TOLL ROAD TRAFFIC FORECASTS:

THEIR FAILURES AND HOW TO FIX THEM

by

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Investment in transportation related infrastructure can create unparalleled benefits across large geographic regions, or it can burden governments and private investors with crippling debt and sub-standard infrastructure. Massive investment into these risky projects is pervasive across the world. In Algeria, the government announced that they planned to invest almost 55 billion US dollars in developing road and motorway infrastructure from 2015-2019. (World Highways, 2014). In Spain, the government is facing a new budget crisis with billions of dollars in bailout money going to companies who borrowed to finance and build massive toll road projects during a period of economic boom. In Canada, total transportation spending for the federal, provincial and territorial governments totalled $19 billion in the 2011-2012 fiscal year. [1] (Transport Canada, 2012, p. 3). Referring to these types of investments as risky is not meant to present them as poor decisions; instead, it is simply meant to illustrate the considerable amount of uncertainty that generally surrounds the outcomes of such projects. Every year, governments devote significant resources to maintaining, upgrading and constructing new transportation infrastructure. Such investment impacts everyone from contractors working on projects, to businesses whose success or failure can depend on the presence of quality motorways, to road users themselves. Transportation investment is a high stakes game financially and the impact it creates can drastically transform entire geographic markets. In addition, road congestion regularly tops opinion polls as an important political issue in communities across North America. Automobile congestion results in wasted fuel, higher carbon emissions, an increased likelihood of accidents, and an increasing number of psychological impacts stemming from missed meetings, late deliveries, less time with families, and other social consequences of longer travel times. (Kutz, 2004) As

[1] Of this $19 billion, federal government spending accounted for $2.8 billion of which 35 per cent was spent on highways, roads and bridges. Of the more than $16 billion spent by the provinces and territories, 78 per cent was directed at highways and roads.

such, it is critically important to provide decision makers and those in control of actually carrying out such infrastructure projects with detailed, accurate information and forecasts regarding all aspects of transportation related projects.

The practice of forecasting future traffic patterns across tolled highway networks spans a number of disciplines. Engineers do extensive analysis of future traffic volumes and trip distribution. Essentially, they are looking at how many people will be driving, where they will be coming and going to and from, and what routes they will take to get there. Their analysis is often similar to that of an economist; in particular with respect to building and choosing the traffic models that lay the foundation for any traffic forecasting or analysis. This paper will focus specifically on the forecasting of transportation networks that involve either the introduction of, or existence of a tolled route. Tolls in traffic forecasts add a new source of uncertainty that can affect the forecasts in many different ways. At a basic level, tolls add additional complexity to both the demand side (road users) and supply side (concessionaires, governments, financiers etc.) of transportation networks. For road users, the toll adds more uncertainty into their route choice decisions. Even in situations where a toll is long established and road users have fully integrated it into their preferences, the toll can still produce unpredictable reactions and decisions, many of which will be outlined later in this paper. On the supply side, private investment generally depends on cost recovery through toll collection (Lemp, 2009) and the uncertainty created by tying cost recovery to future traffic volumes places an even higher burden on the traffic forecaster. Fortunately economists are well equipped with tools to address and in some cases mitigate this uncertainty; although, as this paper will explain, they have not necessarily done a particularly good job of it in the past. The economist's perspective at its most basic level is about asking whether or not the introduction of a toll will create or destroy surplus across new and existing road users. It also focuses on how the benefits of the road itself and the toll revenues are dispersed among road users, tax payers, governments, and private concessionaires. A somewhat parsimonious description might be to say that economists take the engineer's predictions and forecasts and then explain that analysis from a creditor's perspective. Conversely, a creditor or a financier will generally focus strictly on financial outcomes and ignore the economic outcomes involving opportunity cost and social externalities. This paper will assess the causes of risk and uncertainty relating specifically to forecasting future traffic volumes on toll roads and subsequently, how such uncertainty influences both financial and economic outcomes. This is not the same as looking at project specific risks as if we were potential financiers or engineers, although many of the sources of risk will be the same. The focus of this paper will be instead placed on the forecasting results themselves. In simpler terms, it will examine why there is such potential for variability in the actual forecasts and why they are so often wrong.

In order to fully understand why the sources of risk and uncertainty are as abundant and as significant as they are, we must first understand the basic framework for forecasting traffic demand on toll road projects. Section 1 will outline this general framework drawing largely from best practices and standards across the discipline. Effectively, it will provide an overview of the process that both economists and engineers use in order to construct toll project forecasts. Section 2 will continue to build upon this survey of the literature by establishing and discussing a list of common risk factors (the "Risk Factors") associated with traffic demand forecasting, specifically related to toll roads. After providing a thorough explanation and literature review of traffic demand forecasting and risk assessment, this paper will then apply that knowledge to a specific toll project, "Project A". This paper will not provide a full cost-benefit assessment of the project, nor will it be concerned with assessing the forecasted results. Instead, it will briefly outline the basic parameters and environment surrounding the project and then utilize the forecast to illustrate the behaviour of the Risk Factors discussed in Section 2. Section 3 will provide this summary of the project and outline a basic methodology for analyzing each Risk Factor. This will allow us to more distinctly understand exactly how the forecasting process is affected by the Risk Factors. Section 4 will present results alongside more detailed explanations of the methodology used for each of the Risk Factors separately. This will allow us to determine the significance, relevance and suitability of the various sources of risk in relation to Project A as well as with respect to toll forecasting more generally. Subsequently, Section 5 will rely on the results of Section 4 as well as the best practices outlined in Section 1 to provide some general discussion and recommendations for traffic forecasting with respect to toll roads. These recommendations will include both ex-ante and ex-post recommendations with the former focusing more on inventive toll structures designed to alleviate risk, and the latter focusing primarily upon the actual forecasting techniques themselves. Finally, in order to supplement these recommendations, Section 6 will outline a specific post-modelling procedure for reducing forecast inaccuracy and explain how it relates to the previously discussed techniques.

1. Traffic Forecasting: Discussing the Details

The World Bank separates the traffic volume forecasting process into three stages. First, the planning stage is where feasibility studies and the selection of the road design takes place. The construction stage follows, and it is during this stage that decisions on toll price levels and the length of the collection period take place. Finally, during the operational stage, toll prices and toll collection periods are often revised and adjusted according to observed traffic volumes as drivers begin to use the road. It is in the construction and operational stage that traffic related projects are exposed to risk. Therefore, these are the stages that an engineer or financial analyst would likely focus on when doing pre-feasibility studies.[2] In the construction phase risks include obtaining site plans, permits and licences, price risk of raw materials, and environmental risks. (Bain, 2009b, p. 4; Phillips, 2008). During the

[2] Pre-construction risks in the planning stage such as the opportunity cost of feasibility studies are generally treated as negligible.

operational phase, risk includes the development of competing routes or modes of transportation. Such development can create significant uncertainty, especially in areas where drivers have high values of time. For example, alternative roads could be paved or improved, or a rail system could be developed that could act as an alternative to a toll road. There are also many different tolling systems, structures and technologies all of which create different challenges for both operators and forecasters.

Robert Bain is a traffic forecasting expert and civil engineer who has done extensive work on examining the risks associated with traffic procedures. His work in conjunction with Standard and Poor's ("S&P") will be used as the foundation for the Risk Factors outlined in Section 2. Bain emphasizes that the most important factor that differentiates toll road projects from some other infrastructure based Public Private Partnerships ("PPPs") is that they expose financiers to demand risk.[3] (2009b). By demand risk, he is referring to potential variability of actual traffic volume on the tolled route. For the purpose of this paper demand risk will refer specifically to this variability in traffic volume, where demanders (drivers) make decisions based on a wide variety of factors that affect driving time and costs of different routes. Some simple examples of these decision factors include, the length of the route, anticipated congestion, route quality (such as whether the road is dirt, gravel or paved), and a wide-variety of behavioural responses to toll payment. Governments shift much of this risk to private investors when they enter into PPPs. In addition, it has been argued that PPP projects result in more efficient design, implementation and management of infrastructure related projects. A study of public projects around the world showed that public road projects overrun in terms of costs by an average of 20.4 per cent. (Canadian Chamber of Commerce, 2013, p. 20)

[3] Although demand risk is a prominent factor in the risk analysis of toll road projects, such risk is limited strictly to toll infrastructure alone. For example, government concessions involving airport management and development or the running of urban water supplies also expose the concessionaires to demand risk. Such examples are not lost on Bain, who references trams as another such example.

In order to properly assess a toll road project and mitigate risk, it is important to establish who will be driving on the newly developed roads early on in the process. The standard distinction in most project evaluations is to establish levels of reassigned or diverted traffic, as well as induced traffic volume and developed traffic volume. The majority of traffic that ends up using a new toll road is traffic that has been reassigned from other possible routes, especially if the project is a new route rather than a route improvement or modification. Induced traffic on the other hand refers to traffic that is brought about by improved service on the new road and developed traffic refers to traffic that is produced as a result of the economic development created along the route. (MOCJ – EXTEC, 2000, p. 1-11) Bain goes one step further and makes a more explicit distinction in defining traffic redistribution by also referring to drivers that change their actual destinations based on the introduction of a new road. For example, if diverted traffic refers to drivers using the new route to get from point A to point B then redistributed traffic would refer to the traffic that, instead of travelling from A to B, now travel from A to C as a result of the new road.

Despite the dizzying amount of choice forecasters have in setting up their traffic models, there are some standard practices and methods that are generally used. In terms of the early modelling stages, a four stage method for traffic forecasting is generally used. This standard procedure is common across the literature and each of the four stages is listed below under Robert Bain's common but unofficial titles: 1) Trip generation; 2) Trip distribution; 3) Mode choice; and 4) Trip assignment. Each of the four stages is discussed in more detail below.

1.1. Trip Generation

Trip generation refers to predicting the number of trips that originate or are destined for a particular traffic zone within the overall network. If a study is focusing on one particular city it would divide the city into zones or regions. Trips are then said to be generated and attracted. Trip generation is based on things like the number of residences in a particular area, as well as socioeconomic factors specific to the region where as trip attraction generally refers to commercial or non-residential land uses that exist within given zones. The way in which trip generation is modelled and estimated is extremely important to any resulting forecasts and there is an extensive catalogue of techniques, variables, and predictive factors used to add detail and depth to these models. There are also several standard publications that provide data on actual geographical zones with land use descriptions and trip generation rates that can be essentially plugged into a traffic modeller's study. That being said, there is no evidence to suggest that greater modelling detail will systematically improve predictive accuracy. (Bain, 2009b)

1.2. Trip distribution

Trip distribution refers to the process of matching trip origins with destinations. In other words, where are people coming from, and where are they going? This portion of the model is often developed using a matrix of possible trip origins and destinations. The process generally focuses on a specific area and makes the logical assumption that most trips occurring within the specific region are contained within a relatively small local area. Essentially the process bases itself upon the fact that the majority of people driving within a given area will not be coming from somewhere a great distance away, or going somewhere far away. The second key aspect of trip distribution is the gravitational aspect which says that within a given area there will be certain areas of high population concentration or high business/workplace concentration where trips tend to gravitate towards. This aspect helps predict congestion in various areas and is also useful when examining the effects of infrastructure development and population growth in specific areas. Table 1 illustrates a typical generic trip distribution table where origins and destinations are matched along rows and columns.

A computerized predictive process then utilizes the factors discussed above to attempt to replicate the actual distribution of road users within a specified traffic network. The construction of this matrix is integral to the fourth stage of the traffic modelling process.

Figure 1 – A Basic Trip Distribution Table

Origin/Destination	1	2	3	…	Z
1	T_{11}	T_{12}	T_{13}		T_{1Z}
2	T_{21}				
3	T_{31}				
⋮					
Z	TZ1				TZZ

1.3. Mode choice

Mode choice or modal split refers to which particular modes of transportation are used to make the trips generated in the first two stages. Typically modal split projections are based on a combination of knowledge of local infrastructure, local survey data and general predictions based on similar projects. Specifically household travel surveys, which can offer much of the data necessary for empirically based model predictions, provide: "(i) household and person-level socio-economic data (typically including income and the number of household members, workers, and cars); (ii) activity-travel data (typically including for each activity performed over a 24 [hour] period activity type, location, start time, duration, and, if travel was involved, mode, departure time, and arrival time; and (iii)household vehicle data. This survey data is utilized to validate the representa-tiveness [sic] of the sample, to develop and estimate trip generation, trip distribution, and mode choice models, and to conduct time-in-motion studies." (McNally, 2008).

When looking at the modal split of a toll road project, forecasters might predict that traffic would be made up of 20% commercial trucks and 80% private motor vehicles. They might also include a percentage of public transportation, or include more detailed information in terms of vehicle types. This is obviously hugely dependent on where the specific route is. Within cities, non-motorized transportation such as cyclists and walkers would likely also be included in the analysis. That said, most toll projects, especially highway projects, do not need to factor non-motorized transport in as it is not likely practical for the toll facility nor practical as a substitute on competing routes. Public transport is also less likely to play a significant role on routes competing with a tolled route. Instead a forecaster may separate private motor vehicles to include some representation of car-pooling. This is especially important when the introduction of a toll may actually induce road users to carpool when they otherwise would not have in the absence of the toll. In addition, competing modes of transportation such as trains, coach buses and planes may enter the analysis on longer routes. (Bain, 2009b). Mode choice is important to forecasters both in terms of examining competing routes and modes, and in terms of revenue forecasting when toll schedules vary based on vehicles.

1.4. Trip Assignment

Trip assignment is the final stage in the four step process and it refers to the actual routes that are taken by road users for each trip. Traffic is assigned to roads and streets using mathematical formulas that take into account expected travel times for specific routes, traffic volumes, road capacity, and the origins, destinations and mode choices determined earlier. Trip assignment can be seen as both the most important step, because it is the step that tells you what will actually happen within your transportation network, and the most fickle step in traffic estimation, because mathematical modelling can be adjusted in countless ways to drastically change the results of this step. Further, as networks become more complex and traffic volumes become higher, mathematical results become less likely to reflect reality. The simplest models look at minimizing travel time by assigning all traffic to the shortest route. More realistic models factor in congestion as routes in a network near their capacities. Most trip assessment procedures also involve some form of simulation where routes are given scores. The lowest travel times are given the best scores and the highest travel times are given the worst scores. Drivers in the simulation are assumed to choose the route between their origin and destination with the best score. Higher travel times are generally treated like a cost so that other factors such as road quality and tolls can be simply added as increased costs of a particular route. The process is usually iterative in such a way that as congestion builds, routes are downgraded (given a lower score) and road users adjust their route choices accordingly. Eventually, the network reaches equilibrium where a road user can no longer improve his/her "score" by switching routes.

Critiquing the four stage trip assignment procedure is far beyond the scope of this paper. The brief outline provided above is simply meant to shed light on the procedure and to provide a base level understanding of the complex processes that produce the outputs of traffic forecasts while also providing the tools to discuss the specific elements Project A's forecast in later sections. .

1.5. Introduction of a Toll

In a toll road structure users are charged a per unit (trip) fee for a specific good (permission to use a specific route). Economically speaking, the toll acts in a very similar manner to an excise tax, such as a fuel tax where fuel taxes are added to the total price of fuel and then collected and redistributed by government. Tolls function similarly as the producers of the road (whether it is the government or a private company) essentially pay the costs in the initial investment and construction stages and then pass this “tax” on to road users during the concessionary period. From a user’s perspective both “taxes” are very similar in that the user is paying a “tax” on a good that he or she will be using directly; in this case on either fuel and or a specific route. Therefore, according to a simple supply and demand analysis, a toll will have a similar effect on a user as a fuel tax would.

An important question that must be asked is whether or not a toll is more efficient than a simple fuel tax. As it turns out, there are a variety of reasons why user specific tolls might be preferred to fuel taxes. First of all it is important to note that excise taxes themselves can be inherently more efficient than a general sales tax since they are applied specifically to the per unit usage of the product being taxed. Further, when excise taxes are introduced on products that create negative externalities such as pollution, or in the case of roads, traffic, the tax can cause a reduction in harmful consumption and or production and therefore result in a net welfare gain if the reduction is large enough. Also, because excise taxes apply to more specific products or markets and are often of a higher magnitude than general sales taxes they can also create stronger incentives for users to decrease their actual consumption of the taxed good. In the case of driving this would imply decreases in negative environmental externalities and congestion. Sales taxes, on the other hand, generally have a much larger base, and while this allows them to be lower in magnitude and thus often more popular politically, they create inefficiency by taxing a general basket of goods equally. Tolls take the specificity of an excise tax a step further by allowing more flexibility in applying the additional “tax” to individual roads, as well as individual users differently. When tolls are used to specifically eliminate congestion on a route then the tax both generates revenue while also possibly increasing net social welfare as the tolled route no longer experiences heavy traffic. The road users left on the tolled route are the ones who value it most highly while others are induced to spread out across other avenues of the transportation network, to choose other means of transportation such as public transportation or carpooling, or to shift their trips to different times of day. This is not to say that tolls are always more efficient than general gasoline taxes. In some cases the drop in demand resulting from the introduction of a toll may be too severe and in situations where a road does not experience high traffic volumes the positive welfare effects of the toll are less likely to be realized.

User-specific efficiency savings

One of the most important ways in which a toll may act more efficiently than a gasoline tax is through its ability to discriminate between actual users. The relationship between traffic and toll revenue has been complicated significantly by the introduction of Electronic Toll Collection (ETC) technologies which differentiate tolls by vehicle class, direction of travel and by time of day. (Bain, 2009b, p. 30) And while these developments have added complexity to the forecasting process, they also allow for even more efficient distribution of the toll burden across road users. If we temporarily assume a toll is introduced only to finance road maintenance costs then a toll can be tailored so as to charge the users who cause the most damage to the road the highest fee. In practice, this means heavy trucks incur the highest costs for highway road maintenance. “According to data from the American Association of State Highway and Transportation Officials (AASHTO), an 80,000 pound, five-axle truck causes as much pavement damage, on average, as nearly 10,000 passenger cars.” (Ankner, 2002). Thus, a toll can be proportionally set to charge users based on the specific vehicle’s weight. In the case of Project A, vehicles are broken into four classes based on weight and number of axels. Newer tolling technologies such as the dynamic tolling allow for even more divisions and even more efficiency. In addition, a gasoline tax can actually be disproportional in this regard since most heavy trucks use diesel engines which have historically had notably cheaper fuel economy than non-diesel cars, although heavy diesel trucks will still likely burn a great deal more fuel than a car or relatively lighter truck. Heavy trucks often also have a less elastic demand curve since the value of time savings is so much higher to them. Again, these factors do not necessarily imply that tolls as a tax are necessarily more efficient in terms of overall social welfare; however, the flexibility they provide in terms of differentiating between their user base is extremely appealing.

Road-specific efficiency savings

Highway tolls are also flexible in their ability to price differentiate between different roads, and different times of day. Introducing a toll on a heavily used valuable road can be used to create a relative price for specific routes in order to eliminate congestion. Again, dynamic tolling that changes based on the amount of congestion on a given road at any given time is the most advanced form of this price discrimination and is the most efficient way of creating these prices (assuming any confusion or uncertainty costs introduced by such a pricing schedule is negligible). This type of dynamic price discrimination isn't possible with a fuel tax. If a fuel tax changed too dynamically by region or by time of day drivers could simply choose to fill up their cars in different regions or at different times of day – e.g. during the lower priced periods. Therefore there are certainly some efficiency gains in using tolls simply from the flexibility that cannot be transferred to a fuel tax.

There are many other complex elements to traffic forecasting and many of the individual elements discussed above have been the subject of extensive academic analysis and debate. Introducing tolls to the forecasting process introduces even more uncertainty and new technologies and methods continually complicate the process. The discussion above should provide a basic enough understanding of traffic forecasting to discuss some of these more complex elements. A more in depth understanding should also be developed through the risk and uncertainty related discussion and analysis that follows.

2. Risk Factors

As was discussed above, the intention of this paper is to examine why toll traffic forecasts are so often wrong. In truth, it is not the simple fact that the estimated results differ from the actual observed outcomes that creates such massive problems for toll projects. These forecasting failures have become such a large issue because there seems to be a fundamental lack of understanding surrounding what factors are driving the forecasting error. If analysts understand the potential sources of error within their forecast, they can prepare for a wider variety of results and make better decisions that can withstand outcomes that differ widely from initial base case predictions. Based on its research into toll road forecasts and results, S&P and Robert Bain compiled a list of common sources of predictive error. Brief explanations of the listed factors are provided below. A subgroup of this list will then be used as the Risk Factors in the analysis sections to examine exactly how they manifest themselves in an actual forecast and what specific implications this has for the project itself. The analysis will also attempt to roughly quantify the effect of the Risk Factors on the forecasting results. Obviously any numerical results will be tied inherently to the data of Project A itself; however, since the analysis focuses on the degree of error resulting in the forecast itself, not the project outcomes, it can provide valuable insights into each variable independent of specific numerical results.

S&P's list of common sources of predictive error contains several items that can have significant impacts on forecasted outcomes. They are: high toll tariffs, time savings less than anticipated, improvement of competitive (toll-free) routes, less usage by trucks, underestimation of ramp up, miscalculation of value(s) of travel time savings, long-term forecasts sensitivity to GDP assumptions, less off-peak or weekend traffic, future land use scenarios or economic performance that did not transpire, and complexity of the toll tariff schedule. (as cited in Bain, 2009b, p.40-45). For the purposes of the methodology in Section 4, only the first seven of these sources of error will be extensively analyzed. Reasons for omitting the remaining three sources of error are discussed below.

The forecast for Project A does not factor in peak and off-peak traffic periods, or differentiate between different times of day or of the week. As was discussed earlier in Section 1, some traffic models attempt to replicate the peaks and valleys of traffic patterns and route choices. The relatively high value of time savings during congested peak periods can often disappear significantly during off-peak stages. The forecasting of peak periods is particularly important for concessionaires as peak periods are typically responsible for about 70 per cent of toll revenue. (Smith, Bain & Kanowski, 2011, p. 28). As such, errors in explaining the individual characteristics and connections between peak and off-peak periods can result in considerable miscalculations. Nevertheless, there are many reasons why a forecaster may choose not to model peak and off-peak periods, the most basic being the fact that if the right data is not available, then blindly trying to make the model more complex will likely add inaccuracy to the forecast. The fact that Project A doesn't include such complexity in its forecast means it cannot be analyzed as a risk factor; however, it does not necessarily mean the forecast is less accurate.

Assessing the degree of risk associated with future land use scenarios and/or economic performance in relation to specific data from Project A cannot yield any meaningful results either in this analysis. Assumptions about future land use can have significant impacts on the traffic modelling process, especially on routes created to access new or planned developments. Nevertheless, they do not directly enter the forecast except in the initial planning stage. As an almost foundational input, they can prominently influence the eventual outcomes; however, they are not easily manipulated within the forecast itself. It is important for forecasters to recognize the inherent risk associated with such assumptions about the future, and not rely entirely on purely speculative developments. Bain suggests omitting such speculative development from base case traffic forecasts. (2009b, p.72). Even though this risk factor will not be modelled explicitly, the way in which it can impact forecast results will be similar to the development of competitive toll free routes, a risk factor that will be analyzed in Section 4.

In terms of toll complexity, toll schedules are often integrally related to the peak/off-peak forecasts discussed above and, although there are still many toll roads that operate under a flat fee schedule, it is becoming more and more common for tolls to vary based on time of day, type of vehicle, direction of travel, season, and even based on the current level of traffic already on the road. Dynamic tolling and diverse payment options can be an effective way for toll operators to extract extra surplus from road users. Nevertheless, these elements also add much more complexity to the forecasting process. By moving away from a parsimonious solution and attempting to model a dynamic toll schedule with diverse user preferences, the forecast itself becomes much more sensitive to exactly how the forecaster projects these elements. Effectively, more things are being modeled and there are more opportunities to introduce errors into the projections. Nevertheless, the analysis being conducted through Project A does not model complex behavioural responses by individuals or a complex toll schedule and thus this element will not be examined as a risk factor.

There are of course many other sources of error in addition to those listed above that can result in incorrect forecasts of toll road projects. For example, the general four step modelling process outlined in Section 1 can be structured in many different ways. Trip generation, distribution, modal split, and traffic assignment can all be modelled in a number of different ways and choosing the appropriate models obviously has a huge effect on the outcomes of any traffic forecast. However, this section focuses primarily on assessing specific sources of error within a given forecasting model. In other words, it will examine the manifestation of forecasting errors within a general model and consequently, the discussion could likely apply to any form of over-arching model. This is done with the purpose of generating discussion and recommendations that can be applied to a wide variety of projects.

Brief explanations of the seven items taken from the S& P's assessment are outlined below, while also introducing possible reasons for their effects on toll road traffic forecasts. The explanations rely heavily on Robert Bain's assessments (2009b), along with many others.

2.1. High Toll Tariffs

High toll tariffs simply refers to toll rates that are set at a per kilometre level above the level that would usually be observed. Such high toll rates are often set where suitable alternative routes are not readily available (MOCJ – EXTEC, 2000, p. 2-10) or when the toll operator is attempting to recover significant capital costs associated with the project's construction. (Bain, 2009b, 40). The difficulty this introduces to forecasting is that predicting a road user's response to the higher toll is more difficult. As has been discussed earlier, when a toll is introduced to a road in a traffic forecast it can be treated as an extra cost of following a particular route for a given user. The problem is that the exact nature of an individual's demand response curve is very difficult to determine. When tolls are set similar to an average there is some data to base a prediction of consumer response upon. As a toll tariff is set higher, the predictive data is less available and consumer responses become more difficult to accurately forecast.

2.2. Time Savings Less than Anticipated

Time savings can be calculated in many different ways and the choice of method itself is not necessarily where the forecasting errors emerge. Issues surrounding time savings stem from forecasters not fully understanding exactly how drivers will view time saving benefits. For drivers taking shorter trips the expected time saving benefits may not be fully taken into account by the users. Also, if there are delays connecting to, or exiting the toll road, drivers may not fully realize the expected time saving benefits. Forecasters need to ensure that time saving benefit calculations contain all information in order to avoid the common errors surrounding these calculations.

2.3. Improvement of Competitive (Toll-free) Routes

Whether or not this source of forecasting error actually becomes relevant is largely associated with who ends up operating the toll upon completion of the project and whether or not there are any agreements protecting the tolled facility from competition. In the case of the former, if the company building the road will not be acting as the concessionaire, then they do not face any risk associated with the improvement of toll-free routes and therefore would not be concerned with these potential developments – although the operator of the toll certainly would. If they do operate the tolling facility after completion of the project, then they will need to factor this into their forecasts as an improved competitive route will divert traffic and revenue away from the tolled route. Many tolling contracts include some form of legal provision discussing the development of competitive routes and some will offer compensation to the concessionaire if competing routes are introduced or improved. California in particular has provided guarantees in contracts that it will not build competing roads during a toll road's concession period. (MOCJ – EXTEC, 2000, p. 2-15). On the other hand, some countries specifically require that in order for a toll road to be allowed, an alternative toll-free road must be available to road users. Regardless of the contract structure, the concessionaire must be aware of the potential for competition from alternative routes and this can be a difficult thing to accurately forecast. The S&P report emphasizes it as a significant source of forecasting error and risk since it "can lead to material cash flow impairment over which the concessionaire has little or no control." (as cited in Bain, 2009b, p. 41).

2.4. Less Usage by Trucks

This is another straightforward source of forecasting error. Trucks generally provide toll concessionaires with a significant portion of their revenue from toll collection. According to the S&P report, a truck-revenue to traffic ratio of three to one is not uncommon. This is to say that if trucks make up 10% of the total traffic on a given toll route they would contribute up to 30% of total revenue. (Bain, 2005). In addition, truck forecasts are not always reliable. Although truck drivers traditionally take time savings and operating costs into account more reliably then other drivers, they also weigh other factors such as the availability of road-side services and trucks stops when choosing routes. In addition truck drivers tend to avoid toll roads as a form of protest, at least for a period of time after they first open. (Bain, 2009b, p. 42). The combination of high revenue percentages and poor forecasting accuracy means that overestimating the usage by trucks can result in significant overestimation of toll revenues.

2.5. Underestimation of Ramp up

Ramp up refers to a period of lower traffic following the introduction of a toll facility where road users have not completely developed their preferences surrounding the new facility. As the name suggests, it is characterized by a period of low usage followed by a steady increase until the road is fully integrated into the travel preferences of road users at some higher and more stable level. The length and progression of this ramp up period is exceptionally important to the concessionaire as a slow ramp up can result in vastly decreased revenues during this period.

Bain suggests conducting rigorous sensitivity tests to assess the resilience of the financial model to alternative ramp up assumptions (2009b, p. 43); however, any assessment of exactly how the ramp up period will develop is going to be highly variable and will be a significant source of potential error in any forecast.

2.6. Miscalculation of the Value of Travel Time Savings

Assessing relative time savings benefits is an integral piece of any traffic forecast. In many countries governments actually publish basic time saving benefits for different types of vehicles and for weekdays, weekends, and holidays. (MOCJ – EXTEC, 2000, p. 5-7). Values for a specific toll road can be increased if that road leads to say an airport or some other destination where the cost of slower or lower quality routes is higher. If the forecaster simply takes these time value numbers to be correct, the Value of Time ("VOT") saved becomes an easy calculation. Nevertheless, treating this as an aggregate one size fits all number is far from ideal. Individuals have different values of time saving amongst each other, but they will also have different values within their own set of trips depending on where they are going and when they are going there. Another way a forecaster might adopt oversimplified and inaccurate time valuation inputs, would be through the assumption that the value individuals place on their time when commuting is equal to their wage rate when working. Using wage rates as a direct proxy for time all time valuation is certainly problematic, but determining the correct valuation can be just as problematic. When empirically informed local statistics are not readily available this choice can become a significant driving force in producing forecasting error. As a general rule, people generally value their time less than their wage rate and as such the VOT is usually expressed as a percentage of the wage rate. Generally accepted VOT percentages will be discussed in more detail later; however, it is important to remember the wide variety of attributes that can cause this variable to differ widely amongst individuals, potentially resulting in significant forecasting error.

2.7. Sensitivity of Long-term Forecasts to GDP Assumptions

The sensitivity of a forecast to long time horizons is technically true for any variable that describes growth over time. Nevertheless, GDP is a particularly powerful variable in traffic forecasts and as such, over a long time horizon can result in drastically different outcomes if it is estimated even slightly incorrectly. GDP projections can enter the forecast through a number of ways, including predicting general traffic growth, predicting the income levels used to calculate drivers' value of travel time, predicting the growth of competitive alternative routes and predicting other developments that may influence traffic levels, user preferences and/or the toll tariff rate set by concessionaires.

3. Application

Having outlined the general traffic forecasting process and subsequently discussed how some specific risks can enter a forecast, the following sections will further explore these risks through the use of scenario and sensitivity analysis on Project A. Examining these elements within the framework of an actual project will illustrate specific ways in which these factors affect the outcomes. In addition, a comparison of financial and economic effects will provide some insight into which stakeholders should be most concerned about which risk factors. Section 3.1 outlines the basic tools of the methodology which includes providing a brief discussion of Project A and the general forecasted outcomes and results of the project. This will lay the framework from which specific individual results can be discussed in quantitative form. The results are presented in Section 4.

3.1. Methodology

Step 1 – Data Assessment and Identification of Risk Variables

Before assessing any of the specific error drivers discussed above it is necessary to provide some relevant information about Project A, its basic parameters and the predicted outcomes of the initial forecast. In order to maintain confidentiality protection for the project, the names of the country, cities, highways and domestic currency will not be used. In addition, the domestic currency - for the purposes of this analysis referred to as KTK - will be artificially set with a nominal exchange rate of 80 KTK per 1 $US in the first year of the project. This will protect the confidentiality of Project A, while not diminishing the value of the results. Artificially adjusting the actual exchange rate in this way will only change the magnitude of the nominal results without affecting the nature of the results in any other way. This tactic for protecting confidentiality was chosen because the analysis of Project A is simply meant to provide a means for presenting the nature of the overarching forecasting issues that may affect all similar projects. Presenting the results in this somewhat artificial currency does not change the fact that the data is based off a real project facing these same sources of error and therefore, slight deviations in magnitude will not reduce the value of the results.

Project A is a proposed toll project along the M12 highway, a major commercial motorway of Country A connecting the capital city to major centres of economic activity in the North and South. Two major sections of highway will be upgraded, constructed and tolled including a portion that passes through the main city center where a significant amount of commercial and social activities are conducted. The project represents a major improvement over the existing road infrastructure and would help mitigate the major congestion problems currently affecting road users commuting to and from the city during peak hours. The project will also affect the M13, an alternative highway route to the west that can be used to bypass the more congested soon to be improved upon sections, albeit at a higher operating cost due to it being approximately 30% longer in distance. Currently, this alternative route is regularly used by long haul truck drivers whose operating costs can be greatly increased by the additional distance relative to other road users. The effect of Project A on these truck drivers will likely have a significant impact on the overall impact of the project. The project is organized through a PPP where a concession company will upgrade, improve and operate the highway for a period of 30 years during which they have the ability to charge tolls on all road users. The project will take 3 years to construct, which is included as part of the 30 year concession agreement. After the concession period the concessionaire will transfer the ownership rights back to the government.

There are two types of highway users, local users and the long haul users. For the technical construction of the forecast, local users were divided into 3 sub-classes: 1) light vehicles, including all motor vehicles with two axles, among them cars, motor cycles, and all sorts of light delivery vehicles, 2) commercial vehicles including passenger taxis, 9 to 14 seat vehicles with two axles and single tires on the each axle with gross weight not exceeding 3,500 kilograms and 3) buses, 15 to 26 seats with weight of more than 3,500 kilograms. The fourth class is made up of long haul users who have the option of using the alternative long haul route to the M12 road that will be tolled. Class four also consists of large trucks and motor vehicles with five or more axles.

Pre-project traffic levels were forecasted using GDP and income growth and a detailed traffic analysis conducted by the transport department to determine historical unadjusted annual average daily traffic values. Travel costs and the value of time for road users was also estimated during this process and the relative merits of different calculation methods will be discussed in the analysis and recommendations sections. The base toll rate was indexed annually for inflation and set originally at

3.5 KTK/vehicle kilometre for class one and increased by a factor of two for class two, five for class three and seven for class four. The forecast does not include any distinctions between peak and off-peak traffic volumes; nor does it explicitly model any ramp up of traffic volumes in the initial years of operation.

Within this framework of Project A, the Risk Factors discussed in Section 2 will be used to demonstrate how variability in these specific factors affects the Net Present Value ("NPV") results of Project A. The magnitude of the differences between feasible changes in the variables will help illustrate the nature of these sources of error. In addition, it is important to examine exactly how sensitive the results are to small changes in these variables as this will further explain exactly how the variables create greater uncertainty for forecasting results in general.

Step 2 – Sensitivity Analysis

The primary method for assessing how the seven Risk Factors discussed in Section 2 impact Project A will be through sensitivity analysis. This analysis will demonstrate how specific incremental changes in the identified risk variables, or the variables that drive them, affect project outcomes within the given set of assumptions of Project A. Sensitivity analysis will be performed on each of the Risk Factors if feasible, and will be used to demonstrate how they specifically drive errors in the forecasting results. The sensitivity analyses will also compare economic and financial results in order to highlight potential differences in effect sizes and subsequently illustrate when some stakeholders may be more or less affected by the forecasting risk than others. In general, different stakeholders will be interested in forecasts for different reasons and sensitivity analyses can subsequently be designed for whatever base case a stakeholder requires. For example, bankers and financiers will be looking at worst case scenarios to see if there is adequate cash to repay the financing of a project in all circumstances. Meanwhile for general financial and economic analysis, mean values of the various outcomes will generally be used to determine the estimated financial and economic welfare gains. It is worth noting that results that focus on mean values - rather than the more or less lower bound case of a banker or financier's analysis – have far greater potential to underperform their predicted values. That is to say there may be a wider confidence band around those mean based results. The potential for forecasters to calculate and utilize such confidence intervals to better explain uncertain results will be discussed in greater detail in Sections 5 and 6. In some cases, sensitivity analysis will not provide enough flexibility to comprehensively examine how a specific Risk Factor creates error within the forecast or, in other cases, the parameters of Project A will not allow for such analysis. In those cases more extensive scenario analysis will be conducted.

Step 3 – Scenario Analysis

Scenario analysis is primarily used when, in order to properly assess the nature of the risk factor, multiple variables are required to change at once. Scenario analysis is simply another method of identifying the nature of risk variables, and will usually be combined with sensitivity tables to allow for consistent discussion of results. Like the standard sensitivity tests it will attempt to quantify the actual impacts of the risk factors on Project A, and determine which stakeholders are most affected. It is again important to remember that the measured effects will be grounded within the specific case of Project A. Thus, even when outlining more detailed scenarios where more variables are changing the analysis does not provide conclusive confirmations or rejections of the Risk Factors. As before, the scenario analysis of Project A simply demonstrates how, and to what degree, the Risk Factors affect project outcomes in a standard generic forecasting framework.

4. Results

4.1. High Toll Tariffs

In order to analyze the affect high toll tariffs have on the forecasting results it is first important to examine the assumptions surrounding the base toll charge and what variables it affects. In the case of Project A, the base toll rate directly affects the revenue generated by concessionaires as well as indirectly affecting the amount of traffic on the various routes as road users weigh the costs of the toll alongside their values of time, and vehicle operating costs. Sensitivity analysis is conducted in Table 2 below on both the financial and economic NPVs in order to show exactly how changes in the base toll rate affect the project outcomes and how sensitive they are to small changes. The results will attempt to illustrate and explain any differences between financial and economic results and the subsequent consequences they present.

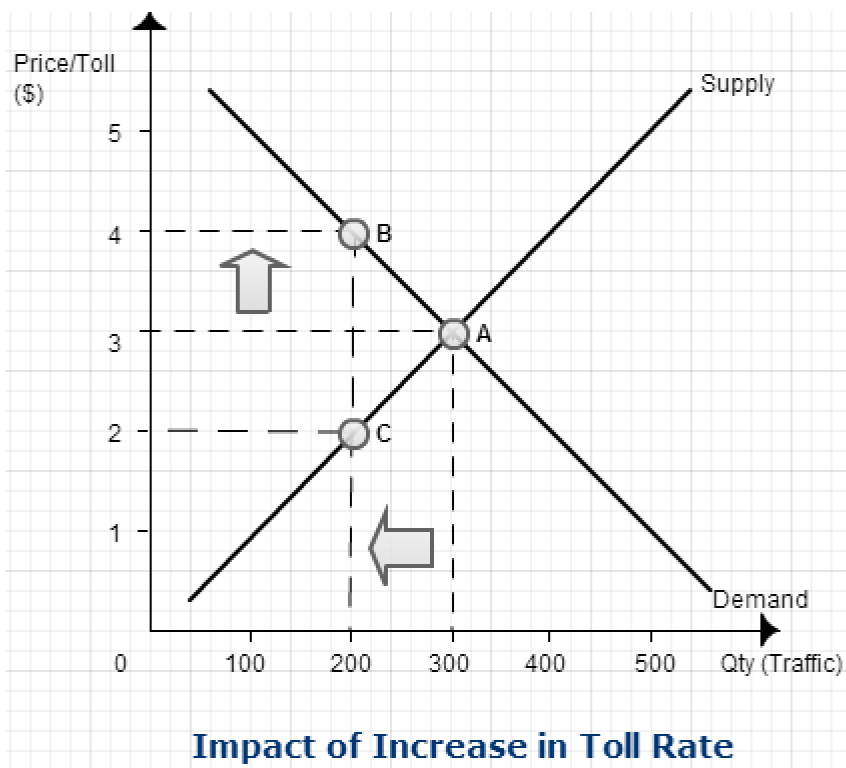
Table 1 - Forecast Sensitivity to Higher than Average Toll Tariff Rates

Percentage Change	Base Toll (KTK)	ENPV (Thousand KTK)	Percentage Change	Base Toll (KTK)	FNPV (Thousand KTK)
100%	7	211,156	100%	7	43,446
90%	6.65	211,433	90%	6.65	40,437
80%	6.3	211,689	80%	6.3	37,416
70%	5.95	211,924	70%	5.95	34,384
60%	5.6	212,137	60%	5.6	31,341
50%	5.25	212,329	50%	5.25	28,286
40%	4.9	212,500	40%	4.9	25,220
30%	4.55	212,650	30%	4.55	22,133
20%	4.2	212,778	20%	4.2	19,025
10%	3.85	213,458	10%	3.85	16,048
0%	3.5	215,507	0%	3.5	13,365

The side by side sensitivity results show several distinct and important differences between financial and economic analyses and the effect toll tariff rates have on their corresponding outcomes. Firstly, the Financial Net Present Value ("FNPV") is increasing in the tariff rate, at least within this reasonable band of rates. The Economic Net Present Value ("ENPV") actually decreases as the toll rate goes up, and when the tariff is set at zero the economic return is actually 229,997,975KTK, almost 15 million KTK higher than the original forecasted ENPV (the "Projected ENPV") .

With respect to the ENPV, it is important to remember that as the toll rate increase, traffic on the route consequently decreases. At this new lower traffic level the demand price is higher than the economic supply price resulting in the destruction of economic welfare. Figure 2 shows an extremely simplistic illustration of this point.

Figure 2 – Basic Welfare Effects of a Toll Increase



As the toll rises from 3 to 4 the quantity demanded subsequently falls from 300 to 200. There is nothing happening to shift the curves and so the price increase results in the situation of point B where 200 road users choose to pay the toll of $4 and the triangle ABC represents lost economic welfare. As the toll continues to rise, this lost surplus will also continue to grow. It is important to note that Figure X is a very basic illustration of this situation and the projected toll is not necessarily set initially at the equilibrium point A.

In addition to the directional differences in NPV effects, the variance of the FNPV is higher than the ENPV as a result of changes to the base tariff rate. This means that the FNPV is more sensitive to changes in the base tariff rate than the ENPV. It is important to note that this greater variance holds true in terms of pure numerical magnitude and as a proportion of the Projected NPV. The ENPV initially drops by 2,728,000KTK after a 20% increase in the base toll; however, each additional 10% increase in the toll decreases the ENPV by less than 300,000KTK – an amount equal to 0.14% of the Projected ENPV. In comparison, the FNPV increases by roughly 3,000,000KTK for every 10% increase in the base toll rate which is 23% of the Projected FNPV.

The S&P reports emphasize the ability of higher toll tariffs to drastically affect forecasting results; however, the results of the two sensitivity analyses show a significant difference between economic and financial results. The financial sensitivity analysis confirms the S&P result for Project A to the extent that the base toll generally represents the toll rate at higher levels. There was not a significant difference between the error created by incremental changes at levels slightly above the base toll and incremental changes well above the base toll. Nevertheless, an increase in the base toll of only 10% caused a 23% jump in the FNPV which can make a significant difference to a project's financial outlook. It is also interesting that the base toll rate does not have a significant effect on the ENPV. Thus, Project A provides some evidence that the problem of forecasts being highly sensitive to higher tariff rates may primarily be one that affects the financial outcomes not the economic ones.

4.2. Improvement of Competitive Routes

There are two significant ways that the improvement of competitive routes can affect the results under the structure of Project A. Firstly, improved competitive routes decrease traffic and congestion on the tolled route. From a financial perspective it is likely that this will yield a decrease in toll revenue. From an economic perspective it may be seen as an overall positive to society; however, when measuring the incremental economic value of the tolled route the existence of an improved competitive route will negatively affect the economic benefits stemming from the tolled route. This is because of the subsequent decrease in relative time saved per vehicle and vehicle maintenance savings for road users of the tolled route. More specifically, when better alternatives are available, the tolled route results in relatively lower time savings and may also have a relatively smaller impact on reducing vehicle maintenance.

The obvious choice for a competing route in the Project A case is the M13 alternative route. This route is a longer route used exclusively by long haul truck users. Obviously using a truck only route as an alternative will mitigate the results slightly; however, it will still demonstrate the manner in which the forecast is affected. Also, given the circumstances of Project A, it is entirely feasible that the M13 route would be improved during the life of the forecast and the subsequent loss of long haul revenue for the tolled M12 sections could have an impact on the realized outcomes.

A positive cross-price elasticity between the M12 and M13 is not clearly defined in the forecast but a similar effect can be tested by using a proxy of sorts to represent improvements to the M13 route. The length of the M13 route can be reduced to represent improvements that might otherwise increase travel time, and/or reduce vehicle maintenance costs. This has the consequence of making the M13 a more attractive and competitive alternative to the M12. In order to assess the impact of an improvement to the M13 alternative route the sensitivity to changes in this representative cross price elasticity effect for long haul users between the two roads will be tested.

Table 2 - Forecast Sensitivity to Alternative Route Improvements

Percentage Change	M13 Distance	ENPV (Thousand KTK)	Percentage Change	M13 Distance	FNPV (Thousand KTK)
-10%	40.50	212,971	-10%	40.50	12,752
-8%	41.40	212,971	-8%	41.40	12,752
-5%	42.75	213,036	-5%	42.75	12,769
-2%	44.10	214,282	-2%	44.10	13,071
0%	45.00	215,507	0%	45.00	13,365
25%	56.25	231,416	25%	56.25	16,232
50%	67.50	248,044	50%	67.50	18,133
75%	78.75	265,084	75%	78.75	19,490
90%	85.50	275,409	90%	85.50	20,134

ENPV and FNPV values decrease as the M13 distance also decreases. Treating the decreased distance as a proxy for road improvements, this relationship shows long haul trucks now foregoing the tolled M12 route for the competitive and now improved M13 route. It is worth noting that once the distance falls by approximately 6% all long haul traffic shifts to the M13 route and there are no longer any effects on the NPVs of Project A. In reality it is unlikely that competitive improvements would shift an entire traffic set from one road to another; however, this result is a consequence of focusing strictly on a single relatively small sub-group.

The situation where the M13 distance increases can be used to represent situations where the alternative route's competitiveness decreases relative to the tolled route. As would be expected both ENPV and FNPV increase substantially as a result of the increased long haul truck traffic; although it is important to note the larger percentage changes used to build the table. These results also support the importance of truck usage to a forecast's results, which will be examined further in the next subsection.

4.3. Less Usage by Trucks

In order to show the significance of truck usage, a slight deviation from standard sensitivity analysis occurs. Because this Risk Factor stems exclusively from the negative effects that unanticipated declines in truck traffic can have on project success the focus will strictly be placed on truck traffic levels and their effects on NPV. It may be possible to conduct sensitivity analyses on the variables that drive trip assignment for trucks; however, this type of analysis would tell us how those background variables affect project results with trucks simply being the medium through which variability is created. Similarly, detailed scenarios could be constructed to create more complex decision making by truck users where their decisions are not as predictable. For this paper, the simple goal is to show how any exogenous decrease in truck traffic can impact the forecasted results. This is a more parsimonious analysis that focuses strictly on truck traffic levels by applying growth multipliers to truck traffic measurements $V_{i,p}$ in each of Project A's forecasted years and creating sensitivity tables by changing the multiplier. For example, the 10% sensitivity measurement is calculated by applying a 10% increase to truck traffic in each year of the forecast. In doing this, we will more clearly demonstrate exactly how truck traffic affects project outcomes. Any further discussion surrounding the actual driving forces behind this risk will occur in Section 5. In analyzing the results below it is important to note that truck traffic initially accounts for only a small proportion of total traffic on the road. As was mentioned earlier, even if only 10% of total traffic is made up of heavy trucks, this group can account for 30% of total revenue. Bain states that this 10% number, or even less, is typical in terms of the proportion of total traffic usually accounted for by trucks (2009b, 37); however, in the case of Project A, truck traffic makes up far less than 10% of total traffic initially. For example, of the expected daily traffic in year 1 without the project, trucks account for only between 1 and 2.5 per cent of total traffic, depending on which section of the M12 highway is measured. As such, the effects of changes in truck traffic may be understated and may be less impactful to Project A in relation to other comparable projects.

Table 3 - Forecast Sensitivity to Yearly Truck Traffic Levels

Percentage Change	Average/Year	ENPV (Thousand KTK)	Percentage Change	Average/Year	FNPV (Thousand KTK)
100%	12,893	223,892	100%	12,893	15,990
75%	11,327	221,796	75%	11,327	15,338
50%	9,761	219,700	50%	9,761	14,684
40%	9,134	218,861	40%	9,134	14,420
30%	8,508	218,023	30%	8,508	14,156
20%	7,881	217,184	20%	7,881	13,893
10%	7,255	216,346	10%	7,255	13,629
0%	6,628	215,507	0%	6,628	13,365
-10%	6,002	214,668	-10%	6,002	13,101
-20%	5,375	213,829	-20%	5,375	12,837
-30%	4,749	212,990	-30%	4,749	12,573
-40%	4,122	212,151	-40%	4,122	12,309
-50%	3,496	211,312	-50%	3,496	12,045
-75%	1,929	209,214	-75%	1,929	11,386
-100%	363	207,116	-100%	363	10,726

At first glance the truck traffic does not seem to play a significant role in determining the ENPV of Project A. Doubling or halving truck traffic in every year on the M12 corridor creates only a 4%

increase and decrease respectively in EPNV. The FNPV is affected slightly more from a proportional standpoint, increasing and decreasing by roughly 20% for identical changes in truck traffic.

The 20% change is reasonably large enough to suggest that Project A justifies S&P's inclusion of truck traffic as a significant risk factor. In addition, it is worth noting that Project A's clearest substitute or alternative route, the M13, is primarily used by long-haul trucks. This combined with the low pre-project truck traffic on the M12 route suggest that truck traffic may be uncharacteristically low for Project A, assuming the M13 is indeed a reasonable substitute for the M12. Regardless, the amount of truck traffic estimated for any project will vary widely depending on a diverse range of non-forecast related factors and this variation will inevitably result in some forecast inaccuracy. How a forecaster can minimize the impact of this inaccuracy is discussed in the recommendations section.

4.4. Underestimation of Ramp Up

In the case of Project A, the ramp up over time is not clearly modelled for Project A. While ramp up should ideally be accounted for by forecasters and planners, often it is ignored, albeit sometimes for practical purposes. (Flyvbjerg, 2005). One of the reasons ramp up is at times ignored is because the exact nature of the demand responses in the initial operating years of a project can be so wildly unpredictable. In addition to possible project delays, start-up problems, and operational growing pains, road users take time before they are able to discover, and efficiently input a new road into their route choice decisions. This complexity induced inaccuracy is also a reason why peak and off-peak traffic levels are sometimes ignored. By attempting to model these elements, a forecaster can increase or decrease accuracy and it is often difficult to tell which situation has occurred. Further commentary on the strengths and weaknesses of this decision will take place in Section 5; however, based on the limitations of Project A determining the specific effect of off-peak traffic changes and ramp up will not be possible. Nevertheless, unlike peak and off-peak traffic, ramp up can reasonably be introduced to the forecast through some very basic scenario analysis. This analysis will be used to show how the ENPV and FNPV are impacted when the traffic levels are adjusted to reflect these slightly more complex processes.

Since the forecast for Project A does not explicitly model ramp up, it needs to be artificially introduced in a manner that does not disrupt the general methodology of the forecast. The scenarios are constructed by introducing a fractional variable R_i such that:

$$Vip = Ri \bullet (Via \bullet (1 + \eta ic \bullet (Cip \div (Ci - 1))))$$

Where V_{ip} represents the traffic level for a given class of vehicle given the project situation, V_{ia} represents the traffic level for a given class of vehicle without the project, η_{ic} represents the price elasticity between the improved and unimproved routes (assumed $\eta_{ic} = -2$) and C_{ip}/C_i-1 represents a generalized vehicle cost ratio between the project and non-project situations.

The first set of analyses employing this variable R_i examines the case where total traffic experiences ramp up, the second set of analyses examines the case where only diverted/generated traffic experiences ramp up. It is worth noting that in reality Project A is not likely to experience ramp up in the same way as a road that did not previously exist. Nevertheless, the scenarios show the hypothetical impact of various ramp up scenarios relative to the no ramp up case.

Table 4 - Project Outcomes with Alternative Assumptions on Timing of Traffic Ramp Up			
Scenario[4]	ENPV (Thousand KTK)	FNPV (Thousand KTK)	Cashflow Loss (2011-2015) (Thousand KTK)
No Ramp Up	215,507	13,365	0
3 year Ramp Up (75, 90, 100)	211,892	12,433	1,603
3 year Ramp Up (50, 80, 100)	208,244	11,459	3,253
5 Year Ramp Up (20, 40, 60, 80, 100)	195,318	8,071	11,361
10 Year Ramp Up (10, 20, 30, 40, 50, 60, 70, 80, 90, 100)	172,986	2,650	17,976

In the total traffic case, introducing ramp up to the forecast has significant implications for both economic and financial results. The smallest adjustment occurs in the first scenario where ramp up reduces traffic levels on the tolled route to 75% of the originally forecasted value in year 1 and 90% in year 2 before returning to 100% of the originally forecasted value by year 3. In this limited case ENPV is reduced by almost 4 million KTK or 1.7% and FNPV is reduced by 932,000 KTK or 7%. With respect to potential debt and financing consequences, project operators face a cashflow loss of 1,603,000 KTK during the first 5 years of the project. In the most extreme case, ramp up occurs over a ten year period with ENPV falling by over 42 million KTK or 20% and FNPV falling by over 10 million KTK or 80%. Cashflow during the first 5 years of the project falls by almost 18 million KTK representing a significant risk for project financiers.

[4] Scenarios are constructed by introducing the fractional ramp up variable R_i for a limited period (3, 5, or 10 years) with the fractional percentage increasing each year e.g. 75%, 90%, 100% in scenario 1.

Table 5 - Project Outcomes with Alternative Assumptions on Timing of Traffic Ramp Up: Diverted/Generated Traffic Only			
Scenario[5]	ENPV (Thousand KTK)	FNPV (Thousand KTK)	Cashflow Loss (2011-2015) (Thousand KTK)
No Ramp Up	215,507	13,365	0
3 year Ramp Up (75, 90, 100)	215,344	13,316	85
3 year Ramp Up (50, 80, 100)	215,181	13,267	169
5 Year Ramp Up (20, 40, 60, 80, 100)	214,598	13,104	493
10 Year Ramp Up (10, 20, 30, 40, 50, 60, 70, 80, 90, 100)	213,326	12,839	746

The diverted/generated traffic only scenario results in far less drastic effects to both the economic and financial results of the forecast. This scenario could be argued to be more realistic for Project A since the introduction of the toll occurs on improved sections of an already existing highway and the pre-existing road users will not necessarily need as much time to integrate a toll into their already developed preferences regarding the route. Nevertheless, the introduction of a toll to an existing traffic route will still cause the road users who already use the route to adjust their decision making alongside the road users who switch from other routes. Consequently, ramp up would likely affect Project A in a manner somewhere in between these two examples. This second group of scenarios should instead be viewed as a conservative lower bound to ramp up effects. In this case, the minimal 3 year 75%, 90%, 100% ramp up scenario only decreases ENPV by 163,000 KTK, FNPV by 49,000 KTK and cashflow in the first 5 years by 85,000 KTK. Even in the more extreme 10 year ramp up case ENPV only drops by 2,181,000 KTK or 1%, FNPV drops by 526,000 KTK or 4% and cashflow over the first 5 years drops by 746,000 KTK. In this case potential ramp up

[5] Scenarios are constructed by introducing the fractional ramp up variable R_i for a limited period (3, 5, or 10 years) with the fractional percentage increasing each year e.g. 75%, 90%, 100% in scenario 1.

is not the most noteworthy risk factor; however, even these smaller reductions in the forecasted results can have significant impacts on project stakeholders.

The significant differences between the two estimates may not be very helpful in informing the decisions of Project A specifically; however, it does illustrate the importance of understanding the demand response of existing traffic when a toll is introduced. Ramp up itself is a difficult process to accurately predict and as the two above examples illustrate, even once a ramp up process has been selected, the forecasts can differ wildly depending on how different groups respond. Further discussion surrounding how to mitigate this variability will take place in Section 5.

4.5. Miscalculation of Time Savings and Future Time Savings

Miscalculation of time savings and future time savings errors are grouped together because the errors they produce will affect the forecasted outcomes in similar ways. Miscalculation of time savings refers more specifically to the method used to determine the value of time savings for road users. The process of valuing time in a forecast essentially stems from two broad calculations; firstly, determining how much time will be saved through use of the tolled route, and then determining what the value of that time saved actually is. There are a number of different factors that can result in savings for road users as a result of spending less time driving on a given trip and assigning numerical values to these factors further complicates the issue. Does the forecaster simply take a VOT number from a government database? And if further calculation is required, what variables factor in? If things like wages or gasoline costs are included, how detailed is this data? And at what level is it aggregated across individuals? Project A calculates the value of time separately for 4 different classes of vehicles and takes into account the number of vehicle occupants and the opportunity cost of those occupants by using wage rate data. Errors stemming from miscalculation in this case could come from the forecaster not properly forecasting the opportunity cost into the future, not modelling a destination such as an airport that inherently increases the relative costs of slower routes, or modelling too much or too little detail in terms of differences between individual road users. The forecaster also needs to understand what variables have been included in a VOT calculation and determine if there are other sources of time savings that need to be accounted for. For example, most VOT calculations will be empirically estimated based on an individual's preferences and opportunity cost as a percentage of their wage rate. Such calculations do not include savings from external inputs such as gasoline or vehicle maintenance. (Bain, 2009b)

The focus is therefore placed on differences between individual road users and differences between the trips they take. For example, an individual with four children and a job working long hours at a law firm, may value time savings on the route to and from work more than an equivalent individual without children, or who simply enjoys driving more. Additionally, that same busy lawyer is likely to value the time savings more on a day when they are rushing to an important meeting or to catch an important flight at the airport, than a situation where they are simply driving to get groceries or accomplish some other day to day task. No forecaster can be expected to perfectly model each eventual road user's preferences over a 30 year period; however, their goal should be to model users in such a way that they capture as much of the nuances present in the market as possible.

Risk as a result of Future Time Savings, on the other hand, is less a result of the inputs and structure of the base model and more associated with general uncertainty that is created over the forecasted period as rode users actually start to use and make travel decisions on the completed project. An example used in the S&P Report is the 'hurry up and wait' phenomenon where road users who save time on a tolled road subsequently have to queue up to rejoin a busy toll-free traffic network at a downtown terminus. If these types of developments are not accounted for by the forecaster then estimates of future time savings could be drastically inflated. The value of time savings attempts to capture the total opportunity cost savings of using the tolled route, rather than a competitive alternative route. As such, the two Risk Factors both result in similar inaccuracy, either through poor modelling or through an improper understanding of how and if road users will actually realize the benefits of a tolled route in the future. (Bain, 2009b).

Sensitivity analysis will be conducted on the value of travel time savings, primarily to demonstrate just how central this measurement is to the forecast. Since Project A is modeled with four distinct vehicle classes, each of which refers to drivers with a different value of time, we will examine outcome sensitivity to changes in only one class' value of time as well as the sensitivity to changes across all four classes. The discussion and recommendations for this section will look at specific practices employed by forecasters and attempt to illustrate the difficulties they face when choosing exactly how best to represent this complex and abstract concept.

Table 6 - Adjusting the Value of Time of a Single Class of Road Users

Percentage Change	VOT Class A (KTK/hr)	ENPV (Thousand KTK)	Percentage Change	VOT Class A (KTK/hr)	FNPV (Thousand KTK)
100%	448.0	323,087	100%	448.0	13,927
75%	392.0	296,166	75%	392.0	13,828
50%	336.0	269,259	50%	336.0	13,707
40%	313.6	258,501	40%	313.6	13,651
30%	291.2	247,746	30%	291.2	13,590
20%	268.8	236,995	20%	268.8	13,522
10%	246.4	226,248	10%	246.4	13,448
0%	224.0	215,507	0%	224.0	13,365
-10%	201.6	204,771	-10%	201.6	13,272
-20%	179.2	194,043	-20%	179.2	13,168
-30%	156.8	183,324	-30%	156.8	13,051
-40%	134.4	172,615	-40%	134.4	12,916
-50%	112.0	161,919	-50%	112.0	12,761
-75%	56.0	135,263	-75%	56.0	12,245
-100%	0.0	108,821	-100%	0.0	11,404

The value of time for Class A alone has a significant impact on the ENPV of Project A. An increase of only 10% increases the ENPV by 5% and doubling the value of time increases ENPV by 50%. Similarly, decreasing the value of time for Class A all the way to zero cuts the ENPV in half. FNPV on the other hand is less affected by changes to the VOT for Class A. Doubling their VOT only increases FNPV by 4% and reducing it to zero only reduces FNPV by 15%.

Table 7 - Adjusting the Value of Time for all Road Users

Percentage Change	ENPV (Thousand KTK)	Percentage Change	FNPV (Thousand KTK)
100%	432,859	100%	15,674
75%	378,729	75%	15,222
50%	324,479	50%	14,701
40%	302,739	40%	14,468
30%	280,975	30%	14,220
20%	259,183	20%	13,955
10%	237,361	10%	13,671
0%	215,507	0%	13,365
-10%	193,616	-10%	13,034
-20%	171,685	-20%	12,676
-30%	150,174	-30%	12,411
-40%	129,155	-40%	12,239
-50%	108,184	-50%	12,052
-75%	55,681	-75%	11,380
-100%	2,853	-100%	10,009

When the sensitivity analysis is extended to the scenario of all road users having their VOT change by the same incremental amounts the results are consistent with that of Class A alone. ENPV is highly variable in relation to the value of time assigned to road users. FNPV is impacted by changes in time valuation; however, it is not as drastically affected as the economic results. These results are consistent with the fact the economic analysis includes opportunity cost valuations of which the value of time is an integral piece. Financial valuation on the other hand does not directly value time monetarily and thus it only enters the forecast through the differing travel decisions of road users.

4.6. Long Term Sensitivity to GDP Assumptions

Showing how sensitive forecasts can be to GDP assumptions will be done through a standard sensitivity analysis demonstrating how economic and financial results change as predicted GDP growth rates change. The simple nature of GDP errors creating forecasting error over long time horizons is a fairly well established notion. This analysis will remain simplistic in order to focus on stakeholder impacts and the degree to which they may be affected. Some basic recommendations for mitigating GDP forecasting risk will be discussed in Section 5.

Table 8 - The Significant Impact of Simple GDP Growth Assumptions

Percentage Change	GDP Growth Rate	ENPV (Thousand KTK)	Percentage Change	GDP Growth Rate	FNPV (Thousand KTK)
100%	0.080	656,667	100%	0.080	48,751
75%	0.070	484,725	75%	0.070	36,676
50%	0.060	361,961	50%	0.060	27,115
40%	0.056	324,358	40%	0.056	23,861
30%	0.052	291,552	30%	0.052	20,887
20%	0.048	262,850	20%	0.048	18,163
10%	0.044	237,667	10%	0.044	15,661
0%	0.040	215,507	0%	0.040	13,365
-10%	0.036	195,948	-10%	0.036	11,256
-20%	0.032	178,636	-20%	0.032	9,315
-30%	0.028	163,265	-30%	0.028	7,529
-40%	0.024	149,579	-40%	0.024	5,877
-50%	0.020	137,357	-50%	0.020	4,346
-75%	0.010	112,035	-75%	0.010	996
-100%	0.000	92,476	-100%	0.000	-1,810

The side by side sensitivity tables for GDP growth rates illustrate similarly significant effects for both the ENPV and the FNPV. Incremental increases in the GDP growth rate cause both NPVs to increase at increasing rates. For example, a 10% increase in the GDP growth rate causes approximately a 10% increase in the ENPV, and a 50% increase in the GDP growth rate causes approximately a 68% increase in ENPV. Incremental decreases in the GDP growth rate result in both NPVs decreasing at decreasing rates. For example, a 10% decrease in the GDP growth rate causes approximately a 10% decrease in ENPV, and a 50% decrease in GDP growth rate causes approximately a 36% decrease in ENPV. In terms of both increases and decreases, the effects of GDP growth rate assumptions are greater as a percentage of the Projected NPV for the FNPV. Doubling the GDP growth rate to 8% per year results in a 265% increase in the FNPV and 'only' a 200% increase in the ENPV.

The Project A results for GDP growth rate seem to confirm the S&P conclusion that toll forecasts are extremely sensitive to GDP assumptions. This result fits very logically with the idea that most long term forecasts will likely be sensitive to GDP growth rates. Nevertheless, the results above give a reasonable expectation as to how significantly changes can affect both the financial and economic sides of the NPV.

5. Discussion and Recommendations

5.1. High Toll Tariffs

The additional risk introduced by high toll tariffs stems primarily from an inability to predict consumer responses. It is not based on forecaster's having to choose between fundamentally different models or analyses; nor does it stem from exogenous changes that occur in the future. There is simply a lack of understanding of how road users will respond to tolls set above average rates. In Section 6 a post-modelling procedure will be discussed that advocates for more review and data tracking beyond the initial forecast. A significant benefit of such practices is that more detailed forecast data can be shared amongst forecasters so as to help inform the assumptions and practices of future forecasts. This sharing of data would drastically reduce the risk from high toll tariffs as it is almost entirely based on a lack of information. Road users will always respond in different ways across different projects, but more data will certainly improve the likelihood of making accurate predictions. Nevertheless, simply relying on more data to predict consumer responses is not going to eliminate the risk of forecast inaccuracy. In addition, it is also often tempting to identify and utilize time series data or trends that are provide favourable results. Therefore, if forecasters do share more data and experiences it will be important to actually use the data in smart and realistic ways.

While the relationship between higher than average tolls and road user decision making may become better understood over time, forecasters and project stakeholders should still exercise caution when planning such projects. Perhaps instead of charging higher upfront tolls, project concessionaires could negotiate longer debt repayment schedules or longer concession periods. Such decisions could be made with the strategic incentive of reducing the uncertainty surrounding driver responsiveness to higher than average toll rates. In Portugal for example, a massive e-toll system introduced in 2011 on previously toll-free highways has faced widespread criticism and resulted in drastically reduced traffic volumes on some of the country's most prominent roads. Partially to blame for the apparent failure is the country's economic downturn causing road users to choose to drive less to avoid gasoline and maintenance costs. But in addition to this, there has been a significantly negative response to the magnitude of the tolls. Driving the 300km from Lisbon to the northern capital Porto costs €22 in tolls for cars and about €36 in fuel. (Wise, 2013). It costs about double that for trucks, so that despite their sometimes lower responsiveness to price changes they have begun to make longer journeys on lower quality secondary roads. Because these projects were financed and in many cases operated by the government, the low traffic volumes are now causing significant losses; a burden that is shifting to taxpayers. The high toll rates are certainly not the only factor reducing potential traffic; however, perhaps a forecast that recognized the uncertainty surrounding high toll tariffs would have changed some of the decisions made by the government and prevented some of these losses.

It is easy to look at a failed toll project in hindsight and blame a high toll for low traffic volumes. Yet what seems like a high toll currently may have appeared perfectly reasonable during the forecasting and construction stages of a project. This is why it is incredibly important for toll forecasters to collect and share data. If project stakeholders have access to relevant and comparable data from similar projects elsewhere they are far less likely to be blindsided by drastically reduced traffic as a response to the toll rate.

5.2. Improvement of Competitive Routes

One of the sources of risk from the S&P report outlined in Section 2 was future land use scenarios and economic development. Although this factor was not analyzed in the context of Project A, the risk stems from some of the same sources as the improvement of competitive routes. Making assumptions about future developments based on development proposals or pure speculation is a dangerous practice and can result in drastic divergences from reality. First of all, development plans can change quickly and if they are factored heavily into the forecast this will immediately damage the forecast when such changes occur. In addition, by modelling future development into a model forecasters are introducing yet another variable that they likely don't have a strong understanding of; that being the demand response of road users to the future development. Even if forecasters can say with 100% certainty that a specific future development will occur, how this development will affect the choices of road users must then be modelled in of itself.

In terms of competitive routes, the development will of course affect the forecast negatively. But the same facts apply in that if this future development is based on speculation then factoring it into the analyses has as much chance to reduce forecast accuracy as it does to increase it. In addition, just as road users don't necessarily respond rationally to the introduction of a toll or the creation of a new route, they may not respond rationally to the improvements along other routes. Road users likely aren't making perfect time valuation calculations in their heads every trip and they also don't have perfect information about traffic volumes or vehicle maintenance costs. Also, as was discussed in Section 1, road users have different values of time amongst each other and amongst themselves at different times and for different trips. Therefore attempting to model future improvements to competitive routes is essentially attempting to model an uncertain process as a result of an uncertain event, thus compounding the potential for inaccuracy.

All that being said, as the results show, even if competitive improvements only affect a small proportion of road users it can impact the forecast. In cases where all road users have several possible route choices, improvements can have significant impacts on toll revenue. However, forecasters should not simply pretend the uncertainty surrounding modelling such improvements does not exist. Forecasters could realistically and easily provide detailed scenario analyses to show how the forecast changes based on a variety of competitive route improvements. Consultation with relevant stakeholders such as debt financiers and future concessionaires could then determine whether to introduce any of this data into the forecast either through basic deflation of the estimates or by introducing a range or confidence interval to forecasted values. They could even attempt to assign a degree of likelihood to the various scenarios, although such a process is likely to be fickle in its own right. The most important thing for forecasters to remember is that no matter what, future developments are going to introduce uncertainty and potentially inaccuracy to the forecast. Forecasters need to highlight and emphasize this uncertainty rather than hide or ignore it.

5.3. Less Usage by Trucks

The S&P report used to identify the Risk Factors in Section 2 also noted that forecasts for truck usage were even more unreliable then those made for cars. (as cited in Bain, 2009b, p. 37) The forecasting error measured for trucks was 33% compared to 26% for light vehicles. (as cited in Prozzi et al., 2010, p. 16). Therefore, even though the sensitivity results might not seem as extreme as some of the factors that affect total traffic volumes, truck traffic errors are more likely to be larger and further from the predicted values. As such, it becomes important for the forecaster to explicitly distinguish truck traffic from other road users beyond just assigning a certain percentage of traffic a higher toll value. Truck drivers will often exhibit drastically different behaviour than other road users. In addition, although it is not even modelled for Project A, peak hours for trucks in many urban areas do not coincide with peak hours dominated by cars. (Kriger, Shiu & Naylor, 2006). Truck drivers across different countries are regulated heavily in terms of their service hours and in 2004 the Federal Motor Carrier Safety Administration ("FMCSA") updated the hours of service rules in the United States with the intention of helping drivers get onto a 24 hour work clock (Hensher & Button, 2008, p. 33.8); however, truck schedules are largely determined by the pick-up and delivery schedules that the products they deliver require. As such, truck traffic may be less able to avoid heavy peak traffic volumes and face higher costs of delay. It is also fair to say that relative to other modes of transport, truck traffic tends to be more heavily concentrated at night, especially given the requirements of just in time delivery policies that require shipments of products to arrive regularly at the start of every business day. Assuming data is available; the forecaster would be better served to model truck traffic as independently as possible.

Another important distinction for the traffic forecaster to make is the segmentation of the truck industry itself. Different types of truck users can have drastically different incentives and respond to tolls in different ways. For example, while truck users may try and avoid paying tolls, some truck drivers are likely to avoid paying tolls at all costs, while others may more carefully weigh the relative costs and benefits. Some of the important distinctions between truck drivers are listed below:

Table 9 – Segmentation Within the Truck Industry

Segmentation[6]	**Example**
Service Area	Local Regional National International
Trip Type	Intra-city Inter-city Through trips
Vehicle Ownership	Owner-operator Company truck
Vehicle Operator	Owner-operator Company employee driver
Fleet Size	Small (less than five trucks) Medium Large

[6] See Prozzi et al. (2010), especially pages 16-20 for a more in depth discussion of these truck user segmentations.

For-Hire or Private Trucking	General for-hire Specialized freight for-hire Private
Vehicle Characteristics	Light Medium Heavy Specialized trucks
Type of Trailer	Dry freight Refrigerated Flatbed Liquid tank Dry hopper Auto rack Household goods
Type of Carrier/Operation	Truckload Less-than-truckload Parcel/express Specialized services

Understanding how these different groups react to tolls and how truck traffic for a given project will be divided amongst these characteristics can be critically important to accurately predicting truck traffic.

Regardless of how much data a forecaster has, increased truck traffic will significantly increase toll revenues. As such, project operators may look to give incentives to truck drivers to utilize the tolled route. While there have been many attempts to create these incentives, assuming additional truck traffic based on the presence of added incentives is a potentially dangerous decision in relation to forecast accuracy. Nevertheless, a 2010 survey of truck drivers in Texas suggested that toll road users felt more favourably towards toll roads than non-toll road users when presented with statements describing the benefits of toll roads. Therefore, it seems that project operators may be better served directing marketing efforts towards such benefits and targeting the existing toll customer base. (Prozzi et al., 2010, p. 24-25). On the other hand, the survey also suggested that "incentives that reduce the costs of using the toll road, such as a fuel tax refund, the allowance of long combination vehicles[7], and the frequent user discounts seem to be more favorably viewed by [truckers who are inherently opposed to toll roads]." (Prozzi et al., 2010, p. 25). Forecasters should be aware of such responsiveness and use this information carefully to inform the forecasting process. It can be used in a more prudent fashion to recognize improperly inflated forecasts and to provide more informed qualitative recommendations to project operators and other stakeholders.

5.4. Underestimation of Ramp Up

The simplest recommendation in relation to ramp up is that forecasters highlight the fact that inaccuracy may be especially high during the first few operational years of a project. When start-up problems diminish, and road users have successfully accounted for the new route in their decision making process a project that initially seems to be operating far below original forecasts may quickly catch up. Forecasters also attempt to model the ramp up period, and many simply reduce forecasted amounts by set percentages during the first 3-6 years of the project; for example, 20% in year 1, 50% in year 2, 80% in year 3 and so on and so forth as was done in the scenario analysis of Section 4. Nevertheless, attempting to predict the ramp up process has the potential to introduce just as much inaccuracy as avoiding the concept altogether. As can be seen from the results in

[7] Long combination vehicles or Longer combination vehicles ("LCVs") refer to tractor trucks connected to multiple trailers as opposed to standard 5 axle semi trailer-trucks with one trailer.

Tables 5 and 6, the different ramp up scenarios result in drastically different outcomes depending on which road users are modelled and how their responses differ. In addition, by manipulating the opening years of the project and then producing them as forecasted results, one may actually be introducing two sources of uncertainty: the inaccuracy of the modeling itself, and the inaccuracy of the assumed ramp up to full demand. (Flyvbjerg , 2005)

In Section 6 a post-modelling procedure will be discussed that suggests the use of confidence bands to better illustrate the potential for variability across the different forecasted values. This technique could be used during the ramp up period, where the bands would likely introduce a wider range, illustrating both the potential outcomes during the period, as well as the decreased confidence in the accuracy of this portion of the forecast. In this way, stakeholders such as project operators and financiers could better plan to shift potential risk away from this operational period and better structure their financing to endure initial low traffic volumes.

There is some evidence to suggest that transportation projects with lower than forecasted traffic during the first year of operations also tend to have lower than forecasted traffic in later years. (Flyvbjerg, 2005). The implications of this are such that a ramp up of demand for the services of an investment may not always exist for some projects (both transportation and non-transportation)or at least it may not operate in such a manner that traffic always catches up to forecasted values in later years. Regardless, projects where useful statistical data is available for both the first year and later years of operation are rare.

From an accuracy perspective, ramp up can be one of the most difficult aspects of a forecast to reliably replicate. The recommendations above provide some basic ways for a forecaster to better illustrate and explain the ramp up period and to better educate project stakeholders so that they can make more informed decisions regarding project operation and financing. In addition, assuming quick or instant ramp up can be used as a bidding strategy to make one company's bid look more profitable than it will likely be. Both organizations submitting calls for bids, as well as companies who contract out the forecasting process should be aware of this tactic. A proper understanding of the benefits accrued during the early years of a project is critical as those years are often the most important in terms of meeting debt service obligations. Additionally, from a simple discounted cash flow perspective, early benefits have greater weight than benefits that come later in the project's life. Consequently, although ramp up is notoriously difficult to assess, it can drastically reduce revenues in the initial operating years of a project, arguably the most critical years of a project's life.

5.5. Miscalculation of Time Savings and Future Time Savings

As has been mentioned many times, there are many ways to set up a forecasting model for toll roads and one of the key variables to establish is the value of time. In the cases where countries do publish average time valuation data it is usually based on a combination of modelling practices and local wage rate data. Other factors such as the relative value of business and non-business trips and the average length of trips may be more or less significant depending on the project.

In terms of actually assigning a numerical value, "40% to 50% of average wage rates seems to be widely accepted for non-'business' trips (where 'business' trips are those made during employers' time). Business trips "tend to be valued at higher rates of up to 80%-100% of the wage rate."(Lake & Ferreira, 2002). Risk stemming from time valuation is less likely to stem from this initial choice of relative valuation. As long as the forecaster bases this valuation on a combination of historical data and realistic assumptions about the present rather than strictly relying on historical trends or strictly relying on a projective model they should avoid introducing their own forecast risk beyond the uncertainty already surrounding road user time valuation. That is to say forecasters should be utilizing a robust framework, rooted in best practices in order to properly establish these initial parameters that help determine the value of time saved, otherwise they risk adding their own bias to the traffic estimates that are based off this initial time valuation.

Unfortunately, uncertainty is naturally inherent to time valuation. Road users may not always properly assess decisions based entirely on the value of time. Particularly with respect to toll roads, drivers will at times choose to sit in heavy traffic rather than paying a relatively modest toll. (Bain, 2009b, p. 69). In addition, even if road users are able to rationally assess and make decisions based on their valuation of travel time, they may not be able to make these decisions because of external factors such as work or family constraints. Also, their preferences may change based on a wide variety of internal behavioural factors such as their mood on a given day. A UK investigation into behavioural responses to road pricing found that road users were constrained in terms of their route choice and/or their departure time for over a third of their trips. This would have the most significant impact on a dynamic toll attempting to influence road users at specific times; however, it still shows that even in the case of a fixed toll, road users may not be reacting in a perfectly free manner to the toll. (Lake & Ferreira, 2002).

The most obvious recommendation for forecasters with respect to time valuation errors is to gather as much information as possible in relation to road user choices. Historical data combined with wage data and a basic model can provide a starting point from which to base this valuation; however, any additional local data or comparable projects can help reveal preferences and modify initial valuations. Time valuation is fickle process to model and it will likely remain that way moving forward. Nevertheless, as long as forecasters seek out and combine solid modelling practices with good data, while supplementing it with available local/preference revealing information they will at least avoid introducing their own foundational inaccuracy to the forecast.

5.6. Long Term Sensitivity to GDP Assumptions

Although it might not be a perfect representation of reality, the traffic forecaster can be excused for using simple GDP growth assumptions. The complexities of advanced GDP growth forecasts are significant and accurately predicting yearly growth levels far into the future is difficult for even the best of experts. As can be seen in Table 8 above, as future GDP assumptions change by even small amounts this drastically changes NPV outcomes, and this result is even more pronounced for longer term 20-30 year forecasts. GDP predictions end up filtering through the forecast in many significant ways and as a result, inaccuracy here can compound over the entire forecast. For example, the value of travel time savings is often influenced by GDP growth assumptions and corresponding wage data. As discussed throughout, forecasting the value of time already has its own inherent accuracy problems. Further inaccuracy in the foundation of that variable can render correct and efficient estimation techniques obsolete.

In order to establish GDP assumptions, forecasters often use historical trend data to project into the future. This analysis relies on the fact that the future will not look particularly different from the past. Unfortunately this isn't always the case and there is no parsimonious way to perfect GDP forecasting. Extensive resources should be used to ensure the forecast is done accurately; however, just as governments, bankers, and other economists often fail miserably in such predictions, the traffic forecaster is unlikely to perfectly predict GDP growth over a 20 plus year period. Forecasters will often include a discussion of such risk and what it means for the overall project as footnotes to their analysis, but it should be presented in a much more prominent fashion. Sensitivity analysis like that conducted in Section 4 can be used to show project stakeholders exactly what potential variances exist. In some cases, the risk can be built into the model either through probabilistic weighting of outcomes or by adding the risk factor into the traffic outcomes that GDP affects.

Additionally, in making GDP projections, analysts need to examine the real exchange rate to see if there exists a significant divergence between the real exchange rate that currently exists and the real exchange rate based on purchasing power parity estimation. A purchasing power parity analysis would assume a real exchange rate of “1”; however, domestic currencies often get overvalued (e.g. Argentina in 2000, Italy in 2006, Turkey in 2013) which will make such projects whose benefits generate cash in domestic currency look favourable with respect to repaying the foreign currency financing. This is potentially misleading since, as the real exchange rate adjusts the value of the domestic currency towards its purchasing power parity value, the project may not be able to service the foreign currency debt. This is less of a problem in North America or Europe where one can get rid of the exchange rate risk by financing in the local currency or swapping the currency of the loans into domestic currency; however, for developing countries it can create a huge risk for project stakeholders. Again, an accurate prediction can be difficult, but ignoring these potential exchange rate issues can have severe consequences later in the forecast.

Regardless of the techniques used, the results in Section 4 show that traffic forecasters should put more emphasis on the influence of GDP assumptions when attempting to forecast further into the future. At the very least forecasts should be provided for several different GDP growth scenarios and strong justification for the methods chosen needs to be provided. Some extreme cases should also be provided as part of these scenarios as like in the Portugal case discussed above, periods of economic downturn will have powerful effects on the project outcomes. Increasing the resources devoted to GDP forecasts, while at the same time educating project stakeholders on the inherent variability of such processes will likely improve forecast accuracy; and, even more so it will allow both forecasters and operators to anticipate and prepare for the inevitable errors.

6. Additional Post-Modelling Procedures

Robert Bain's techniques and research are prevalent throughout the field of traffic forecasting, and he, along with other professionals, academics, and governments continue to research ways in which the problem of inaccurate forecasts can be mitigated. In 2011, as part of a larger initiative regarding toll road forecasts, the Australian government commissioned a report by Bain (Smith, Bain & Kanowski, 2011) investigating the causes of over-optimistic toll road forecasts with the purpose of identifying potential remedies. The recommendations of this report focus on adopting a new approach to traffic forecasting that focuses much more heavily on the post-modelling context.

The specific results of the report are less important for this Section than the detailed four-step post-modelling procedure presented in the appendix of the report. The procedure has not been widely put to the test; however, it seems to better identify sources of forecasting error, as well as illustrate the potential extent of such error. It is argued that this "approach…provides an auditable framework that makes assumptions, judgments and so forth explicit". (Smith, Bain & Kanowski, 2011, p.46). Essentially, the framework provides an opportunity for the forecaster to better explain his assumptions and provide a more detailed explanation for the overall structure of the forecast. In doing so, they are able to provide at worst, a more thorough understanding of the circumstances surrounding the project, and at best, a more accurate forecast. The four stages of this post-modelling approach are detailed below.

Stage 1

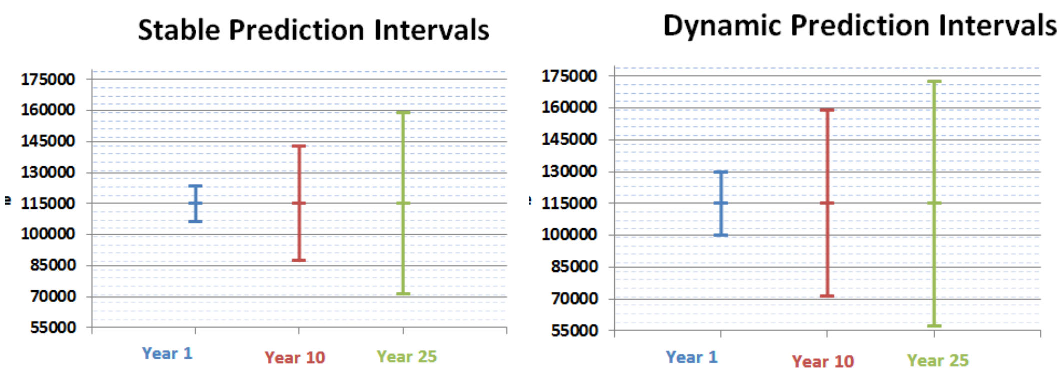
Stage 1 of the procedure first calls for an independent review of the entire forecast, from the basic modelling to the end results produced. The purpose of this review is to eliminate potential biases of the initial review as well as to test the performance of the assumptions made across the modelling process. Independently reviewing a traffic forecast is not a particularly drastic policy. A

2012 American report on toll road forecasting also called for independent forecasts where potential biases of stakeholders are not able to impact the results. (Samuel, 2012). After this additional review, the original forecast can be adjusted to account for any errors or biases.

The next portion of Stage 1 is to apply basic prediction intervals to the forecasted results to provide a more detailed depiction of result variability. The standard prediction intervals Bain suggests in the Australian report are based off analysis of national traffic forecasts conducted by the UK Department of Transportation in 2011 (as cited in Smith, Bain & Kanowski, 2011, p.44). The resulting prediction intervals are therefore approximated with the formula: $\pm 2.5\% \cdot \sqrt{n}$ where n is the number of years into the forecast. Bain's research suggested that these standard prediction intervals are likely to be much larger for developing or new traffic networks then they would be for established highway networks.[8] As such, Bain derived the following prediction intervals: $\pm 7.5\% \cdot \sqrt{n}$ for established or "stable" highway networks and $\pm 10\% \cdot \sqrt{n}$ for more developing or "dynamic" networks. In the case of Project A, the more stable prediction interval could likely be applied since the project focuses primarily on improvements and upgrades to existing highway networks. An example of how these prediction intervals expand over time is shown below in Figure 3. Figure 3 is simplified in that it shows a situation where estimated or average traffic is constant in each year of the forecast.

[8] See Tayman, Smith & Rayer (2008) for a similar result.

Figure 3 – Stage 1 Prediction Intervals with Constant Traffic



Stage 2

Much like Section 4 above, the focus of Stage 2 in Bain's post-modelling procedure is the various sources of risk prevailing throughout the project. The stage is dubbed a "Risk Workshop" and requires a detailed review of all the assumptions being made to support the forecast. The difference between this risk analysis and that provided in Section 4 of this paper lies in the specific variability being assessed. Where Section 4 tended to show the variability of the results based on different assumptions, the Risk Workshop is meant to examine the likely variability of the assumptions themselves. For example, with respect to possible assumptions surrounding GDP growth across the length of the forecast forecasters, stakeholders and experts would assess and examine the current assumptions alongside all other possible assumptions and use their expertise, hopefully alongside empirical evidence to determine if any adjustments need to be made to the initial assumption set. The purpose of this exercise is not to determine which variables produce the widest variability in the results; but to try and ensure model inputs have the highest likelihood of producing accurate results.

Stage 3

Stage 3 is somewhat of a refresh for the entire forecast. It consolidates the results of stages 1 and 2 and makes necessary adjustments to the forecast. It also utilizes "top-down and bottom-up sense checks" to strengthen the process. Top down checks involve things like comparing forecasting results to historical trends or outcomes based on historical forecasts and ensuring that the forecasted results compare in a reasonable way. Bottom-up checks involve some basic sensitivity or robustness checks of model outputs to various input values. After these checks the forecaster can update the forecast as necessary.

Stage 4

The final stage of the post-modelling procedure is designed specifically for investors and stakeholders to assess and finalize their potential bidding strategies by combining an assessment of their own proclivity towards risk and the results from the forecast following the post-modelling analysis.

While the purpose of this extra analysis is to add extra tools to a forecast, it is arguable that forecasters are in fact already doing a lot of this work. For example, the sensitivity assessments, the testing of basic models and the setting of prediction intervals are often part of a standard forecast; however, they are not necessarily being used in the post modelling context to increase forecast accuracy, or in a way that maximizes their ability to provide more detailed explanations to relevant stakeholders of the forecasted results. Bain's approach consolidates these practices, along with adding some additional testing, and structures it in such a way that it results in a more thorough understanding of the forecast and potentially a more accurate prognosis. In addition, he argues that "one of the key aims of the 3- (or 4-)stage approach is to promote institutional learning." (Smith, Bain & Kanowski, 2011, p.46). This idea of creating a more transparent environment for forecasters to share data was prevalent throughout the recommendations section and it would almost certainly drastically improve traffic forecasting results. Knowledge of how forecasts respond over the long-term is likely to continue improving the forecasting process and the analysis and documentation such post-modelling activities provide will further feed into this improvement.

7. Conclusions

The recommendations in Section 5 largely fit within the structure of Section 6, although some of the recommendations relate to the pre-modelling framework rather than this post-modelling world. The primary two results in their simplest forms are that: 1) all assumptions should be informed by as much information as possible and tested in a variety of ways across different stages of the forecast and 2) even if a forecaster has absolute confidence in his or her assumptions there is still inherent variability across the forecast and as much information regarding how this variability could affect the results as possible should be provided to stakeholders and potential investors.

With respect to 1), assumptions surrounding basic modelling, specific inputs, behaviour of road users and any other aspect of the forecast where the forecaster must decide something should be examined carefully. These assumptions need to be as grounded in reality as possible. Consequently, forecasters should rely on expert knowledge, historical data and best practices as much as possible. In addition, other forecasts are potentially the best resource for future predictions of traffic behaviour so forecasters should look to others for insight as well as ensuring transparency and accessibility in their own work.

With respect to 2), whether it is simply confidence bands being placed on the results such as in Stage 1 of Bain's post modelling procedure or more detailed sensitivity checks of the results, as much information as possible with respect to the potential variability of results should be provided. This is particularly important to investors and project financiers since it has a direct impact on project profitability.

Part of the problem in getting forecasters to be more prudent and follow these practices is the inherent risk-seeking incentive created by the project bidding process. All forecasts have inherent uncertainty to them, and the process through which the forecaster attempts to estimate both the general environment as well as how that environment will respond and adapt to the introduction of a toll is fraught with potential errors. But beyond that, if a company wants to acquire a contract then there is a competitive incentive to inflate their bid, potentially creating a winner's curse, and likely reducing forecast accuracy as a result. Governments too have an incentive to accept a bid that projects higher traffic volumes and revenues. A toll project becomes a lot more politically palatable when the benefits are presented as clear and considerable. As Bain says "errors arise from the not insignificant yet commonly understated forecasting challenge. Bias derives from strategic game-playing designed to win potentially lucrative long-term contracts." (Bain, 2009a) If forecasts are able to avoid the bias toward optimism and abide by the above results in order to reduce and respond to forecasting errors, they may provide a much more informed determination of toll road forecasting accuracy - and hopefully an improved one as well. There is no doubt that forecasting accuracy has been noticeably poor in the past; however, some projects are endowed with more risk than others and as long as that risk is noted and accounted for by the forecaster then a result far different from a predicted base case is not as devastating. Prediction error is not necessarily a problem if it itself can be predicted or anticipated. The task of building such forecasts will require additional effort and an adjustment to standard forecasting practices. It will require the integration of econometric and statistical analysis, traffic models, engineering, planning, and financial analysis. And if we treat a forecast as a multidisciplinary effort, integrating the skills and perspectives of economists, engineers and others, it will only strengthen the connection between that forecast and the world it is trying to predict.

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