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16th World Conference on Transport Research (WCTR 2023)

# Assessment and economic regulation of transport infrastructures in the case of PPP and PFI

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## Abstract

Papers based on systematic literature reviews demonstrate that the scientific literature on PFIs and PPPs have been captured by industrial economics and, more specifically, by the theoretical developments on the principal-agent relationship. We propose in this communication to explore another paradigm, that of identifying the foundations of the public economy that deserve to be revisited in cases of public-private partnership. To do this, we will deal with what we consider to be the main economic controls of a transport policy, which suggests five questions.

The WACC being in principle higher in a PPP case, what are the implications for the level of subsidy?

Since the WACC is higher in the case of PPP/PFI, under what conditions can this option be profitable for public finances?

Is the optimal tariff that which optimizes the welfare function or that which optimizes the income of the private partner?

Must the optimal ranking of various projects be based on the socio-economic rate of return (ERR), on the financial internal rate of return (IRR) or on another criterion?

What happens to the value for money criterion in the case of the evaluation of a program of several projects?

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## 1. Introduction

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This communication proposes a synthesis of twenty years of research works on the theme of PPPs and PFIs which have been produced by their authors at the request of the International Transport Forum and the OECD or which have been presented at various World Conferences on Transport Research. Two of these papers received the Award for the Best Communication (WCTR at Istanbul in 2004, written with Pablo Jensen, and at Rio in 2010, written with Bruno Faivre d'Arcier).

The scientific literature on PFIs and PPPs clearly demonstrates that these issues have been captured epistemologically by the approach taken by industrial economics and, more specifically, by the theoretical developments of the principal-agent relationship. This has been consistently confirmed by papers based on systematic literature reviews. For example, in their extensive bibliometric analysis de Castro e Silva Neto *et al.* (2016) underlined that “Most of the existing work is focused on aspects of contract design, risk sharing, and analyzing contract performance and benefits”. In the same way, Wang *et al.* (2018) reported, “However, we have not yet been able to find any articles which discuss the PPP research process from the Public Administration perspective.” Even when the macroeconomic dimension is addressed, the work generally fits into the principal-agent paradigm (Maskin & Tirole, 2008).

We propose in this communication to explore another paradigm, that of *identifying the foundations of the public economy that deserve to be revisited in cases of public-private partnership*. To do this, we will deal successively with what we consider to be the five economic controls of a public transport policy which will be addressed in the order reported in Table 1.

Table 1. Questions asked by PPPs/PFIs to public infrastructure management for five government controls.

<b>Government controls</b>	<b>Content of the control</b>	<b>Main issues for PPP&amp;PFI</b>
<b>Financing rules</b>  (Section 3)	The use of an infrastructure or the provision of a service may be free or subject to tariffs. This is the central problem of financing by the user or the taxpayer.	The weighted average cost of capital (WACC) is in principle higher in a PPP case. <i>What are the implications for the level of subsidy?</i>
<b>Regulation and market mechanisms</b>  (Section 4)	Franchise or agreements between the government and mainly publicly-owned companies or opening up to competition from private operators.	Since the weighted average cost of capital is higher in the case of PPP/PFI, <i>under what conditions can this solution be profitable for public finances?</i>
<b>Pricing</b>  (Section 5)	The pricing of an infrastructure or service has the dual objective of covering costs and directing demand, and is the result of a political choice.	<i>Is the optimal tariff that which optimizes the welfare function or that which optimizes the income of the private partner?</i>
<b>Assessment</b>  (Section 6)	Objective function and assessment methods.	<i>Optimal ranking must be based on the socio-economic rate of return (ERR) or on the financial internal rate of return (IRR).</i>
<b>Investment decisions</b>  (Section 7)	Choice of investments and optimal ranking of candidate projects.	<b>The importance of value for (public) money in the assessment of a program of various projects.</b>

## 2. Accuracy of vocabulary and empirical resources

Although there is no standard distinction between a public-private partnership (PPP) and a private finance initiative (PFI), it is generally accepted that the PPP is a broader concept which refers to a collaboration between the public and private sector for the delivery of public services and infrastructure including, for example, the system of

concession.

The Private Finance Initiative (PFI) was originally launched in the UK in 1992 by Prime Minister John Major, and greatly expanded by the Blair government. The PFI involves an infrastructure project that is funded by private sector equity and debt funding and then paid for by the public sector through monthly payments over the life of the project.

Thus, a PPP can be either a concession or a PFI. In what follows, we will not have to make (unless otherwise indicated) a distinction between them and will consider a general case of PPP/PFI. On the other hand, we will distinguish between public and private options which can be “stylized” as follows:

- In the “public” option, the operator in charge of the project is a public entity or a non-profit private company like Network Rail in Great Britain. In both cases, we will call it a “public operator.” It is not intended to make profits, but should cover the investment and operating costs, including the financial charges of its loans, through commercial receipts. The latter can comprise tolls paid by the users, or a shadow toll paid by the public authority. In the case of a loss-making project, it is assumed that the deficit is compensated by the public authority: a subsidy, determined on the basis of a cost-benefit analysis established *ex ante*, must then complete the expected receipt, so that the operator is ensured that the cost is covered.

- In the “private” option (PPP/PFI) the mechanism is the same, except that the private operator may have more onerous loan conditions than a public operator and that it must ensure the remuneration of its private equity, and therefore generate a profit.

All the empirical results reported below correspond to financial data relating to concrete projects observed in France in the 2000s and 2010s (highways and high-speed rail lines). To follow the rules that were imposed on them, the public operator could not commit to a project unless their IRR was at least 8%. For any value under that, a compensatory subsidy was required in order to reach that threshold. Based on financial market conditions, the risk premium and usual gearing, the weighted average cost of capital for a private operator was close to 10%. This meant that for any value of the project’s IRR lower than 10%, a subsidy was required by the private operator to ensure its financial balance.

While it is well accepted that the WACC is higher in the case of a PPP, the literature has pointed to more significant differences that can exceed 300 bps (Fernandes & al., 2012, Vecchi & Hellowell, 2013). It appears that the more recently observed magnitudes are closer to 200 bps (McKinsey, 2017, Bonnafous & Faivre d’Arcier, 2018). In sections 3 and 4 below, we will stick to the assumptions of 8% and 10% as observed in the French case. The theoretical calculations would obviously be applicable to other values for which the question would always be whether a private operator can offset this additional cost through more efficient management.

The calculations and simulations presented in this paper were based on three different samples of transport infrastructure projects in France. The very first calculations were based on sample 1 of 17 toll highway projects which were in competition in the 1990s. Subsequent work also concerned 17 new toll highway projects which were in competition in the 2000s (CGPC & IGF, 2003) and constituted sample 2. Finally, sample 3 concerns 39 railway projects commissioned between 2010 and 2021 (Bonnafous, Brunel & Marlot, 2017). What these samples have in common is that the project assessments include ERR, IRR and NPV (Net Present Value) calculated according to consistent rules for each sample.

### 3. Financing rules and need for subsidy (with the “a-b-c-d model”)

In what follows, the calculations are based on a particularly simple model that allows us to make several calculations on the financial profitability of a project and the subsidies that may result from it. Let us consider a project corresponding to a stylized but nonetheless classical time series of the costs and benefits represented in figure 1. We take into account only the financial elements that enter into the calculation of financial profitability. If the commissioning is assumed to occur on date  $t = 0$ , the annual cost between the dates  $-d$  and 0 is  $c$ . Starting at the commissioning date, the net benefit generated is assumed to take the form  $(a + b \cdot t)$ . As parameters  $a$  and  $b$  are carried over in the discounted cost of the investment,  $a$  can be interpreted as the first year rate of return.

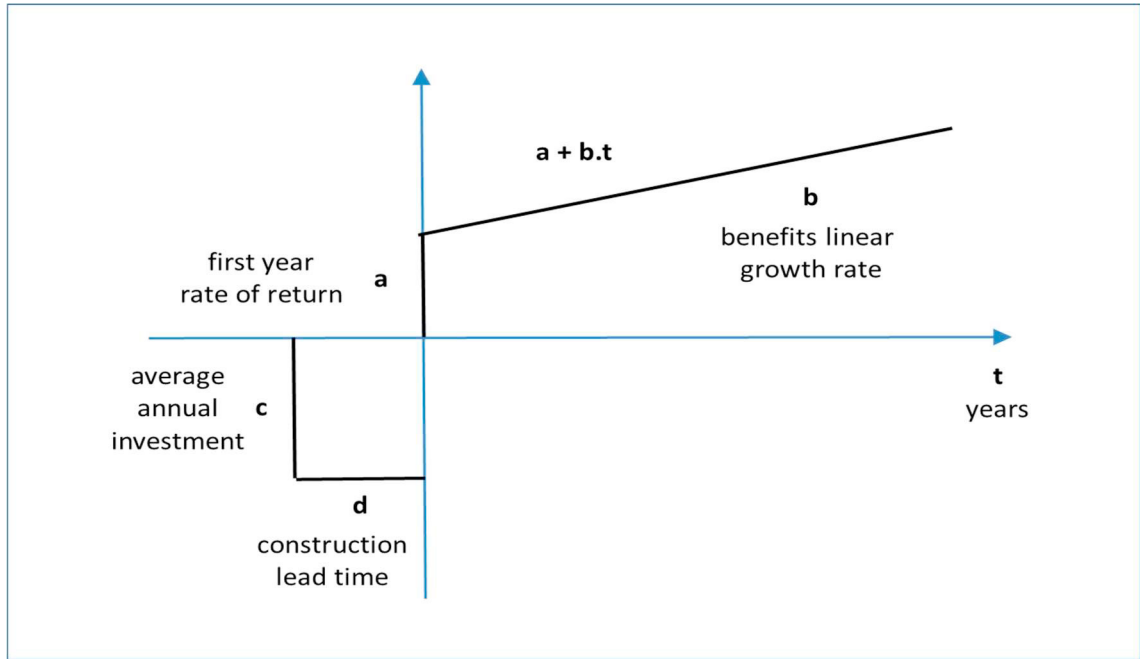


Figure 1: Costs and benefits time series.

The project's internal rate of return (IRR), which is the discount rate which cancels its net present value  $NPV_f$  is therefore a function of four parameters:  $c$ ,  $d$ ,  $a$  and  $b$ . It must be compared with a rate of return that an operator (public or private) is entitled to expect.

We use the following notation:

- $\alpha$  is the discount rate used to calculate the financial NPV of the project,
- $\alpha_0$  is the IRR of the project, i.e. the discount rate which cancels the  $NPV_f$ ,
- $\delta$  is the supplement of IRR that the subsidy brings to the operator,
- $\tau$  is the subsidy rate, i.e. the proportion of  $c$  financed by the subsidies.

For the discount rate  $\alpha$ , and the updated balance sheet from date  $-d$  to  $T$ , the net present value is:

$$NPV_f = \int_{-d}^0 -c.e^{-\alpha.t} .dt + \int_0^T (a + b.t).e^{-\alpha.t} .dt \quad (1)$$

We will assume that the discount is extended to infinity, which is without impact on the results which interest us because of the small weight of the distant future, and the convergence of the integral function in equation (1) when  $T \rightarrow \infty$ . The equation becomes:

$$NPV_f = \frac{1}{\alpha} \left[ c(1 - e^{\alpha.d}) + a + \frac{b}{\alpha} \right] \quad (2)$$

The project's IRR,  $\alpha_0$ , is therefore an implicit solution of the equation:

$$c(1 - e^{\alpha_0.d}) + a + \frac{b}{\alpha_0} = 0 \quad (3)$$

A subsidy rate  $\tau$  reduces the annual cost of construction  $c$  to  $c.(1 - \tau)$  and brings the IRR  $\alpha_0$  to  $(\alpha_0 + \delta)$  so that equation (3) becomes:

$$(1 - \tau)c(1 - e^{-(\alpha_0 + \delta)d}) + a + \frac{b}{\alpha_0 + \delta} = 0 \tag{4}$$

of which we can deduce the expression of the subsidy rate:

$$\tau = 1 - \frac{a(\alpha_0 + \delta) + b}{c(\alpha_0 + \delta)(e^{(\alpha_0 + \delta)d} - 1)} \tag{5}$$

The relation between  $\tau$ , the subsidy rate, and  $\delta$ , the increase of the project’s IRR expected by the operator, depends on parameters  $c$ ,  $d$ ,  $a$ ,  $b$  and, of course,  $\alpha_0$ . These parameters are also linked to each other by equation (3) that defines the IRR  $\alpha_0$  of the project. This implies certain difficulties in the study and the representation of these functions that we can overcome with cross curves. If we wish to represent this double dependence, it is necessary to freeze these five parameters and only vary those whose role we want to highlight. This requires using the classical method of abacuses.

One of these abacuses is shown here (figure 2) for which we vary only the pair of values  $a$  and  $b$ . The annual cost of construction  $c$  is fixed at a normed value of 25, and the duration  $d$  of this construction is fixed at 4 years. Each pair of values  $a$  and  $b$  obviously corresponds to a value of  $\alpha_0$ , the intrinsic IRR of the project. Three cases are distinguished, which correspond to three levels of the intrinsic IRR of the projects (2%, 5% and 8%) and therefore to three pairs of values of  $a$  and  $b$ , as they were estimated with the data of sample 2 of the projects (see section 2).

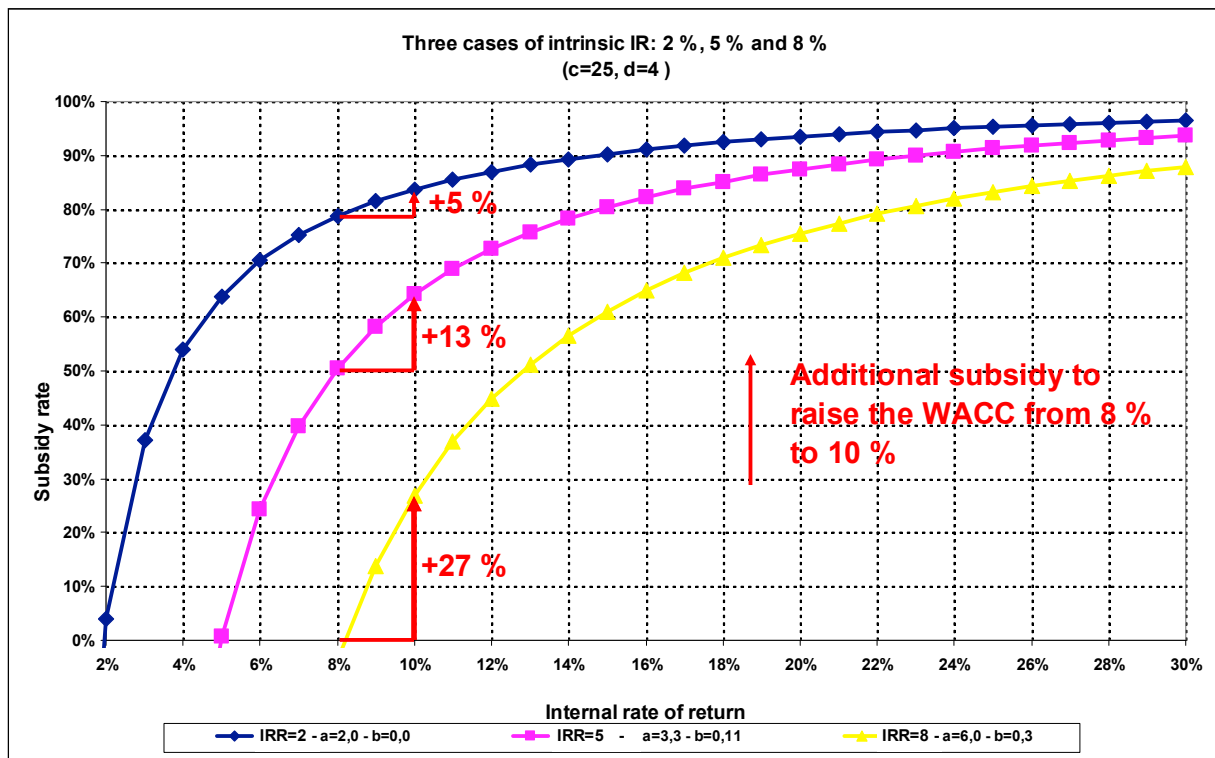


Figure 2: Intrinsic IRR, subsidy rate and targeted IRR.

With the values of WACC that we have chosen for the public option (8%) and for the private option (10%), the highest value of  $\alpha_0$  (8 %) corresponds to a zero subsidy in the public option but to one of 27% of the construction costs with a private partnership. In the median case, with  $\alpha_0$  having a value of 5%, the public operator requires a

subsidy close to 50% and the changeover from public to private requires raising this subsidy by 13%. In the case where  $\alpha_0$  is only 2%, the private operator requires a subsidy of 79% of the costs, which is increased by only 5% in the case of continued recourse to a private operator.

Here we see the first trace of the paradox of financial profitability which explains the dynamics of PPP (Bonnafous, 1999): with equivalent efficiency of the operators, the lower the profitability of the project, the lower the cost of passing from a public operator to a private operator. This result is obviously the consequence of the concavity of the function expressed in equation (5) and of the fact that its derivative as a function of  $\delta$  is as high as  $\alpha_0$  is low.

Note that under the assumption of equivalent performance of a public operator and a private operator, the first option is less costly for public finances. It is then a question of knowing the conditions in which the efficiency of the private operator can compensate a WACC higher than that of the public operator, i.e. that the conditions for which a PPP may relieve public expense are united.

#### 4. Can resorting to a PPP/PFI be profitable for public finances?

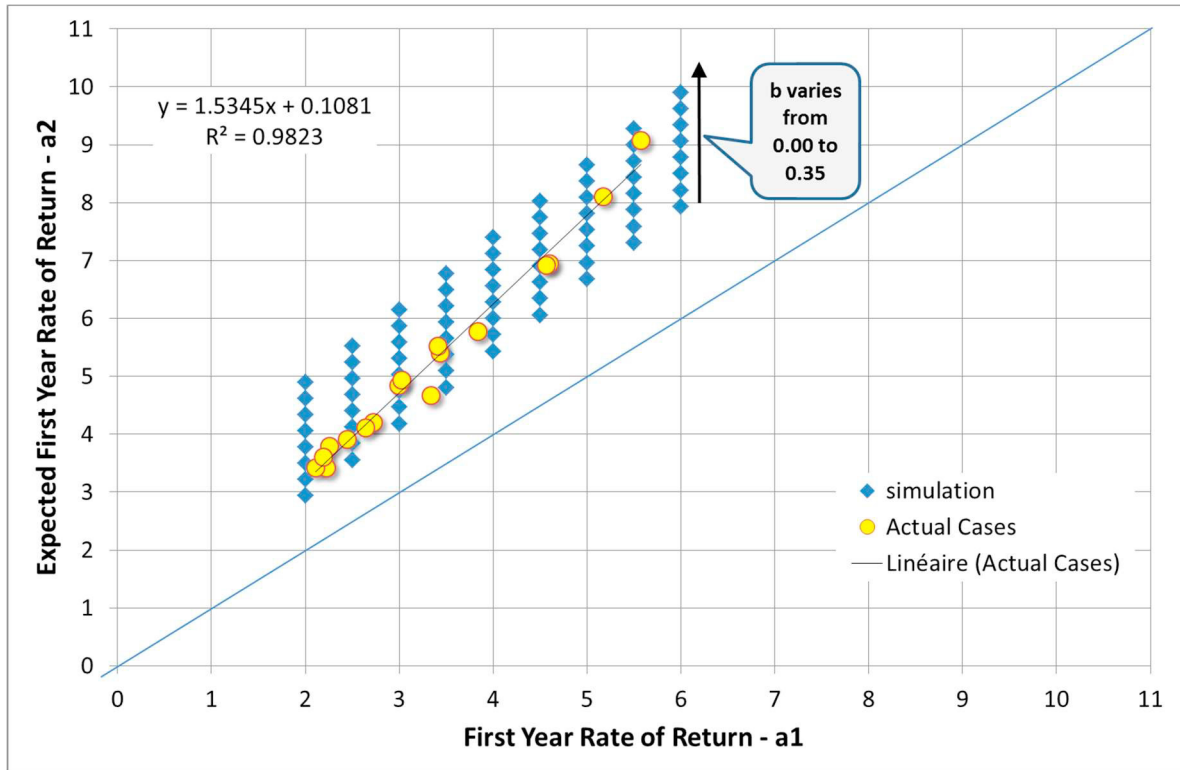
The calculation used to address this question was systematically undertaken using concrete data from sample 2 which concerns 17 toll highway projects. We will not enter here into the detail of the calculations which were published elsewhere (Bonnafous & Faivre d'Arcier, 2018), but will simply present the main results illustrated in the 4 following figures.

For each of the 17 projects, the parameters of the model were calculated from the official assessment records of these projects. They are noted  $a_1$ ,  $b_1$ ,  $c_1$  and  $d_1$  in the following and can be considered as the values linked to the characteristics of the project built and operated by a public operator (as was the case when these assessments were carried out, i.e. before the privatization of highway concessions in France). For each project, the level of subsidy is calculated to ensure an IRR of 8% for the public operator.

On the basis of equations (1) to (5), we calculate for each project what the values of the 4 coefficients, denoted  $a_2$ ,  $b_2$ ,  $c_2$  and  $d_2$ , should be for a private operator so that an IRR of 10% is guaranteed to them with the same level of subsidy as for the public operator. This gain of efficiency can be obtained by modifying the parameters:

- By increasing the rate of return of the first year:  $a_2 > a_1$ ,
- By improving the gradient of the annual benefit over time:  $b_2 > b_1$ ,
- By reducing the construction cost:  $c_2 < c_1$ ,
- By reducing the project's lead time:  $d_2 < d_1$ .

It is possible that the private operator is more efficient in all four domains, but we will proceed with simulations to assess the effort to be made for a single parameter. Thus, Figure 3 represents the efficiency gain required for parameter  $a_2$ . The actual values for each project in the sample are shown in yellow, but variations of  $a_2$  have been simulated for variations of parameter  $b$  within the empirically observed dispersion of values of  $b$  (blue dots).



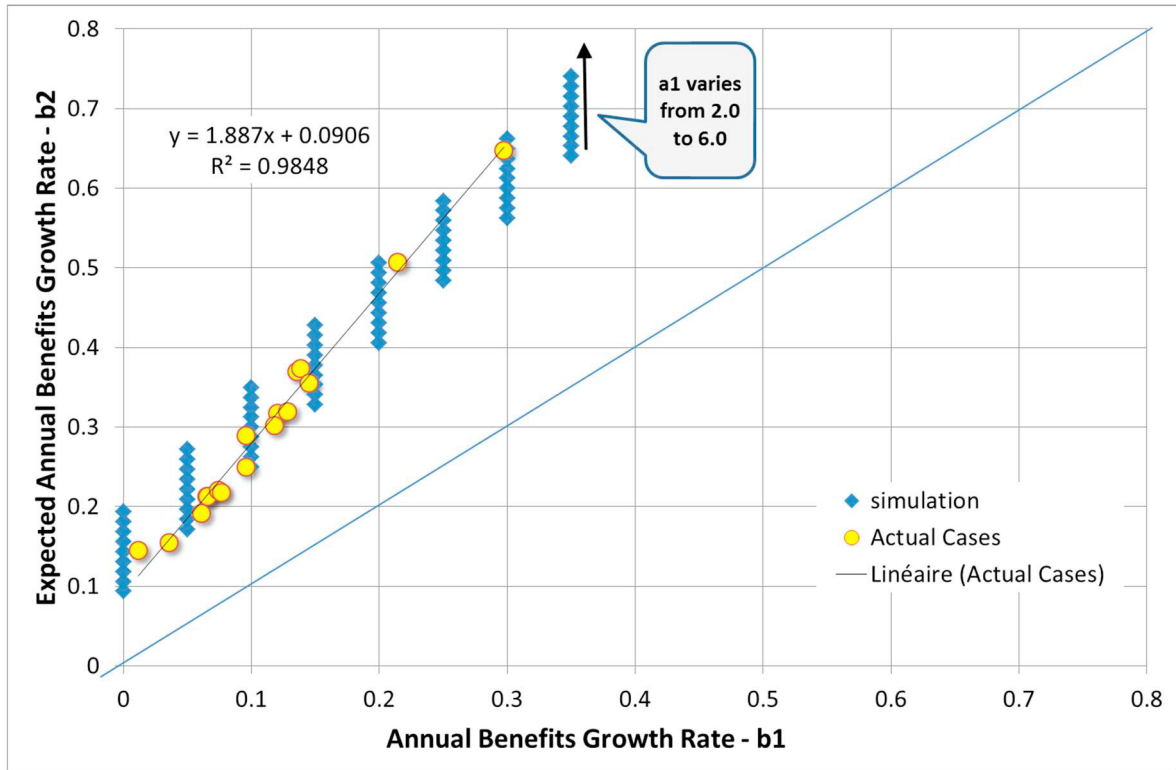
Source: Bonnafous, A. & Faivre d’Arcier, B. (2018)

Figure 3: Efficiency gain required on the rate of return  $a_2$  for the first year.

The calculation based on actual projects shows that in these cases, the gain in efficiency required on this parameter  $a_2$  would be between 40 and 70%. Viewed on the basis of an initial analysis, such a result seems unreachable. However, one cannot omit the fact that  $a$  represents a difference between the revenues and the operating costs for the first year after opening. This means that a limited gain on the costs can have a significant effect on this difference, in particular for projects which have a low value of  $a$ , located on the left of figure 3.

Figure 4 represents the efficiency gain required for parameter  $b_2$ . The aim is to calculate the values that  $b_2$  must reach with the same data and for the ranges of values of  $a_1$  and  $b_1$ . The result evidently shows values of  $b_2$  noticeably higher than  $b_1$ .





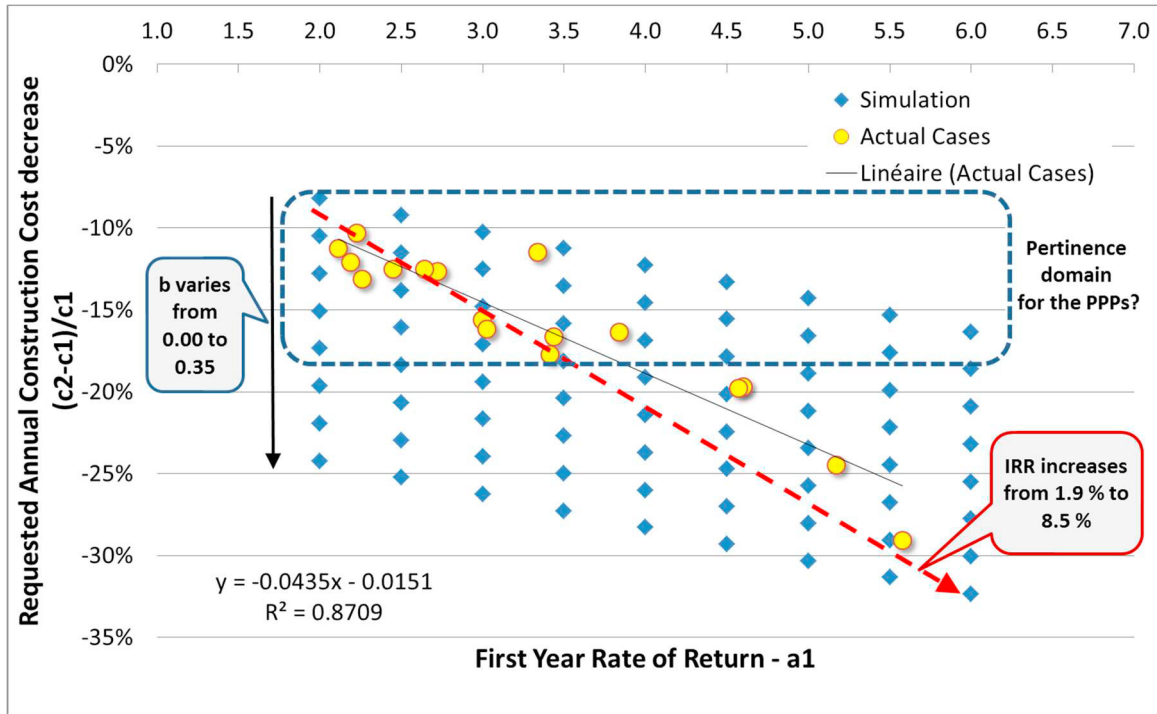
Source: Bonnafous, A. & Faivre d'Arcier, B. (2018)

Figure 4: Efficiency gain required on the growth of benefits  $b_2$

It shows that in almost every case,  $b$  should be doubled to reach the swing point. This strong variation comes partially from the small value of  $b_1$ . We note that the value required for  $b_2$  is higher when  $a_1$  is high. Once again, this is a very ambitious gain in efficiency.

Figure 5 shows the reduction in construction costs (in relative value of  $c$ ) that the private operator must provide to increase the IRR from 8% to 10%. In order to reach equality with public subsidies, it appears that according to the values of  $a$  and  $b$ , these savings vary between 10% and 30%.

It seems that once again, the challenge is relatively ambitious for the private operator. However, if we consider certain major construction projects of the same nature, cases have been observed in France for which the public operator has recorded a drift of over 18% for the costs initially anticipated, in particular in the case of the Paris-Strasbourg high-speed railway line in the 2000s. In the cases of PPP/PFI these excesses are rather rare. This is why we show in Figure 5 a potential pertinence domain for PPPs, which corresponds to this order of magnitude but obviously with a question mark.

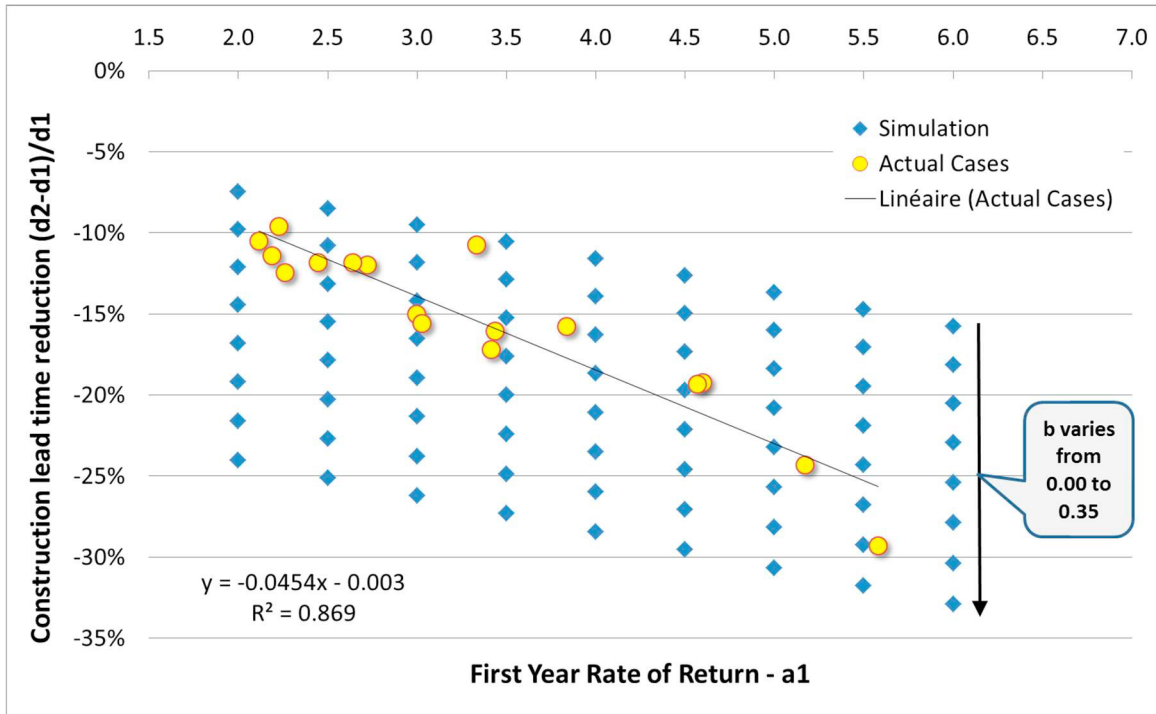


Source: Bonnafous, A. & Faivre d’Arcier, B. (2018)

Figure 5: Efficiency Gain required on the construction costs  $c_2$

In this graph, the dotted red line with arrow shows the trend of the project’s initial IRR. We again observe that the lower the project’s IRR, the lower the effort of efficiency. This confirms the hypothesis that it is indeed for the least profitable projects that the PPP can be a good solution. For example, for the 7 least profitable projects, the efforts to lower costs remain below 13% whereas they are more than double for more profitable projects. This result confirms the paradox according to which, contrary to what intuition suggests, recourse to a PPP has every chance of being more efficient for public finance when the financial profitability of the projects is poor.

It is noteworthy that on top of this effort for  $c_2$ , it is also possible to lower the discounted cost of the investment by faster construction, i.e. by action on  $d$ , as shown in Figure 6.



Source: Bonnafous, A. & Faivre d'Arcier, B. (2018)

Figure 6: Efficiency gain required on construction lead time  $d_2$ .

The value of the swing point of this lead time  $d_2$  shows that the necessary reduction of lead time is between 7% and 33%, i.e. for a construction project assumed to last 4 years, thus a reduction of 3 to 15 months. A major project (400 million euros) such as the Millau viaduct, which was the subject of a concession, was built in 3 years and two months, i.e. two months less than the scheduled time. This was a particularly complex and innovative project. For certain more classical construction projects, for example highways, gains of 3 to 6 months on a 4-year project are not unlikely.

Note that, as for  $c_2$ , the higher the values of  $a_1$  and  $b_1$ , the greater the reduction of the construction lead time must be (and therefore the higher the IRR). Once again, we find an additional sign of the paradox of financial profitability.

In total, these simulations on the 4 parameters show that the efficiency efforts required seem considerable and often impossible when considered separately. Reality obviously does not correspond to this logic because the operators are led to make joint efforts for all the parameters. Concrete PPP/PFI experiences suggest that the handicap of a higher WACC can be overcome, and even overcome quite easily for projects with low financial profitability.

Thus, in the French case of new highways built and managed under a concession system open to competition from the 2000s, proof was quickly provided that the level of subsidy necessary to reach a target IRR could be significantly reduced with a private operator despite a higher WACC. For example, in the case of the A41 highway, which was a short but extremely expensive section of highway in the middle of the Alps between Geneva and Annecy, central government was expecting to provide a subsidy of €250 million, estimated on the basis of previous projects entrusted to non-profit companies. However, two of the bidders proposed to take on the franchise without any subsidy. The contract was signed in 2005 with one of them and the highway section was opened 38 months later in December 2008. Recent experiences of PPP on new high-speed lines have confirmed this kind of performance.

## 5. Optimal pricing in the case of PPP/PFI

The analysis of optimal pricing for the use of an infrastructure in the event of a PPP has already been the subject of a publication (Bonnafous, 2010). We shall not present the calculations in detail here, but limit ourselves to a few results. In order to simplify the calculations, we have made two hypotheses: first, it is assumed that the function of the toll is to finance the highway on which it is collected, which amounts to considering that the pricing of the use of toll-free roads (chiefly taxes on fuel) covers the marginal external costs. It has also been assumed that the traffic on a franchised highway is a decreasing linear function of the toll (which is well verified in the real toll variation ranges).

With this assumed equilibrium between external costs and taxes, the evaluation of a project can be formulated in a very simplified way: the variation in the welfare function for the project  $\Delta W$ , depends solely on the subsidy multiplied by the public funding scarcity coefficient  $\varphi$  and the discounted user surplus  $S$ . The subsidy is defined as the difference between the discounted investment and operating costs  $C$  and the discounted revenue from the project  $R$ . This function is therefore written as follows:

$$\Delta W = \varphi \cdot Sub + S = \varphi(R - C) + S \quad (6)$$

It is noteworthy that the discounted revenue is frequently lower than the costs, thus making subsidies necessary. This is generally the case of most of the more recent highway and railway projects in France. Since the discounting calculations are performed at constant prices, we assume that toll  $p$  remains unchanged over the discounting period and that discounted demand  $d$  can be expressed by a linear function of  $p$  written as:

$$d = d_0 - \beta \cdot p \quad (7)$$

This results in discounted revenue:

$$R = d_0 \cdot p - \beta \cdot p^2 \quad (8)$$

Regarding the discounted user surplus, for a price level  $p$ , it is written as:

$$S = \frac{\beta}{2} \left( \frac{d_0}{\beta} - p \right)^2 \quad (9)$$

Equations (6), (7) and (9) can be represented on the same graph insofar as it shows the respective variations of  $\Delta W$ ,  $R$  and  $S$ , as a function of the same variable  $p$ . To facilitate the interpretation of Figure 7 below, function  $\Delta W + \varphi \cdot C$  is represented as an ordinate,  $C$  being considered a constant value independent of the toll.

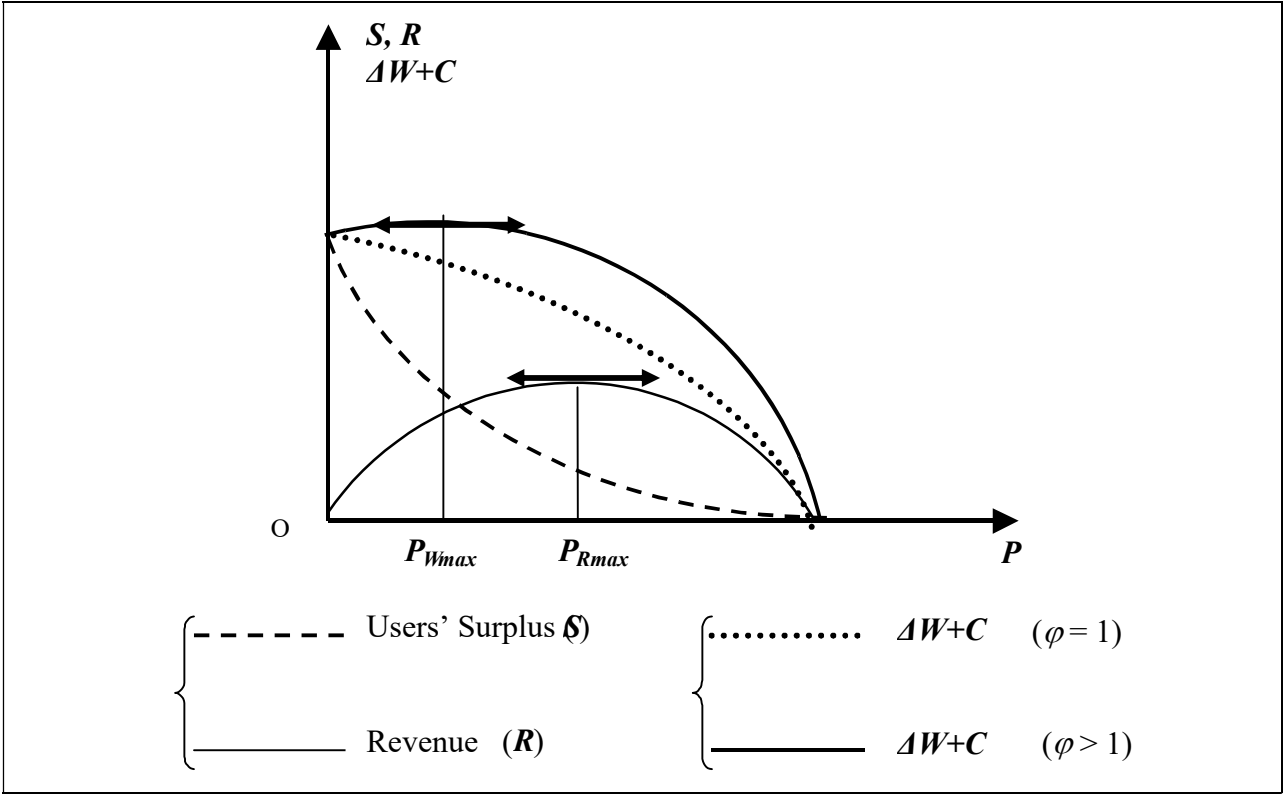


Figure 7: The utility function for two values of the public funding scarcity coefficient.

According to whether we consider the welfare function without scarcity of public funds, or this function with a scarcity coefficient higher than 1 or the revenue function, we obtain three optimal tolls:

- The first is no toll. As was been clearly stated by Jules Dupuit, the inventor of the concept of surplus, as far back as 1849, in the case where the scarcity of public funding is not considered, ( $\varphi=1$ ) the welfare function, which he referred to as social welfare, has a maximum value when  $p=0$ . If a toll were introduced in this case, the resulting decrease in the user surplus (which he called “welfare loss”) would always be greater than the increase in revenue. According to our hypothesis that the demand function is linear, it is easy to demonstrate that the maximum revenue, for example, is equal to only half the maximum user surplus when the toll is zero. We know that the full user surplus could only be internalized with entirely discriminatory pricing. Otherwise, it is not possible for the welfare function to increase with the price.
- If we take account of the scarcity of public funding, the welfare function does not decrease for the lowest toll values: in our graph, when the toll increases from 0 to  $P_{Wmax}$  the welfare function increases when  $\varphi>1$ . Beyond  $P_{Wmax}$  the loss of user surplus, expressed by a decrease of  $S$ , begins to dominate and the welfare function decreases. Once again, although he used neither equation nor curve, Jules Dupuit understood this collective utility of toll in the case of insufficient public funds. The value of the toll which maximizes  $\Delta W$  can be deduced easily from equations (6), (7) and (9):

$$P_{W \max} = \frac{\varphi - 1}{2\varphi - 1} \times \frac{d_0}{\beta} \tag{10}$$

- Lastly, if we consider only the monetary components of the project, we observe that the toll which maximizes revenue (denoted by  $P_{Rmax}$ ) is higher: it is easy to deduce from equation 7 that this toll is equal to exactly half the toll that cancels demand (the value for which all traffic transfers onto toll-free routes) and which is written as:

$$p_{Rmax} = \frac{d_0}{2\beta} \quad (11)$$

Regarding the real evolution of the various toll highways in France, we can assume that, with the generalization of PPPs, the “welfare oriented” toll was abandoned in favor of “profit oriented” tolling according to the objective to minimize subsidies. To verify this, we need to estimate the orders of magnitudes of the optimal tolls  $P_{Wmax}$  and  $P_{Rmax}$ . Estimates of this type have been presented in detail in the publication mentioned above (Bonnafous, 2010) and use the SIMCALECO model (Chevasson, 2007) developed at the Laboratoire d’Economie des Transports to reconstruct evaluation calculations based on official assessment regulations.

One of the possible uses of this model is therefore to simulate the sensitivity of the CBA to the values of parameters such as mortality or CO<sub>2</sub> values. In our case, the aim is to simply to consider the sensitivity of revenue, the user surplus and the welfare function in relation to a single parameter: the toll.

The characteristics of the structure considered correspond to a reference scenario intended to represent, rather than a specific project, one that could be termed an “average” project representative of recent projects. The toll of the reference scenario is close to the average toll levied on the franchised network in the 2000s (0.066 euro/vehicle-km for private cars). The assignment of traffic between the road network and the franchised highway is simulated using a LOGIT model whose parameters were estimated on the basis of real traffic assignments observed on alternative itineraries (with and without tolls). The resulting demand function provides a good linear approximation, with a value of  $p$  which cancels any demand for the highway at 25 cents per vehicle/km, i.e. the value of  $d_0 / \beta$ , which cancels  $R$  in equation (8).

Thus, the numerical application of the previous analysis is easy and permits calculating the values of  $P_{Wmax}$  and  $P_{Rmax}$ .  $P_{Wmax}$  obviously depends on the public funding scarcity coefficient  $\varphi$ , as shown in Figure 8.

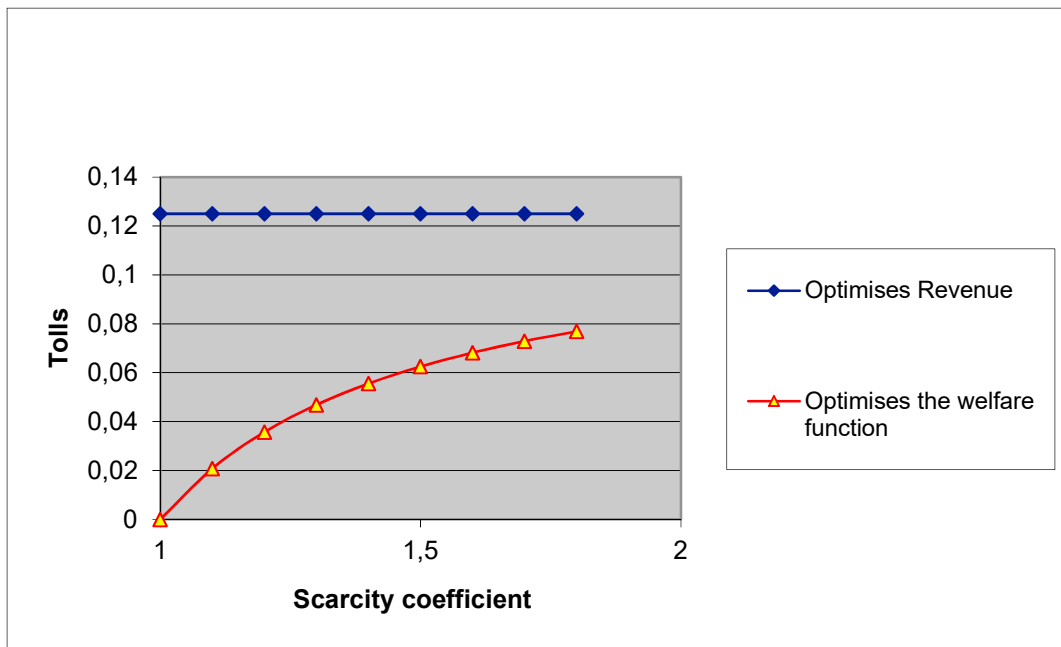


Figure 8: The two optimal tolls as a function of the public-funding scarcity coefficient.

The toll per vehicle-km that was observed in 2020 on French highways of the previous generation corresponds to a value of 6.4 with inflation-related corrections. Figure 8 shows that this toll is barely more than half the toll that would maximize revenue. If we interpret it as a toll that maximizes the welfare function, it would correspond to a value of the scarcity coefficient  $\varphi$  of almost 1.5, which is fairly reasonable compared with the available estimates of  $\varphi$  (Ponti & Zecca, 2007, Cahu 2009). This suggests that the implicit scarcity function used to determine the tolls

prior to the reforms of the 2000s was higher than the coefficient of scarcity that was officially fixed at 1.3 in order to evaluate investments (Ministère de l'Équipement, 2004 & 2005). This said, the calculation of the toll has never explicitly set out to maximize the welfare function.

The finding is more meaningful for the tolls on recent franchises: allowing for price increases, the 14 cent toll on the A88 would be exactly equal to toll  $P_{Rmax}$  in our numerical example which maximizes the revenue, and the 11.3 cent toll on the A65 would be 19% below this. In view of the likely fluctuations in the evaluations of  $P_{Rmax}$  in concrete cases, our estimate (12.5 cents in 2005) should be taken as an order of magnitude – but one that is surprisingly close to the tolls that have been introduced on the recently opened highway sections.

It is therefore as though toll policy is established on the basis of the principle of revenue maximization (or minimization of subsidies), after a long period of welfare-oriented pricing. This observation and our interpretation of it are fully compatible with the change in evaluation methods that took place in 2005.

## 6. Objective function, assessment methods and come-back on the optimal pricing

In addition to the significant development of PPPs in the 2000s, a specific factor led the Ministère de l'Équipement to reconsider the possible uses of the standard economic calculations. It took the form of the conclusions of the working group of the French Planning Authority chaired by Daniel Lebègue (CGP, 2005). The group's task was to consider the appropriate value for what is generally known in France as “the discount rate of the Plan”, which had been set at 8% for some twenty years. In addition to the strong theoretical reasons supporting a lower rate (Gollier, 2002), the fact of the matter was that this 8% rate was ill-suited to effectively take environmental externalities into account in the economic calculation, since it led to a very low weighting given to the distant future. A 4% rate was recommended by Lebègue's Report and was also included in the official instructions for evaluation methods (Ministère de l'Équipement, 2005).

The effect of this recommendation was to generate a large number of new projects that were considered to be profitable, i.e. all those with a socio-economic internal rate of return (ERR) of between 4% and the previous rate of 8% and whose net present value (NPV) therefore became positive. It also increased the number of candidate projects, which are those whose optimum date of commissioning has passed (provided that their immediate socio-economic internal rate of return is higher than the official discount rate). This increased the need to rank potential projects and program them in the order that maximizes the welfare function.

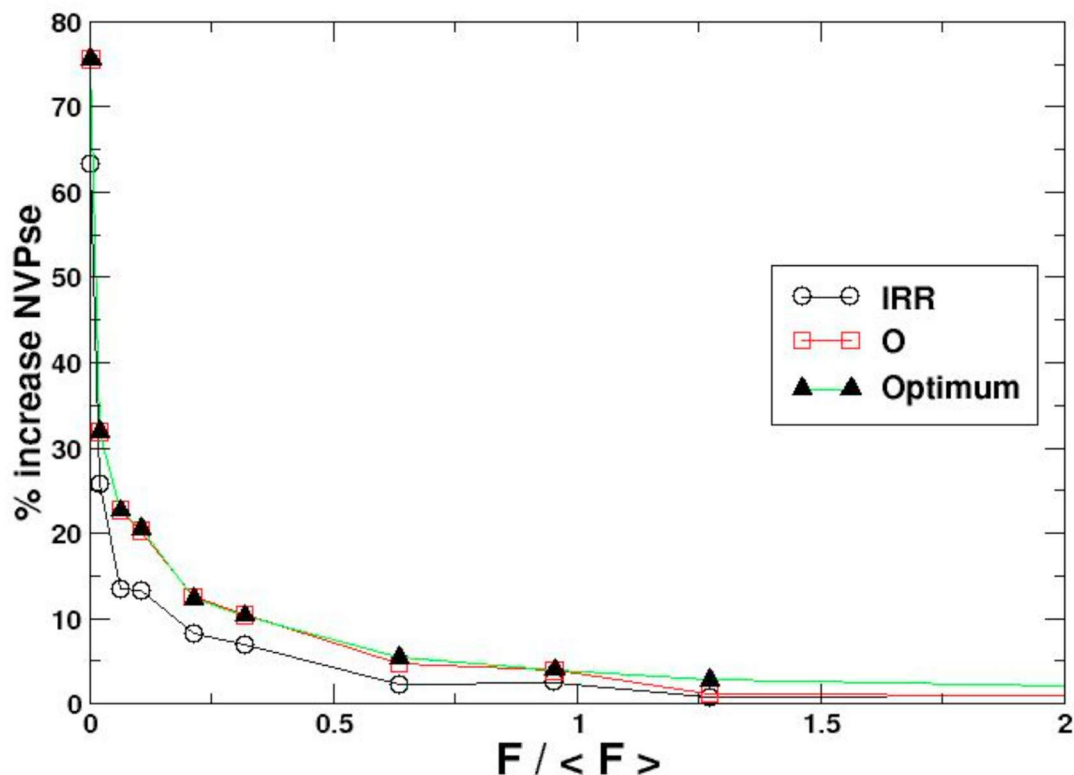
Concurrently with this, research findings were published that were to influence the official instructions. A numerical simulation of the implementation of projects under different public finance constraints ( $F$  on the abscissa in Figure 9 below) was conducted in order to compute the increase in the welfare function for several orders of implementation. These results (Bonnafous & Jensen, 2005) showed that, in comparison to the order of implementation that had been applied in the past, i.e. when projects were ranked in order of decreasing socio-economic rate of return (ERR), ranking projects in order of decreasing financial internal rate of return (IRR) increased the welfare function for the entire program, this increase being as great as the constraint on public finance is severe. This is obviously explained by the fact that projects with a high IRR require lower subsidies, which means that more projects can be built under a given financial constraint.

But the most important finding relates to two other simulated programs. The first of these is the implementation program that maximizes the increase in the welfare function by means of a numerical exploration algorithm. This algorithm, used by physicists, was summoned because for 17 projects the number of possible orders ( $17! = 3 \cdot 10^{14}$ ) forbids an exhaustive examination of all the possibilities. Fortunately, several tools capable of efficiently exploring the “landscape” of different combinations have been developed by physicists, for example, the “simulated annealing” which is used in this determination of the ranking called “optimum” in figure 9. The second is a program in which projects are implemented on the basis of the ratio of the socio-economic Net Present Value (NPV) to the amount of subsidies the project needs. In practice, the two programs turn out to be identical, which we can consider to be an empirical demonstration of the main result, namely that the project ranking that optimizes the welfare function is that in which the projects are implemented in decreasing order of the NPV/Subsidy ratio.

As part of the same research program, William Roy (2005) performed a theoretical demonstration that adds to this numerical demonstration. The Ministry of Transport was aware of this work and, in 2005, revised the Directive of 2004 which laid down the required evaluations. The new formula takes account of the Lebègue report's

recommendation to lower the discount rate to 4% but also requires the calculation of the NPV/Subsidy ratio.

### Relative gain within the ranking shown by decreasing order of ERRs.



Source: Bonnafous, A. & Jensen P., (2005)

Figure 9: Comparative socioeconomic NPV of programs ranked by financial IRR, by the NPV/public subsidy ratio (O) and by the “optimum” subject to financing constraints F.

It is noteworthy that compared to the previous practice in which projects were ranked according to their ERRs, the relative gain provided by the use of this ratio increases as the public financing capacity decreases and may attain a level of 10 to 20% or so with very active constraints.

It should be noted that this ratio between the discounted net community welfare benefits and costs and the discounted net government finance (or subsidy), more commonly called Value for Money, is accepted internationally. It has resisted the paradigm of “Wider Economic Benefits” (UK Department for Transport, 2005; Vickerman, 2007) and has even been reinforced by the development of public-private partnerships (Grimsey & Lewis, 2005 and Yuan *et alii*, 2009).

It is quite clear that this must be consistent with the pricing policy described in the previous section: in order to optimize a program of projects, it is necessary to select both the optimum ranking of projects, as we have just described, and the level of toll which also optimizes the welfare function of the program.

In reality, we reasoned on the simplified case of the optimal pricing of a project but, with regard to a program of projects, the question of optimal pricing no longer arises as we have formulated it: pricing has consequences on the



subsidies required by each project. Thus for given subsidies (i.e. for a given budgetary constraint) it is a question of determining the tariff which optimizes the Net Present Value of the program whose ranking is itself supposed to be optimized.

The result already demonstrated (Bonnafous, 2010) is both simple and surprising: by denoting  $P_{op}$  this optimal programming toll and with the notations of the previous section, we have demonstrated that:

$$p_{op} = \frac{d_0}{\beta} \left(1 - \frac{2C \cdot \beta}{d_0^2}\right) \quad (12)$$

To verify that this toll is lower than or equal to one that maximizes revenue ( $d_0/2\beta$ ), we can put in the maximum revenue value ( $d_0^2/4\beta$ ) denoted as  $R_{max}$  and the corresponding subsidy value denoted as  $S_{min}$ , which is therefore the minimum subsidy equal to  $(C-R_{max})$ . Eq. (12) then becomes:

$$p_{op} = \frac{d_0}{2\beta} \left(1 - \frac{S_{min}}{R_{max}}\right) \quad (13)$$

With the same empirical values we used in the previous section, this gives us an order of magnitude of  $P_{op}$  shown in Figure 10.

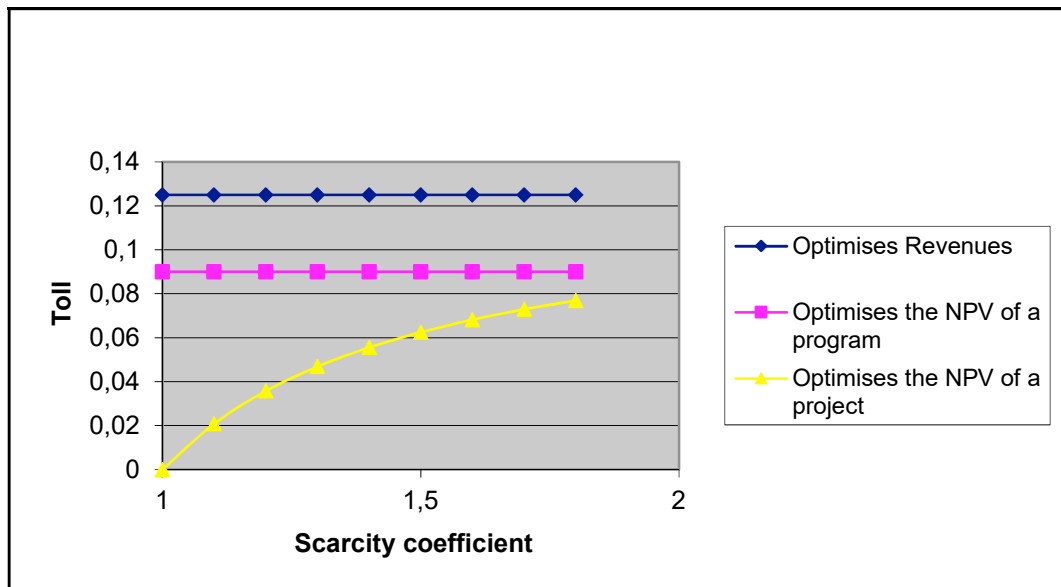


Figure 10: The optimal programming toll independent of the public-funding scarcity coefficient.

This optimal programming toll depends only on the cost of the project and the parameters characterizing the demand function. This result, formalised according to Eq. (13), can be interpreted in terms of the project's financial efficiency: when this is higher, with maximum revenue covering a large share of the costs, it is socially beneficial to close the gap by subsidy. If maximum revenue is higher than costs, the subsidy is zero and  $P_{op}$  becomes  $P_{Rmax}$ .

In this case, a franchise contract between government and operator does not require a specific clause on tolls, even if users need to be protected from excessive charges, because it is not in the operator's interest to charge tolls exceeding  $P_{Rmax}$ . On the other hand, the question does arise as to how any surplus should be shared out between franchisor and franchisee. Conversely, when the operation's financial rate of return is low, the minimum subsidy takes on greater importance and, if it reaches the maximum revenue level, the  $P_{op}$  is zero. In this case, a toll does not bring any welfare gains and the scenario is typically that of a partnership contract as defined under French law, such as those used for some toll-free stretches of motorway.

Eq. (13) even suggests a specific rule: toll-free infrastructure (possibly based on a partnership contract) would be the right solution whenever the maximum discounted revenue fails to cover at least half of the discounted cost

## 7. Evaluation of a multi-year investment program

Once the method has been established to define the optimal ranking of a program of projects, the question arises of the evaluation of a different program envisaged or already carried out. The following is taken from a preparatory report of the Round Table of the International Transport Forum presented in October 2021 (Bonnafous, 2021) on the topic “Broadening the scope of transport appraisal to capture the full impact of investments”.

The decision-maker had to choose among  $n$  projects  $i$ , characterized by their net present value  $\Delta W_i$  and by their subsidy need  $Sub_i$ . Under the constraint of the  $B_t$  budget limiting public expenditure to year  $t$ , the value of the welfare gain  $\Delta W$  generated by all the projects carried out can then be written as:

$$\Delta W(x) = \sum_{i=1}^n x_{it} \Delta W_i \quad (14)$$

$$Avec \quad B_t = \sum_{i=1}^n x_{it} Sub_i$$

where the  $x_{it}$  are variables which have a value of zero when the project is not carried out in year  $t$  and equal to unity when the project is carried out in that year. This value of  $\Delta W(x)$  observed for the programming period must obviously be compared with the value of  $W$  which would be realized by an optimal program, i.e.  $W_o$ . This optimal program is easily established by assuming the projects carried out in decreasing order of the ratio  $\Delta W_i / Sub_i$  and by saturating the budget constraint  $B_t$  each year. We can then define a global indicator of the effectiveness of the program by the relation:

$$IGE = W(x)/W_o \quad (15)$$

This indicator can also characterize the effectiveness of investments made over the duration of the program, by highlighting ex-post the loss in value compared to what an optimal program would have been, as well as characterize the effectiveness measured ex-ante of a program planned for a given period but deliberately set in a non-optimal order.

This last case may result, for example, from an objective of spatial equity. The indicator would then have the merit of proposing a measure of social loss, in the sense of the present loss of value is clearly linked to this political choice.

With the help of SNCF Réseau's economic services, this overall efficiency indicator was put to the test on a concrete case of programming investments and taking into account an optimal ranking (Bonnafous, Brunel | Marlot, 2017). It turned out that this company has an obligation to comply with certain rules in terms of infrastructure financing, in particular it can only make an investment if it does not jeopardize the balance of its accounts over time (the case of the public option presented in section 2). Thus, when the expected toll revenues do not cover the full costs, the investment can only be undertaken if a subsidy ensures its financial equilibrium (i.e. an IRR of at least 8%). All candidate projects are thus subject to a socio-economic evaluation, according to the regulations in force (Government, 2014) and a financial profitability evaluation resulting in the need for a subsidy.

We thus use sample 3 with 39 candidate projects that were the subject of evaluation. These data correspond to commissioning spread between 2010 and 2021 for the projects selected and included in planning contracts between the Government and the regions (CPER).

To calculate the overall efficiency indicator of the program thus implemented, i.e. the IGE defined by equation (13), we must calculate the net present value of the optimal program according to the definition we have for it, that is to say an order of realization, under budget constraint, according to the decreasing values of the NPV / Subsidy.

We therefore established this optimal program according to the following particularly simple algorithm: 1) The sum of the subsidies for projects actually commissioned in year  $t$  defines the budget constraint  $B_t$ , in accordance with the second equation of the system (12).

- 2) The projects are assumed to be carried out in descending order of the NPV / Subsidy, using each year  $t$  the maximum possible  $B_t$  subsidies deemed available.
- 3) When the  $B_t$  constraint is not saturated, i.e. it could be overridden by the last project considered, this project is assumed to be carried over to  $t + 1$  and the unused part of  $B_t$  is added to  $B_{t+1}$ .
- 4) The time series of NPVs thus produced is updated in the first year of the program.

The optimal program is thus established over a period for which the investments of the real program (referred to as CPER below) have been put into service or were in progress. This results in an optimal program with an overall NPV of 1,270 million euros, while the actual program NPV over this period is only 110 million euros. This corresponds to an IGE of only 9%.

However, it should be noted that this result, which suggests a significant destruction of value of 91% compared to what could have been achieved, is largely explained by the presence, in the CPER program, of investments whose NPV is negative. If we simulate, under the same budgetary constraint, the CPER program by removing investments with negative NPVs, the result is much less spectacular because the NPV amounts to 1,175 million euros, which corresponds to an IGE of 92%.

These results, summarized in Table 2 below, suggest that in the absence of optimal programming, a minimum requirement for the socio-economic profitability of the selected projects, for example the requirement of a positive (or very weakly negative) NPV, would be likely to considerably improve the efficiency of the investment policy in terms of value creation.

Table 2: General Efficiency Index for 3 programs.

	<b>Ranking optimal</b>	<b>Ranking (CPER)</b>	<b>Ranking CPER NPV &gt;0</b> +
<b>NPV of the program</b>	1270	110	1175
<b>IGE of the program</b>	100%	9%	92%

Source: Bonnafous A., Brunel J. & Marlot G. (2017)

In the absence of being able to rationally shed light on such choices, for example by promoting an evaluation with a parameter of aversion to inequalities, this ex-post approach based on a general index of efficiency has at least the merit of revealing the focus of concern, i.e. how much territorial equity can cost in terms of loss of social value.

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More generally, this last exercise reminds us that the question of the optimal ranking of investments has been relatively neglected by the literature. It also suggests that valuation is not only used to get closer to a second-best optimum that favors the creation of value, it is also used to determine the destruction of value caused by a decision that is not optimized.

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