Managing Uncertainty and Risk in Travel Forecasting: A White Paper

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TMIP

Better Methods. Better Outcomes.

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1.0 Introduction

Travel forecasts are an important element of the process that transportation agencies use to plan and implement policies and investment programs to accomplish objectives related to mobility. Agency goals typically involve providing fast, safe, efficient transportation while minimizing negative impacts to the environment or the public. The achievement of these goals is constrained by finite financial and other resources.

Travel forecasts could make significant contributions to the process by which policies are analyzed and projects selected for development. Travel models attempt to quantify the speed and convenience of the transportation system and its resulting usage—key elements of system efficiency and environmental or social impacts. In the case of revenue projections for toll facilities or transit lines, forecasts can also contribute to an assessment of financial feasibility of new or existing systems.

Unfortunately, the potential usefulness of travel projections has not been fully realized. A series of studies have compared forecasted and actual usage and concluded that forecasts frequently exceed actual demand, often by significant amounts.

A number of suggestions have been made regarding how the forecasting process could be improved. These include:

- Improve oversight or governance.
- Examine the distribution of outcomes from a reference class of past projects.
- Quantify the likely distribution of outcomes.
- Be aware of the considerable potential for error and bias to influence projections.

All of these have a role in improving the accuracy of the forecasts. However, as the last point suggests, forecasting accuracy can never be assumed. Both forecasters and users must always be aware of the considerable uncertainties that surround all travel projections and the chance that estimated usage levels will not be achieved if a particular policy or program is implemented.

This paper describes the uncertainties and risks associated with travel forecasts and suggests methods for their management. There are many ways of defining risk and uncertainty. In this paper, these terms are used according to the International Standard ISO 31000 (2009) definition of risk: “effect of uncertainty on objectives.” By this definition, risk has two elements—a probability that an event will or will not occur (uncertainty), and a consequence (the impact on an organization’s objectives).

While errors can be detected and resolved, uncertainty and risk cannot be avoided, only managed. Risk and reward are often linked, with higher returns being generated from opportunities that present higher levels of risk. In transportation, most programs or projects include uncertainties in costs, benefits, and revenues which must be borne in order to obtain the intended mobility outcomes. The key is not to blindly avoid all risks but rather to manage the program of projects so that risks are balanced with expected benefits.

The remainder of this paper discusses the following:

- Techniques for improving the accuracy of forecasts.
- Approaches for quantifying uncertainties.
- Strategies for managing forecast risks.

2.0 Improving Accuracy of Forecasts

Travel forecasts have been an integral element of the transportation planning process for over 50 years. During that time frame, they have been used to help plan and justify the Interstate Highway System, major fixed guideway transit facilities, toll roads, and various policy initiatives. These systems have improved mobility for many Americans and the planning process deserves much credit for these successes.

Although transportation programs and policies have generally succeeded in improving mobility and minimizing impacts, the role of forecasts has been relatively modest. This is partly because forecasts are only one element of a large and complex process to define and implement projects and programs. Another factor contributing to its modest role is the fact that forecasts are not perceived as being sufficiently accurate to be a decisive element of the decision-making process.

Retrospective reviews of the accuracy of travel forecasts compared to actual usage patterns confirm these perceptions. Several studies of forecasted versus actual travel demand have found that projections of usage typically misstate actual volumes to a considerable degree. Examples include:

- In 1992, Pickrell compared forecasted observed and actual daily ridership for seven United States rail transit systems and found that only one system (Washington Metro) carries over half of the forecasted ridership.[1] Actual ridership for the remaining six cities were under half of the forecasted levels.
- In 2005, Flyvbjerg, Holm, and Buhl reported that international rail forecasts were overestimated by an average of 105.6% and that 84% of rail projects have actual traffic levels more than 20% below forecasted. International road projects did better, underestimating actual traffic by 8.7%. Even so, one half of all road projects have errors exceeding ±20% and one quarter have errors that exceed ±40%.[2]
- Lewis-Workman and White reported that only three of 19 United States fixed-guideway transit projects completed between 1990 and 2002 carry more riders than projected. Another five were carrying, or might soon carry, at least 80% of the forecasted number. The remaining 11 were well below the predicted value. Of the 18 projects built between 2003 and 2007, eight were carrying at least 80% of the forecasted ridership and 10 were well below the predicted value.[3]
- Bain studied 104 international toll road projects and found that, on average, these roadways carried 77% of the forecasted ridership, with the worst attracting only 14% of the forecasted ridership.[4]

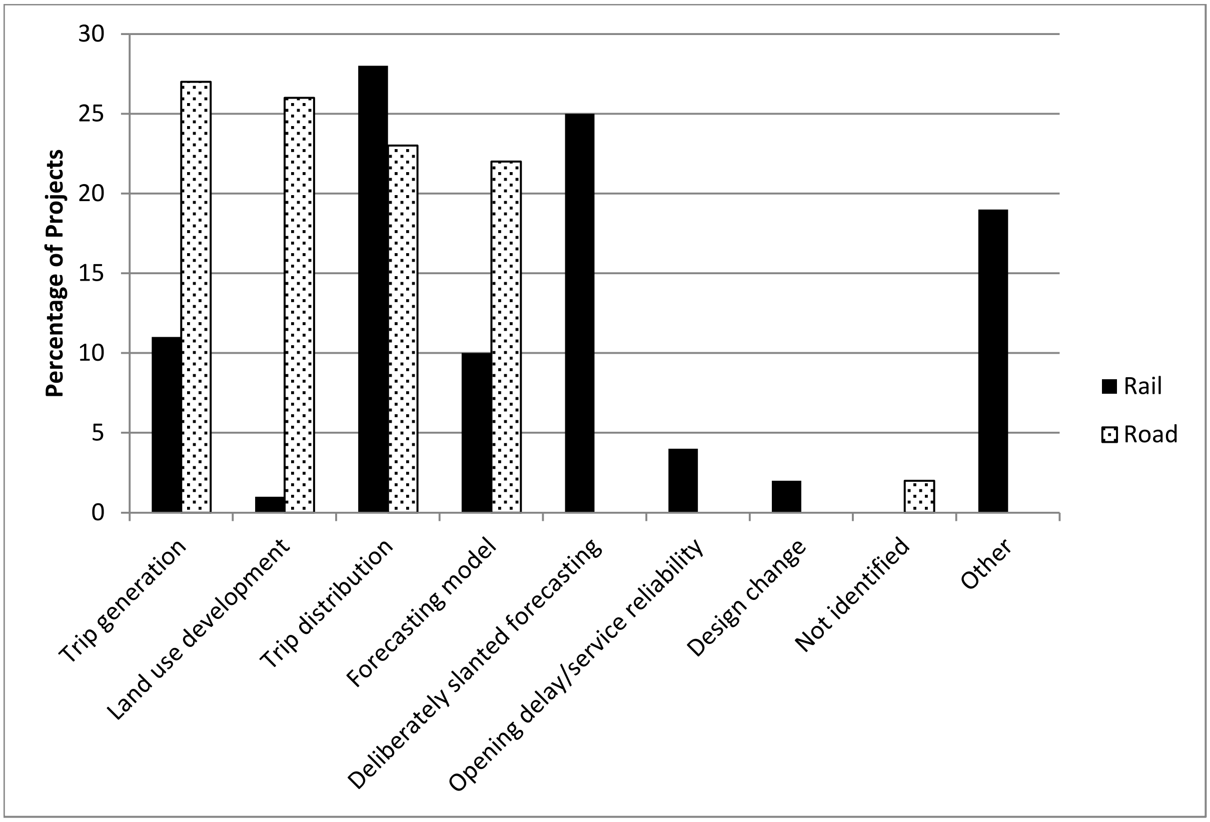
[1] Pickrell, Don H. “A Desire Named Streetcar, Fantasy and Fact in Rail Transit Planning.” Journal of the American Planning Association, Vol. 58, Number 2, Spring 1992.

[2] Flyvbjerg, Home, and Buhl. “How (In)accurate Are Demand Forecasts in Public Works Projects?” Journal of the American Planning Association, Vol. 71, No. 2, Spring 2005.

[3] Federal Transit Administration with Support from Vanasse Hangen Brustlin, Inc. “The Predicted and Actual Impacts of New Starts Projects – 2007.” April 2008.

[4] Bain, Robert. “Error and optimism bias in toll road traffic forecasts.” Transportation, 28 February 2009.

Each author has attempted to diagnose the sources of forecast inaccuracies. Flyvbjerg's assessment of the causes for forecast errors presented in Figure 3 is typical and shows that inaccuracies are related to problems with input assumptions and the models (or model components) that are used to generate forecasts. A substantial number of projections were also deliberately slanted to achieve a predetermined outcome.



Source: Flyvbjerg

Figure 1. Stated causes of inaccuracies in traffic forecasts.

Lemp and Kockleman have compiled a list the key drivers of forecast failures for toll roads from multiple sources.[5] The reasons that forecasts often misstate actual usage include:

- Optimism bias;
- Poorly estimated values of time;
- Reliance on a single value of time;
- Mis-prediction of future land-use conditions, overall trip generation, and trip destination;
- Mis-estimation of travel time savings;
- Unforeseen competition provided by parallel free roads; and
- Underestimation of ramp-up duration and severity.

[5] Lemp, Jason and Kockelman, Kaa. "Understanding and Accommodating Risk and Uncertainty in Toll Road Projects." Presented at TRB, January 2009.

- Failure to understand truck travel or time-of-day/day-of-year variations

These findings suggest that some improvements are possible through careful design, development, and application of forecasting tools. A companion paper to this document, "Improving Existing Travel Forecasting Models and Processes," describes potential improvements to the practice of travel forecasting and the accuracy of forecasts. These approaches include the following:

- Improve the practice of forecasting
    - Develop an awareness of forecast requirements
    - Remember the limitations of forecasting tools
    - Consider alternative techniques
    - Adopt a sequential forecasting protocol
    - Understand and document forecast uncertainties
    - Conduct peer reviews
- Collect better data
    - Demographic information
    - Transportation supply
    - Usage counts
    - Travel demand patterns
    - Data validation
- Confirm reliability of input assumptions
- Improve capabilities of existing forecasting tools
    - Refine geographic units of analysis
    - Stratify models according to time of day
    - Stratify models by socioeconomic class
    - Maintain consistency among all forecasting elements
    - Develop effective highway and transit travel time functions
    - Run highway assignment models to full convergence
- Confirm model validity
    - Review accuracy of modeled transportation supply
    - Confirm geographic distribution of travel
    - Confirm model choice patterns
    - Confirm model response to change

A common theme of each these steps is that a successful set of forecasts is the product of a person who utilizes knowledge of current conditions, tools (such as models) to show what may happen, and judgment to develop the actual projections of future travel demand and impacts on mobility. Each aspect of this process is important—successful projections cannot be developed without data, effective analysis procedures, and judgment. In each, the person responsible for assembling projections plays a key role. The forecaster must actively review each element of the process to confirm that the data are accurate and the results make sense. Projections that have not been scrutinized by the forecaster and by independent reviewers are just raw numbers. It is the combination of internal and external review that transforms these numbers into useful insights.

While these actions will undoubtedly improve the forecasting process, Pickrell, Flyvbjerg, and Bain all suggest that improvements to the forecasting process, alone, are unlikely to lead to significant improvements in forecasting accuracy. Instead, substantial inaccuracies appear to be inevitable, particularly when attempting to understand travel behaviors occurring 30 years into the future or examining usage of a new facility for which no history is available. Suggestions for improving outcomes include the following:

- Bring the forecasting horizon closer to the present to reduce the potential factors that can cause projections to go awry. These factors include changes in the local economy, the evolution of travel patterns, or competing transportation modes. Short-term forecasts would also remove the effect of projections of reduced automobile speeds and increased costs, which have rarely proven accurate. [Pickrell]
- Apply reference class forecasting approaches to reduce inaccuracy and bias. These tools take an “outside view” of the project being forecasted based on usage experience from similar projects that are already open. [Flybjerg]
- Acknowledge uncertainty. Forecast error is unlikely to be eliminated by technical changes in the way models are developed and applied. Given this situation, forecasters should communicate the uncertainty of projections and the financial and political risks that accompany these projections. It is possible to construct forecasts with a mathematical probability that it falls within a stated range. However, it is more valuable to acknowledge that uncertainty exists and cannot be eliminated. [Pickrell]

The next sections describe the process that can be used to acknowledge forecast uncertainties and risk.

3.0 Acknowledging Forecast Uncertainties

One of the recommendations from Section 2.0 is acknowledging the existence of uncertainty and, if possible, quantifying its potential impacts. This section discusses three potential approaches:

- Developing a risk listing that enumerates project attributes and uses experience with similar projects to estimate forecast likelihood.
- Preparing independent forecasts of travel demand.
- Quantifying forecast uncertainties.

3.1 Risk Listing and Assessment of Prior Experience

As Pickrell noted, it is important to understand and acknowledge forecasting risks. One technique is to utilize the risk listing approach described by Bain.[6] This approach (illustrated in Table 1 and Table 2) involves comparing the characteristics of a potential project or program to a series of characteristics that prior experience has shown to be related to relatively low traffic risk (low risk scores) or higher traffic risks (high risk scores). This comparison can be presented to decision makers to provide insights into the likelihood that actual usage will or will not match forecasted values. It is important to note nearly all of the project characteristics that are indicative of higher risk levels relate to the project circumstances rather than the methodology used to forecast demand. These circumstances include

- Being a new facility rather than an extension or modification to an existing road;
- Being in an area with little local experience with toll roads;
- Having a complex or relatively expensive toll rate structure;
- Being in an area with a relatively weak local economy;
- Lacking protection from competition; and
- Being dependent on new corridor development or growth.

The only aspects that relate to the forecasting methodology pertain to the approach used to survey potential users and whether model parameters are locally derived or imported from elsewhere.

[6] Bain, Robert. “Error and optimism bias in toll road traffic forecasts.” Transportation, 28 February 2009.

Table 1. Example Risk Listing (Part I).

Project Attributes	Good — Traffic Risk Index: Scores — Bad (0 1 2 3 4 5 6)	(7 8 9 10)
Tolling culture	Toll roads well established—data on actual use available	No toll roads in the country—uncertainty over toll acceptance
Tariff escalation	Flexible rate setting/escalation formula; no government approval	All tariff hikes require regulatory approval
Forecast horizon	Near-term forecasts required	Long-term (30 years+) forecasts required
Toll facility details	Facility already open	Facility at the very earliest states of planning
	Estuarial crossing	Dense urban network
	Radial corridor into urban area	Ring-road/beltway around urban area
	Extension of existing road	Greenfield site
	Alignment—strong rationale (tolling points and intersections)	Confused/unclear road objectives (not where people want to go)
	Alignment—strong economics	Alignment—strong politics
	Stand-alone (single) facility	Reliance on other proposed highway improvements
	Highly congested corridor	Limited/no congestion
	Few competing roads	Many alternative routes
	Clear competitive advantage	Weak competitive advantage
	Only highway competition	Multi-modal competition
	Good, high capacity connectors	Hurry-up and wait
	Active competition protection (e.g., traffic calming, truck bans)	Autonomous authorities can do what they want
Surveys/data collection	Easy to collect	Difficult/dangerous to collect
	Experienced surveyors	No culture of data collection
	Up-to-date	Historical information
	Locally calibrated parameters	Parameters imported from elsewhere (another country?)
	Existing zone framework	Develop framework from scratch

Source: Bain, Robert. "Error and optimism bias in toll road traffic forecasts." Transportation, 28 February 2009

Table 2. Example Risk Listing (Part II)

Project Attributes	Good — Traffic Risk Index: Scores — Bad (0 1 2 3 4 5 6 7 8 9 10)	
Users: private	Clear market segments	Unclear market segments
	Few, key origins & destinations	Multiple origins & destinations
	Dominated by a single journey purpose (e.g., commute, airport)	Multiple journey purposes
	High income, time sensitive market	Average/low income market
	Tolls in line with existing facilities	Tolls higher than norm (extended ramp up)?
	Simple toll structure	Complex toll structure (discounts, frequent users, variable pricing)
	Flat demand profile (time-of-day, day-of-week, etc.)	Highly seasonal or "peaky" demand profile
Users: commercial	Fleet operator pays toll	Owner-driver pays toll
	Clear time/operating cost savings	Unclear competitive advantage
	Simple route choice decision-making	Complicated route choice decision-making
	Strong compliance with weight restrictions	Overloading of trucks is commonplace
Micro-economics	Strong, stable diversified local economy	Weak/transitioning local/national economy
	Strict land-use planning regime	Weak planning controls/enforcement
	Stable, predictable population growth	Population growth dependent on many exogenous factors
Traffic Growth	Driven by/correlated with existing, established and predictable factors	Reliance on future factors, developments, structural changes etc.
	High car ownership	Low/growing car ownership

Source: Bain, Robert. "Error and optimism bias in toll road traffic forecasts." Transportation, 28 February 2009

A similar message is presented in NCHRP Synthesis 364[7]. This report included a comparison of forecasted and actual toll revenues for 26 projects opened between 1986 and 2004. Comparisons are presented for the first 5 years of operation (for projects where this data was available). Of the 105 observations, 13 were within ±10%. Of the remaining observations, only 10% were cases where revenue was underestimated. The remainder represent cases where actual revenue is less than 90% of forecasted revenue. Over half of all roads generated 30% less revenue than forecasted and a quarter generated 50% less revenue than forecasted.

These projects were categorized into four groups and the relationships between forecast error and group were identified. The results of this analysis are presented in Table 3. In general, forecasts for projects in an already-developed area with relatively modest toll rates were reasonably accurate. Projects that depend on high-development growth rates, new travel patterns, or high tolls were considerably less accurate, with actual traffic being between 50% to 70% of forecasted volumes.

[7] Kriger, David; Shiu, Suzette; and Naylor, Sasha. “Estimating Toll Road Demand and Revenue.” National Cooperative Highway Research Program Synthesis 364, 2006

Table 3. Toll Road Performance by Category.

Authority/Facility	Characteristics	Performance	Explanation
Group 1 – High congestion, suburban			
Three facilities: • State Road and Tollway Authority (GA)/GA 400 • North Texas Tollway Authority/George Bush Expressway • Illinois State Toll Highway Authority/Illinois North South Tollway	• Well-developed urban/suburban part of large metropolitan area • Higher corridor income • Substantial corridor Traffic • High value of time • Good connections to Facility • No competitive non-tolled alternatives • Modest projected traffic growth	Approximated or exceeded projections	• Moderate toll rates • Very rapid adjustment of traffic patterns following opening • Moderate traffic growth in first 2–3 years, then growing more slowly
Group 2 - Outlying			
Seven facilities: • Oklahoma Turnpike Authority/John Kilpatrick • Oklahoma Turnpike Authority/Creek • Florida's Turnpike Enterprise/Veteran's Expressway • Florida's Turnpike Enterprise/Seminole Expressway • Florida's Turnpike Enterprise/Polk • Transportation Corridor Agencies (CA)/Foothill North • Orlando–Orange Expressway Authority/Central Florida Greenway North Segment	• Less established traffic patterns • Less integral to the existing network • These were partial beltways • Usually serving above average income areas, but with less established development patterns • Further from employment centers • Moderate-to-high toll rates (although usage inelastic because drivers already accustomed to paying tolls	Mean ranged between 61% and 67% of forecasts, on average, with considerable variation	• Substantial forecast revenue growth (35% average over first 4 • years) • Forecast error appears to result from • overestimation of initial base period usage (high ramp-up rates)
Group 3. Developed Corridors			
Five facilities: • Harris County Toll Road Authority (TX)/Hardy • Harris County Toll Road Authority (TX)/Sam Houston • Transportation Corridor Agencies (CA)/Foothill Eastern • Transportation Corridor Agencies (CA)/San Joaquin Hills • Santa Rosa Bay Bridge Authority (FL)/Garcon Point Bridge	• Corridors with more developed or already established traffic patterns • Usually constructed in large metropolitan areas or active tourist areas • "Solid" projected time savings • Moderate projected revenue growth	Mean ranged between 51% and 60% of forecasts, on average, with considerable variation	• Impacts of nearby non-tolled alternatives underestimated • Overestimated time savings • Overly optimistic economic forecasts • Failure to account for recessions • Overestimated corridor growth rates • High toll rates • Limited history of toll use in area • Unusual ramp-up problems • Expansion of competing non-tolled network
Group 4. Least Developed			
Eight facilities: • E-470 Public Highway Authority (CO)/E-470 • Toll Road Investment Partnership (VA)/Dulles Greenway • Osceola County (FL)/ Osceola County Parkway • Orlando–Orange Expressway Authority (FL)/Central Florida Greenway South Segment • Orlando–Orange Expressway Authority (FL)/SR-417 • Florida's Turnpike Enterprise/Sawgrass Expressway • Pocahontas Parkway Association (VA)/ Pocahontas Parkway • Connector 2000 Association (SC)/ Greenville Connector	• Specific traffic generator serving as project basis (e.g., airport) • Located in undeveloped area • Toll road expected to stimulate development • High revenue growth rates • Assumed periodic toll rate increases	Mean ranged between 61% and 67% of forecasts, on average, with considerable variation	• Substantial forecast revenue growth (35% average over first 4 years) • Forecast error appears to result from overestimation of initial base period usage (high ramp-up rates)

Source: Muller and Buono reported in NCHRP Synthesis 364 Estimating Toll Road Demand and Revenue

Many of these risk factors apply to situations beyond toll road forecasting. For instance, the Federal Transit Administration (FTA) also views forecasts of current-year conditions to be more reliable than forecasts with long-term horizons. FTA typically limits forecast assumptions regarding automobile operating costs and parking fees to current values to avoid the uncertainties associated with the future magnitude and impact of these factors on transit ridership.

The factors that are associated with forecast accuracy could easily be incorporated into a statement of forecast uncertainties. Project characteristics that are known to be related to past forecasting problems should be disclosed to forecast users. It is important to emphasize that these uncertainties are not forecasting deficiencies that can be addressed by better models or more data, but rather are an intrinsic characteristic of the project.

Such statements should not suggest that a project with uncertain forecasts is necessarily one that should not be pursued. There are many cases in history where business decisions were made without a full knowledge of the market acceptance of a new product. Some of these products, in fact, have paved the way for a company's success. Instead, uncertainty suggests the need to plan for a range of outcomes so that the project or organization does not fail if demand were to be less (or more) than forecasted.

3.2 Generate Alternative Forecasts by Independent Parties and Independent Means

Section 2.0 suggests that forecasts might become more reliable by using a broader array of tools (e.g., reference class models or a variety of conventional forecasting methods) and two or more independent groups of forecasters. This approach would reduce the chance that forecasts are results of model inaccuracies or forecaster optimism bias. If the forecasters are truly independent of the project, it would also reduce the pressure to slant a forecast to meet a particular outcome.

Independent forecasts involve engaging multiple groups of forecasters to prepare projections. Ideally, these forecasting teams might share information that describe the project and, possibly survey data, but otherwise would prepare forecasts with very little interaction on the nature of their analysis methods or input assumptions. After both parties complete their work, outcomes could be compared to identify common outcomes and differences. These results could provide key insights into potential uncertainties that could be particularly helpful in cases that are judged to be "High Risk," as defined in Section 4.0.

A version of this approach was been used in the development of high-speed rail forecasts for the State of Florida. FTA has also used independent reference class models to evaluate some New Starts forecasts.

It is important for these different forecasts to be disclosed so that decision makers and the public have a more complete understanding of the range of potential outcomes. Different alternative forecasts should not be characterized as being "right" or "wrong." Instead similarities or differences should be used to highlight what is relatively certain and what is unknown.

3.3 Quantifying Forecast Uncertainty

Although a listing of risks and independent review can be helpful, in many cases it is necessary to quantify forecast uncertainties in a more meaningful way. Several approaches have been used:

- Conduct sensitivity analysis in which individual model inputs and assumptions are varied to determine the effect on forecast outcomes. These tests are helpful in demonstrating the models' response to input assumptions and the potential variability of outcomes. Since input values are individually adjusted and are arbitrarily set, these tests do not attempt to estimate the likelihood of occurrence.
- Prepare a series of scenarios that describe both optimistic and pessimistic conditions. These stress tests help to establish the best and worst expected outcomes but provide no indication of the probability that any particular outcome will occur.
- Conduct a quantitative risk analysis in which probability distributions for key model inputs and assumptions are prepared. This can be done by applying Monte Carlo techniques to generate thousands of different input sets and then running the forecasting procedures to forecast demand for each case.

Because travel forecasting models can run for hours or days, Adler et al., suggest using Response Surface Analysis techniques to develop a simplified equivalent of the full travel forecasting model for use in the Monte Carlo simulation[8]. With this technique, a simple equation is used to generate an estimate of the key figure of merit (traffic) as a function of the input variables that are the key drivers of uncertainty. Adler et al. provided an example application of this technique to the Orlando I-4 Express Lanes project that includes the following steps:

1. Begin with a detailed macroscopic simulation model and travel demand model and conduct sensitivity analysis to identify input variables that are key drivers of forecast outcomes. In Orlando, these included population growth, value of time, other network capacity improvements, and toll rates. With the exception of toll rates, which the road's operator sets, these represent the most important input uncertainties.
2. Develop probability assumptions for each of the three uncertain variables based on: (a) accuracy of past population forecasts and likelihood of economic downturns; (b) surveys and sampling errors associated with value of time; and (c) likelihood of other system enhancements estimated by DOT engineers.
3. Account for covariance among input variables using historical data (when known) or Delphi techniques (when not known).
4. Run the travel forecasting model for nine different combinations of key inputs for each of seven forecast years representing an array of values of time, growth, networks, and toll rates.
5. Develop a simple equation to estimate traffic and revenue as a function of the uncertain variables.

$$Traffic = C_1 + C_2 growth + C_3\left(\frac{tollRate}{VOT}\right) + C_4 \ln(rampUp) + C_5 roadEC + C_6 Road150 + yearCon)$$

Where: *Traffic* = Number of daily one-way trips using express lanes

Growth = Ratio of dwelling units in forecast year to dwelling units in 2010 minus 1

tollRate = Average toll rate in Year 2010 dollars

rampUp = Number of years project has been in operation

[8] Adler, Thomas; Doherty, Michael; Klodzinski, Jack; and Tillman, Raymond. "Methods for Quantitative Risk Analysis for Travel Demand Model Forecasts" Paper submitted to Transportation Research Board, August 1, 2013.

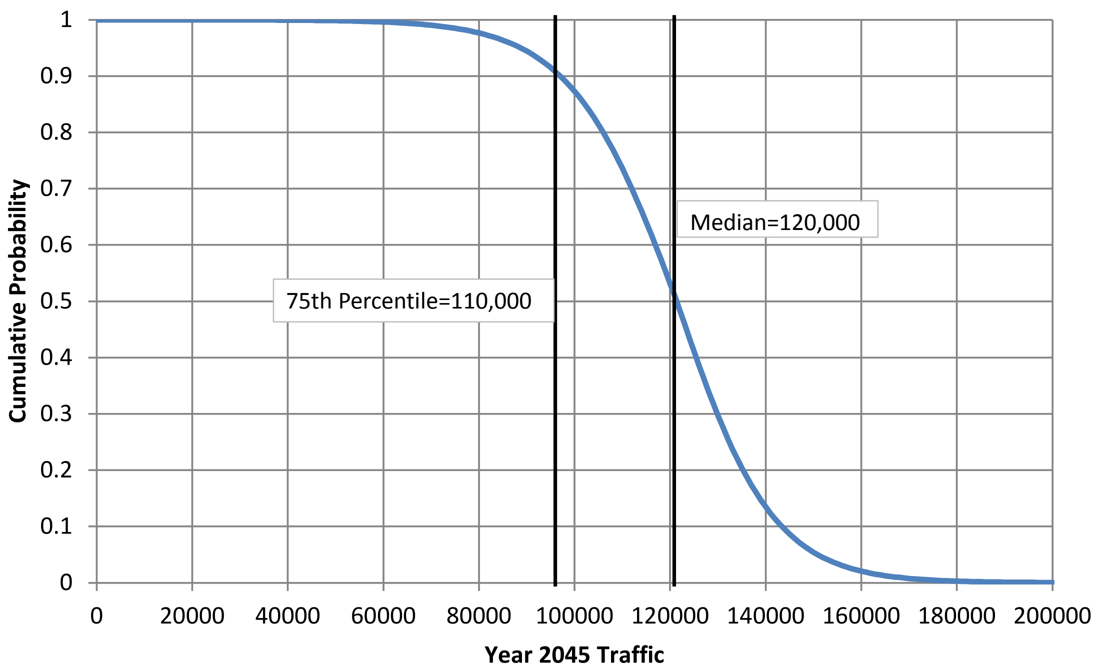
roadEC = Road improvements associated with E+C conditions

road150 = Road improvements required to maintain all roads below V/C of 1.5

yearCon = Vector of constants representing the year

6. Use Monte Carlo simulation to draw between 100,000 and 1,000,000 sets of inputs and compute traffic and revenue for each case to develop a probability distribution of likely outcomes.

The outcome of this process is a probability distribution of traffic and revenue similar to that shown in Figure 2. This chart shows both the median value of traffic and the traffic volume that will be exceeded with an estimated probability of 75%.



Source: Adler et al.

Figure 2. Example Traffic Distribution.

3.4 Limitations of Uncertainty Assessment

Use of tools such as risk listings, sensitivity and scenario analyses, and quantified risk analyses help forecasters and decision makers understand the dimensions of uncertainty that surround each project or program. It is important, however, to remember that while they help to understand uncertainty, they also have limitations that must be understood. These limitations include the following:

- Risk analysis tools generally do not address problems associated with the structure and operation of the travel demand model, itself. Travel models are very complex systems with many interacting elements. Careful and thorough model testing can only begin to establish the validity of travel forecasting models. Frequently, combinations of conditions can occur in the future that have no parallel in observed data used to develop the model. As a consequence, the model sensitivity to these conditions cannot be verified by comparing results to actual travel demand. Instead, the model can only be tested for reasonableness, which leaves open the possibility that model results will not match future outcomes.

- The probability distributions of key input variables are largely unknown. Past forecast experience, survey standard errors, and professional experience are good indications of input uncertainty. However, the future is unknown and may or may not resemble past experience. Therefore, the probability of input conditions not being achieved may be materially different from the assumptions used in a Monte Carlos analysis.
- Covariance between variables is particularly important and must not be bypassed. Employment, income, and willingness to pay can be affected simultaneously by an economic downturn. These variables should not be treated as three separate parameters with independent distributions.

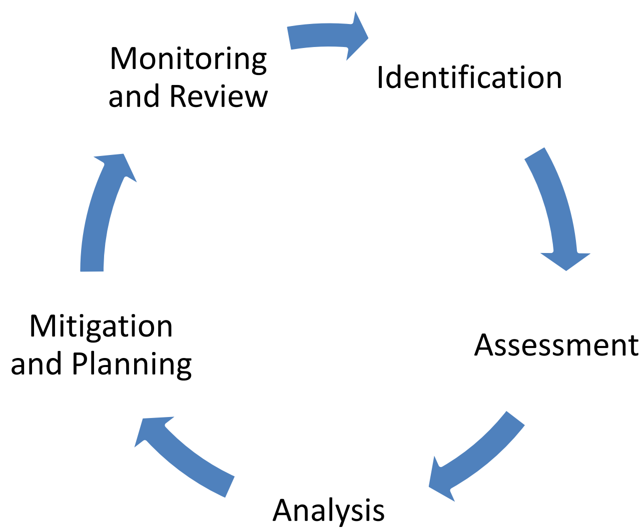
All of these factors mean that, as with the forecasts themselves, the actual uncertainty associated with those forecasted volumes may differ from the predictions associated with any of the tools presented in this section.

4.0 Managing Forecast Risks

In many cases, forecasts of travel demand have an important impact on the decision for public and private entities to invest in transportation infrastructure. The consequence of an erroneous (low) forecast ranges from a sub-optimal set of public transportation investments to a failure to meet an organization's financial obligations. Risk is also present if the actual demand is higher than forecasted. For example, critical pieces of infrastructure may be undersized if the demand is underestimated, requiring the owner to make expensive upgrades.

The process of understanding uncertainties and managing their impact is becoming increasingly important in a wide array of organizations, including transportation agencies. A full discussion of risk management is beyond the scope of this document, but it is introduced in a report by Janet D'Ignazio for NCHRP 20-24.[9] International experience in this subject is presented in a report prepared by Curtis et al. for FHWA.[10]

Risk management occurs at multiple levels in an organization—the enterprise, the program, and the project. As shown in Figure 3, the process is iterative and repeated over time.



Source D'Ignazio, et al.

Figure 3. Cyclical Nature of the Risk Management Process.

The first step is **risk identification**, which is the process of determining which risks (or underlying uncertainties) might affect an organization's objectives. This is most often accomplished with brainstorming sessions or survey techniques using an experienced, qualified, and diverse team. Identified risks are stored in a risk register that organizes this knowledge and initiates later steps of the process. Risks are stated in terms of their impact on the organization's objectives. Example forecasting-related risks that might be stored in a risk register include "Poor selection of projects undermining the organization's credibility" and "Inadequate revenue to

[9] D'Ignazio, Janet; Hallowell, Matthew; Molenaar, Keith. "Executive Strategies for Risk Management by State Departments of Transportation." NCHRP 20-24(74). May 2011.

[10] Curtis, Joyce et. al. "Transportation Risk Management: International Practices for Program Development and Project Delivery. FHWA Office of International Programs. August 2012.

support operating or financing costs." Actual demand not equaling forecasted usage is not, in and of itself, a risk; however, the consequences of bad forecasts on an organization's reputation, financial integrity, or achievement of mobility goals could be risks.

The next step is **risk assessment**, which involves defining both the likelihood and consequences of the risk. A probability-impact matrix (see example in Figure 4) can prioritize risks in a qualitative manner. If there is a high probability that a given forecasted traffic volume will not be achieved, but there is relatively little impact to the organization, then the overall risk is "Low." This could happen if a new (non-tolled) roadway is built before the area is developed with the objective of reducing construction costs or accelerating economic development. As long as the development and traffic eventually occur, there may be limited risk associated with actual volumes being lower than forecasted in the short term.

By contrast, if the roadway were designed to be tolled and financed using revenue bonds, then the same forecast error could lead to a high chance of inadequate cash to cover the required payments and a serious consequence—financial default. This situation would have a "High" risk assessment.

Likelihood \ Impact	VL	L	M	H	VH
VH	M	M	H	H	H
H	L	M	M	H	H
M	L	L	M	M	H
L	L	L	L	M	M
VL	L	L	L	L	M

Assessment Guide

H = Unacceptable. Different approach required.

M = Some impact. Additional management attention needed.

L = Minimal impact. Monitor to ensure risk remains low.

Source: D'Ignazio, et al.

Figure 4. Probability Impact Matrix.

Risks with a high or medium assessment may warrant a more complete **risk analysis.** Risk analysis can utilize the forecast uncertainties analysis discussed in 3.0. Historic experience with certain types of forecasts (Section 3.1), independent forecasts (Section 3.2) and more detailed sensitivity and Monte Carlo analyses (Section 3.3) are useful in understanding the probabilities that certain risks will occur. The analysis must focus on the risks (consequences) rather than individual uncertainties. For instance, if the risk is inadequate cash flow to cover debt service, then the probability of both revenue and operating costs being different from the forecast must be evaluated, since either could lead to financial difficulty.

The next step is **risk mitigation and planning.** This involves identifying a response strategy for each significant risk. There are four basic types of response:

1. **Avoid**. Change the project so that the risk does not occur. For example, a tollway might not be built beyond the limits of current development.
2. **Transfer**. Contract with an entity better able to mitigate and manage the risk. A tollway may be sold to a concessionaire or to a tolling agency with multiple roadways. Bear in mind that risk transference usually involves a cost.
3. **Mitigate**. Develop a strategy to decrease the likelihood or impact of a risk. This could include an incremental project development strategy that adds lanes (and project costs) as demand warrants rather than building the entire project at once. Impacts of lower revenue could be offset by higher debt service coverage ratios.

4. **Accept**. If none of the three previous strategies is adopted, then the risk is accepted either deliberately or by default.

The final step is **risk monitoring and updating.** In this activity, the risk register tracks the status of previously identified risks and new risks can be added as they are discovered. As needed, risk mitigation steps can be implemented in response to changing conditions.

It is important to recognize that risk is not necessarily bad. In many cases, risks also represent opportunities. In the investing world, returns are linked to risk—low risks mean low rewards and high risks mean that there is a chance for a higher reward, but also the risk of a loss. In transportation, the same thing could apply. A major high-occupancy/toll (HOT) lane initiative could result in a significant increase in mobility and cover its operating and capital costs. It also could accomplish much less. Risk analysis does not seek to eliminate the uncertainty but rather to determine whether the potential reward is worth the risk.

5.0 Conclusion

Forecast uncertainty and risks are an inevitable element of all transportation projects and programs. Much can and should be done to reduce error in the forecasting process so that forecasts are as accurate as possible. However, forecast uncertainties will remain even after risk mitigation strategies are employed. Some of these uncertainties are related to the characteristics of the project itself, but others can be ameliorated to some degree by better data and forecasting methods.

The risk management process can help determine whether forecast uncertainties could create significant problems for the organization. If so, then a formal process to quantify uncertainties and plan tactics to mitigate negative impacts could be warranted.

It is important to remember that nearly all endeavors involve some form of risk. The key is to balance potential downside risks against the potential benefits of implementing the project or program.

NOTICE

Federal Highway Administration