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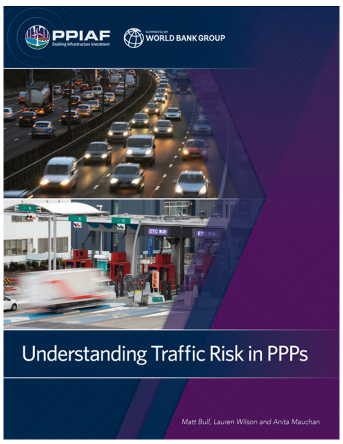
Understanding Traffic Risk and Traffic Forecasting

Low traffic volume, and the low toll revenues that result, contribute greatly to the failure of toll road public-private partnerships (PPPs). This risk has several sources, including forecasting error, uncertainty inherent to the forecasting process, and bias. While some level of traffic risk will always be present in highway PPPs, governments, the private sector, and financiers can take steps to reduce and manage this risk through robust forecasting techniques and selecting the appropriate project structure. The PPIAF-funded guide, *Toll Road PPPs: Identifying, Mitigating, and Managing Traffic Risk*, provides guidance to government officials, financiers, and the private sector as they seek to reduce traffic risk and strengthen highway PPP projects in developing countries. This brief is part of a series that summarizes the content of the guide. Other briefs in this series and the guide can be downloaded from the PPIAF website.

INTRODUCTION



Despite the failure of several high-profile toll highway PPPs, developing country governments remain eager to develop highway PPPs and if possible transfer traffic and revenue risk to the private sector as a way of reducing their own financial exposure and long-term liabilities. Yet governments often have a limited capacity to understand the nature of traffic and revenue risk and the technicalities of the traffic forecasting process. While traffic risk is present nearly always and everywhere, it can be mitigated; what residual risk remains can be allocated to the party that can most efficiently manage it. A clear understanding of the nature of traffic risk and the underlying traffic forecasting process is therefore a key factor in the successful delivery of highway PPP projects.

DEFINING TRAFFIC RISK

PPPs are often viewed as the ideal solution for governments balancing limited budgets and growing infrastructure demands. The notion of the private sector raising finance to fund construction and improvements to highway infrastructure against future toll payments from road users can be attractive to cash-strapped governments in both developed and developing countries. However, implementing such projects is often not as straightforward as many governments envision.

One of the most common factors contributing to the failure of toll highway PPPs is traffic volume (and the resulting toll revenues) that turns out to be significantly different than that originally forecasted.

The risk of actual traffic being lower (or higher) than forecast, and the inaccuracy of traffic forecasts, is referred to as **traffic risk**.

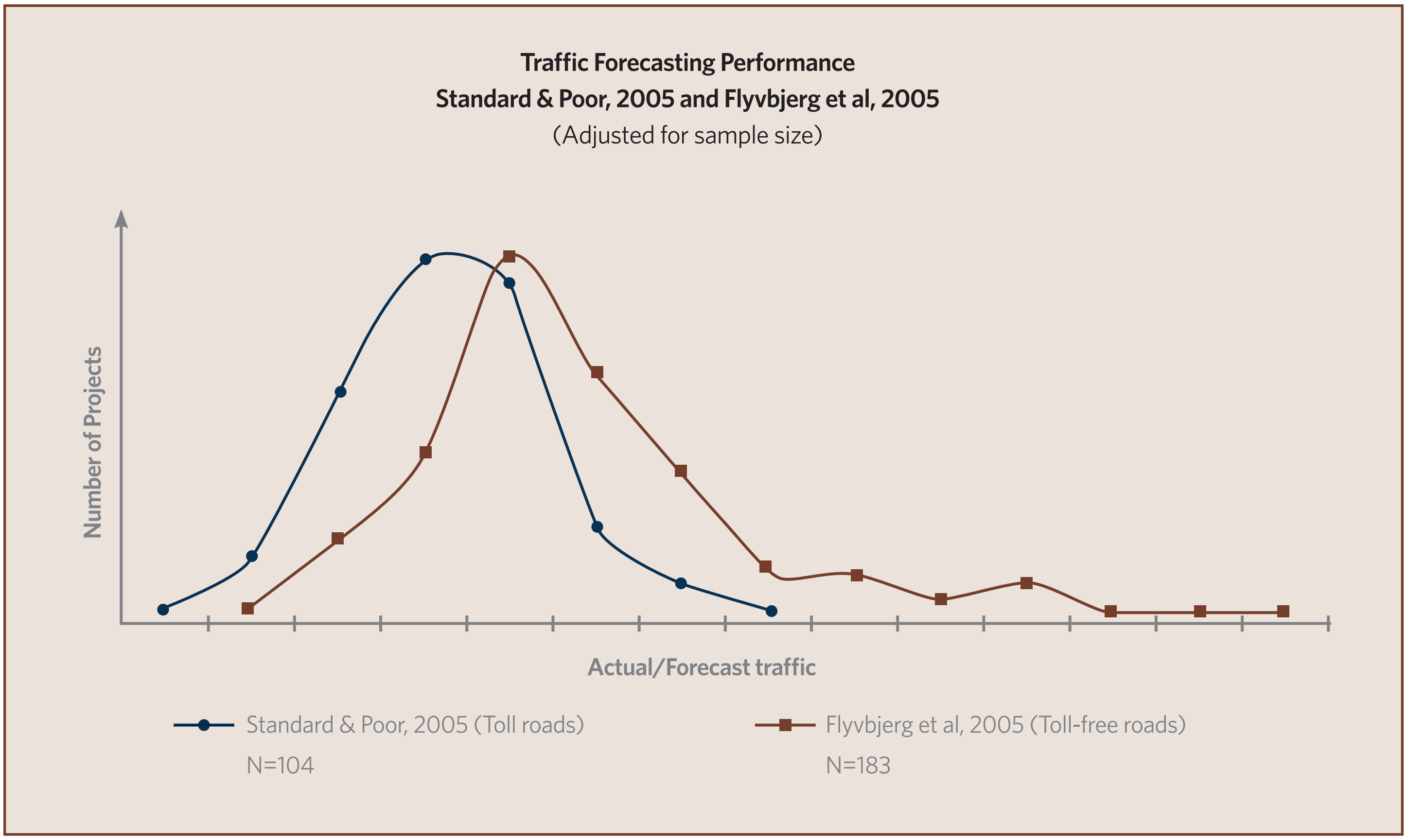
Traffic risk has crystallized in many projects and has led to numerous financially distressed toll road assets. This in turn has led to high-profile bankruptcies, renegotiations, and government bail-outs. More profoundly, due to these failures, private financiers are now significantly more aware of traffic (and revenue risk) and they have become more risk averse towards highway PPP projects.

HOW BAD IS TRAFFIC RISK?

Empirical evidence on the performance of toll road traffic and revenue forecasts suggests that inaccuracies are frequently observed. The conclusions of several empirical studies indicate that the range of these inaccuracies is often large and may be skewed toward overestimation.

Bain's 2009 study[1] compares the findings of the Standard and Poor's[2] and Flyvbjerg et. al.[3] research undertaken in 2005 for toll roads and non-tolled roads respectively. The study compared the distribution pattern of the ratio of actual to forecast traffic as an indicator for traffic forecasting accuracy. A ratio above 1.0 indicates that the forecast underestimates the actual traffic, while a ratio below 1.0 indicates overestimation. Bain notes that the similarity in the shape and the standard deviation of the two distribution patterns reflects the prediction error present in both datasets. He postulates that the distribution of Standard & Poor's samples leans towards overestimation because of optimism bias, claiming that traffic forecasts for toll roads are subject to systematic optimism bias, which differentiates the two data sets.[4]

FIGURE 1: EMPIRICAL RESEARCH ON TRAFFIC RISK



THE IMPORTANCE OF THE TRAFFIC STUDY

Traffic studies play an essential role in the development of transport infrastructure and are required at all stages of highway project development. They inform the decision to undertake the project as inputs to the calculation of the financial and economic justification of the project. They also inform the design of the highway, ensuring that sufficient road capacity is provided to accommodate future traffic growth while maintaining high standards of service, and assessment of the environmental and socio-economic impact of the highway.

Traffic forecasts will also inform the allocation of traffic risk during procurement (or negotiation) of a private partner. Traffic studies are also the basis for revenue forecasts for tolled highways and will help determine the financial viability of the project. These forecasts will also determine the size of the public subsidy, which might be required to make the project financially viable, and will ultimately be used by public authorities or lending institutions to secure financing.

Traffic forecasting is subjective and requires forecasters to make assumptions about the future. These assumptions can result in forecasting errors that contribute to traffic risk. Governments, private sector firms, and financiers can undertake due diligence and peer reviews to reduce the likelihood that the traffic forecasts are overly optimistic or overly conservative.

WHAT DOES A TRAFFIC STUDY TELL US?

A traffic study is designed to answer all traffic-related questions asked by highway designers, financiers, environmental engineers, sociologists, economists, politicians, and the public. To provide these answers, the practitioner must first create an artificial representation of the existing transport situation. The new or improved highway infrastructure is then introduced into the existing transport situation to enable the future demand, in terms of traffic volumes, to be predicted.

A traffic study for a new (or improved) highway will:

- Identify the existing traffic demand that could use the new highway (in-scope);
- Estimate the proportion of the "in-scope" traffic that will use the new highway (traffic capture); and
- Predict future year traffic growth (traffic forecasting).

The main output of a traffic study is a set of traffic forecasts and, in the case of tolled highways, revenue forecasts. Numerous forecasting assumptions underlie the production of forecasts, which combine to produce the forecaster's "best estimate." It is critical that these assumptions are well understood by all affected parties and alternative forecast scenarios prepared to test the financial viability of the highway for a range of future outcomes.

PRODUCING TRAFFIC FORECASTS

An important first step toward increasing awareness of traffic risk is an understanding of how traffic forecasts for tolled highways are developed. A computer-based traffic simulation model forms the core of a traffic study. A typical simplified methodological approach for a traffic study designed to provide traffic and revenue forecasts for a new greenfield tolled highway is provided in Figure 2. This simplified example does not include the consideration of transfer from other modes of transport (e.g. public transport), which can be included in more complex forecasting procedures.

Traffic and Highway Surveys

Traffic and highway surveys form the basis of a Travel Demand Model, which is built to accurately represent the existing highway traffic situation in a study area. The surveys should provide sufficient data to accurately reflect the existing traffic conditions in terms of traffic volumes, trip patterns, travel times, and network characteristics. Typical surveys include traffic counts (manual, video, and/or automatic), origin-destination surveys (interviews, mobile phone, registration plate, household, or internet), travel time surveys, and surveys of the existing highway network in terms of speeds, capacities, and distances between points (called nodes) on the highway network.

The surveys provide a snapshot of the traffic situation at the time of surveying. Surveys should be undertaken during typical traffic conditions or "neutral" days and months of the year to describe average traffic conditions. Longer term traffic counts (using automatic equipment) and serial traffic surveys will minimize the risk of sampling error but will not mitigate the risk completely.

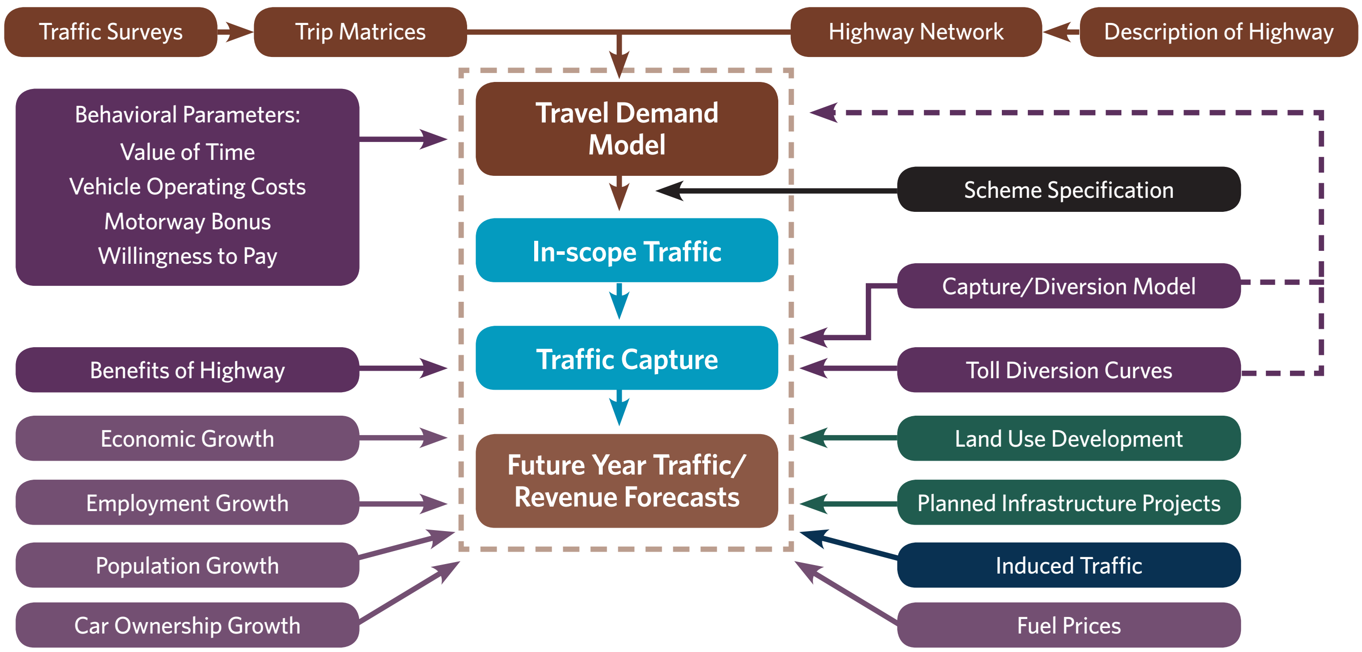
Travel Demand Model

The Travel Demand Model is typically a computerized representation of the existing traffic situation on a highway network. In developed countries, complex multi-user strategic models are typically used to predict tolled highway demand. However, these types of models rarely exist in developing countries and forecasters often focus exclusively on highway demand, building a travel demand model from first principles or updating an existing model.

Travel Demand Models are created with at least three major components (all of which involve some degree of estimation on the part of the traffic forecaster):

- **Trip matrix:** Describes the travel patterns between different geographical areas (often referred to as zones) of the study area. Trip matrices normally represent a specific time period of traffic (e.g. morning/evening peak hour, off peak hour, 24 hour/daily traffic volumes).

FIGURE 2: TYPICAL METHODOLOGICAL APPROACH TO TOLLED HIGHWAY TRAFFIC STUDIES



- **Network:** The trip matrix is then loaded on to a computerized representation of the transport network. Each road link in the network is coded according to its speed, capacity, length, and speed-flow relationships (which recognizes that speed deteriorates when highway capacity is approached).
- **Behavioral parameters:** With the trip matrix loaded onto the network, the model then calculates the economic utility of each trip using the highway network in terms of total travel cost or time via each route. It does this by applying key parameters (such as vehicle operating costs and value of time) to create a single, common representation of travel cost or time (often referred to as generalized cost).

Traffic is then generally assigned to the least cost route through an iterative procedure, taking into consideration the rest of the traffic on the highway network. The Travel Demand Model is calibrated[5] to the existing traffic conditions and validated[6] using supplementary traffic survey data to demonstrate its suitability to be used to predict the demand for new highway infrastructure. Validation criteria are used to demonstrate that the model is "fit for purpose" and adequately represents the existing traffic situation.

Traffic Capture

An additional forecasting step is then introduced, unique to tolled highway forecasting: the assessment of drivers' willingness to pay a toll for the benefits offered by a new highway compared to the alternative routes available. This essential step brings with it additional unknowns regarding the decision of future drivers to pay a toll to enjoy the benefits offered by the new highway, and the accuracy of the model to accurately forecast those benefits. This step is generally believed to introduce the most significant risk to the accurate production of traffic and revenue forecasts for tolled highways and may explain why forecasts for tolled highways have been poorer than for un-tolled highways.[7]

Travel Demand Models attempt to simulate human behavior with a monetized (or time-based) representation of behavioral parameters that affect route choice, including Value of Time and Motorway Bonus and Vehicle Operating Costs. The 'generalized' cost (or time) is then calculated for each trip represented in the model. A simplified calculation of the generalized cost of a trip made on a tolled highway is provided below:

Generalized cost = (travel time x value of time) + (distance x vehicle operating costs) + toll Tariff – Motorway Bonus

Elements of the generalized cost equation which are difficult to estimate accurately include the highway users' value of time and the motorway bonus. Often these two parameters are combined together to create a "willingness to pay" parameter. This includes the monetization of the time savings and the value that highway users place on the superior design, safety, comfort, convenience, and journey time reliability offered by the new highway.

The allocation (or "capture") of traffic between a tolled highway and non-tolled alternatives is based on a comparison of generalized cost for each route option available to all trip movements represented in the trip matrices. These generalized cost comparisons can either be undertaken within the Travel Demand Model itself or externally in a supplementary model using a logit type capture model or diversion models, which calculate the tendency to use a tolled highway based on the relative generalized cost or time difference between the highway and non-tolled alternatives[8].

Future Year Forecasts

The accurate prediction of the growth of future trip movements, in terms of their volume, trip patterns, and route choices, is possibly the second most difficult element of traffic forecasting after the prediction of the initial capture of traffic by the tolled highway.

Future demand for the tolled highway is derived from forecasting the drivers of traffic growth, such as future economic, employment, and population growth, car ownership growth, and fuel prices. By analyzing the relationship between these drivers and historic traffic growth, it is often possible to establish a mathematically significant statistical relationship that can be used to forecast future traffic. A statistically significant historical relationship may inform future growth patterns but it should not necessarily be assumed that the relationship is transferable to long term forecasting[9]. Long term traffic growth predictions are generally assumed to decline over time due to increasing uncertainty surrounding the forecasts and the ability of historical relationships to inform long term forecasts.

The impact of any planned improvements to the existing highway network (in addition to the project under consideration) and other transport modes should also be included in the future year forecasts. Typically, a range of "scenario" traffic forecasts are produced based on sets of pessimistic (Low Case), best-estimate (Base Case), and optimistic (High Case) forecasting assumptions. Sensitivity tests undertaken on the key drivers of demand, often accompanied by a risk analysis, inform the range of output forecasts and indicate the key parameters around which forecasting errors will impact the accuracy of the forecasts the most severely.

SUMMARY

Traffic risk is present in all highway PPPs. Traffic risk results from the nature of traffic forecasting, which is prone to the triple problem of forecasting error, uncertainty about the future, and biases.

An important first step toward increasing awareness of traffic risk is an understanding of how traffic forecasts for tolled highways are developed, and how forecast complexity will vary with the type of project. All traffic forecasts are based on assumptions, and it is critical for all parties to understand these assumptions and how they may affect the forecasts. Traffic capture by the tolled highway is determined by a combination of time savings, vehicle operating cost savings, and how drivers value features such as superior highway design, comfort, safety, convenience, and reliability of the tolled road.

The accurate estimation of the initial traffic capture by a new toll highway is considered the most significant risk in traffic forecasting. The second most significant risk is believed to be the prediction of future traffic growth. A range of forecasts based on pessimistic, best-estimate, and optimistic forecasting assumptions should be provided, along with sensitivity tests, to indicate the key forecasting parameters around which forecasting errors will impact the accuracy of the traffic.

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1 Bain, Robert. "Error and optimism bias in toll road traffic forecasts." Transportation 36.5 (2009): 469-482.

2 Bain, Robert, and Lidia Polakovic. "Traffic forecasting risk study update 2005: through ramp-up and beyond." Standard & Poor's, London (2005).

3 Flyvbjerg, Bent, Mette K. Skamris Holm, and Søren L. Buhl. "How (in)accurate are demand forecasts in public works projects?: The case of transportation." Journal of the American Planning Association 71.2 (2005): 131-146.

4 For a detailed discussion on optimism bias, please see *Toll Road PPPs: Identifying, Mitigating and Managing Risk* (PPIAF 2016)

5 Calibration seeks to replicate observed traffic data by adjusting the highway network, trip matrices, and/or behavioral parameters.

6 Validation requires the comparison of the model outputs with an independent set of traffic data such as traffic counts, origin-destination data and travel time surveys, and making logic checks.

7 Flyvbjerg B, Holm M and Buhl S (2005), How (In)accurate are Demand Forecasts in Public Works Projects? Journal of American Planning Association, Volume 71, No.2, Spring 2005, American Planning Association, Chicago, IL.

8 "Discrete Choice Methods with Simulation," Kenneth Train, University of California, Berkeley, National Economic Research Associates, 2002.

9 *Toll Road Traffic & Revenue Forecasts*, An Interpreter's Guide, R. Bain, 2009