and quantitative analysis utilized the actual traffic counts to compare against the forecast traffic. It is important to note that in both these analysis, the actual ground traffic counts need not be 100% accurate and are subject to their own set of data collection errors. Hence the inaccuracy estimates measured here might vary based on the errors present in the actual traffic information.

4.3. Qualitative analysis

Similar to the analysis used by Flyvbjerg et al. (2005), the qualitative analysis involved interviewing modelers in the Twin Cities who have had experience working with the Twin Cities travel demand models. The goal was to obtain their perspectives on the modeling process, which might provide some useful insights into reasons for inaccuracies in forecasting.

A total of seven people were interviewed in this process and the interviews were conducted between May–June 2008. The interviewees varied in terms of their actual hands-on experience with the models and ranged from modelers who were actually involved in the technical development of the model to planners whose expertise were limited to using the results from the model for various roadway projects. The interviews were conducted with both private sector consultants and employees of public agencies and conducted either via email and over the phone.

Each of the interviewees were asked a standard set of five questions, which are provided below:

1. your understanding of the possible sources of error in the Twin Cities models,
2. with the current expertise in modeling that we have, what could have be done differently with model development in 1970s, 1980s,
3. how does the Twin Cities model compare with other models that you have worked with or had an opportunity to look at,
4. how would you respond to criticisms against modeling? Many people argue that the most models underestimate/overestimate the traffic forecasts and hence it is not worthwhile to be spending time, money and efforts on modeling,
5. have there been instances on political compulsions influencing the model forecasting in the Twin Cities?

A complete copy of the seven interviews is not presented here for brevity but a summary of the responses from the interviews are provided below.

While each interviewee provided different reasons for inaccuracies in traffic forecasts, the inability of the model to understand and predict fundamental societal changes was the most often stated reason. The change in the labor force due to increased participation of women was one of the commonly quoted examples of the model's inability to properly account for travel behavior. Other factors such as increases in mobility, auto ownership, influence of the internet and technology on travel were also provided as examples of the model's inability to understand and incorporate societal changes.

Another very important reason often provided by the interviewees were errors in the socio-economic inputs that fed into the model along with the locational distribution of forecasted demographics. The development of socio-economic forecasts used in older models was done exclusively by the Metropolitan Council and Mn/DOT without any input from local communities. The involvement of local communities in the 1990s helped correct this error to a certain extent. However, community participation introduced new errors into the modeling process due to aggressive forecasting by local communities, without any thought as to where the growth should be allotted or any understanding of ways to meet the infrastructure requirements of the forecasted population and employment. It is only in the last 8–10 years that communities have started to understand the importance of realistic socio-economic forecasts. The difference between planned and actual highway network construction was also provided as another reason for inaccuracy in forecasts.

The technical and computational limitations in the older models made it difficult for modelers to track errors, conduct sensitivity tests etc. to ensure the reasonableness and accuracy of their forecasts. The complicated nature of the models also resulted in limited oversight to a select few individuals, which meant fewer discussions and fewer people looking at the model forecasts to ensure reasonableness.

From a technical standpoint, the trip distribution model came in for criticism because a basic understanding of the basic trip patterns in the region is still lacking. Other technical aspects of the model criticized by interviewees, include the assigned importance of home based work (HBW) trips compared to other purposes, traditional focus on principal arterials with little importance to assignment on collectors/minor arterials, inability of the model to handle peak spreading and the assumption of a fixed percentage of daily traffic for the peak periods and the handling of special generators, especially big ones such as the Mall of America.

The interviewees agreed that, compared to other regions, political compulsions were less of a major influencing factor in traffic forecasts for the Twin Cities. Some of the interviewees indicated that in terms of model input assumptions such as roadway capacities, socio-economic inputs, private consultants were more likely than public employees to face pressure from the clients. Public agencies in the Twin Cities face less political pressure, however, sometimes there is a "push" to use existing or expected assumptions which may not sync with the data in hand.

All interviewees agreed models were required for accurate forecasting. The view of the interviewees was that criticisms against the use of modeling in forecasting arises when, for example, results are used by policy makers who lack an understanding of the process behind the numbers or when policy makers apply a macro level model to a micro level study area without adequate changes to the parameters of the model given the difference in the scale of analysis. Additionally issues arise from the lack of understanding that models are best used for highlighting differences between various scenarios rather than providing absolute numbers. The interviewees also argued that models need to be looked at as only one of many tools to help in the decision making process. Use of alternative techniques to models, such as growth rates, will work only in few scenarios. Hence models are absolutely essential to forecasting the future.

5. Understanding reasons for forecast inaccuracy

One of the primary objectives in this research was to test for the presence of inaccuracy in roadway traffic forecasts using Twin Cities data. Another important objective of this research was to identify the reasons for the presence of inaccuracy in traffic forecasts. Such an analysis would ideally involve looking at input assumptions (roadway network, socio-economic forecasts, trip rates etc.) that went into creating the forecasts for each of the projects in the database. The difficulties encountered in the data collection efforts of this research project combined with minimal documentation provided in each project report, and finally the inability to obtain actual model files from 1970 and 1980 models highlighted the in-feasibility of such an approach.

Rather than attempt to collect the input information for each of the project reports in the database, it was decided to collect input information that might have been used in the regional travel demand model to prepare forecasts. As indicated in the above data section, most forecasts in the database were prepared based on the regional travel demand models, modified by ground counts and turning movements. So comparing model inputs to actual numbers would help shed light on the reasons for forecast inaccuracy.

In the quantitative analysis, errors in the socio-economic inputs that feed into the model along with the locational distribution of forecasted demographics were identified as important reasons for forecast inaccuracy. Some of the interviewees indicated that the demographic forecasts were over-optimistic especially in the 1970s, when forecasts were governed by the Metropolitan Council's growth objective of "4 million by the year 2000".

Table 2 provides a comparison of demographic forecasts to the actual numbers, estimated as an inaccuracy ratio. The demographic forecasts were prepared by Metropolitan Council for the 7-county metro in March 1975 for future years 1980, 1990 and 2000 and used in the respective regional travel demand models. The actual Census demographics for Minnesota was obtained from the datanet hosted at the Minnesota Land

Table 2
Comparison of demographic forecasts.

Average inaccuracy estimated using 1975 Metropolitan council forecasts County	**1980 Population**	**1990 Population**	**2000 Population**
Anoka	0.08	0.01	−0.07
Carver	0.02	0.19	0.04
Dakota	0.17	0.19	0.19
Hennepin	0.10	0.08	0.06
Ramsey	0.12	0.17	0.22
Scott	0.02	0.04	−0.11
Washington	0.11	0.27	0.22
Total 7-county	**0.11**	**0.12**	**0.10**

Table 3
Summary of travel behavior inventory (TBI) data.

Variables	**Travel behavior inventory data**						**Percentage change**	
	1949	**1958**	**1970**	**1982**	**1990**	**2000**	**1990–1970** (%)	**2000–1970**
HBW average trip length: miles	na	na	6.6	8.1	9.2	11.4	40%	74%
HBW average trip time: minutes	na	na	19.8	na	21.2	25.6	7%	29%
Trips per capita	1.8	2.5	2.7	3.4	3.9	4.2	43%	54%
Trips per household	na	7.5	8.9	9.1	10.1	10.3	14%	16%
Persons per household	na	na	3.3	2.7	2.6	2.5	−22%	−25%
Workers per household	na	na	1.3	1.4	1.4	na	9	na
Auto occupancy: HBW	1.1	1.1	1.2	1.2	1.1	1.1	−10%	−12%
Auto occupancy: overall	1.6	1.6	1.5	1.3	1.3	1.4	−14%	−10%
Percentage of women in labor force*	na	na	49%	60%	68%	73%	39%	49%

**Source*: 2005 Twin Cities Transportation System Performance Audit.

Management Information Center (LMIC) and the National Historical Geographical Information System (NHGIS) (Land Management Information Center, 2008; Minnesota Population Center, 2008).

The comparison indicates a trend of overestimation in demographic forecasts with all counties showing an inaccuracy ratio of greater than zero except for the year 2000 forecasts for fast growing suburban Anoka and Scott counties. The results from the comparative analysis indicate the presence of errors in the demographic forecasts used in the travel demand models, which may have contributed to the inaccuracy in the roadway forecasts.

Another component of the modeling process that may have contributed to the overall inaccuracy in traffic forecasts is the trip generation/travel behavior component. The regional travel demand models used in the Twin Cities are typically based on the Travel Behavior Inventory (TBI) survey. The TBI is a Twin Cities comprehensive travel survey conducted jointly by the Metropolitan Council and Mn/DOT about every 10 years. The travel characteristics estimated from the TBI are used to update the regional travel demand model for forecasting purposes (Metropolitan Council of the Twin Cities Area, 2003).

Since it was not possible to obtain the actual model files from the 1970s and 1980s, we instead looked into the TBI data for an understanding of travel behavior characteristics used in the models to produce forecasts. Table 3 provides a summary of the TBI data from 1949 to 2000. It can be seen that the average home-based work (HBW) trip length, trips per capita and trips per household show an increasing trend while the auto occupancy and persons per household show a decreasing trend.

The regional travel demand models were developed based on the actual TBI data for the base year and typically used similar travel characteristics for the forecast year. So a 1990 traffic forecast prepared using the 1970 travel demand model would use travel characteristics from the 1970 TBI for the base year traffic and characteristics similar to 1970 TBI for 1990 traffic forecasts. The 1970 model used to prepare 1990 traffic forecasts would most likely not have incorporated the following changes between 1970 and 1990, given below:

- a 40% increase in home-based work (HBW) trip lengths,
- a steep increase in trip making characteristics—a 43% increase in trips per capita, a 14% increase in trips per household, a 39% increase in women labor force participation,
- a 22% decrease in persons per household combined with a 9% increase in workers per household,
- a 10% decrease in HBW auto occupancy and a 14% decrease in overall auto occupancy.

The inability of travel demand models to incorporate such fundamental shifts in travel behavior could be an important reason for inaccuracy in traffic forecasts.

Another possible reason for inaccuracy in roadway traffic forecasts could be the differences between the assumed highway network and the actual in-place network. Most roadway projects suffer a gap between the planning stage and actual construction/implementation stage, which is magnified by delays encountered during actual roadway construction. In addition, roadway alignment plans undergo many changes. The initially analyzed alignment might be very different from the actual in-place alignment. In some cases, forecasts include the presence of entire roadways that fail to be constructed within that forecast year.

It was not possible to identify the roadway network assumptions for each project report in the database. Therefore we decided to conduct a macro-level analysis by comparing the network assumptions from the Transportation Policy Plans (TPP) and other comprehensive plans against the actual year of roadway construction. The TPP is prepared by the Metropolitan Council as part of the comprehensive development guide also called the Regional Development Framework (RDF) for the Twin Cities seven-county metropolitan area. The TPP describes the transportation policies and plans that the Metropolitan Council plans to implement

Table 4
Comparative analysis of highways identified in the 1976 regional development framework.

Highways[a]	From	To	Year built
I-35E	West Seventh Street	I-94	1984–1991
I-35E	I-35	State Highway 110	1981–1985
I-94 (Mpls)	US 12	57th Ave N	1980–1982
I-494	State Highway 5	I-494	1982–1986
US 10	Ramsey Co Rd J	State Highway 47	1990
US 169 (W River Rd)	86th Ave N	Northtown Corridor	1983
US 169/ State 101 (Shakopee Bypass)	US 169	State Highway 13	1976–1980
US 169/212	**I-494**	**State Highway 41**	**1994–1996**
Co Rd 18 (Hennepin)	**5th Street S**	**Minnetonka Blvd**	**1994**
Co Rd 62 (Hennepin)	**Co Rd 18**	**I-494**	**1985–1986**
Northtown Corridor	**US 169**	**I-94**	**Not built yet**
Northtown River Crossing	**US 10**	**US 169**	**1998**
LaFayette Expressway (52)	**I-494/State Highway 110**	**State Highway 55/52**	**1985–1994**
I-335	**I-94**	**I-35W**	**Control Section eliminated in 1979**

[a] New facilities expected to be constructed to complete the 1990 Metropolitan highway system.

between the plan's adoption year and the plan's forecast year to meet the regional goals of the RDF. The Metropolitan Council's current 2030 Transportation Policy Plan was approved and adopted by the council on December 15, 2004 (Metropolitan Council of the Twin Cities Area, 2004).

Table 4 provides a comparison of the roadways identified in the 1976 RDF and expected to be completed by 1990 against the actual year of construction of each roadway. These highway network assumptions would have been used in the regional travel demand models to produce forecasts for 1990 and later.

The rows highlighted in bold in Table 4 are highways that did not get completed by 1990 and in some cases ended up not being built at all. For example, the I-335 alignment, proposed in the 1976 RDF, between I-94 and I-35W, has been eliminated from consideration by Mn/DOT and there are currently no plans to construct this section. Similarly the section of Northtown Corridor between I-94 and US 169 has still not been completed even though it was identified to be completed by 1990. The differences between assumed networks and planned networks arise, namely because of construction delays, funding issues, public opposition, shift in regional planning goals etc. Nevertheless, such differences between assumed networks and in-place networks contribute to the inaccuracy in project forecasts.

This macro-level analysis indicates that the inaccuracies in roadway forecasts arise from different sources, some of which have been described above. While the difficulties in data collection limited the type of detailed analysis that could have been otherwise conducted, the results highlight the differences between forecasted and actual inputs that feed into the model forecasting process, which consequently result in forecast errors.

6. Conclusions

The objective of this study was to use Minnesota data to estimate the inaccuracy present in roadway forecasts and identify the reasons for inaccuracy. The illustrative analyses indicated a trend of underestimation in roadway forecasts. This was especially true in the case of higher volume roadways and higher functional classification roadways, such as freeways. A simple OLS model shed light on the factors influencing forecast inaccuracy and the pattern of influence of each variable on overall traffic inaccuracy. Variables such as the number of years between the report year and forecast year, roadway functional classification, roadway direction, year of report preparation and roadway status significantly underestimated traffic forecasts.

The qualitative analysis helped identify, from a modeler's perspective, possible sources of inaccuracy in traffic forecasts. Identified errors in model inputs such as demographic forecasts, trip making characteristics and network differences all contribute to the total inaccuracy in roadway forecasts, though the extent of any one variable's contribution is difficult to estimate with the data available. Modeling methodologies such as the use of capacity constraints, improvements in equilibrium assignment techniques, and mode choice routines change over time, which increases methodological inconsistencies that also contribute to the differences in roadway traffic forecasts prepared over various years.

The data collection efforts on this research project were much more laborious and time consuming than anticipated. The unavailability of the data in electronic format, lack of proper documentation, poor record keeping and data archiving procedures complicated the data collection process and subsequent analyses. Many of the older model files were in paper format and disappeared from the archives, compounded by the turnover in office personnel and changes in office venues.

Based on experiences conducting this study, one of the most important recommendation we can make, is to emphasize the benefits gained by agencies when record keeping and data archiving procedures are consistent and up-to-date. A documented history would make it easy to look back at the modeling process (inputs, assumptions, technical methods); thus much more could be learned from other types of analyses (sensitivity analysis, backcasting procedures) in investigating the reasonableness of traffic forecasts.

By nature of any process that looks at the long-term health of a system, the forecasting task is a complicated one. It is especially difficult to anticipate changes or control for errors in model forecasts. In some cases, it is almost impossible to predict or incorporate factors outside the control of the planning agency. For example, the worldwide financial crises or threats to national security are known to influence the travel patterns of individuals; nevertheless, it is not easy to know to what extent these issues will be a problem in future years.

Societal changes such as improvements in technology, internet use and rising gas prices contribute to changes in the way people travel and make residential and employment decisions. Most modelers interviewed as part of this research acknowledged the lack of a proper understanding of travel behavior and trip distribution could be possible sources for model errors. The

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Table A1
Summary of project reports in the database.

Id	Report	Description	Report Year	Forecast Year	Number of Years	Total No. of Forecast Links	Total No. of Actual Traffic Links[a]	Avg. Inaccuracy	Variance	Min. Inaccuracy	Max. Inaccuracy
1	SPAR-202	I-394—Third Ave Distributor from 13th Street N to Washington Ave	1978	2000	22	117	20	−0.24	0.14	−0.80	0.50
2	TA-M372B	Proposed New Alignments on TH 5 and County Road 30 from Birch Street to Island View Road (Waconia)	1991	2010	19	48	14	0.69	2.01	−0.11	4.00
3	TA-M329	PropTH 10/TH 610 from Prop TH169(Osseo By-Pass) to TH35W	1985	1987/ 2000/ 2010	15	157	56	0.00	0.10	−0.45	0.94
4	TA-M335	CSAH 14 from CSAH 17 to East Carver County Line	1985	2003	18	3	3	−0.59	0.01	−0.67	−0.49
5	TA-M336	TH35W From TH694 to Prop TH10	1985	2000	15	58	34	−0.07	0.07	−0.37	0.66
6	TA-M337	TH 100 from CSAH 10 to TH 394	1986	2000	14	92	58	0.25	0.13	−0.09	1.88
7	TA-M343	Lake Street from W River Rd to Mississippi River Blvd	1986	2000	14	22	14	0.21	0.06	−0.11	0.60
8	TA-M238	I 94: Tunnel to TH 51(Snelling Ave)	1979	2000	21	37	24	−0.30	0.02	−0.80	0.14
9	TA-M240	TH 55—Pine Bend to Hastings	1980	2000	20	28	12	0.11	0.29	−0.25	1.24
10	TA-M242	TH 120 from Lower Afton Road to TH 244	1980	2005	25	232	92	0.43	1.32	−0.58	6.61
11	TA-M245	TH 13—TH 35E Interchange Area	1980	2003	23	24	10	0.04	0.13	−0.32	0.58
12	SPAR-208	TH 61—South of Warner Rd to the Washington County Line	1978	2002	24	36	12	−0.01	0.05	−0.45	0.17
13	SPAR-208A	TH 61—Intersection of Warner Rd and Burns Ave	1979	2002	23	18	10	0.33	0.23	−0.08	0.90
14	SPAR-210	TH 36—Lexington to Dale	1978	2003	25	24	14	−0.02	0.06	−0.30	0.31
15	SPAR-220	TH 51 at TH 212	1978	2002	24	12	8	−0.11	0.01	−0.21	0.10
16	SPAR-224	TH 35E—TH 35W to TH 110	1979	2000	21	52	44	−0.43	0.02	−0.68	0.00
17	SPAR-227	TH 94—TH 35E Capitol Approach	1979	2002	23	31	16	−0.35	0.01	−0.54	−0.20
18	SPAR-246	TH 35 and Crystal Lake Road	1980	2003	23	16	8	−0.35	0.25	−0.64	0.46
19	TA-M255A	TH 51 from Como to TH 36	1982	2004	22	120	32	0.07	0.05	−0.36	0.51
20	TA-M286	TH 35 and Little Canada Road	1981	2005	24	28	14	0.19	0.15	−0.29	0.69
21	SPAR-215	TH 494 from TH 36 to Mississippi River Bridge	1979	2003/ 1993/ 1983	24	76	50	−0.10	0.11	−0.62	0.97
22	SPAR-202A	I 394—From TH 10—CSAH 15 in Wayzata to Washington Ave in Minneapolis	1978	2000	22	150	62	−0.16	0.27	−0.84	1.84
23	TA-M345	TH 7—From TH 41 to TH 101	1986	2000	14	118	20	0.53	1.22	−0.01	4.56
24	TA-M346	CSAH 1—Nesbitt Ave to Yukon Ave	1986	2000	14	56	18	0.00	0.12	−0.33	0.63
25	TA-M307	TH 394—TH 100 to Washington Ave; TH 100—Th 7 to TH 394		2000		158	82	−0.16	0.15	−0.63	1.07
26	TA-M253	Proposed TH 394 from West Juntion (TH 101) to Junction Washington Ave (Dtwn Mpls)	1980	2000	20	100	26	−0.28	0.12	−0.84	0.50
27	TA-M253 Distributor Addendum	Year 2000 forecast in the vicinity of 3rd Ave	1982	2000	18	20	9	0.02	0.18	−0.38	0.58
28	TA-M302	TH 169 Mississippi River Bridge—Anoka	1983	2005	22	56	16	0.09	0.15	−0.52	0.68
29	TA-M207A	TH 94 and CSAH 13 (Woodbury Area)	1978	2003	25	8	8	−0.14	0.10	−0.35	0.38
30	TA-M289A	I-694/TH 61 No Build	1983	2005	22	12	8	−0.33	0.02	−0.43	−0.13
31	TA-M309	TH5—CSAH 4 To Ring Road (Prairie Center Drive)	1904	2000		48	18	−0.18	0.07	−0.64	0.12
32	TA-M311	TH 56 From TH 52/55 To I-494	1984	2000	16	60	28	0.34	0.37	−0.51	1.27
33	TA-M326	Washington County Forecasts For Selected Routes	1985	2000	15	106	102	−0.20	0.21	−0.69	2.23
34	TA-M358	TH 494 from TH 12 (394) to TH 55	1987	1990	3	28	10	−0.06	0.01	−0.13	0.04
35	TA-M298	TH50—CSAH 5 & I-35 Ramps	1983	1987	4	16	8	−0.25	0.06	−0.53	0.10
36	TA-M308	TH 13 From I-35W To Cliff Road	1984	2000	16	32	18	0.44	0.64	−0.37	1.80
37	TA-M296A	I-94/TH61/Etna Street	1983	2006	23	12	8	0.08	0.10	−0.13	0.58
38	TA-M299	TH 280—Interchanges between Kasota & County Road B	1983	2008	25	52	34	0.12	0.24	−0.66	1.63
39	TA-M304	TH 694 from TH35E To TH 35W	1984	2008	24	48	34	−0.06	0.02	−0.31	0.44
40	TA-M301	TH 96 From I-35E To TH 61	1983	2008	25	72	28	−0.27	0.04	−0.60	0.11
41	TAS 3065A-14	TH 36 From TH 51 To TH 35E	1969	1985	16	40	38	−0.09	0.07	−0.68	0.40
42	TAS 3074B	TH 61 From Ramsey County Road C To Whitaker St In White Bear Lake	1967	1990	23	64	38	0.11	0.39	−0.71	1.31
43	TAS 3074C-14	TH 61 At TH 36 and County Road C	1968	1985	17	14	14	0.21	0.13	−0.16	0.87
44	TAS 3080	I-694 And White Bear Ave	1967	1986	19	8	8	0.07	0.01	−0.08	0.16
45	TAS 3081	TH 5—Jct TH 51 and Co Rd B2	1967	1985	18	28	22	0.13	0.14	−0.55	0.91

46	TAS 3081A-14	TH 51 From TH 36 To Hamline Ave	1968	1990	22	36	26	−0.08	0.11	−0.33	0.96
47	TAU 3061A	TH 694 From TH35E To TH 36	1965	1986	21	22	18	0.06	0.15	−0.56	0.83
48	TA-M300	TH 55 From Western City Limits To TH61	1983	2008	25	36	18	−0.34	0.07	−0.64	0.15
49	TAS 3066A-14	TH 94 Vicinity Of Sixth Street In St. Paul	1969	1985	16	15	10	0.37	0.24	−0.19	1.16
50	TA-M292	Airport South Study (TH77, I-494, TH5)	1983	2000	17	176	102	−0.21	0.08	−0.74	0.69
51	TAU 3065	TH 36 at Hamline Ave	1963	1983	20	18	8	−0.39	0.03	−0.68	−0.27
52	TAU 3066	TH 94—Ninth and Broadway In St. Paul to West End of Bridges 6755/ 6756	1963	1983	20	14	12	0.01	0.18	−0.37	1.28
53	TAU 3069	TH 94—Pillsbury Street To Snelling Ave in St. Paul	1964	1984	20	8	6	−0.08	0.00	−0.12	−0.06
54	TAU 3070	TH 35E—Maryland Ave Interchange	1964	1975	11	4	4	−0.22	0.01	−0.29	−0.14
55	TAU 3073	TH35E—TH694 To North Ramsey County Line	1964	1985	21	24	24	0.10	0.05	−0.29	0.54
56	TAU 3073A	TH 96—TH35E to TH 61	1966	1985	19	26	10	−0.01	0.15	−0.46	0.45
57	TAU 3074	TH61—From I-94 to TH 212	1964	1986	22	26	8	−0.06	0.30	−0.59	0.59
58	TAU 3074A	TH61—From TH36 to .4 mi North Of County Road C	1965	1988	23	12	10	0.65	0.39	−0.09	1.60
59	TAU 3075	TH8—From Northeastern Junction Of I-35W to Stinson Blvd.	1964	1984	20	12	6	−0.48	0.02	−0.58	−0.29
60	TAU 3076	Half Cloverleaf Interchange At TH 51 and County Road B-2	1964	1980	16	8	8	0.06	0.08	−0.20	0.46
61	TAU 3077	TH 5—Toronto Avenue to Banfil Street in St. Paul	1965	1985	20	22	6	−0.60	0.04	−0.79	−0.36
62	TAU 3078	TH 280—Kasota Ave Interchange, and West Frontage Rd, and Connecting Ramps	1965	1986	21	16	6	−0.10	0.00	−0.13	−0.06
63	PSU3203A	TH101/13—West City line of Shakopee to .21 miles West of City Line of Savage	1962	1982	20	10	10	−0.54	0.00	−0.62	−0.49
64	PSU3203B	TH13—TH101 West Of Savage To .75 Mi West Of I-35W	1962	1982	20	18	10	−0.44	0.02	−0.62	−0.27
65	TAS3081B-14	TH51—TH36 to Hamline Avenue	1969	1990	21	26	22	0.00	0.12	−0.36	0.96
66	TAS3082-14	I-94—From Mounds Boulevard To I-494/694	1968	1985	17	46	38	0.25	0.26	−0.70	1.36
67	TAS3084-14	TH280—From Franklin Avenue To NPRR Bridge	1968	1985	17	18	8	−0.19	0.01	−0.35	−0.07
68	TAS3085-14	University Avenue—Park Street To Marion Street	1968	1985	17	26	14	0.10	0.11	−0.32	0.76
69	TAU3204A	TH13—TH19 East Of New Prague to TH 282 North Of Lydia (Scott County)	1964	1988	24	60	16	−0.40	0.08	−0.66	0.12
70	TAU 3205	I-35—From South Scott County Line to CMSTP&P Railroad	1963	1975	12	8	8	0.07	0.19	−0.48	0.52
71	TAU 3223	TH10—From Elk River To Big Lake	1963	1983	20	34	12	−0.04	0.56	−0.99	0.90
72	TAU 3451A	I-94—From I-494/694 To .5mi East Of CSAH 19	1964	1989	25	18	14	0.06	0.14	−0.26	0.63
73	TAU 3451B	I-94—From .5Mi East Of CSAH 19 to the St. Croix River	1964	1989	25	32	18	0.04	0.43	−0.48	1.32
74	SPARS 2	TH 212—TH 120 to proposed CSAH 19, I-69—Temporary TH 212 To County Road 68	1970	1985	15	26	12	0.84	0.85	−0.16	2.20
75	SPARS 2A	TH 212—TH 120 to proposed CSAH 19, I-694—Temporary TH 212 To County Road 68	1970	1985	15	32	16	1.49	1.91	−0.16	3.59
76	SPARS 3	TH52—Pine Bend to Proposed TH 61 near Hastings	1970	1985	15	26	14	0.95	0.29	0.01	1.68
77	SPARS 4	TH 61—From I-494 to County Road F	1970	1985	15	140	86	0.44	1.31	−0.84	6.82
78	SPARS 15	TH 169—From I-494 to CSAH 61	1970	1985	15	18	18	−0.07	0.17	−0.78	0.65
79	SPARS 16	TH 55 and 52- From TH 49 to TH 56	1970	1985	15	36	24	1.08	2.43	−0.54	5.70
80	SPARS 17	TH 56—From Linden Street to CSAH 26	1970	1985	15	38	22	0.04	0.25	−0.37	1.48
81	SPARS 18	TH 56—From Richmond St. to Grand Ave.	1970	1985	15	34	22	0.24	0.18	−0.24	1.02
82	SPARS 19	I-494/I-694—From Mississippi River to TH 212 (TH 5)	1970	1985	15	44	42	1.30	0.90	0.24	4.31
83	SPARS 32	TH 3—From TH 52 and TH 55 to Salem Church Rd.	1970	1985	15	32	20	1.12	0.60	−0.30	2.39
84	SPARS 33	TH 51(Snelling Ave.)—From I-94 to Pierce-Butler Route	1970	1990	20	40	28	−0.09	0.08	−0.51	0.57
85	SPARS 37	TH 10, Jct. TH 10 with TH 96 and I-35W with TH 96	1971	1985	14	16	16	−0.29	0.04	−0.76	−0.08
86	SPARS 45	TH 51 (Snelling Ave.)—From TH 5 to Pierce Butler Route	1971	1985	14	80	63	0.09	0.16	−0.49	1.04
87	SPARS 48	TH 169—From TH 282 to TH 21	1971	1990	19	18	14	−0.29	0.12	−0.75	0.04
88	SPARS 49	TH 10—From Egret Boulevard to University Ave. in Coon Rapids	1971	1985	14	20	16	−0.07	0.16	−0.68	0.44
89	SPARS 53	I-35E—From W. 7th St. to Kellog Blvd.	1971	1990	19	46	16	0.22	0.13	−0.43	0.66
90	SPARS 60	TH 61—From I-494 to County Road 19	1971	1985	14	50	36	1.06	2.21	−0.38	5.92
91	SPARS 61	CSAH 18—From Smetana Rd. to CSAH 3	1971	1975	4	64	26	0.53	0.76	−0.48	2.44
92	SPARS 65	TH 10—From Egret Blvd. to University Ave.	1971	1985	14	17	14	0.14	0.03	−0.19	0.32
93	SPARS 69	TH 100—From I-494 to Benton Ave.	1971	1985	14	44	21	−0.20	0.03	−0.41	0.17
94	SPARS 72	I-94—From Dowling Ave. to TH 12	1971	1985	14	52	40	0.13	0.25	−0.64	1.08
95	SPARS 73	TH 10—Proposed Cloverleaf Junction for TH 65	1972	1985	13	8	8	−0.04	0.02	−0.15	0.14
96	SPARS 75	TH 52—From Mendota Rd. to Annapolis St.	1972	1985	13	84	52	0.06	0.21	−0.60	1.36
97	SPARS 75A	TH 49 (Dodd Rd.)—From TH 110 to I-35E	1974	1985	11	62	38	1.70	7.97	−0.40	12.78
98	SPARS 77	TH 95—From TH 61 to CSAH 18	1972	1992	20	16	16	1.43	0.62	0.24	2.50
99	SPARS 78	TH 55—From 52nd St. to 44th St.	1972	1985	13	27	16	1.25	2.16	−0.29	3.69

Table A1 (*continued*)

Id	Report	Description	Report Year	Forecast Year	Number of Years	Total No. of Forecast Links	Total No. of Actual Traffic Links[a]	Avg. Inaccuracy	Variance	Min. Inaccuracy	Max. Inaccuracy
100	TAS3562C	TH 55—From Kimball to 3.5 Mi. SE of Jct. TH 25 in Buffalo	1967	1990	23	98	56	−0.25	0.12	−0.83	0.73
101	TAS3562D	TH 55—From Kimball to 3.5 Mi. SE of Jct. TH 25 in Buffalo	1967	1990	23	50	14	−0.57	0.07	−0.81	−0.10
102	FEIS New U.S. Hwy 10	New U.S. Hwy 10—Between Egret Boulevard and I-35W	1987	2000	13	52	44	−0.19	0.07	−0.61	0.22
103	FEIS TH 3	TH 3—(Is actually TH 52)—From Jct. TH 55 to Jct. I-494	1987	1990	3	40	36	−0.19	0.28	−0.77	1.09
104	FEIS TH 77/I-494	TH 77/I-494—From E. 86th St. to E. 70th St. and from 12th Ave. S. to 34th Ave. S.	1904	1990	86	128	126	0.42	0.87	−0.26	7.94
105	FEIS I35E	From TH 110 (Dakota County) to I-94 near downtown St. Paul	1982	2006	24	18	18	−0.35	0.04	−0.64	0.06
106	DEIS TH 610/TH 252	TH610/TH252—From I-94 in Maple Grove to TH 10 in Coon Rapids/From I-94 in Brooklyn Center to TH 610 in Brooklyn Park	1981	2000	19	82	74	−0.22	0.18	−0.81	1.14
107	FEIS US-12/I-394	US-12/I-394—From between SR-101 and I-94	1982	2000	18	294	250	0.09	0.30	−0.61	1.87
108	20-Year Plan For District 9	I-35W—From I-35E to TH 49	1989	2010	21	18	16	0.02	0.07	−0.36	0.35

[a] Average Annual Daily Traffic (AADT).

impact of fundamental societal changes on traffic forecasts and the dependence of irreversible infrastructure decisions on these forecasts makes it imperative for modelers to better understand them and incorporate them rather than blindly utilizing existing trends into the forecasting process. For example, analysis of recent labor force data show increasing participation of older men and women (65 years and above) in the labor force (Gendell, 2008). The data not only shows increase in worker participation rates but also increasing full-time employment rates for this 65+ age group. This finding reverses the long run decline in employment for this age group and will have implications on travel as the percentage of older adults in the work force increases.

From a modeler's perspective, it would really help for non-modelers/decision makers in charge of funding decisions to obtain a better understanding of the forecasting process before making decisions based on model results. Most interviewees in this analysis acknowledged that a basic understanding of the science behind the forecasts, limitations and applicability of traffic forecasts would go a long way in diffusing criticisms against modeling. Some of the issues in the current scenario are the absence of any clear scientific approach in modeling, lack of transparency in the modeling process and lack of proper evaluation of alternatives. There is significant effort expended in developing the models but not much in the way of evaluating, interpreting and explaining the model results.

Modeler's develop travel demand models based on their intrinsic assumptions, knowledge and predictions of human behavior. These assumptions and predictions about future conditions are based on the available past and present data. The use of forecasts to justify policy decisions results in a reversal of "cause-and-effect", where present decisions are based on predictive future events. As Robinson (1988) points out, this approach is underlined with paradoxes and the consequences of such paradoxes are typically ignored in the attempts to predict the future. This calls for a fundamental rethinking of the meaning, purpose and use of forecasting and modeling methodologies and a move towards adopting a comprehensive view rather than a narrow project related focus. Instead of expecting models to predict the most likely future, Robinson (1988) calls for the use of techniques that can provide us with different possibilities and impacts of the alternative futures.

The philosophical, institutional and methodological nature of modeling makes it extremely difficult to predict future conditions in an unbiased manner. While many of the factors that influence model forecasts are beyond the control of modelers, there are some improvements that can be made to improve the model's predictive ability. For example, modelers typically use model validation techniques to evaluate a model's forecasting ability by comparing the model predictions with observed data, not used in model estimation (Zhao and Kockelman, 2002). While this technique assesses the model's ability to reproduce base year conditions, it does not ensure acceptable model performance for future predictions. Future model forecasts are subject to input and other inherent uncertainties and these factors change over time. The current model validation techniques do not capture these dynamic conditions. Use of techniques such as "back-casting", where modelers work backwards from some idea of a desirable future, could be used to improve model's performance. Moreover, a shift in thinking from using absolute numbers in to using ranges would diffuse criticisms against modeling. Acknowledgement of the inherent uncertainties in the modeling process coupled with a sensitivity analysis using ranges to show the variation in traffic forecasts with changes in the various inputs would certainly help the forecasting and decision making process.

Table A2
Lookup Table to be used along with Figs. 3 and 4.

Id	Report	Id	Report	Id	Report
1	SPAR-202	37	TA-M296A	73	TAU 3451B
2	TA-M372B	38	TA-M299	74	SPARS 2
3	TA-M329	39	TA-M304	75	SPARS 2A
4	TA-M335	40	TA-M301	76	SPARS 3
5	TA-M336	41	TAS 3065A-14	77	SPARS 4
6	TA-M337	42	TAS 3074B	78	SPARS 15
7	TA-M343	43	TAS 3074C-14	79	SPARS 16
8	TA-M238	44	TAS 3080	80	SPARS 17
9	TA-M240	45	TAS 3081	81	SPARS 18
10	TA-M242	46	TAS 3081A-14	82	SPARS 19
11	TA-M245	47	TAU 3061A	83	SPARS 32
12	SPAR-208	48	TA-M300	84	SPARS 33
13	SPAR-208A	49	TAS 3066A-14	85	SPARS 37
14	SPAR-210	50	TA-M292	86	SPARS 45
15	SPAR-220	51	TAU 3065	87	SPARS 48
16	SPAR-224	52	TAU 3066	88	SPARS 49
17	SPAR-227	53	TAU 3069	89	SPARS 53
18	SPAR-246	54	TAU 3070	90	SPARS 60
19	TA-M255A	55	TAU 3073	91	SPARS 61
20	TA-M286	56	TAU 3073A	92	SPARS 65
21	SPAR-215	57	TAU 3074	93	SPARS 69
22	SPAR-202A	58	TAU 3074A	94	SPARS 72
23	TA-M345	59	TAU 3075	95	SPARS 73
24	TA-M346	60	TAU 3076	96	SPARS 75
25	TA-M307	61	TAU 3077	97	SPARS 75A
26	TA-M253	62	TAU 3078	98	SPARS 77
27	TA-M253 distributor addendum	63	PSU3203A	99	SPARS 78
28	TA-M302	64	PSU3203B	100	TAS3562C
29	TA-M207A	65	TAS3081B-14	101	TAS3562D
30	TA-M289A	66	TAS3082-14	102	FEIS New U.S. Hwy 10
31	TA-M309	67	TAS3084-14	103	FEIS TH 3
32	TA-M311	68	TAS3085-14	104	FEIS TH 77/I-494
33	TA-M326	69	TAU3204A	105	FEIS I35E
34	TA-M358	70	TAU 3205	106	DEIS TH 610/TH 252
35	TA-M298	71	TAU 3223	107	FEIS US-12/I-394
36	TA-M308	72	TAU 3451A	108	20-Year plan for district 9

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Appendix A

Summary of project reports in the database is given in Table A1. A lookup table of the project identifier with the actual report number, used in Figs. 3 and 4 is provided in Table A2 in the Appendix.

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