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Abstract

The assessment of infrastructure investments is often affected by inaccuracy in traffic forecasting, optimism bias and overvaluation of expected benefits. In general, even when such misrepresentation is not strategically introduced by proponents to push their projects, valuators and decision makers must cope with the existence of a risk of demand levels below expectations and consequent problem of overinvestment.

In this sense, the concept of option value suggests that flexible or reversible projects may have a higher economic net present value compared with rigid schemes characterised by sunk costs. However, conventionally used cost benefit analysis (CBA) is very seldom used to manage such problem due to the complexity of the issue (for example when introducing a complete risk analysis). Moreover, such CBAs are still conceived as a static tool to decide ex-ante about an investment.

In this paper we develop a theoretical framework and a practical application of CBA to formally manage such uncertainty and help the decision makers by postponing some decisions to the following running phase. The idea is to assess the project as split into smaller functional sections and bind the construction of a further section to the compliance of a pre-determined "switching rule". In practical terms, we adapt a normal CBA procedure to manage also the time dimension of time of investments to reallocate risks already in the early design stage of transport infrastructures.

The purpose of the paper is twofold. Firstly, we introduce a way to extend conventional CBA methodology to manage the phasing of projects. Secondly, we demonstrate both theoretically (with a simplified model) and practically (with a more complex case study) the positive effect of phasing under certain conditions (limitedness of sunk-costs due to phasing, predominance of capacity problems). By numerically developing the CBA of the Turin – Lyon high speed rail project, we show how to reduce the risk of overestimation of traffic and its positive effect in terms of NPV of the project: if forecasts are optimistic, only the most effective parts of the scheme will be built. If the traffic forecasts are correct, the new infrastructure will be built as a whole in steps and will generate the highest net benefits.

Keywords: cost benefit analysis, option value, optimism bias, strategic misrepresentation, benefit shortfall, planning fallacy, forecasting

1. Introduction

The assessment of infrastructure investments is often affected by inaccuracy in traffic forecasting, optimism bias and overvaluation of expected benefits. In general, even when such misrepresentation is not strategically introduced by proponents to push their projects, valuators and decision makers must cope with the existence of a risk of demand levels below expectations and consequent problem of overinvestment.

In their broad work in the field, Flyvbjerg et al. (2003) analyse in deep the issue of inaccuracy in traffic forecasting in megaprojects, together with the specular issue of cost overruns. They found that in large-scale rail projects actual traffic is on average 51.4% lower than expected (with a standard deviation of 28.1), while large-scale road projects experience an actual traffic 9.5% higher than expected (with a standard deviation of 44.3). In analysing the possible causes of such inaccuracies, Flyvbjerg (2008) rejects conventional technical explanations of bad forecasting techniques, as these would result in normally or near-normally distributed errors with an average near zero. Instead he suggests that psychological (optimism bias) and political-economic explanations (strategic misrepresentation) better account for inaccurate forecasts. An approach to bypass both optimism bias and strategic misrepresentation is proposed: starting from the work of the Princeton psychologist Daniel Kahneman, who won the Nobel prize in economics in 2002, Flyvbjerg proposes to develop *Reference Class Forecasting*. A reference class forecast of a given planned project is based on knowledge about actual performance in a reference class of comparable projects already carried out. By the identification of a (broad enough and statistically significant) reference class of past projects, this places the project in a statistical distribution of outcomes from the class of reference projects. This methodology is thus very simple, but – as the author states – *"the real challenge in doing a reference class forecast lies in assembling a valid dataset that will allow a reliable forecast. Such datasets are rare in real-life policy-making and planning."*

The high uncertainty in transport forecasting is strongly linked with the concept of option value, analysed in deep by Dixit & Pindyck in 1994. They suggest that flexible or reversible projects may have a higher economic net present value compared with rigid schemes characterised by sunk costs, because there is a value in waiting to invest when it allows to adopt a better decision on the basis of more information.

Chu & Polzin (2000) gave an important contribution in the field of timing rules for investments, starting from the transport literature on investment timing (e.g. Szymanski, 1991 and Chu & Polzin, 1998) and from the economic literature on the timing of irreversible investments under uncertainty (e.g. McDonald & Siegel, 1986 and Dixit & Pindyck, 1994). In their work they provide a set of analytical rules for timing major transport investments; they demonstrate that, even in conditions of (relative) certainty on traffic forecasting, the "build now" solution may not be the one that provides the higher net present value.

It is thus apparent that the problem of uncertainty, and the consequent possible value of waiting to invest, has been already deepen in the transport and economic literatures. However, cost benefit analysis (CBA) is very seldom used to manage such problem due to the complexity of the issue (for example, when introducing a complete risk analysis) and the large amount of required data. Moreover, such CBAs are usually still conceived as a static tool to decide ex-ante about an investment.

In this paper we develop a theoretical framework and a practical application of CBA to formally manage such uncertainty and to help decision makers to calculate when postponing some decisions to the following running phase gives better value. The idea is to assess the project as split into smaller functional sections and bind the construction of a further section to the compliance of a pre-determined "switching rule". This rule, somehow innovative in theory, has been already applied in practice in a few cases. For example in the case of the Swiss Lötschberg base tunnel, opened in 2007, the second construction phase can start only when demand had reached a pre-defined level. As traffic in the first two years of operation has grown in line with the forecasting (113 trains/day versus 114, Schreyer, Sutter & Maibach, 2009[1]), the doubling of the tunnel has been planned.

In practical terms, we adapt a normal CBA procedure to manage also the time dimension of time of investments to practically reallocate risks already in the early design stage of transport infrastructures.

The paper is organised as follows. Firstly we will study a theoretical model in order to better understand the issue. Secondly, we will present the CBA of a possible "switching rule" strategy applied to the planned New Turin-Lyon Railway, a new mixed use high speed rail between Italy and France. In the end, we will derive possible reflections.

2. A theoretical case study

To better focus the issue, we make some considerations on a simplified theoretical case of new infrastructure. We look at a case of parallel phasing - easier to model – then we will make some consideration on serial phasing in the following sections.

Let's consider an infrastructure, say a tunnel, quickly connecting "A" with "B". Firstly, we simply assess a single tube version and a twin tube version of the tunnel, which provides higher capacity.

[1] Nevertheless, this effect have been achieved by compensating a minor dynamic in freight traffic (64 trains/day versus 72), partly generated by the economic crisis, with an higher increase of passenger traffic (49 versus 42).

Costs

Let I be the investment cost of the single tube of the tunnel and θ the construction time.

For the sake of simplicity, let’s assume that:

- the cost is uniformly spread through the construction period;
- operating and management costs are constant over time and equal to a k fraction of the I investment cost;
- construction starts in year 0.

The twin tube version of the same tunnel costs $2 \cdot s \cdot I$, $s \leq 1$ being the possible savings due to the simultaneous construction of both the tubes.

Expected traffic and capacity issues

Let q_0 be the expected traffic in the θ first year of operation, growing at an α annual growth rate possibly up to the saturation of the q_{MAX} capacity of the single tube infrastructure. We also make the hypothesis that the traffic will not exceed the twin tube tunnel capacity within the analysis horizon. The saturation year t_s for the single tube version can be determined by imposing $q(t_s) = q_{MAX}$. We than have $q_0 \cdot e^{\alpha \cdot [t_s - \theta]} = q_{MAX}$ and thus $e^{\alpha \cdot [t_s - \theta]} = \frac{q_{MAX}}{q_0}$. If we call f the first year traffic/capacity ratio $f = \frac{q_0}{q_{MAX}}$ of the single tube tunnel, we obtain $e^{\alpha \cdot [t_s - \theta]} = \frac{1}{f}$. The saturation year is thus simply defined by the relation $t_s = \theta - \frac{\ln(f)}{\alpha}$.

Benefits and social balance

Let’s assume the benefits to be proportional to traffic: $B(t) = b \cdot q(t)$. The twin tube version of the tunnel will just provide higher capacity with the same performances, so the yearly unit benefits b will be the same in the two cases[2].

We assume the social costs of saturation to be so high that we want to avoid them in any case by expanding anyway the tunnel as soon as it is needed.

If we call NPV_1 and NPV_2 the net present values of respectively the single tube alternative and twin tubes alternative, we obtain the quite trivial consideration that $NPV_2 > NPV_1$ if simply $t_s \leq T$, i.e. twin tube tunnel is a better alternative if saturation is expected within the analysis horizon.

Nevertheless, this does not mean that building both the tubes now is the best choice.

Building of one section after the other and introduction of a “switching rule”

Let’s now introduce a different scenario. As said, the idea is to split the project into smaller functional sections and bind the construction of a further section to the compliance of a pre-determined rule. In practice:

- We build now the first tube of the tunnel, thus having an I investment cost.

[2] This also allows us not to distinguish existing traffic (diverted from other routes) from generated traffic, which usually enjoys lower benefits. Thus the b unit benefit should be intended as an average benefit for all the users, both existing and diverted. No *rule of half* is thus needed.

- After opening the new infrastructure to operation, we check the actual q_0 traffic in the tunnel in the first year and it's α growth rate in the first years.
- We decide if and whether to build the second tube on the basis of the actual traffic volume and growth. In this case we pay the second tube I instead of $\frac{2sI}{2}$.

We will call this procedure "switching rule". In this case the rule is the reaching of the maximum capacity of the first section: we start to build the second section of the infrastructure in year t_s-θ, i.e. θ years before the first section gets saturated according to actually observed traffic and growth rate in the first years of operation.

In Figure 1 and Figure 2 we represent traffic and capacity, with respect to time in the "build together now" scenario and in the "build separate upon switching rule" scenario.

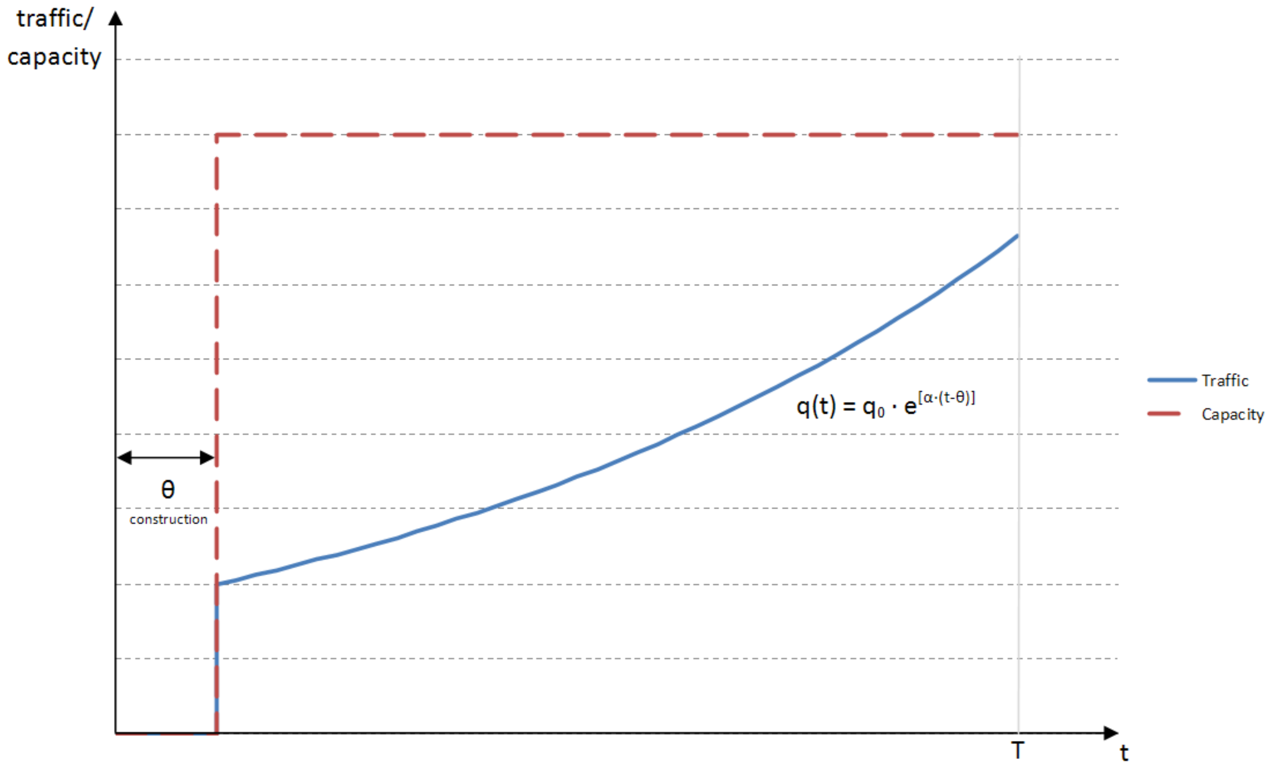

Figure 1 – Traffic and capacity in the "build together now" scenario.

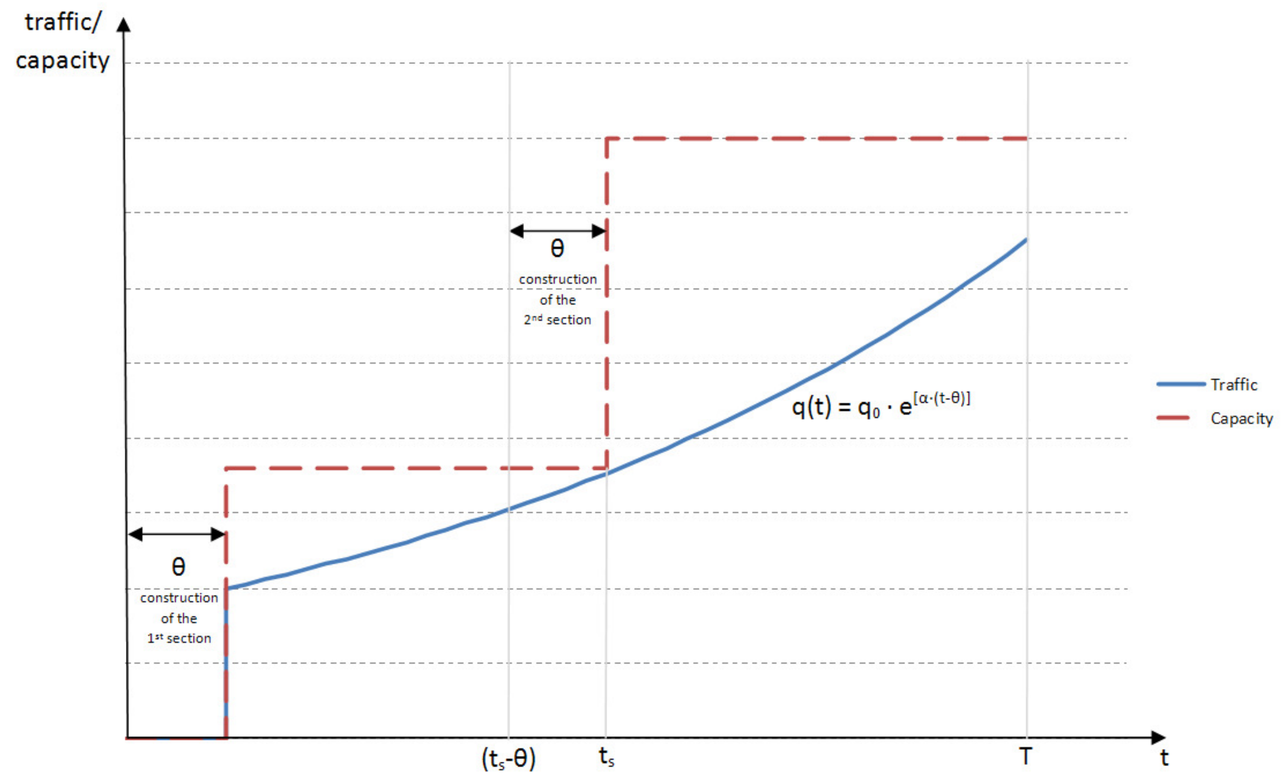

Figure 2 – Traffic and capacity in the “build separate upon switching rule” scenario.

In absolute terms, building separately the two sections will cost $2 \cdot I$ which is higher than the $2 \cdot s \cdot I$ cost of building them together; however, shifting the second part of the investment forward in time will reduce its actualised value because of the discount rate. We thus want to know for which *s* value it is better to build the two tubes together now instead of waiting, on the basis of the “switching rule”.

We define $NPV = \int_0^T [B(t) - C(t)] \cdot e^{-rt} dt$, being *T* the analysis horizon[3] and *r* the social discount rate. We then write the NPVs of the “build together now” scenario and of the “build separate upon switching rule” scenario. We are obviously considering the case of $t_s \leq T$ (otherwise the single tube is the best solution from the beginning). We obtain:

Build together now	$NPV_2 = -\int_0^\theta \frac{2 \cdot s \cdot I}{\theta} \cdot e^{-rt} dt - \int_\theta^T k \cdot 2 \cdot s \cdot I \cdot e^{-rt} dt + \int_\theta^T b \cdot q_0 \cdot e^{[-rt+\alpha \cdot (t-\theta)]}$
Build separate upon switching rule	$NPV_{2sr} = -\int_0^\theta \frac{I}{\theta} \cdot e^{-rt} dt - \int_\theta^T k \cdot I \cdot e^{-rt} dt + \int_\theta^T b \cdot q_0 \cdot e^{[-rt+\alpha \cdot (t-\theta)]} - \int_{t_s-\theta}^{t_s} \frac{I}{\theta} \cdot e^{-rt} dt - \int_{t_s}^T k \cdot I \cdot e^{-rt} dt$

[3] No residual value is considered, however this does not affect the results as it would be the same for both scenarios.

In order to know which s simultaneous construction savings value would make the “build together now” alternative preferable, we impose $NPV_2(s) \geq NPV_{2sr}$, and we obtain:

$$s \leq \frac{\dfrac{k\left(e^{-Tr}-e^{-rt_s}\right)}{r}-\dfrac{e^{r\theta}-1}{r\theta e^{rt_s}}}{\dfrac{2\left(e^{-r\theta}-1\right)}{r\theta}+\dfrac{2k\left(e^{-Tr}-1\right)}{r}}+\frac{1}{2}$$

A simpler form can be obtained if $T \to \infty$ (and $r > 0$, which is obvious); the term $e^{-Tr} \to 0$, resulting:

$$s \leq \frac{1}{2e^{rt_s}} \cdot \frac{k\theta + e^{r\theta} - 1}{k\theta - e^{-r\theta} + 1} + \frac{1}{2}$$

To better understand the result, in Table 1 we make some examples with indicative fictional values.

Parameter	Description	Case 1	Case 2 Lower 1st year traffic	Case 3 Less benefits	Case 4 Lower growth rate
I	Investment costs, single carriageway	100	100	100	100
T	Analysis horizon, (starting from year 0)	45	45	45	45
r	Discount rate	0.035	0.035	0.035	0.035
θ	Construction time, single carriageway	5	5	5	5
k	Yearly O&M costs, as a fraction of the *I* investment costs	0.01	0.01	0.01	0,01
q_0	First year of operation expected traffic	10	<u>5</u>	10	10
q_{MAX}	Capacity of the single carriageway	15	15	15	15
α	Expected traffic growth rate	0.03	0.03	0.03	<u>0.02</u>
b	Unit benefits	1	1	<u>0.5</u>	1
$f = q_0 / q_{MAX}$	First year flow/capacity ratio	0.67	0.33	0.67	0.67
$t_s = \theta - \ln(f)/\alpha$	Saturation year, single carriageway	18.52	41.62	18.52	25.27
$NPV_2(s)$	Build together alternative NPV	304.3 - 228.8*s	152.2 - 228.8*s	152.2 - 228.8*s	252.5 - 228.8*s
NPV_{2sr}	Switching rule alternative NPV	123.7	11.57	-28.42	87.1
s	Maximum cost for build together to be better, as a fraction of build separate cost	0.79	0.61	0.79	0.72

Table 1 – Fictional examples of maximum build together costs for the “build together now” alternative to perform better than the “build separate upon switching rule” alternative. Underlined values change among the cases.

The s parameter in the last line says that with the given numbers, phasing is better unless a joint construction allows savings of more than 20 to 40%. In general, even when a negative NPV is expected, a “switching rule” strategy can better perform if sunk-costs due to phasing are limited. As we will see, this seem to be the case of the New Turin-Lyon Railway analysed in the following section.

Uncertainty and sensitivity analysis

We have seen that planning infrastructures as split into smaller functional sections on the basis of a “switching rule” can provide net benefits, due to discount rate, if the construction costs don’t rise too much due to phasing. However, this is probably not the most important advantage of a “switching rule” strategy. Transport literature suggests traffic forecasts to be often overestimated for many different reasons: sensitivity analyses play thus a central role in transport project appraisal and the performance of the "build separate upon switching rule" scenario increase considerably if we perform a sensitivity analysis on traffic forecasts.

Let us consider the Case 1 in Table 1. We fix $s = 0.8$ (i.e. building both tubes together costs 80% than building the tubes separately, in absolute terms) and we perform a sensitivity analysis with respect to the q_0 first year traffic and another one with respect to its α growth rate. We obtain the NPV curves, for the build-together alternative and for the switching-rule alternative, represented in Figure 3and in Figure 4.

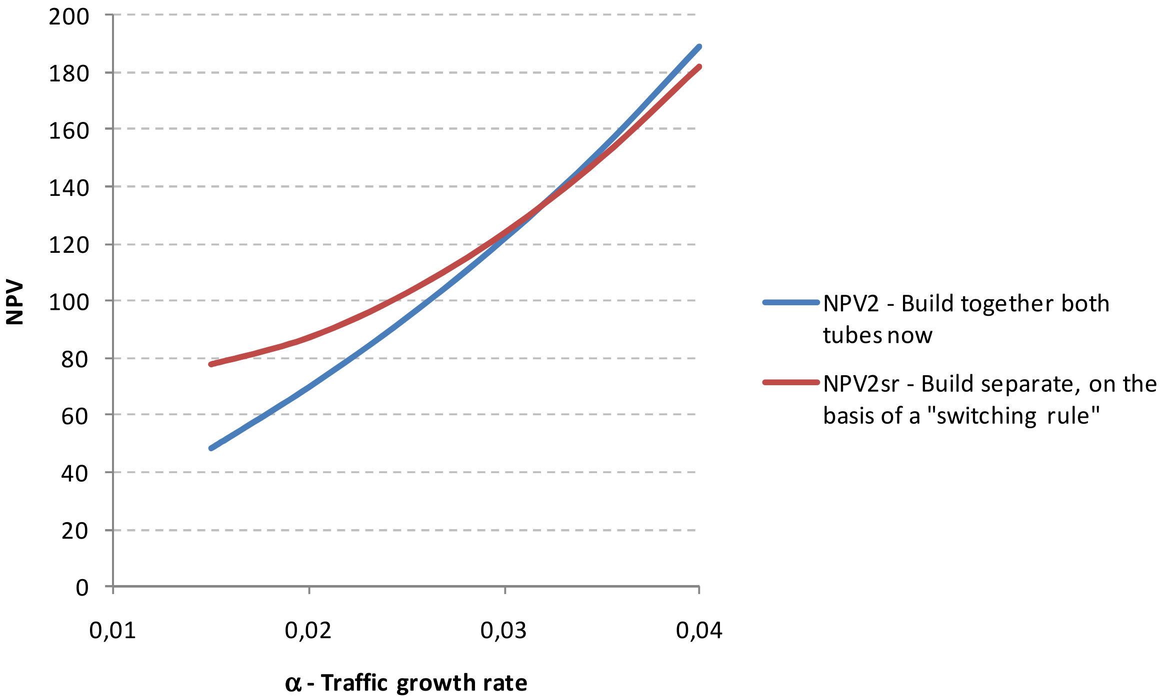

Figure 3 – Variation of NPV net present value of the "build together now" and "build separate upon switching rule" scenarios with respect to the α traffic growth rate.

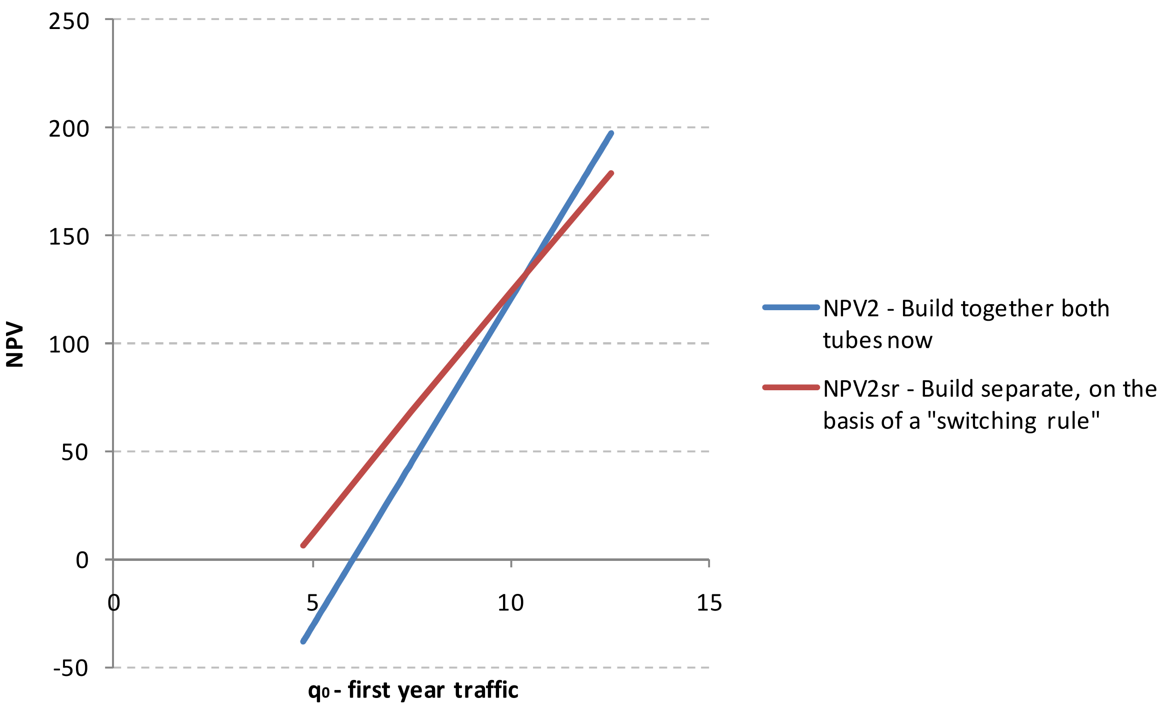

Figure 4 – Variation of NPV net present value of the "build together now" and "build separate upon switching rule" scenarios with respect to the q_0 traffic in first year of operation.

It is quite easy to understand that if actual traffic is lower than expected, a "build separate upon switching rule" strategy performs better, because it allows to shift the decision of building the second section of the infrastructure when it is really needed, allowing to save costs in actualised terms. If traffic forecasts were particularly bad, for example because of major external factors like global changes in the economical context, a "switching rule" strategy could lead to completely reconsider the second section, thus allowing significant public resources savings. In general, we could apply to the previous analyses a probability curve of the variable, like the ones in Flyvbjerg (2003). As all probabilty curves tend not to be normal, but overoptimistic, the option value associated to the "switching rule" scenario is higher.

It is clear that reality is quite more complex than the simple case analysed here. For example, if additional capacity is not the main expected benefit and if we are considering serial phasing, there could be incremental benefits for each built section and, through elasticity, also incremental generated demand. However, gaining information from the demand response in the first phase can still help in better plan the second phase (for example, by better calibrating the traffic model). This could be again the case of the New Turin-Lyon Railway, analysed in the following section.

Summary of theoretical findings

In this section we built a simple theoretical model to manage three different scenarios and calculate the respective NPV: a single tube tunnel (NPV1), a double tube tunnel built jointly (NPV2) and a double tube tunnel built in two phases, with the second phase started only according a "switching rule" on demand level (NPV2sr). While the comparison between NPV1 and NPV2 is trivial, we analysed when NPV2sr is higher than NPV2, i.e. when phasing a project is better than a simultaneous capacity expansion.

We found two results. Firstly, we derived the conditions under which the "switching rule" performs better depending on extra-cost associated to simultaneous construction (s). This happens when the actual value of the posponed second phase cost is lower than the extra-cost associated to phasing. The case is even more significant when no extra-cost exist (s=1), typically when building sequential sections of an infrastructure with different saturation levels (see the case in next section).

However, the most important contribution of planning an infrastructure in sequential functional sections on the basis of a "switching rule" is related to uncertainty. Phasing, in fact, allows to postpone decisions to a time when more information is available, typically after the first part of the the infrastructure has been built and traffic can be observed. Thus, the true benefit of phasing upon a "switching rule" is related to the value of the option of not building the second tube in case of lower than expected traffic.

3. The case of the New Turin-Lyon Railway and the "FARE" proposal

The theoretical approach applied to a very simple example in the previous section helped us to better understand the issue: phasing the construction of an infrastructure by splitting it into smaller functional sections can improve socio-economical performances by gaining information and reducing overinvestment risks, if sunk costs due to phasing aren't too large.

In this section we present a more complex case study on the issue with respect to a real planned infrastructure: the New Turin-Lyon Railway.

Short chronicle

The New Lyon-Turin railway Line (NLTL in the following), whose project has been developed since 1990, is today a part of the TENt network. It is nowadays included into the Priority Axis n. 6 (*Lyon-Trieste-Ljubljana-Budapest-Ukrainian border*).

This megaproject is promoted mainly by the Italian and the French government, with the aim to improve the freight capacity with respect to the existing line, dating from 1871 (but recently upgraded). The new line will have a total length of nearly 250 km, and will involve the building of a 50 km-long base tunnel, plus three of nearly 20 km each.

Despite governmental support, during the last two decades, the project faced strong opposition by the population and the local authorities of the Italian Susa valley. These opponents highlight not only the strong environmental impact of the new line, but also its very high costs which don't seem to be counterbalanced by benefits; they argue also about the underutilization of the existing line, whose traffic has even been decreasing during last 15 years.

In late 2005, the first prospecting tests in the valley were blocked by huge demonstrations and struggles. To get off this situation, the Italian Government established a Technical Observatory, which included representatives of all involved authorities (three Ministries, Regione Piemonte, Torino province and city, municipalities and mountain districts)[4], as well as of railway agencies.

Between 2006 and 2009, the Observatory verified all controversial issues, but it succeeded in reaching only some partial agreement. This result led anyway to a modification of the project, which has been confirmed as a priority by the EU.

In the meanwhile, the local authorities developed an alternative proposal, based on the application of a "switching rule", named "FARE"[5], which has however never been subjected to a public comparative assessment – neither economic nor environmental.

Our goal is now to provide a simplified assessment of such project, focusing mainly on the theoretical aspects which has been illustrated in previous paragraphs. We show in this paper the preliminary draft results

[4] Andrea Debernardi was member of this Commission as a technical representative of the "Lower Susa Valley Mountain District".

[5] "FARE" (that sounds in Italian like "doing") is the acronym for *"Ferrovie Alpine Ragionevoli ed Efficienti"* (Reasonable and Efficient Alpine Railways).

of an independent analysis, with the purpose of showing the benefits of phasing infrastructures upon a "switching rule" in a case of high uncertainties on the future demand.

The NLTL project

Following the last Italian project (LTF, 2010), the NLTL will connect Lyon to Turin through the Savoy and the Susa valley. The first section will include a new HST line running directly from Lyon to Chambèry, as well as a new mixed line connecting the freight by-pass of Lyon agglomeration (*Countournement Fret de l'Agglomeration Lyonnaise* = CFAL) to the *Sillon alpin* through the Chartreuse tunnel (23 km). The second section will reach the French Maurienne valley through the Belledonne tunnel (20 km); while the third one will cross the boundary with a 57 km-long base tunnel outgoing near Susa. Finally, the fourth section will run through the lower Susa valley, including the Orsiera Tunnel (19 km), till Turin. Sections 2, 3 and 4 will have a design speed of 220-250 km/h. A further section, not included in the official project but needed for its functionality, is the freight by-pass of the Turin agglomeration.

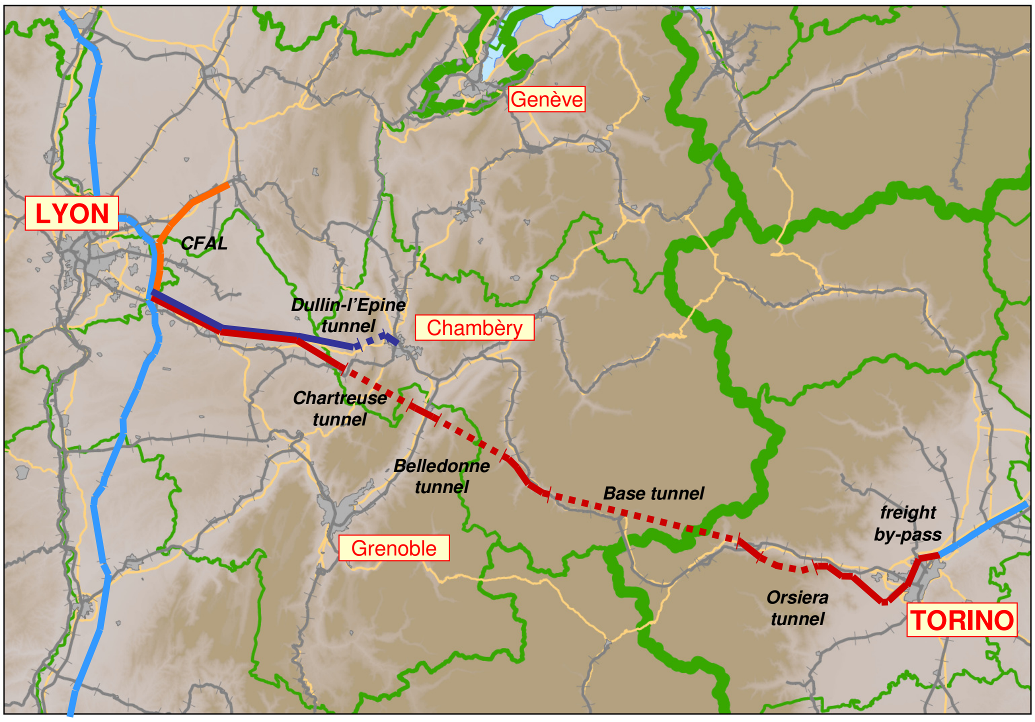

Figure 5 - The new Lyon-Turin railway line project

The investment costs involved by this megaproject are very high: nearly 25 billons Euro, of which more than 10 for the base tunnel.

Because of its dimension and complexity, the French side project has been split in five functional sections, both serial and parallel, whose construction is spread from 2012 to over 2035. On the contrary, the Italian side project holds only one section, which includes both the base and the Orsiera tunnel and has to be completed in 2023.

Our evaluation has been developed following the official guidelines of the European Commission (DG REGIO, 2008), integrating missing values with those suggested by the simplified guidelines of the Italian Infrastructure Manager (RFI, 2005). Due to the lack of detailed data for the Lyon-Chambèry section, the analysis excluded the new HST line Lyon-Chambery; moreover, it included the Turin freight by-pass, which in our opinion seems necessary to support traffic growth on the new cross-border railway line.

The total socio-economical actualised value of investment, maintenance and operating costs for the new line, discounted at a rate of 3.5%, is about 16 billion Euros, with an actualised residual value of 1.35 billion Euros (on a 2014-2064 analysis horizon).

The benefits have been defined on the basis of the freight demand forecasts developed by the Technical Observatory (Osservatorio, 2008), which indicate a rail traffic of 31.6 Mt in 2030. These forecasts appear to be rather optimistic, if compared with the actual negative trend: between 1997 and 2009, rail freight traffic on the corridor decreased from 10 Mt/year to less than 3. In the same period traffic remained constant also on the parallel highway, before falling down because of the global crisis[6]. On the other hand, passenger demand at the same horizon has been assumed to be 1.4 million passengers/year for international services, and 7.1 (of which 6.2 on the Italian side) for local services. The first figure derives from the official project, while the second results from our estimates taking into account the "S-bahn" like service program for Turin metropolitan area, which is planned to reach the lower Susa valley.

Even using the official traffic forecasting, the actualised benefits reach in total nearly 10 billion Euros, with a clear preponderance of operating cost savings and environmental effects of freight traffic. On the contrary, time savings for international passenger traffic play a minor role[7].

Finally, the Net Present Value of this option is equal to -7 billion Euros.

The "FARE" proposal

This proposal, advanced by the lower Susa valley mountain district in 2008, follows some technical evidences about network capacity, resulting from the Observatory's analysis: on the one hand, the existing line appears today to be very far from saturation (its capacity being at least 20 Mt/year); on the other hand, any important traffic increase is destined to generate bottlenecks in the railway network of Turin, before than in the mountain section.

Therefore, it is possible to imagine for the building of the new line a specific timing starting from the most saturated section, namely the Turin by-pass, and gradually approaching the base tunnel[8]. Following FARE proposal, this timing could involve five stages, including a '0' phase, corresponding to the full utilization of the existing line, and four building phases.

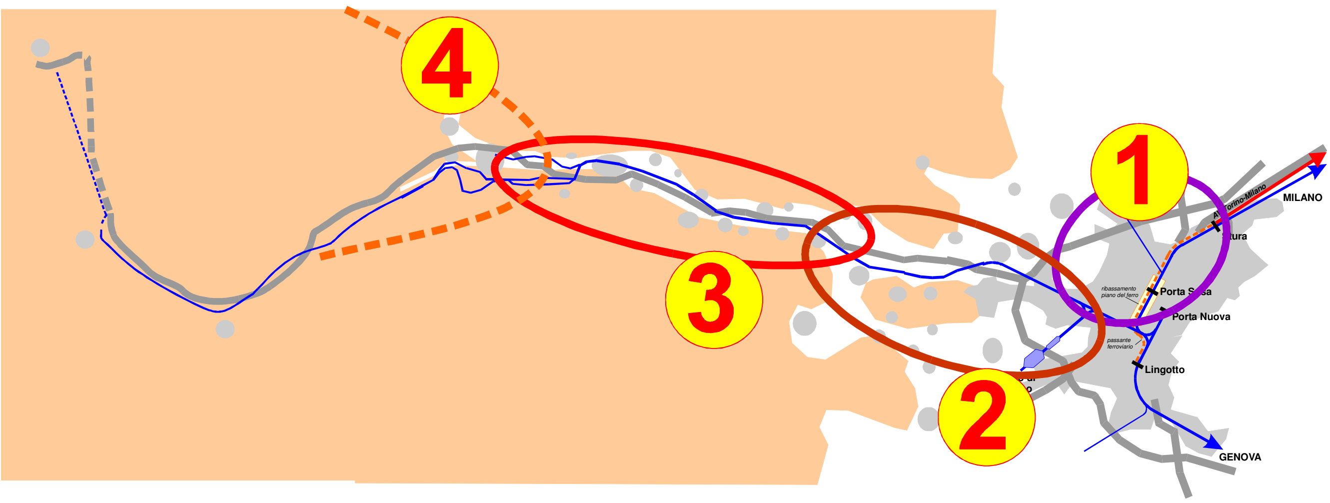

Figure 6 - The four building stages included in FARE proposal

[6] 12.6 Mtons passed through the Frejus road tunnel in 1997, 13.1 Mtons in 2007 and 10.2 Mtons in 2009. The quite close Monte Bianco road tunnel, which somehow represents an alternative paths for a part of the traffic, even experienced a reduction from 12.7 Mton in 1997 to 8.6 Mton in 2007 and 7.6 Mton in 2009 (BAV, 2010).

[7] In the absence of accurate enough data about the generalised transport costs and origin-destination trip matrices, we assessed the benefits for diverted traffic using the *rule of half*, as theory suggests.

[8] Our analyses suggest that sections will be saturated progressively, from Turin to the base tunnel.

Moreover, the FARE option is characterised by the application of a switching rule: the building of each stage must start if and only if the *actual* traffic trend would have required it. This way, if forecasts are optimistic, only the most effective parts of the scheme will be built. If the traffic forecasts are correct, the new infrastructure will be built as a whole, in steps, without introducing any capacity constraint but solving them as soon as they become reality.

The CBA of this option has been developed on the same model used to assess the NLTL project: we maintain the same construction costs of the NLTL scenario, i.e. no sunk-costs due to phasing have been introduced. The FARE strategy also proposed major functional changes that would probably allow major cost saving with low benefit reductions, but we didn’t consider those changes in this simplified analysis[9]. In the meanwhile, the proposed switching rule has been applied independently to the French side building stages, too.

Considering the traffic forecasts of the technical Observatory, this option has a total actualised cost of 12.2 billion Euros, which is only partially counterbalanced by benefits (7.3 billion Euros). Nevertheless, the better timing of the building results in an increase of NPV, which is now equal to -5.5 billion Euros.

New Turin-Lyon Railway Cost Benefit Analysis	NLTL M€	FARE M€
<u>Costs</u>		
Investment costs	-12,839	-9,699
Infrastructure O&M costs	-2,279	-2,279
Additional regional service subsides	-89	-89
Indirect taxation losses	-890	-185
Residual Value	1,350	1,084
Sub-Total	**-14,747**	**-11,327**
<u>Railway user benefits</u>		
- operating costs reduction – freight (existing)	667	587
- time savings - freight (existing)	1,315	958
- time savings – passengers (existing)	403	365
- generalised costs reduction – diverted freight	1,983	1,287
- generalised costs reduction – diverted passengers	914	914
Sub-Total	**5,282**	**4,111**
<u>Decongestion benefits</u>		
- freight	182	165
- passengers	533	469
Sub-Total	**715**	**634**
<u>Social costs reduction</u>		
- freight	2,961	1,539
- passengers	1,020	1,021
Sub-Total	**3,981**	**2,560**
Marginal Opportunity Cost of Public Funds (MOCPF = 0.15)	-2,212	-1,675
NPV (r = 3.5%)	**-6,981**	**-5,540**

Table 2 – Preliminary results of our independent CBA of the New Turin-Lyon Railway. Build together strategy (NLTL) versus build separate upon "switching rule" strategy (FARE) with reference to official traffic forecasts (Osservatorio, 2008).

Our analysis suggests that even if official traffic forecasting would actually occur, the FARE strategy would provide a better (less negative) socio-economical performance for nearly 1.4 billion Euro.

[9] In particular, our analysis do not take account of the cost savings obtained by the adoption of a lower design speed (180-190 km/h), which was proposed in FARE option following the evidence of poor benefits associated to time savings for international passenger traffic and no benefits at all for freight. A reduction of design speed could results also in a shortening of tunnels.

Sensitivity analysis

From the theoretical point of view, the most interesting aspect of the FARE proposal is probably its higher resilience to traffic change. For this reason, our study included a broad sensitivity analysis referred to demand forecasts changes, both on the absolute value of traffic and on the time shifting of the forecast first year traffic[10].

The results are synthesised in Figure 7, showing how the NPV of NLTL (red lines) decreases at any lowering of forecast demand, as well as at any temporal shifting of the traffic curve. In the extreme case of null traffic, the benefits go to zero and the Net Present Value becomes equal to the project's costs. On the contrary, when traffic reduces, the NPV of FARE proposal tends to increase, reflecting the postponement (or even the cancellation) of some building stages with their costs. Quite obviously, in the case in which the switching rule is adopted on a serial project with a '0' stage, a traffic zeroing causes the annulment not only of benefit, but also of costs, and of NPV, too.

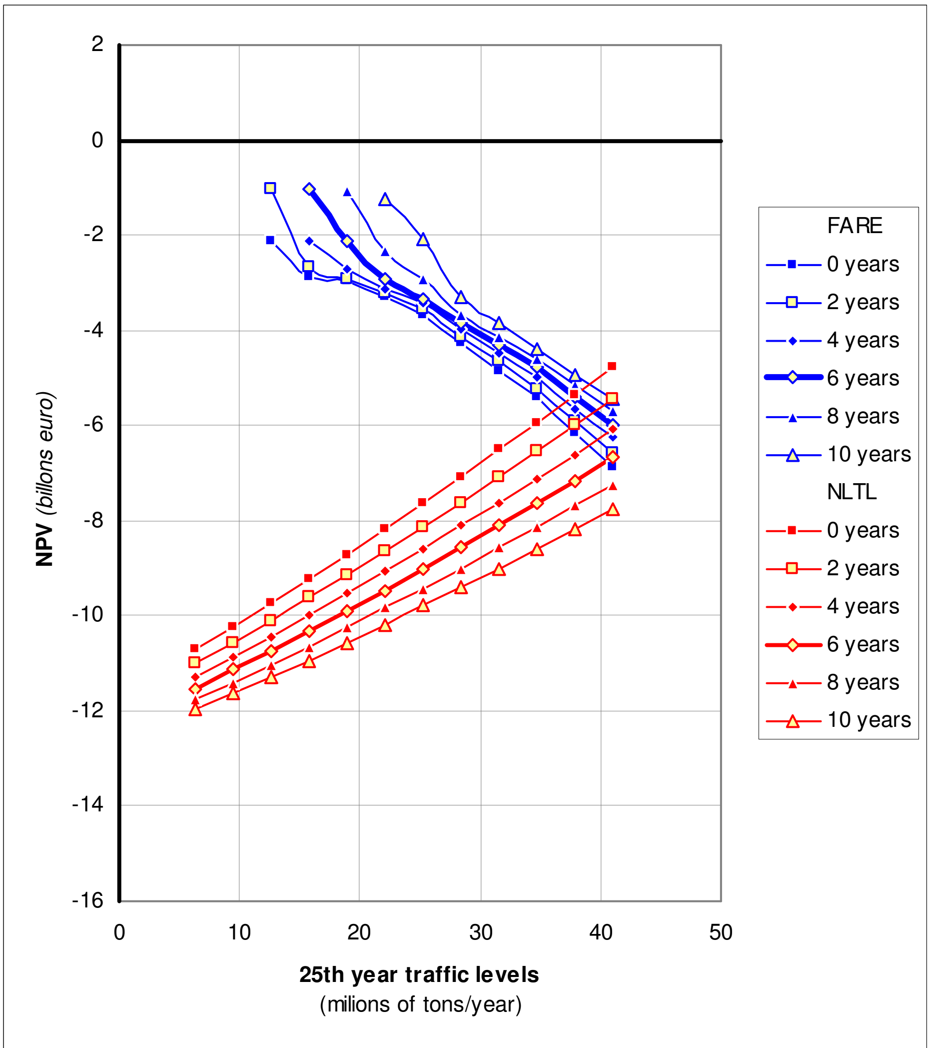

Figure 7 – Sensitivity analysis of the build together strategy (NLTL) versus build separate upon "switching rule" strategy (FARE) with respect to the traffic level in 25th year of operation and to the time shifting of the forecasted first year traffic.

[10] Since in 2009 traffic was far well below the reference traffic, first year forecasted traffic level may be reached forward in time.

Sensitivity analysis thus suggests that the phasing FARE strategy will always provide better socio-economical performances than the NLTL project up to an actual traffic at the 25th year of 35-36 to nearly 50 million tons/year according to time-shifting of the forecast. For example, if traffic will be of some 20 tons/year instead of the forecasted 30 tons/year in 2030, the NPV of FARE is 6-10 billions Euro higher than NLTL one. Obviously, since NPV is negative, those better performances have actually to be interpreted as less negative.

4. Final considerations

The purpose of the paper was twofold. Firstly, we introduced a way to extend conventional CBA methodology to manage the phasing of projects. Secondly, we demonstrated both theoretically (with a simplified model) and practically (with a more complex case study) the positive effect of phasing under certain conditions (limitedness of sunk-costs due to phasing, predominance of capacity problems).

In general terms, it is not always possible to plan linear transport infrastructure this way. but we think that potential phasing is quite a common situation. There are differences between parallel phasing (like the theoretical model analysed here) and serial phasing (like the FARE proposal for the New Turin-Lyon Railway, characterised by near-to-zero phasing extra costs). In parallel phasing most of the time and operating benefits are usually achieved as the first section is completed, but cost savings from building the sections together may be significant. Conversely, serial phasing may provide only a part of the benefits for each completed section, but cost savings from building the sections together are usually smaller. However, if capacity is the main issue (and not speed upgrade, for example), both cases can well fit this rule. In terms of sensitivity analysis, this flexible strategy intrinsically performs better than a rigid one, if costs don't rise too much.

By numerically developing a simplified and independent CBA of the new Turin – Lyon railway line project, we showed that a phasing strategy on the basis of a "switching rule" like the "FARE" proposal can reduce the risk of overestimation of traffic and provide positive effect in terms of NPV of the project: if forecasts are optimistic, only the most effective parts of the scheme will be built. If the traffic forecasts are correct, the new infrastructure will be built as a whole in steps and will generate the highest net benefits. Because of the many educated guesses and inputs, we don't make any consideration on the overall opportunity of this megaproject, even if the clearly negative results suggest prudence and need for a deeper public CBA, in particular with respect to the recent traffic fall.

Another possible positive effects of a "switching rule" strategy, may be achieved if the network manager is linked to the train operating company – still quite a common in situation in the railway sector: a "switching rule" could act as an incentive to increase traffic in order to reach the required traffic and obtain the financing of the second section (this seems to be the case of the Lötschberg base tunnel, Schreyer, Sutter e Maibach 2009).

In a more general sense, the switching rule seems to involve some clear incentive to develop "fair" traffic forecasts throughout the whole decision process. Ex-post analysis , whose importance has been increasingly stressed in recent years in the scientific debate (e.g. EVA TREN, 2008 or Short & Kopp, 2005), this way right enters the planning and assessment phase of the whole project itself. This issue can assume a major role for megaprojects, whose traffic often may not be treated as an "external" and independent factor, just because the complex relationships existing between extending network plans and transportation policies both at national and international level. Returning on the Swiss case, it can be argued that the quite good traffic performances of Lötschberg base tunnel result not only from exact traffic forecasts, but also from comprehensive and coherent policies aiming to enhance demand shift from road to rail (Metz 2004).

In conclusion, our approach tried to solve a common problem faced by analysts making a CBA under uncertain conditions. Even if powerful and theoretically based tools exist to manage such uncertainty, for example introducing option values, such approaches require not only the basic data – already difficult to find

– but also the variance of such data. In many cases it is simply impossible to obtain such data with a sufficiently reliability. For this reason, we think that, in some conditions, introducing in the decision-making process some “switching rules” on demand levels might be a good way to manage “on the road” the uncertainty of forecasts. Ideally, it is like reducing year by year the variance (the uncertainty) of demand forecasts by observing the actual demand and taking decisions on new expansions consequently. The payoff is the extra-cost associated to phased projects. It can be estimated ex-ante by engineers and compared with the quantifiable flexibility benefits (in some cases, it can even be near-to-zero, in linear capacity expansion projects like the Turin – Lyon freight line). The tool to make this comparison can be, as we showed, the CBA in the usual form that reveals perfectly adapt to manage such rules in a reasonably simple way.

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