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Stochastic risk in forecasting vs. policy oriented uncertainty: the case of alpine crossings

Julien BRUNEL¹

Abstract : This paper focuses on uncertainties in traffic forecasting. Three major sources of uncertainties are observed for freight demand models. The first one is the model specification itself. We are not interested by it. The second one concerns uncertainties over forecasting hypotheses. A mean to control such uncertainties lies in the introduction of risk in the Costs Benefits Analysis (CBA). Two directions have been taken by this research. The first one is the theoretical framework of CBA under uncertainty mainly developed after Dixit and Pindyck (1994). The second one is more empirical and uses Monte Carlo simulations. Major results of these researches are presented. Then, we apply them to a large transport investment simulation. These tools cannot be used for all kinds of uncertainties. The second part of this paper deals with the third source of uncertainties i. e. policy oriented uncertainties. For them, previous methods are useless. The current Alpine crossings context shows that transport policy is a major determinant of traffics. Furthermore, long term forecasting cannot exclude the possibility of changes in transport policy. This uncertainty should be controlled. It is the role of strategic modeling.

Keywords: Risk, uncertainty, traffic forecasting, Monte Carlo simulation, transport policy, Strategic models, Alpine crossings.

¹ Laboratoire d'économie des transports, Université Lumière Lyon 2 – 14, av. Berthelot – 69363 Lyon cedex 07
– julien.brunel@let.ish-lyon.cnrs.fr.

Introduction

Risk analysis in practice recently gives up to a consistent literature in the field of transport economics. Skarmis and Flyvbjerg (1997) review some of them and compare observed costs and traffics to forecasted ones for seven large transport infrastructures in Denmark. They conclude that costs overruns are common. In their sample, more than an half of transport infrastructures have known a 50% or more costs overrun. Traffics forecasting is not more reliable. A traffic overestimation of 50% or more is observed for two thirds of them. Later, Bruezlius et al. (2002) prolong this review and arrive to the same conclusion over the frequency of traffics overestimation and costs overruns. Flyvbjerg et al. (2003) are interested by cost overruns. In their 258 transport infrastructures sample, costs overruns concern nearly 90% of investments with a mean of 28%. The probability of costs overrun is statistically significant. They also show that costs escalation is more frequent for railway projects than for road ones. Neither geographical location nor realization date are significantly involved in costs overruns.

In a sample composed by five Dutch and three Finnish projects, Nijkamp and Ubbels (1999) do not see such underestimation of costs when they only look upon infrastructure costs evolution during the realization period. For them, costs overruns are mainly explained by the rise of prices or extensions and changes of the initially forecasted project. In France, a Cour des Comptes audit (Cour des Comptes, 1999) assumes that traffics forecasts for French highways were not so far from observed traffics. This can be explained by the fact that French central administration implemented since the start of toll highways realizations during the 70s pertinent demand models.

Generally, these before and after surveys explain that it is unrealistic to exclude traffics overestimation or costs escalation. Stated differently, it shows that a transport investment is not a risk free exercise. Furthermore, the difference between the observation and the forecasts is not insignificant. Economic evaluation is however a method that does not traditionally include uncertainties. The standard

methodology of investment evaluation also called the Costs Benefits Analysis (CBA) compares forecasted revenues of an investment to its expected costs. The difference between discounted expected revenues and costs gives the Net Present Value (NPV) of the investment. The investment has to be realized as soon as NPV is positive.

As traditional CBA does not include risk analysis, many researches have developed models of investments evaluation under uncertainty. The purpose of this paper is to go back on these researches. In a first part, we show what kind of uncertainty can be included in the CBA. One can in effect distinguish three major sources of uncertainties for traffics forecasting models. The first one concerns the model specification itself. It deals with the ability of making a pertinent, consistent demand model or, in other words, with the epistemological issue of the reality representation. In this article, we leave this issue. The second major source of uncertainty concerns the hypotheses made over the evolution of the system. For freight demand models, it is now well known that one of the major determinant of traffic growth is the industrial growth. A prevision model built on this assertion has to formulate hypotheses over economic growth. These hypotheses can appear wrong *ex post*. This kind of uncertainty can be treated in an economic evaluation. One can assume that industrial growth dispersion in the past will be the same in the future. We speak about a stochastic risk because, thanks to past observations, one can turn this uncertainty into a probabilistic distribution of events.

The third issue for uncertainties in forecasting is the policy oriented uncertainty. We no more speak about stochastic risk because alternative policies cannot be associated to a probabilistic distribution of events. So, this kind of uncertainty cannot be controlled using above tools. This risk is however important. Traffics are in effect sensitive to the legislation and political changes cannot be excluded for long term forecasts. Strategic modeling is often used to control such uncertainties. The Alpine crossings context will help us to illustrate our purpose.

As long as this paper goes, we are also sensible to the institutional changing context of transport investments. In Europe, the European Commission supports the idea of Public-Private Partnerships

(PPPs) (European Commission, 2001). This kind of partnership is also held up elsewhere in the world. It then will be useful to keep these institutional changes to study forecasting uncertainties.

How can we conciliate CBA and risk?

This first part reviews several attempts of CBA modeling under uncertainty. The introduction of uncertainty in CBA permits a renewal of this research field. A first attempt lays with Arrow and Lind's model. Its conclusion is however no more consistent in the current privatization context of transport infrastructures. It then leads to two techniques that conciliate risk and CBA: empirical simulations based on Monte Carlo procedures and a theoretical renewal of CBA under uncertainty. These procedures are illustrated by a simulation.

CBA under Uncertainty: A Review

In a famous paper, Arrow and Lind (1970) introduces uncertainty in the public investment evaluation. Their model supposes an investment with an uncertain net benefit. Its net benefit is equal to $\bar{B} + X$ where \bar{B} is the expected net benefit and X a stochastic term with a zero mean. A private agent will invest if the expected net benefit is superior to the cost of risk (stated k_X) or if $\bar{B} > k_X$. If not ($\bar{B} < k_X$), the investment will not occur.

If the investment is undertaken by the state, the return of the investment is shared by every taxpayers. It then becomes $(\bar{B} + X)/n$ for each of the n taxpayers. The corresponding risk cost is stated $k_{X/n}$ for each taxpayer and it is $n \cdot k_{X/n}$ for the collectivity. Arrow and Lind then demonstrate that, for large n , $k_X > k_{X/n}$ and that $\lim_{n \rightarrow +\infty} (k_{X/n}) = 0$. They show that the cost of risk is always superior for a single private agent than for a large number of taxpayers. It is then optimal to share the cost of risk among a

large number taxpayers. Furthermore, in some cases, it can occur that $k_x > \bar{B} > k_{x/n}$ where the investment will be undertaken collectively whereas it will not be by a single private agent.

This model explains that in presence of uncertainty over benefits, it is optimal to have a publicly financed investment. This result is however contested by the changing institutional context of transport investments. More voices support the use of private funds to finance transport infrastructures. Private funds seem in effect more efficiently used than public ones (Malatesta and Dewenter, 2002). The scarcity of public funds is furthermore amplified by a slowly economic growth and, in European Union, by Maastricht criteria over public deficits. The economics of transport infrastructures is then moving from the public good analysis where roads are paid by the state to the club-good analysis where there are paid by users (Gomez-Ibañez and Meyer, 1993). PPPs, as mentioned before, are illustrative of these changes.

In a context of privatized transport infrastructures, risk becomes a major concern for private investors. In parallel, CBA under uncertainty have recently known major improvements. Two directions were followed by these researches.

The first one is the application of Monte Carlo simulations in CBA. This was for instance purposed by Tsamboulas et Kapros (2003) to evaluate a freight village financial viability. This simulation concerns the value of three parameters: the investments costs, the revenue and forecasted volumes. The distribution of these parameters is obtained by a Delphi method. Monte Carlo simulations are also used by many risk simulation software (@Risk, Crystall Ball², Riskease³ or Infrisk⁴). This method needs a probability distribution of model parameters. It is why *ex post* evaluations of projects have such a crucial importance. This direction has an empirical concern and it has been developed since the implementation of risk analysis software using Monte-Carlo procedures.

² A free demonstration version is available online at www.decisioneering.com.

³ A free demonstration version is available online at www.riskease.com.

⁴ Information online at www.worldbank.org/wbi/infracin/infrisk.html.

The other direction of these researches purposes to introduce uncertainty in CBA from a theoretical point of view. This way has mainly been explored by Dixit and Pindyck (1994). In the transportation field, Chu and Polzin (2000) give an empirical application of the optimal timing investment rule under uncertainty. We go back over the major results of this literature

Dixit and Pindyck (1994) build the theoretical framework to include uncertainty in CBA. Their main purpose is to represent the benefits of the investment thanks to a geometric Brownian. This process can be written

$$dB = \alpha B dt + \sigma B dz$$

where B is the benefit, α the annual rate of growth of B , σ^2 the variance of future benefits and t the time. α and σ are fixed. dz is a simple Brownian motion as $dz = \varepsilon_t \sqrt{dt}$ with ε_t following a standard normal distribution.

Assuming that the cost of the investment, noted K , is fixed and known ex ante, NPV can be written

$$NPV(t) = [V(t) - K] e^{-\rho t} \quad (1)$$

where ρ is the discount rate and $V(t)$ is the value of the project given by $V(t) = B(t)/(\rho - \alpha)$ (Dixit and Pindyck, 1994). Then, Dixit and Pindyck show that, under uncertainty, it is optimal to invest when the project value is over the critical threshold $V^* = (\beta / (\beta - 1))K$ with $\beta = 0.5 - \alpha / \sigma^2 + \sqrt{(\alpha / \sigma^2 - 0.5)^2 + 2\rho / \sigma^2}$. The optimal timing to invest is

$$t_u^* = L\eta[C_u(K / V(0))] / \alpha \quad (2)$$

where $C_u = (\beta / (\beta - 1))$ (Chu and Polzin, 2000).

Under certainty of future cash flows, NPV maximization leads that it is optimal to invest when the ratio between the value and the costs of the investment is upper than the threshold $C_c = \rho / (\rho - \alpha)$.

The optimal timing is then (Chu and Polzin, 2000).

$$t_c^* = \ln[C_c(K/V(0))] / \alpha \quad (3)$$

This analysis differs from standard CBA. Indeed, the last one explains that it is optimal to invest when NPV becomes positive. The following simulation will show that it gives different solutions.

An application to a large transport investment

We apply this model to a simplified representation of a large transport investment. This project should represent the railway project between Lyon and Torino. Following parameters are used. The total cost of the project is $K=10000$ k€, expected benefits in $t=0$ are $B(0)=250$ k€, the rate of benefits growth is $\alpha=0.05$, the discount rate is $\rho=0.08$ (it is the French official discount rate value).

These parameters correspond to an optimistic forecast of the Lyon-Torino project. It gives an internal rate of return (IRR) of almost 5% against 2 or 2,5% according to the latest economic evaluations of the project (LTF, 2003). It can be explained by two phenomena. This model supposes a geometric growth of benefits. It is rarely the case for railway project. This hypothesis is however limited by the discount rate. Furthermore, the model supposes that benefits immediately follow the investment. In reality, a long period separates them due to the building time. For a major transport investment, it is not unusual to verify between these two dates a period of almost ten years.

Using such values, we apply above equations to solve the NPV maximization problem. If we first assume that there is no uncertainty over future benefits, then optimal timing to invest is 23 years (equation 2). The previous graphic shows NPV depending on the investment date. It is interesting to realize that NPV is positive since the fourth year. Waiting increases NPV until it reaches an optimum almost twenty years later.

Under uncertainty, optimal timing to invest is 27 years (equation 3). It is optimal to invest four years later if we take into account uncertainty. This is one of the most important conclusion of this literature. The introduction of uncertainty leads to postpone the investment because optimal timing to invest

under uncertainty is always later than optimal timing under certainty. Here, it is shown empirically. Dixit and Pindyck (1994) demonstrated it formally.

In order to illustrate the evolution of NPV under uncertainty, a simulation is made. It can be reported to the other direction taken by CBA to include uncertainties with Monte Carlo simulations. The model is modified. We assume a continuous linear growth of benefits. The growth is noted α . NPV of the investment under certainty depends on the investment timing:

$$NPV(t) = \int_t^{+\infty} (B + \alpha\theta) e^{-\rho\theta} d\theta - Ke^{-\rho t} \quad (4)$$

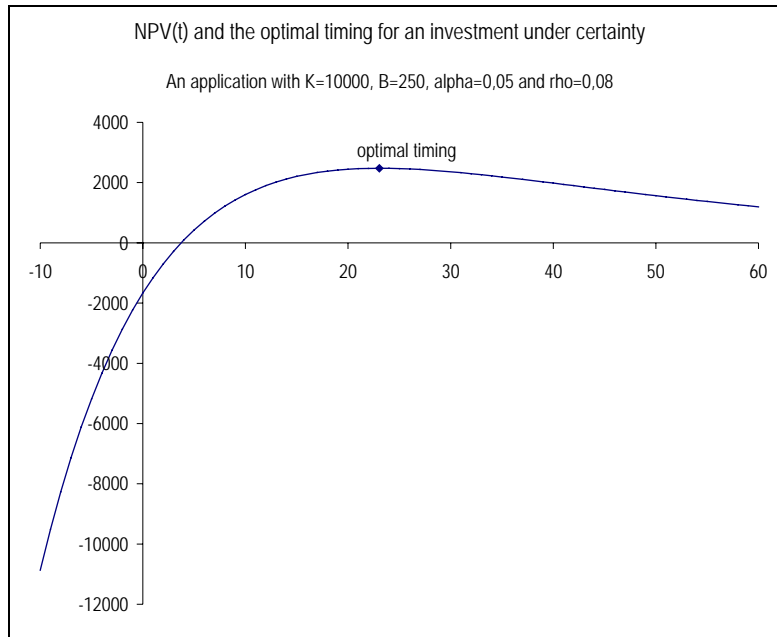
where B is the benefit in $t=0$, K the investment cost and ρ the discount rate. The equation (4) is developed:

$$NPV(t) = \left[\frac{Be^{-\rho\theta}}{-\rho} + \frac{\alpha\theta e^{-\rho\theta}}{-\rho} + \frac{\alpha e^{-\rho\theta}}{-\rho^2} \right]_t^{+\infty} - Ke^{-\rho t} \quad (5)$$

Then,

$$NPV(t) = \left[B + \alpha t + \frac{\alpha}{\rho} \right] \frac{e^{-\rho t}}{\rho} - Ke^{-\rho t} \quad (6)$$

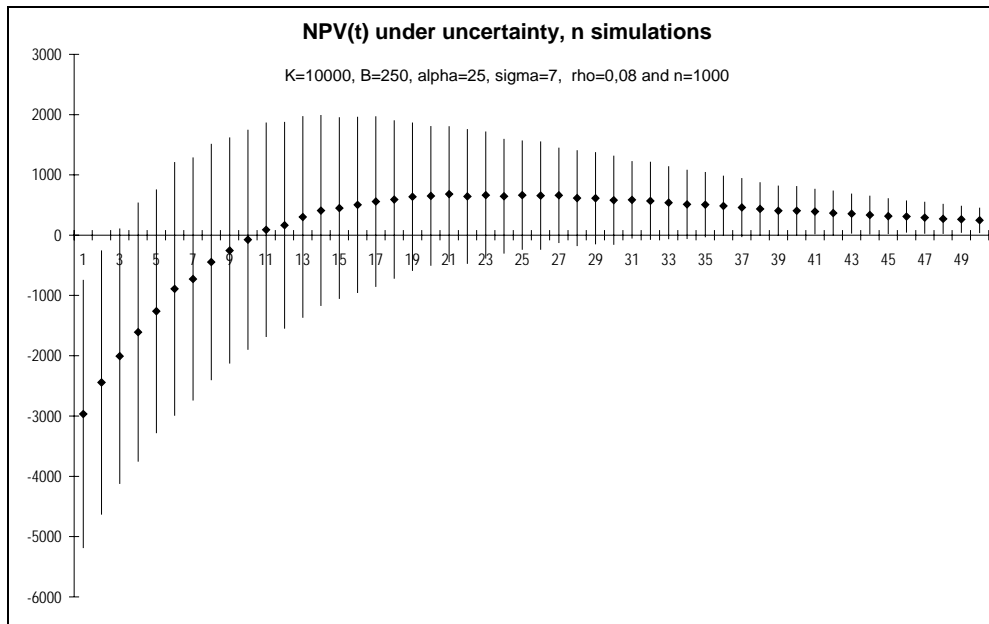
This equation is represented by the following graphic.



Parameters value is the same than in the previous simulation except for the (now linear) growth of benefits. We take $\alpha=25$. According to this graphic, optimal timing to invest under certainty is $t^*=25$ years. Then, a Monte-Carlo procedure is implemented on this model. It is modified with the introduction of a stochastic component. Uncertainty concerns the growth of benefits. We suppose that benefits can be written $B(t) = B + (\alpha + \sigma\varepsilon_t)t$ where $\varepsilon_t \sim \mathcal{N}(0,1)$. The second term of the addition under brackets represents the stochastic component. Equation (6) then becomes

$$NPV(t) = \left[B + (\alpha + \sigma\varepsilon_t)t + \frac{\alpha + \sigma\varepsilon_t}{\rho} \right] \frac{e^{-\rho t}}{\rho} - Ke^{-\rho t} \quad (7)$$

The simulation lies in the generation of one thousand ε_t following a Standard Normal distribution. It is made for each year until $t=49$. It is supposed that $\sigma = 7$. The following graphic reproduces the results of these simulations. It represents for each year the mean of the simulations and its 95% confidence interval.



This graphic illustrates advantages to postpone an investment after its certain benefits optimal timing when uncertainty is introduced. As long as time passes, even if expected NPV is decreasing, the 95% confidence interval is reduced or, stated differently, uncertainty decreases. For instance, one should notice that the 95% confident interval always gives a positive NPV in $t=39$ years.

This part shows two means to control uncertainties in CBA. It illustrates that the introduction of uncertainty in CBA is possible. Uncertainty produces a cost of risk. It leads to invest later than in an hypothetical certain future world.

This analysis is however restricted by a limited risk inclusion. Monte-Carlo simulations or the theoretical analysis of CBA under uncertainty only cover the risk on model parameters (i. e. costs or benefits). It does not include risk over exogenous parameters and, among them, policy oriented uncertainties. Policy oriented uncertainties means uncertainties that concern the transport policy. It is the issue developed in what follows.

What kind of uncertainties cannot be included in CBA?

Policy oriented uncertainties are significant. For instance, transport policy has a great influence over modal split because of the legislation or the taxation. The importance of transport policy over traffics is the first concern of this part. It is illustrated by the Swiss transport policy over the Alpine crossings. Then, it is shown that this kind of uncertainty plays a new role in the context of transport infrastructure privatization. As the investor is no more the state, he is not handling transport policy. Policy uncertainties represent a real risk for a long term investment. Unfortunately, there are few means to control them. Strategic modeling is the more obvious one. This kind of models is presented.

Policy Oriented Uncertainties

Transport policy is one of the main long term determinant of traffics. Alpine crossings current context clearly shows it. Since 2001, Switzerland progressively abandons a restrictive rule over road transport prohibiting the circulation of more than 28 tons trucks. It has been substituted by a new taxation scheme. This scheme is composed by two main taxes. The first one is a specific tax over trucks in transit by Swiss paid on major road passes (the so-called Taxe sur le Transit Alpin or TTA). The second is a load and distance function tax paid by all trucks circulating in Switzerland (the Redevance Poids Lourds liées aux Prestations, called RPLP). The implementation of this new scheme should be responsible for changes in flow assignments over the Alps.

The former Swiss regulation transferred many Alpine traffics from their “natural” Swiss passes to Austrian or French ones. Recent changes of Swiss transport policy will certainly end this situation. Three studies should be mentioned. The first one (SES, 1997) was made by the French statistical department of Transport Ministry (Service d'économie et de statistiques, called SES). It supposes that, without Swiss restrictions over more than 28 tons trucks, these last ones would follow the same itineraries than less than 28 tons trucks. The impact of Swiss policy is then assessed comparing this

theoretical no rule situation with the observed distribution of flows. This study estimates that 460 000 evicted vehicles transit by France, 310 000 by Austria and 40 000 by the Swiss rolling road. This study does not consider other Swiss rules applied to all road traffics as the night circulation prohibition. It is why it could be seen as a low evaluation of Swiss policy impact.

A second study also made by the SES (Meteyer, 2000) proposes a more sophisticated traffic affectation model including both more than 28 tons trucks and night circulation prohibitions. It estimated that 1,5 millions of more than 28 tons trucks are evicted from Swiss passes. Two thirds of them take French passes, the others Austrian ones.

A third work is made by Belgian researchers thanks to the multi-modal multi-products network model NODUS (Beuthe et al., 1999). This study estimates that 25 millions of tons are transferred from Switzerland to France or Austria. 11 millions of them pass through France and 14 by Austria.

Traffic transfer from Switzerland

	France	Austria
SES, 1997	9,2 Mt	10,2 Mt
Meteyer, 1999	20 Mt	10 Mt
Beuthe et al., 1999	11 Mt	14 Mt

Note: The value of 20 tons loaded per vehicle is used to convert vehicles into tons

The last two studies also simulate the effects of the new Swiss taxation scheme. The first one esteems that French and Austrian crossings should respectively loose 400 000 and 500 000 trucks. The second studies estimates that depending on the level of the RPLP level, French and Austrians passes can respectively loose from 1 to 4 millions tons and from 1 to 5 millions tons of traffic volume. According to them, policy changes in Switzerland should reduce French or Austrian crossings traffic volumes by 20%.

Transport policy is therefore a major determinant of traffics. If the investment is public, policy risk should not be considered as a risk because the investor is also the decision maker. One should however

nuance this idea. The democratic nature of occidental political systems introduces a kind of uncertainty over future transport policy even for public investments. Switzerland is a direct democracy. Citizens are allowed to decide political orientations by popular initiative referenda if 50 000 signatures are collected in its support. Such referenda are frequent even for transport infrastructures related issues. It increases policy oriented uncertainties. Furthermore, Maggi (1992) underlines that, unless Switzerland has a crucial location in Europe, Swiss transport policy is dominated by local issues.

For private investments, policy oriented uncertainties are even more obvious. The investor has no right in decision-making. Moral hazard situations are likely to occur between the investor and the decision-maker (i. e. the politician). For long term infrastructures, PPPs viability asserts credible agreements between politicians and private investors. These agreements should try to control this kind of uncertainty. From the economist point of view, it is also hard to deal with such uncertainty. Political alternatives are not probabilistic events. We cannot introduce it in CBA. One can however test traffic sensitivity to transport policy. A common tool for it lies in strategic modeling. It is the issue of the next part.

Strategic Modeling: a short overview

Strategic modeling should be a mean to control this specific uncertainty. By strategic modeling, it means long-term multi-modal models of transport demand. This meaning is often given in the literature (Crainic and Laporte, 1997). A short review of freight strategic models shows that these long-term models are often used to simulate traffic sensitivity to policy alternatives.

Among freight strategic models, we should notice STAN model (Guélat et al., 1990). This model is a strategic network model in which costs are assigned to every nodes and every links. Costs include fixed, transport and delays costs. This model has been applied several times. It has been used to assess the impact of the realization of a large railway link in Brazil (Crainic et al., 1990). It has also been applied to simulate the impact of alternative policies over multi-modal transport at the occasion of the

European research program STEMM (1999). Other applications of STAN are national freight models in Norway (NEMO), Sweden (SAMGODS), Canada or Finland.

Otherwise, these recent years, several European research programs contribute to develop other strategic models. STREAMS (2000) program develops a strategic model for both passengers and freight transport. It is applied to a 2020 reference scenario and modelers mention that this model can be run for other policy scenarios. PETS (2000) uses a strategic model to evaluate the impact of a social marginal cost pricing over modal split in several European contexts.

In France, the Quinquin Freight Model (Gabella-Latreille, 1997) is a national multi-commodity strategic model conceived as a help for decision-making. This model focuses on traffics elasticity to industrial production and on the influence of prices and delivery time on modal split. It simulates several alternative policies.

This short review of major strategic models shows that there are often conceived as a help for decision-making. It is however useful to keep in mind that strategic modeling can be used to control policy oriented uncertainties. It should be a mean for private investors to reduce the risk of moral hazard. Such models still have a great role to play for long term forecasts.

Conclusion

In this paper, uncertainties and CBA are discussed. In the first part, we point what kind of uncertainty can be included in CBA. Uncertainty must be turned into a probabilistic distribution of events. It could be easily made for uncertainty among costs or revenues. Before and after evaluations of transport infrastructures can give the necessary probabilistic distribution of events. Two directions have been followed by this analysis. The first one is more concerned by a theoretical integration of uncertainty in CBA. The second has an empirical focus and applies Monte Carlo procedures. Then, a simulation is purposed for a large transport infrastructure. Both methods are used.

This analysis however excludes exogenous parameters from this risk analysis. It does not prevent from unpredicted shocks. A crisis like the 1973-1974 oil shock cannot be anticipated by this methods. Policy oriented uncertainties are no more included by this risk analysis. It is emphasized in it in the second part of this paper.

Transport policy is a long term determinant of traffics. Alpine crossings show this with Swiss current transport policy. In a context of transport infrastructures privatization, this kind of risk is even more significant. Means to control such uncertainties are few. Strategic modeling is then introduced. This long term kind of models allows to evaluate traffic sensitivity to transport policy. It is possible to simulate the effects of contrasted policies. This kind of models were traditionally used as a help for decision-makers. They can also provide a tool for risk management.

This paper gives an overview of uncertainties in forecasting. Two major sources of uncertainties are explored. Tools to reduce these two kinds of uncertainties are presented. It is however only an overview and these crucial issues certainly need demand far more attention. Moreover, strategic modeling is only introduced. Our current work is precisely the elaboration of an Alpine strategic model.

The context of transport infrastructures privatization is also mentioned. It is shown that it is possible to control uncertainties over costs or revenues. On the contrary, policy uncertainties are difficult to control with CBA. Strategic modeling should help to understand traffic sensitivity to transport policy. It would be useful to see how does this kind of uncertainty is controlled by private investors. The increasing number of PPPs procedures affords case-studies opportunities. One should then observe if PPPs agreements explicitly mention policy oriented uncertainties and how risk is shared among the two partners.

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