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Explaining success and failures in PPP transport projects: an econometric approach

Lourdes Trujillo[1]
University of Las Palmas de Gran Canaria, Spain.

Federico Inchausti-Sintes[2]
University of Las Palmas de Gran Canaria, Spain.

Javier Campos[3]
University of Las Palmas de Gran Canaria, Spain.

Casiano Manrique-de-Lara-Peñate[4]
University of Las Palmas de Gran Canaria, Spain.

There are a multitude of factors, both internal and external, that may affect the development and success of any transport project. 'Success' is both context-dependent and quite difficult to measure. This paper distinguishes between four types of 'success' variables: (lack of) cost overruns; (lack of) time delays; (ex-post) level of traffic; and (generated) revenues. Each variable is modeled in a binary way (using discrete choice models), with each model estimating the relevance of various explanatory factors on the probability of success. Internal factors are found to have the greatest effect on that probability, and PPP projects seem to be prone to budget overruns and delays. Governance factors, such as the tender process, renegotiations, and issues related to penalties, among others, can all produce complications. Since the public authority has control over most of these variables, these results could be used to improve the 'success' of these projects.

Keywords: *PPP projects, transport sector, bivariate probit models*

1. Introduction

Luck or wisdom? What determines the success or failure of a public-private partnership (PPP) project in the transport sector? After exhaustively examining a large dataset of road, rail, air and maritime projects, the BENEFIT project[5] has concluded that a myriad of causes, both internal and external, may affect the development and success of any project, but also that these causes may be identified and analysed.

[1] C/Saulo Torón s/n, Despacho D.2.18, CP 35017, Las Palmas de Gran Canaria, Spain. T: +34 928451809, F: +34 928458183, E: lourdes.trujillo@ulpgc.es. Corresponding Author
[2] C/Saulo Torón s/n, Despacho D.3.01, CP 35017, Las Palmas de Gran Canaria, Spain. T: +34 928458212, F: +34 928458183, E: federico.inchausti@ulpgc.es
[3] C/Saulo Torón s/n, Despacho D.2.04, CP 35017, Las Palmas de Gran Canaria, Spain. T: +34 928451792, F: +34 928458183, E: javier.campos@ulpgc.es
[4] C/Saulo Torón s/n, Despacho D.2.21, CP 35017, Las Palmas de Gran Canaria, Spain. T: +34 928451810, F: +34 928458183, E: casiano.manrique@ulpgc.es

In general, any PPP agreement raises a number of economic issues, which not only include the question of when PPPs are preferred to other mechanisms (such as traditional procurement) but also relate to its various dimensions such as the efficiency of the tender, the contracting environment, the impact of renegotiation, and funding and financing options. In most cases all these issues ultimately boil down to one key question: what is the relationship between the two parties involved in the development of the project – the private sector and the public administration – and how might their divergent interests and procedures converge to a common end?

During the 1980s and 1990s, PPPs were predominantly employed as an alternative approach to fund infrastructure when governments lacked the resources to tackle large or medium size projects. Although this mechanism had occasionally been used in previous projects, its use has expanded in recent years as PPPs have increasingly been considered to increase the success of a project by sharing the risk between the private and the public parties and by connecting the remuneration (of the private partner) to specific performance goals (Ng & Loosemore, 2007). Nonetheless, this type of partnership has proved far from being a panacea or a 100% recipe for success. In fact, many PPPs are prone to renegotiation as in any other kind of project, particularly in the transport sector (Domingues & Miranda, 2016), and rely heavily on critical factors for success (such as a reliable revenue stream as pointed out by Grimsey & Lewis, 2002).

As mentioned above, the tendering procedure, economic planning and/or the economic context (Galilea & Medda, 2010) are just some of the issues that may jeopardize or improve the prospects of a project. The advantage of the two first factors is that they can be pre- established by the parties, although this does not necessary imply perfect control over them throughout the project. For instance, the degree of project debt financing may become unbearable because of an unanticipated change in demand that erodes revenues and reverses the, a priori, good economic planning. In many cases, bad performance leads to the parties having to renegotiate and thus, in increased costs and delays. The economic context, on the other hand, is governed by forces that are exogenous to the project, and that increase overall uncertainty. This paper aims to define the extent to which these causes, plus others, explain project success. However, even when these causes have been identified, it is difficult to measure them. To progress towards this aim, this paper employs indicators that seek to build upon previous academic findings and insights (Vanesslander et al, 2015; Voordijk et al, 2015; Pantelias et al, 2015; Roumboutsos et al, 2016; and Mladenovic et al, 2016).

On the other hand, the definition of 'project success' itself is also a continuing matter of debate in the field. Jugdev and Müller, for example, said: "success is an interesting word. The word connotes different things to different people and is very context-dependent" (Jugdev and Müller, 2005, page 19). Oisen (1971) had previously specified success as being related to cost, time and quality, the so-called "iron triangle"; although these have since evolved to include a wider range of criteria such as those of Shenhar et al. (2001). Nevertheless, even when there is agreement over specific success criteria, the way to measure them is far from clear, and greatly affected by the context. In this study, the following four measurement criteria for success have been selected: cost and time underruns (lack of cost and time overruns); and revenue and traffic achieved ex-post in relation to forecast values. The first two provide information during the construction process, while the latter two furnish data about success when the transport project is completed. Their values have been approached in a binary way so as to model them in a probabilistic framework; making use of discrete choice models.

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[5] BENEFIT is the acronym of Business Models for enhancing Funding and enabling Financing for Infrastructure in Transport, a European research project within the Horizon 2020 framework, which has studied between 2015-2017 the characteristics and results of the PPP transport projects in Europe. For details, see www.benefit4transport.eu

Specifically, current state-of-the-art analysis of PPP projects – even though they have developed strongly in both theoretical and practical case studies - lacks this kind of methodological approach. The dataset includes 56 transport cases, of which 41 are PPPs and 15 purely public projects.

2. Literature review

Success criteria differ among authors and are very context-dependent. As a first approach, iron triangle has been challenged, adapted and enriched over the years.[6] For instance, Shenhar and Dvir (2007) opt for a diamond approach rather than a triangle, to provide a more reliable assessment of risk and benefits and avoid potential gaps. Additionally, multilateral organizations, like the World Bank, stress the importance of the institutional framework (Amos, 2004).

The main empirical approach to project success in the literature – index numbers aside – has been to focus on cost and time (Flyvbjerg et al, 2003 and 2004; Sweis et al, 2008; or Assaf and Al-Hejji, 2006). Both variables can provide a reasonable approach in the short term when the project is being carried out, but lose their utility in the longer run.

Once the infrastructure is available, new criteria are needed. A project can be considered a success in terms of cost and time in the first phase, but falter in the long term because of lack of a demand, as highlighted by Shenhar and Dvir (2007) with the example of the Los Angeles Metro. In this sense, Lim and Mohamned (1999) distinguish between the micro and the macro point of view to stress the necessary distinction between the short term (completion) and the long term (more oriented towards customer satisfaction).

Another issue is that of the potential relationship among these variables. Flyvbjerg et al. (2004) checked that delayed projects are prone to increasing costs. This relationship was also found and analysed in other studies about the causes of time overruns in the construction industry (Memon et al, 2011). Torp et al. (2016), specifically study this relationship between cost and time delays by drawing on evidence from Norwegian construction projects.

The way in which these explanatory variables are analysed takes different forms. Mir and Pinnington (2014), use bivariate correlation and multiple regression tests to study the importance of different variables that contribute to project success. Osei-kyei and Chan (2015) review studies on the critical success factors for PPP projects and conclude that the most widely used approach is the case study. Domingues and Miranda (2016) use probit models to identify the main factors that explain the renegotiation of PPP projects.

This research follows a path that is in line with previous studies undertaken in this field where 'success' indicators along with 'success factors' have been explicitly defined. Our major contribution lies in scrutinizing the relationship among these variables using a bivariate probit model based on a large and non-previously exploited dataset.

3. Dataset

The dataset comprises 56 transport cases, of which 41 are PPPs and 15 public projects. Practically all these cases were obtained from the COST Action TU1001 (Roumboutsos et al, 2013; 2014) and the Omega Center Megaproject, which in turn were taken from 19 European and four non-European countries covering all means of transport.

[6] Chronologically, see for example: Pinto & Slevin (1988), Pinto & Prescott (1988), Atkinson (1999), Andersen et al. (2006), Brown, Adams & Amjad (2007), Chow and Ng (2007), Kolltveit et al (2007), Shenhar and Dvir (2007), Mir and Pinnington (2013), Ferrari et al. (2015) or Joslin and Müller (2016).

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The development of all 56 cases has been further decomposed into discrete intermediate stages (or 'snapshots') to provide more detailed data about their evolution. Nevertheless, the number of snapshots varies with each project, depending on the availability of information. The sum of these snapshots means that the dataset comprises 183 observations. The monitoring of each project has been carried out through the application of indicators. These indicators have been validated and revised by Vanesslander et al. (2015), Voordijk et al. (2015), Pantelias et al. (2015), Roumboutsos et al. (2016) and Mladenovic et al. (2016). The indicators are: financial-macroeconomic context; an availability and reliability index (IRA); cost savings; revenue support; governance; remuneration attractiveness; revenue robustness; market efficiency; and financing indicator; each of these are explained in detail in Appendix A.

4. The model

The aim of this study is to provide some empirical evidence regarding the factors that explain the "success" of a transport infrastructure project. Such 'success' is empirically approached by four variables: cost underruns (lack of cost overruns); time underruns (lack of time delays); actual versus forecast traffic, and actual versus forecast revenues. Note that cost and time variables are more focused on the short term (when the infrastructure building is still in progress), whereas traffic and revenue variables are more oriented towards the long term (when the infrastructure is already available for the users). However, the distinction between short and long term to contextualize the variables is blurred. Most infrastructure projects evolve at different stages; in which some phases become available while the rest remains in progress. During this process, some phases may, or not, incur budget overruns or delays. At the same time, as soon as certain phases become available, the project can generate demand/traffic and revenues which may, or not, exceed the traffic or the revenue forecast. The inclusion of 'snapshots' (intermediate stages) also helps to capture these different developments.

On the other hand, while the inclusion of variables such as cost overrun, or time overrun can be addressed easily, 'actual versus forecast traffic' and 'actual versus forecast revenue' are more qualitative and need to be analysed with caution. For instance, the revenue or level of traffic may not meet expectations; however, this does not necessarily imply that the project is a 'failure', but simply that expectations have not been met.

The endogenous variables take discrete values (binary outcomes), which involve the use of binary outcome models (micro econometric models). Finally, both pairs of variables (cost and time underruns; and revenue and traffic forecast) will be tackled simultaneously assuming correlation between them through the error term (equation (1)). This assumption involves the use of a bivariate probit model (Cameron & Trivedi, 2009). A bivariate probit has the following functional form (equation 1):

$$y_i = \sum_{j=1}^{n} X_{ij}\beta_j + u_i \qquad \text{being} \begin{bmatrix} u_i \\ e_i \end{bmatrix} N : \left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 & \rho \\ \rho & 1 \end{bmatrix} \right) \qquad (1)$$
$$q_i = \sum_{j=1}^{n} X_{ij}\gamma_j + e_i$$

Where sub index i denotes cases, y_i and q_i are the endogenous variables, X_{ij} represents the variable/factor j per case i, β_j and γ_j the parameter estimated by the model; and u_i and e_i are the error terms that are assumed correlated (ρ). The explanatory variables are those mentioned in the dataset: Financial-macroeconomic context; IRA; cost savings; revenue support; governance indicator; remuneration attractiveness; revenue robustness; market efficiency; and financing indicator. Finally, two dummy variables for PPP projects and the economic crisis have also been included. The former takes value 1 if the project is PPP, and zero in other cases. The latter takes value 1 if the project started in 2008 or later, and zero in other cases.

The discrete values of the four endogenous variables are as follows:

$$\textit{cost underrun} \begin{cases} 1 \text{ if cost is below budget or on budget (i.e. lack of cost overruns)} \\ 0 \text{ if cost is over budget (i.e. cost overruns)} \end{cases}$$

$$\textit{time underrun} \begin{cases} 1 \text{ if time is ahead of schedule or on time (i.e. lack of time delays)} \\ 0 \text{ if time is delayed} \end{cases}$$

$$\textit{revenue forecast} \begin{cases} 1 \text{ if revenue is exceeding forecast or as forecasted} \\ 0 \text{ if revenue is below or far below forecasted} \end{cases}$$

$$\textit{traffic forecast} \begin{cases} 1 \text{ if traffic is exceeding forecast or as forecasted} \\ 0 \text{ if traffic is below forecasted} \end{cases}$$

Alternatively, if the number of snapshots had been more balanced by cases, panel data models may have been applied. The highly unbalanced structure of the dataset implies that pool regressions provide more reliable results. (Wooldridge, 2002; Baltagi, 2005; and Cameron & Trivedi, 2009).

5. Results

Table 1 and Table 2 show the estimates of the four bivariate models (cost and time underrun; and revenue and traffic forecast, respectively). Both internal and external factors matter to explain project success. Variables such as *financial economic setting*, *governance*, *cost savings*, and *revenue support* have a significant effect on the cost underrun equation whereas, in the time underrun equation, the significant variables are: PPP, *crisis*, *financial-macroeconomic context*, IRA, *governance*, *remuneration attractiveness*, and *revenue robustness*. Similar reasoning can be undertaken regarding the revenue and traffic forecast model. In the revenue equation, PPP, *crisis*, IRA, *revenue robustness*, and *financing scheme* show a significant and positive effect. Whereas, in the traffic equation, the *financial-macroeconomic context*, IRA, *cost savings*, *remuneration attractiveness* and *revenue robustness* are the variables that better explain project performance.

The parameter "athrho" is the estimate of ρ. It is positive and significant in both models, which implies that both endogenous variables are positively and significantly correlated. The estimates of the models in Tables 1 and 2 show the linear change in utility but not in probability. The elasticities shown in Tables 3 and 4 provide the percentage change in the probability of success given a one percent change in the explanatory variables.

Table 1. Cost and time underrun estimation (bivariate model).

	Log pseudo likelihood = -112.011	Observations 124
		Wald Chi2(22)= 66.18 Prob Chi2=0.0001
	Coefficients	**Robust Std. Error**
Cost underrun:		
PPP	-0.392	0.450
Crisis	-0.083	0.333
Financial-macroeconomic context	3.11**	1.354
ARI	2.838	0.945
Governance	2.263**	0.980
Cost savings	1.431**	0.669
Revenue support	5.567***	1.561
Remuneration attractiveness	0.034	0.426
Revenue robustness	0.349	0.426
Market efficiency	-0.011	0.726
Financing scheme	0.204	0.742
Constant	-4.410***	1.618
Time underrun:		
PPP	-0.862**	0.418
Crisis	-0.971***	0.318
Financial-macroeconomic context	2.092*	1.185
ARI	2.786***	0.977
Governance	5.368***	1.181
Cost savings	-0.386	0.596
Revenue support	1.400	1.658
Remuneration attractiveness	-1.293**	0.593
Revenue robustness	-0.995**	0.503
Market efficiency	-0.038	0.719
Financing scheme	-0.662	0.725
Constant	-3.756***	1.485
athrho	0.887***	0.231
rho	0.710	0.114

***p<0.01, **p<0.05, *p<0.

Table 2. Revenue and traffic estimation (bivariate model).

	Log pseudo likelihood = -89.792	Observations 128
		Wald Chi2(20)= 91.35 Prob Chi2=0.000
	Coefficients	**Robust Std. Error**
Revenue forecast:		
PPP	-1.022**	0.509
Crisis	-0.895**	0.460
Financial-macroeconomic context	1.411	1.365
ARI	2.245**	0.963
Governance	1.000	1.014
Cost savings	0.503	0.615
Revenue support	4.826***	1.711
Remuneration attractiveness	0.900	0.627
Revenue robustness	1.762***	0.695
Market efficiency	-0.549	0.668
Financing scheme	-2.187**	0.914
Constant	-1.497	1.836
Traffic forecast:		
PPP	-0.309	0.429
Crisis	-0.462	0.323
Financial-macroeconomic context	3.854***	1.291
ARI	2.022***	0.965
Governance	0.884	1.122
Cost savings	1.092*	0.668
Revenue support	4.477***	1.629
Remuneration attractiveness	1.878***	0.614
Revenue robustness	0.818*	0.501
Market efficiency	-1.594***	0.663
Financing scheme	0.205	0.747
Constant	-5.863***	1.585
athrho	16.029***	1.533
rho	1	7.36e-14

***p<0.01, **p<0.05, *p<0.1

Table 3 shows the elasticities of the probability of the cost and time underrun model. PPPs reduce the possibility of finishing a project successfully (either below budget or on budget and ahead of schedule or on time) by 0.35% respect to both public projects and the concession of operation projects. On the other hand, the *economic crisis*, an external factor, negatively affects the success of the project. Specifically, projects undertaken during the crisis years were 0.34% less likely to finish successfully. Another external factor is the *financial-macroeconomic context* (macroeconomic environment and financial market development): this variable has a positive effect on the probability. A 1% increase in this variable increases the probability of finishing the project successfully by 1.014%.

On the other hand, internal factors such as IRA or *governance* provide the greatest change in the probability of success. Thus, a 1% increase in them increases the probability of success by 1.23% and 1.85%, respectively. In other words, improvements in the reliability and the availability of the infrastructure, as well as in the contractual conditions, increase the probability of success in term of cost and time. This variable is particularly relevant because it shows the highest effect on the probability and because the public authority can have greater control over it. Finally, the last significant variable in the model is revenue support where a 1% improvement means an increase in the probability of success of about 0.41% (i.e. those projects that better generate revenues and exploit potential sources of revenue, increase their probabilities (by 0.41%) of finishing the project successfully in term of cost and time.

Table 4 highlights the results regarding elasticity in the revenue and traffic forecast model. Firstly, neither PPP projects nor the economic crisis affect the probability of both revenue and traffic forecast. On the other hand, an increase in 1% in the financial-macroeconomic context improves the probability of success by about 1.24%. In relation to the internal factors, the followings variables increase the probability of success in terms of revenue and traffic: IRA, the capacity to keep costs under control (cost savings), the ability of the project to generate revenues and exploit its potential sources of revenue (revenue support), and both the income and the revenue streams weighted against their risks (remuneration attractiveness and revenue robustness). A 1% increase in these factors are associated with a 1.08%, 0.21%, 0.49%, 0.54% and 0.26% increase in the probability of matching the revenues and the traffic forecast, respectively. Finally, the political attractiveness of the project funding scheme (market efficiency) leads to a decrease in the probability of matching the revenues and the traffic forecast by about 0.35%.

Table 3. Elasticities of cost and time underrun.

	ey/ex	Robust Std. Error
PPP	-0.352*	0.200
Crisis	-0.347**	0.156
Financial-macroeconomic context	1.014**	0.472
IRA	1.232**	0.544
Governance	1.851***	0.461
Cost savings	0.076	0.132
Revenue support	0.414**	0.197
Remuneration attractiveness	-0.287	0.184
Revenue robustness	-0.196	0.152
Market efficiency	-0.007	0.152
Financing scheme	-0.181	0.349

*** p<0.01, **p<0.05, *p<0.10

Table 4. Elasticities of the revenue and the traffic forecast.

	ey/ex	Robust Std. Error
PPP	-0.126	0.177
Crisis	-0.202	0.144
Financial-macroeconomic context	1.248***	0.432
IRA	1.084**	0.545
Governance	0.311	0.405
Cost savings	0.211*	0.125
Revenue support	0.491***	0.176
Remuneration attractiveness	0.547***	0.179
Revenue robustness	0.267*	0.163
Market efficiency	-0.354***	0.152
Financing scheme	0.090	0.327

*** p<0.01, **p<0.05, *p<0.10

6. Conclusions

The aim of this study has been to provide some empirical evidence regarding the factors that explain the 'success' of a transport infrastructure project. Our first conclusion, from a technical viewpoint, is that a case study dataset – in particular, the one generated from the BENEFIT EU research project (see www.benefit4transport.eu) – can be used to find and measure common factors regarding the development and results of these transport projects. In fact, by expanding the information using intermediate stages or 'snapshots', we have been able to apply a bivariate probit model to obtain reliable estimates of the qualitative relationship among explanatory variables.
Secondly, both internal and external factors explain the probability of success both in term of cost and time; as well as in terms of revenue and traffic forecast. However, internal factors seem to provide the greatest effect on the probability of success so that, for example, while an unexpected economic shock may adversely affect the project funding, and thus, its success, managers and policymaker's may work upon these variables to overcome the external negative effect and keep the project on track.

For instance, when focusing on the time lapse between the moment the project is awarded and the period when the infrastructure has not yet been finished, most attention should be oriented towards monitoring the following factors: PPP; IRA; *governance*; and *revenue support*. These variables are associated with the public-private partnership, the reliability and availability of the infrastructure, the contractual conditions (number of bidders, bonding requirements, clauses enabling the service to be updated and/or price changes, among others) and the capacity to generate revenues and potential sources of revenue within the projects, respectively.

On the other hand, in the long term: IRA; *cost savings*; *revenue support*; *remuneration attractiveness*; and *revenue robustness* offer the greatest effect on the probability of success in term of revenue and traffic. These variables are associated with the reliability and availability of the infrastructure, the capacity to keep costs under control, exploit the project's potential sources of revenue; and its income and revenue streams, weighted by their respective risks.

Thus, policymakers should improve the incentives mechanism related to cost and time aspects so as to bend the propensity of PPPs to incur in budget issues and delays. In this sense, aspects relating to governance can play a relevant role toward this aim. In sum, the public authority has a great degree of control over all aspects related to governance - such as: the tender process; any renegotiation; the encouraging of competition between bidders; increasing penalties in case of delays or cost overrun; and monitoring and controlling the expected cost of the project – and they should make greater use of this power to increase the success rate of PPP projects.

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Appendix A

The variables can be defined in the following way:
the *macroeconomic and financial context* indicator is based on international indices and it measures the business environment or the capacity to achieve sustained economic growth. Specifically, it comprises two elements: growth; and macroeconomics and financial terms. The World Economic Forum provides information about the former which is publicly available: the so-called '*global competitiveness index*'. This index aims to evaluate the capacity of a country to achieve sustained economic growth. The second is based on both macroeconomic and financial indicators such as inflation, general government final consumption expenditure, GDP per capita growth, the unemployment rate, Standard & Poor's global equity prices and domestic credit to the private sector.
IRA measures the reliability (% time of disruptions during operation) and availability (% time of availability of the transport infrastructure or the days in a year that the infrastructure is available to the users). Both reliability and availability take value 0, 0.5 or 1; 0 being not reliable/available and 1 fully reliable/available. Algebraically, the composite indicator is:

$$IRA = \frac{[(1 + Reliability)(1 + Availability)]}{4}$$

Cost savings is based on several indicators that seek to measure the efficiency of the projects to keep costs under control in terms of construction and operation. The cost-saving function is comprised of the following two sub-functions: the construction cost and the operation/maintenance cost; which, at the same time, are built on the following group of variables. Regarding the construction cost sub-function:

level of civil works (x_1),

capability to construct (x_2),

capability of the Contracting Authority to monitor construction (x_{ca2}),

level of optimal construction risk allocation (x_3),

adoption of innovation (x_4),

capability to innovate (x_5), and

capability of the Contracting Authority to plan (x_{ca1}).

The capability of the Contracting Authority to monitor construction (x_{ca2}) seeks to answer questions related to re-negotiations during the project implementation period, stakeholders' support of the project or the good project management record of the public authority. In the case of the capability of the Contracting Authority to plan (x_{ca1}), this variable focuses on the political decision to adopt a PPP or public procurement or the development of studies about the feasibility of the project, among other aspects.

On the other hand, regarding the operation/maintenance cost, the variables are:

life cycle planning (x_6),

capability to operate (x_7),

level of optimal operation risk allocation (x_8), and

capability of the Contracting Authority to operate (x_{ca3}). The latter address issues such as the experience of the public authority to operate the specific infrastructure.

All these variables take value 1 if the answer is positive or 0 otherwise. Algebraically, the cost saving element can be expressed as follows:

$$CS = x_2 x_3 x_{ca2} - (x_1 - x_1 x_2 x_3) + x_4 x_5 x_{ca1} - x_6 x_7 x_8 x_{ca3}$$

during the construction phase and $CS = x_6 x_7 x_8 x_{ca3} - x_{COR}$ during the operation phase; where x_{COR} represents the cost overrun of the construction phase in percent (%). If CS=0, not cost saving is observed. On the other hand, if CS<0, cost overruns may be observed.

Revenue support is also a composite indicator that tries to approach the ability of the project to generate revenues and exploit its potential sources of revenues. As in the case of the cost saving, it is composed of sub-functions with their respective variables:

the level of competition for greenfield projects (x_{11}) and brownfield projects (x_{16}) which refer to the position of the infrastructure in the transport network or the degree of 'exclusivity'.

Revenues from the greenfield part of the project as: share of greenfield (x_{10}), capability to manage traffic demand (x_{12}), level of optimal risk allocation demand (x_{13}), satisfaction level (x_{14}),

Revenues from the brownfield part of the project: share of brownfield (x_{15}), capability to manage traffic demand (x_{17}), level of optimal risk allocation demand (x_{18}), satisfaction level (x_{14}), Revenues from other transport activities from within the project or even from different transport projects (cross-subsidization): Share of other transport projects (x_{16}), capability to manage traffic demand (x_{17}), level of optimal demand risk allocation demand (x_{18}), satisfaction level (x_{14}),

Revenues from other non-transport activities from within the project or other non-transport projects: share of non-transport activities (x

Other wider impacts (positives or negatives) such as economic, environmental, social, or institutional).

The variables associated to 'revenue support' take values from 0% to 100%; being 0% not addressed or included by the project and 100% fully addressed or not included by the project. The sub-functions are combined in the following manner to yield the 'revenue support':

$$RS = (x_{11} + x_{16})sb + x_{10}x_{11}x_{12}x_{13}x_{14} + x_{15}x_{17}x_{18}x_{19} + x_{16}x_{12}x_{13}x_{14} + x_{20}x_{21}x_{2};$$

being sb the share of brownfield.

Governance is comprised of two dimensions: efficiency/effectiveness and contractual flexibility. Those interested in the indicator are referred to Clarke (2004, 2007) and Mallin (2004, 2006), among others. This indicator focuses on transactions, but not on stakeholders' issues. According to Li *et al* (2012), it helps to reduce transaction cost. Briefly, the development of this indicator implies the following dimensions:

Efficiency/effectiveness of governance:

The client selected only one service provider [bidder] to participate in the pricing stage (G_1).

The client and the key service providers [bidders] collectively estimated the expected project cost (G_2).

Encouragement of competition between bidders (G_3).

Integration of design and construction (G_4).

The key service providers [contractor] paid a penalty if completion dates were not met (G_5).

The key service providers [contractor] solely carried the risk of rising costs (G_6).

The client and key service providers [contractor] [to share] shared equal proportions of profit due to cost underruns (G_7).

Bonding requirements (G_8).

All exploitation, commercial/revenue & financial risks are shared (G_9).

Contractual flexibility:

Clauses enable both updating of service and price changes (G_{10}).

Clauses indicate that client has an option to terminate the agreement without cause (G_{11}).

G_1, G_2, G_5 and G_6 take value 0, 0.5 or 1 being 0 'negative response' and 1 'totally affirmative response'. The other variables take value 0 (negative response) or 1 (affirmative response).

Algebraically, the overall governance indicator is:

$$GI = \frac{\sum_{i=1}^{n} G_i}{n}$$

Remuneration attractiveness (*RA*) reflects the attractiveness of the remuneration scheme for investors. It is composed of 'cost recovery' (*CR*) (income streams) and 'risk of income' (*RI*). The former can be defined as the share of coverage of project costs assured by the funding scheme (%). The latter is the sum of the product of the share (%) of income/s on total revenues (include multiple source of income) and the risk of the income/s source/s. That is, $RI = \sum_{i=1}^{h} a_i \sum_{j=1}^{w} b_j$

being a_i the share of the i^{th} income on total revenues and b_j the risk of the j^{th} source of risk of the income streams. Finally, the *RA* indicator is: RA=RA*W if CR >0, where W represents the weight of *RI* in the remuneration.

Revenue robustness' (*RR*) is identical to the *RA* indicator. The main difference between both indicators is semantic. Revenues refer to those incomes generated by the projects (subsidies are not included) while remuneration refers to the stream of incomes received by the project manager. Algebraically, the formula is equal to the *RA* indicator. Thus, this indicator is formed by 'cost recovery' and 'risk of revenues' instead of 'risk of income'.

Market efficiency' (*ME*) is a composite indicator that reflects the political attractiveness of the project funding scheme from the perspectives of the efficiency of utilization of the transport infrastructure and the acceptability of the funding scheme for voters. More precisely, this indicator includes the following dimensions:
Adherence of the infrastructure usage of pricing scheme to (social) marginal cost of infrastructure use (smc_1). Two key questions are: does the pricing scheme reflect scarcity (airports and ports) or congestion (roads and railways)? Does the pricing scheme reflect the internalization of the environmental impact and infrastructure costs? This is scaled from 1 to 4; being 1 not related and 4 fully related.
Application of consistent marginal cost pricing scheme in competitive infrastructure (smc_2). This involves analyzing any change in the pricing when there is similar infrastructure available. This dimension takes value 1 if the answer is yes and 0 otherwise.
The formula for the 'market efficiency' indicator is: $ME = smc_1$ if smc_2 >0
The *Financing indicator* (*FI*) reflects an expanded version of the weighted average cost of capital (*WACC*) of the project that is able to consider financing contributions from both public and private sources. The mathematical form of the indicator is:

$FS = 1 - WACC_{project}^{adjusted}$ and $WACC_{project} = K_E \frac{E}{E+D+G} + K_D \frac{D}{E+D+G} + K_G \frac{G}{E+D+G}$

$WACC_{project}^{adjusted}$ is the *WACC* (Brealey *et al*, 2011) of the project but adjusted by the theoretical cost of funds assigned to the different sources of equity and debt

$(WACC_{project}^{adjusted} = \frac{WACC_{project}}{Z}, Z \in \mathbb{Z}^{+})$.

K_E represents the cost of the equity of the project. If the data is available, the Capital Asset Pricing Model (CAPM) is used for the estimation. In case of missing data, theoretical values are used as the source of this equity contribution.
K_D is the cost of debt of the project. Information about loan interest rate or bond coupons are used to approach this cost. Theoretical values are used in the absence of such information.
K_G is the cost of public sector funds of the project.
E is the equity financing contribution (in monetary value or share %) to the project.
D is the debt financing contribution (in monetary value or share %) to the project.
G is the public sector financing contribution (in monetary value or share %) to the project.
z is the range of the theoretical scale that has been used to price the cost of funds for the various sources of equity and debt. In general, is assumed to be a positive integer number (in this case).