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Factors affecting the cost performance of transport infrastructure projects

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The research objective of this paper is to identify the key factors that affect the cost performance of all types of transport infrastructure projects. The method used is the fuzzy set QUALITATIVE COMPARATIVE ANALYSIS (fs QCA), which allows identifying combinations of factors that affect the cost performance. Results show that 30% of the projects, which are on cost, are explained by a good institutional context, a high ability to save costs, high revenue robustness, high transport market efficiency and acceptability and a mostly public financing scheme as core conditions, combined with good governance as peripheral condition. Also, 29% of the projects, which are over cost, are explained by an unfavourable financial-economic context and mostly a private financing scheme as core conditions, combined with inadequate governance as a peripheral condition. In the on-cost analysis, financing scheme and governance appear to be 'positive', while in the over-cost analysis, they appear to be 'negative', thus acting consistently and showing their importance, since they contribute respectively to the achievement or not of the cost target. These results can provide useful lessons to academics, practitioners, policy makers and all other stakeholders involved in transport infrastructure projects.

Keywords: *cost performance, fuzzy set qualitative comparative analysis, transport infrastructure projects.*

1. Introduction

Transport infrastructures are critical components for the competitiveness and economic growth (Nazemzadeh et al., 2015) and for the social and regional-economic development as well (OECD, 2011; International Transport Forum, 2002). The demand for the transportation of goods and persons is growing, therefore the need for extending the capacity of transport infrastructures is

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becoming higher as well. Hence, there is a need for constructing new infrastructures, improving the efficiency and capacity of the existing ones and maintaining them (Vita & Marolda, 2008). In Europe, immense amounts of money are invested in constructing new transport infrastructures and maintaining existing ones.

Since new transport infrastructures are constructed and existing ones are further developed, it is deemed critical to enhance the awareness about factors leading to successful transport infrastructure projects. A project is deemed successful when it meets its goals (Edkins et al., 2012). In project management, one of the main project goals is 'cost': projects attempt to be on budget (Newell and Grashina, 2003). Thus, cost is used as a success indicator (dependent variable) in this analysis.

More particularly, the purpose of this paper is to identify the factors that affect the cost performance of transport infrastructure projects of various types: seaports, roads, airports, rail, tram/rail, bridges/tunnels and metro. We define success as the achievement of the cost target (being on cost) and failure as the non-achievement of the cost target (being over cost). A fuzzy set Qualitative Comparative analysis (fs QCA) is conducted for the cost outcome. The results of this paper can provide useful lessons to academics, practitioners, policy makers and all stakeholders involved in transport infrastructure projects.

Section 2 presents a literature review, showing the factors that contribute to the success and failure of infrastructure projects. Section 3 describes the method used and also the cases, indicators and models that are tested. In Section 4, results show the combination of factors that affect the cost performance of transport infrastructure projects. In section 5, we further discuss the results, focusing on the cases that appear to be the most relevant to the solution paths. In section 6, in the conclusions, the main findings are presented and linked to the literature.

2. Literature review

A literature review is conducted to see which are the main success and failure factors of transport infrastructure projects, according to other relevant scientific research, and therefore to see if our findings confirm what has been already found in literature or if they differ to some extent (see Table 1). The literature review is largely based on seven major construction and project management journals[5]. We should also point out that some of these results define failure as the combination of having both cost overruns and delay.

We first of all observe that literature mostly refers to success in general. Also, many papers examine general construction projects and not specifically transport infrastructure projects, as we do. Even when transport infrastructure projects are studied, then the sample is composed only by one type of transport infrastructures (e.g. roads) or a few (e.g. rail, road, fixed and link projects). This paper tests a set of cases coming from all types of transport infrastructures (airports, seaports, roads, rail, metro, tram/rail, bridges/tunnels). Also, the projects examined in literature are mostly projects located in developing countries and not in developed countries, as our sample, which focuses on European projects. Last but not least, most often, the literature sample used is composed of projects that are only public-private partnerships (PPPs) or public projects, whereas our sample in this paper includes PPPs and public projects as well.

Literature points to different factors affecting cost performance of infrastructure projects. This section presents the factors found in literature according to the framework (typology indicators) that is used for the analysis in this paper. The typology indicators used are the following eight: 1)

[5] Construction Management and Economics (UK), International Journal of Project Management (UK), Journal of Construction Procurement (UK), Journal of Construction Engineering and Management (US), Engineering, Construction and Architectural Management (UK), Journal of Management in Engineering (US) and Project Management Journal (US).

Institutional Context, 2) Financial & Economic Context, 3) Governance, 4) Cost Saving, 5) Remuneration Attractiveness, 6) Revenue Robustness, 7) Transport Market Efficiency and Acceptability and 8) Financing Scheme (see Section 3 & Appendix B). These indicators are identified by Roumboutsos et al. (2016b) and we use them here to structure the literature review.

Table 1. Factors that affect the success and failure of infrastructure projects, as identified in literature and being clustered per variable of the present analysis

Clusters	Factors	Author
Institutional context		
On cost	External Environment: political & social (including political support & stability & public/community support)	Chan et al. (2004) (see also Akinsola et al., 1997; Belout, 1998; Chua et al., 1999; Songer & Molenaar, 1997)
	Less corruption	(Galilea & Medda, 2010; Hammami et al., 2006; Percoco, 2014)
	Effective rule of law/Regulatory quality	(Delhi & Mahalingam, 2013; Hammami et al., 2006; Mota & Moreira, 2015; Percoco, 2014)
	Favourable legal framework	Osei-Kyei & Chan (2015)
	Institutional quality	(Hammami et al., 2006; Zagozdzon, 2013)
	Role of political and institutional environment where the projects are sited	Castano (2011) and Mahalingam & Kapur (2009)
Cost overrun	Political/social: public opposition, high service charge to end users	Chan et al. (2010)
	Inappropriate government policies	Chan & Park (2005)
	Bureaucratic indecision	Morris (1990)
	Inappropriate organizational structure	Flyvbjerg et al. (2003); Kaliba et al. (2008)
	Unconducive Regulatory environment	Azhar et al. (2008); Shibani & Arumugam (2015)
	Deliberate cost underestimation	Flyvbjerg et al. (2003); Nijkamp & Ubbels (1999);
	Manipulation of forecasts	Flyvbjerg et al. (2003); Wachs (1987)
	Private information	Arvan & Leite (1990); Flyvbjerg et al. (2003)
	Lack of well-established legal framework	Chan et al. (2010)
Financial-economic context		
On cost	External Environment: Economic, industrial and the level of technology	Chan et al. (2004); (see also Akinsola et al., 1997; Chua et al., 1999; Kaming et al., 1997; Songer & Molenaar, 1997; Walker & Vines, 2000)
	Macro-economic stability	(Hammami et al., 2006; Mota & Moreira, 2015; Zagozdzon, 2013)
	High public debt	Hammami et al. (2006)
	Available financial market	Chan et al. (2010)
Cost overrun	Currency devaluation	Fouracre et al. (1990)
	Rises in interest charges	Fouracre et al. (1990)
	Price fluctuation	Mansfield et al. (1994)
	Macro-economic factors	Azhar et al. (2008); Shibani & Arumugam (2015)
	Non-conducive financial market	Chan et al. (2010)
	Unstable cost on material	Azhar et al. (2008); Chan & Park (2005)
Contractual governance		
On cost	Procurement-related factors	Chan et al. (2004) (see also Kumaraswamy & Chan, 1999; Walker, 1997; Walker & Vines, 2000)

	Transparent & competitive procurement process	Osei-Kyei & Chan (2015)
	Suitable/appropriate risk allocation	Osei-Kyei & Chan (2015)
	Transparent and adjusted contracts	Mota & Moreira (2015)
	Clarity of roles and responsibilities among parties	Osei-Kyei & Chan (2015)
Cost overrun	Cost of unforeseen service and utility	Fouracre et al. (1990)
	Wrong method of cost estimation	Azhar et al. (2008); Chan & Park (2005)
	Completion time of project	Odeck (2004)
	Misallocation of risk	Chan et al. (2010)
	High transaction cost	Chan et al. (2010)
	Poor contract management	Mansfield et al. (1994)
	Inaccurate estimates	Mansfield et al. (1994)
	Cost underestimation	Flyvbjerg et al. (2003); Nijkamp & Ubbels (1999)
	Lack of competition	Chan et al. (2010)
	Lowest bidding procurement	Azhar et al. (2008); Chan & Park (2005)
	High bidding cost	Chan et al. (2010)
	Length of bidding and negotiation process	Chan et al. (2010)
Remuneration attractiveness		
On cost	Economic viability	Mota & Moreira (2015)
	Government providing guarantees	Osei-Kyei & Chan (2015)
Cost overrun	Inadequate funding of project	Morris (1990)
	Problematic payment of completed works	Mansfield et al. (1994)
	Inadequate dedicated funding process	Flyvbjerg et al. (2003); Pickrell (1992)
Financing scheme		
On cost	Financial capabilities of private sectors	Osei-Kyei & Chan (2015)
Cost overrun	Poor financing	Flyvbjerg et al. (2003); Mansfield et al. (1994)
Transport Market Efficiency & Acceptability		
Cost overrun	Political/social in nature: public opposition, high service charge to end users	(Chan et al., 2010)
Cost Saving		
On cost	Project management factors	Chan et al. (2004) (see also Belout, 1998; Chua et al., 1999; Walker & Vines, 2000)
	Project participants related factors	Chan et al. (2004); (see also Belassi & Tukel, 1996; Chan & Kumaraswamy, 1997; Chua et al., 1999; Dissanayaka & Kumaraswamy, 1999; Hassan, 1995; Songer & Molenaar, 1997)
	Suitable/appropriate risk allocation	Osei-Kyei & Chan (2015)
	Good feasibility studies	Osei-Kyei & Chan (2015)
	Detailed project planning	Osei-Kyei & Chan (2015)
	Technology innovation	Osei-Kyei & Chan (2015)
	Pre-project planning & clarity in scope	Tabish & Jha (2011)
	Effective management control	Chan et al., (2010)
	High level of know-how from both partners	Mota & Moreira (2015)
	Project-related factors: type, nature, complexity & size	Chan et al. (2004) (see also Akinsola et al., 1997; Belout, 1998; Chua et al., 1999; Songer & Molenaar, 1997)
	Previous PPP experience	(Hammami et al., 2006; Zagozdzon, 2013)
	Strong private consortium	Osei-Kyei & Chan (2015)
Cost overrun	Poor project design and implementation	Morris (1990)
	Changes in specification	Fouracre et al. (1990)
	Technical uncertainty	Flyvbjerg et al. (2003); Kaliba et al. (2008)
	Forecasting errors and inadequate planning	Flyvbjerg et al. (2003); Nijkamp & Ubbels

process	(1999); Pickrell (1992)
Poor project management	Azhar et al. (2008); Chan & Park (2005)
Long period between design and tendering (pre-construction)	Azhar et al. (2008); Chan & Park (2005)
Additional work, improper planning	Azhar et al. (2008); Chan & Park (2005)
Misallocation of risk	Chan et al. (2010)
Lack of suitable skills and experience	Chan et al. (2010)
Lack of innovation and design	Chan et al. (2010)
Length of implementation phase & pre-construction phase	Cantarelli et al. (2012); Flyberg et al. (2004)
Accurate project planning & monitoring	Doloi (2013)
Design efficiency	Doloi (2013)
Effective site management	Doloi (2013)
Contractor's efficiency	Doloi (2013)
Lengthy lead time	Chan et al. (2010)
Shortages of materials	Mansfield et al. (1994)
Strategic behaviour	Arvan & Leite (1990); Flyvbjerg et al. (2003)
Inadequate decision making process	Morris (1990)

3. Method-cases-indicators-models

This section describes how the fuzzy set Qualitative Comparative Analysis (fsQCA) method works, what the main characteristics of the cases used are, how the variables inserted in our models are selected and which are the models that we are testing.

3.1 Method description

FsQCA is a comparative method that offers a middle path between quantitative and qualitative methods (Ragin, 2008). It is called comparative because "it explores and finds similarities and differences in outcome across comparable cases by comparing configurations of conditions" (Ragin, 1987, 1994; 2000; 2003; Rihoux & Ragin, 2008; Rihoux, 2008, as cited in Marx & Dusa, 2011)[6]. The method identifies which conditions (variables) are necessary and sufficient to bring about a certain outcome. This is different from statistical methods, which focus on how explanatory variables independently affect the explained variable (dependent variable).

There are two reasons why fsQCA is used. First, it is highly appropriate for analysing small N cases or intermediate N cases (around 40-50 cases). Previous research has pointed out the benefits of using fsQCA on a medium-sized dataset, compared to traditional regression analysis (Vis, 2012). But fsQCA is not useful in very small samples (e.g. less than 12 cases) (Fiss, 2008). Second, fsQCA forces researchers to achieve conceptual clarity through the calibration procedure, in which cases are assigned to sets (Appendix A).

The steps of fsQCA include: (1) the identification of the outcomes that we want to analyse and the selection of relevant conditions, the combination of which will have an impact on the outcome, 2) the calibration of values into sets, 3) the construction of a truth table[7], 4) the minimization of

[6] According to Ragin (2008), fuzzy sets are at the same time qualitative and quantitative because they are case-oriented and variable-oriented. They are case-oriented because they focus on sets and set membership (qualitative states). Case-orientedness is about preserving the rich information about the complexity of the cases (configuration of case). Fuzzy sets are also condition-oriented, which refers to the comparison and the degree of membership of a case on a variable/condition. This aspect provides a basis for precise measurement, which is very important in quantitative research.

[7] Another step could be also added before the construction of the truth table. This step includes checking for necessary conditions (Rihoux & Ragin, 2009). A necessary condition is a condition, which should be present so as the outcome to occur, but its presence does not guarantee the occurrence of the outcome. In general, a necessary condition is interpreted as a superset of the outcome, whereas a sufficient condition is interpreted as a subset of the outcome. The truth table is an analysis of sufficiency (Rihoux & Ragin, 2009).

consistent configurations to form a solution formula, and 5) the interpretation of solutions (Rihoux and Ragin, 2009). The selection of outcomes and conditions is made based on the research question and the in-depth knowledge of the cases and variables of the researcher, respectively. The maximum number of conditions that can be used depends on the number of the cases (see in Marx and Dusa, 2011).

The calibration, which is the most important step after the data gathering in the fsQCA, refers to assigning specific membership scores to cases, on a scale from 0, meaning 'fully out of the set', to 1, meaning 'full membership in the set' (Verhoest et al., 2014) (see Appendix A).

The interpretation of the results is mainly based on the **consistency** and **coverage** values, which are indicated in the solution formulas. In the sufficiency analysis, consistency measures the proportion of cases sharing a given combination of conditions that agree in displaying the outcome under examination; like significance of a correlation (Ragin, 2008). For example, if four out of four cases are consistent, the proportion is 1.0, if seventeen out of twenty cases are consistent, the proportion is 0.85. Some scientists consider a consistency of 0.75 as a satisfying consistency, which shows that a set relation exists but others set an even higher and stricter threshold and accept only 0.85 or higher. A consistency score should be as close as possible to 1.0 (perfect consistency). Low consistency is caused by including irrelevant conditions and/or missing crucial conditions, using inadequate values for the conditions, and miscalibrating the conditions or outcomes (Legewie, 2013).

Coverage, in the sufficiency analysis, assesses the degree to which a cause or causal combination ''accounts for'' or covers occurrences of the outcome (Ragin, 2008). When there are quite a lot of paths to the same outcome, the coverage of any given causal combination may be small. Thresholds are not as strict for the coverage as for the consistency.

The same measures of consistency and coverage can be used also for the necessity analysis. Consistency, in the necessity analysis, measures the degree to which occurrences of the outcome agree in displaying the causal condition thought to be necessary. Coverage in the necessity analysis, shows the degree to which occurrences of the condition are paired with occurrences of the outcome (Ragin, 2008) (Figure 1).

Type of set-theoretic relation		
Procedure	Cause *(X)* is a subset of outcome *(Y)* (sufficiency)	Outcome *(Y)* is a subset of cause *(X)* (necessity)
Step 1	Assess consistency using $\Sigma[min(Xi,Yi)]/\Sigma(Xi)$	Assess consistency using $\Sigma[min(Xi,Yi)]/\Sigma(Yi)$
Step 2	If consistent, assess coverage using $\Sigma[min(Xi,Yi)]/\Sigma(Yi)$	If consistent, assess coverage using $\Sigma[min(Xi,Yi)]/\Sigma(Xi)$

Figure 1. Assessing consistency and coverage (Ragin, 2008; p.63)

How to calculate consistency of cases in the sufficiency analysis? One should sum up all the membership scores of the cases that are consistent in a causal condition or causal combination and divide that number by the sum of all the membership scores in a cause or causal combination. Consistent is considered a case with a membership score in a causal condition or combination of conditions that is less than or equal to the membership score in the outcome. For example, we have twelve cases that are all consistent and their sum of membership scores to causal condition or combination equals 4.7. Thus consistency will be *1.0 (4.7/4.7)*. But if we assume that one of the twelve cases has a membership score in the causal condition or combination of conditions *(X)* greater than in the outcome *(Y)*, then this condition is not consistent; or alternatively we could say that it is consistent partially. If we assume that the

membership score in the *X* that was initially 0.7 increases to 1.0 and thus it is greater than the membership score in the *Y* which is 0.9, then consistency equals *0.98 (4.9/5)* (see Figure 1-step 1-column 2). This is because the additional value up to which the membership score is consistent is 0.2, which is added in the numerator, while the denominator is increased by 0.3 since it sums all the membership scores, consistent and inconsistent. In other words, for the numerator we sum the *min* (X_i, Y_i^8), meaning that we select the lower of the two values (see Figure 1).

Coverage in the sufficiency analysis is calculated by using the consistency formula and simply changing the denominator by substituting the sum of the membership score in the outcome $\Sigma(Yi)$ for the sum of the membership score in the cause or causal conditions $\Sigma(Xi)$ (Ragin, 2008).

3.2 Cases

The data used for this analysis are retrieved from the database of the Horizon 2020 project BENEFIT, funded by the European Commission. These data are collected through desk research and interviews with direct stakeholders of transport infrastructure projects. The projects come from different transport modes and different European countries. The interviews are made based on questionnaires developed especially for our research work. These questionnaires include the key characteristics related to financing and funding transport infrastructures and the achievement of different performance targets. The information collected based on the answered questionnaires for each of the cases (projects) is available on www.benefit4transport.eu. The dataset in this analysis is composed by 51 projects, covering all types of transport infrastructures. Based on the number of projects used, the maximum number of conditions[9] that could be used is eight. Thus, eight conditions are effectively used.

3.3 Indicators & models

For selecting the actual indicators for the analysis, firstly, the factors that affect the performance of transport infrastructure projects were identified. According to Roumboutsos et al. (2016b), the basic elements of the transport infrastructure investments are the: 1) Business Model, 2) Financing scheme, 3) Funding scheme, 4) Governance/Contractual arrangements, 5) Implementation context and 6) Transport mode context. As we can see in Table 1, indeed we can cluster the factors that affect the cost performance of transport infrastructure projects per the elements that Roumboutsos et al (2016b) identified.

Then, the main characteristics of these elements were also identified and listed in typologies created through desk research based on supporting theory. For each characteristic, indicators are proposed, which help measuring the characteristic. From these characteristics and indicators per typology, either the most critical ones are selected or the indicators are aggregated in one overall indicator, so as to simplify our calculations and interpretation of results. For a detailed overview per indicator, see Vanelslander et al. (2015) and Pantelias et al. (2015) (also for a brief presentation Appendix B).

The typology indicators used are the following eight: 1) Institutional Context, 2) Financial & Economic Context, 3) Governance, 4) Cost Saving, 5) Remuneration Attractiveness, 6) Revenue Robustness, 7) Transport Market Efficiency and Acceptability and 8) Financing Scheme.

Both the necessity and sufficiency of conditions for the cost outcome to be present (positive) or absent (negative) are analysed. When the cost outcome is present, it means that a transport infrastructure project is on or below costs, while its absence implies that the project is over cost.

The more the value of the typology conditions comes closer to '1', the more positively they affect the respective outcome and vice versa. Based on this, the main hypothesis used is that the presence of the conditions will lead to the presence of the outcome and that the absence of the conditions will lead to the absence of the outcome.

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[8] Where *i* shows reference to individual *X* or *Y* values or specific observations of *X* or *Y*.
[9] In fsQCA, by 'conditions', we mean the variables/indicators that are used in the analysis.

In models where restricted samples (after simplification) are used, the number of conditions retained in our models has to be reduced. Solutions are simplified by including in a second set of analyses only the core conditions that were shown in the solution of the initial model, and by leaving out the non-relevant and the peripheral conditions. As the core conditions are part of the simplest solution (i.e. parsimonious solution) of the initial model, the aim is to check if one could further simplify solutions by including only core conditions. More specifically, the core conditions refer to the conditions included in both the parsimonious solution[10] and the intermediate solution[11] and hence are the most relevant conditions to use to simplify the models, in search for the simplest and strongest paths. Crucial is pointing out that in this second set of analyses (simplified), the set of conditions which is used for the sufficiency analysis of the presence of the outcome is not necessarily the same set of conditions which is used for the sufficiency analysis of the absence of the outcome. One should take this into account when comparing and interpreting results across these analyses. However, not all initial models can be simplified, namely in case all conditions are core.

By formulating the above hypotheses ex ante, one can use the intermediate solution (rather than the complex solution). An intermediate solution has certain advantages. First, it is in between the complex and the most parsimonious solution in terms of complexity. Second, an intermediate solution is a subset of the most parsimonious solution and a superset of the complex solution (Schneider & Wagemann, 2012). When running an intermediate solution, simplifying assumptions are made to obtain a simpler minimal formula.

Two steps are hence followed to conduct this analysis: 1) initial analysis of the models, using the maximum number of conditions allowed, and 2) simplification method based on which only core conditions are used for re-running the analysis, based on the simpler models created.

For the presence of the outcome (on cost), we first assume that all conditions are present and, vice versa, in case the outcome is absent, all conditions are specified as being absent. The initial model that is used for testing the full sample of the projects is the following:

Table 2. Initial model tested for the full sample analysis

Model	Involved projects	Included conditions
Model for the presence and the absence of the 'cost' outcome	Full sample	Institutional context, Financial-economic context, Cost saving, Governance, Remuneration attractiveness, Revenue robustness, Transport market efficiency & acceptability, Financing scheme

This model is tested in order to see which are the combinations of factors that affect the cost performance of transport infrastructure projects.

4. Results of model analysis

Section 4.1 presents the results of the full model analysis, whereas Section 4.2 presents the analysis results of running the simplified models, both with cost as the outcome.

[10] The parsimonious solution uses any and all *remainder* rows so as to simplify the solution. Logical remainder: in QCA, limited diversity is shown through the empty cells in the truth table, i.e., no cases that belong to these rows are contained in a data set. These empty rows are called "logical remainders." Being able to identify logical remainders and in this way making limited diversity visible is one of the strengths of QCA (Legewie, 2013). The parsimonious solution should only be used if we are certain that the assumptions made to create the solution are justified (Elliot, 2013).

[11] The intermediate solution includes selected simplifying assumptions to reduce complexity but should not include assumptions which might be inconsistent with the theoretical and/or empirical knowledge (Legewie, 2013).

4.1 Initial full model analysis

The necessity analysis is conducted for eight conditions and is presented in Table 3. The high Financing Scheme condition's consistency is almost 0.90 (0.8979) for the projects being on cost and thus this condition is considered necessary. This means that a high value of Financing Scheme will almost always appear in the solution paths of the presence of the cost outcome.

Table 3. Necessity analysis of the cost outcome

Conditions	Consistency	
	Presence	Absence
High Institutional Context	0.78 (0.71)[12]	0.65 (0.45)
Low Institutional Context	0.39 (0.60)	0.57 (0.66)
High Economic & Financial Context	0.59 (0.70)	0.57 (0.51)
Low Economic & Financial Context	0.59 (0.65)	0.66 (0.55)
High Governance	0.79 (0.72)	0.65 (0.44)
Low Governance	0.39 (0.60)	0.59 (0.68)
High Cost Saving	0.62 (0.75)	0.51 (0.46)
Low Cost Saving	0.56 (0.60)	0.72 (0.59)
High Remuneration Attractiveness	0.55 (0.64)	0.64 (0.55)
Low Remuneration Attractiveness	0.62 (0.69)	0.59 (0.49)
High Revenue Robustness	0.62 (0.63)	0.69 (0.52)
Low Revenue Robustness	0.53 (0.69)	0.52 (0.51)
High Transport Market Efficiency and Acceptability	0.47 (0.69)	0.47 (0.52)
Low Transport Market Efficiency and Acceptability	0.68 (0.63)	0.72 (0.50)
High Financing Scheme	0.8979 (0.65)	0.82 (0.45)
Low Financing Scheme	0.23 (0.64)	0.36 (0.72)

The sufficiency analysis shows that 30% of the projects on cost are explained by a good Institutional Context, high Cost Saving, high Revenue Robustness, high Transport Market Efficiency and Acceptability and a cheap Financing Scheme as core conditions, combined with good Governance as a peripheral condition (Table 4-solution 1). The consistency of 0.78 is satisfying.

Table 4. Sufficiency analysis of projects on cost (cut-off: 0.75)[13]

Conditions	OUTCOME: presence of 'cost'	
	Solution 1	Solution 2
Institutional Context	●	•
Financial-Economic Context		●
Governance	•	●
Cost Saving	●	●
Remuneration Attractiveness		○
Revenue Robustness	●	○
Transport Market Efficiency and Acceptability	●	

[12] The values in the parenthesis show the necessity coverage score which is expected to be higher than 0.33. "The necessity coverage evaluates the empirical importance of already consistent necessary conditions or configuration of conditions. More specifically, it refers to the proportion of cases disclosing both the condition and the outcome among cases disclosing the condition" (Bol & Luppi, 2013).

[13] This solution: 3 Primes (Marked all).

Financing Scheme	●	•
Individual Consistency	0.78	0.77
Coverage (Raw)	0.30	0.23
Coverage (Unique)	0.14	0.07
Number of cases	4	1
Some relevant cases	Larnaca and Paphos International Airports, Deurganckdock Lock, Port of Leixoes, E39 Orkdalsvegen Public Road	Herrentunnel Lübeck
Overall Consistency/Coverage	(0.80/0.37)	

Note: A black circle illustrates the presence of the involved condition, a white circle indicates the absence of the involved condition. A large-sized circle denotes a core condition, and a small-sized circle refers to a peripheral condition. Blank spaces refer to no clear results or 'don't care' (Ragin & Fiss, 2008).

The absence of the outcome shows that 31% of the projects over cost are explained by an expensive Financing Scheme, good Institutional Context and Governance as core conditions, combined with low Cost Saving and low Remuneration Attractiveness as peripheral conditions (Table 5-solution 2). The consistency is high (0.84).

Table 5. Sufficiency analysis of projects being over cost (cut-off: 0.88).

Conditions	OUTCOME: absence of 'cost'	
	Solution 1	Solution 2
Institutional Context		●
Financial-Economic Context	●	
Governance		●
Cost Saving	○	○
Remuneration Attractiveness	○	○
Revenue Robustness		
Transport Market Efficiency and Acceptability		
Financing Scheme	○	○
Individual Consistency	0.87	0.84
Coverage (Raw)	0.28	0.31
Coverage (Unique)	0.002	0.03
Number of cases	1	1
Some relevant cases	C-16 Terrasa Manresa toll motorway	C-16 Terrasa Manresa toll motorway
Overall Consistency/Coverage	(0.85/0.31)	

Note: A black circle illustrates the presence of the involved condition, a white circle indicates the absence of the involved condition. A large-sized circle denotes a core condition, and a small-sized circle refers to a peripheral condition. Blank spaces refer to no clear results or 'don't care' (Ragin & Fiss, 2008).

4.2 Simplification method - simplifying the initial full sample models

As explained in Section 3, we further simplify the solutions found, by testing simplified models composed only by the conditions which appear as core in our initial solutions, as presented in Section 4.1. Only the core conditions are included, in order to enhance the models in terms of consistency or/and coverage and make them simpler.

This is not the case for the initial model for the on-cost outcome analysis, which cannot be simplified because all conditions are core. Thus for the on-cost outcome analysis, the strongest solution of the initial analysis (solution 1-Table 4) will be used for our conclusions.

The initial model for the over-cost outcome analysis is simplified by selecting the four core conditions (of solutions 1 & 2-Table 5): 1) Institutional Context, 2) Financial-Economic Context, 3) Governance and 4) Financing Scheme.

The new model, presented in Table 6, gives slightly worse results in terms of consistency and coverage. However, it is significant to observe that now all conditions appear with a negative sign and in the two new solutions the same two conditions (Financial-Economic Context & Financing Scheme) appear as core conditions.

The second solution, which is the strongest one in terms of both consistency and coverage, shows that good Financial-Economic Context and cheap Financing Scheme as core conditions, combined with inadequate Governance, explain 29% of the projects being over cost, with a consistency of 0.83.

Table 6. Sufficiency analysis of projects being over cost - simplified (cut-off: 0.82)

Conditions	OUTCOME: absence of 'cost'	
	Solution 1	Solution 2
Institutional Context	○	
Financial-Economic Context	●	●
Governance		○
Financing Scheme	●	●
Individual Consistency	0.82	0.83
Coverage (Raw)	0.27	0.29
Coverage (Unique)	0.01	0.02
Number of cases	1[14]	2
Some relevant cases		Barcelona Europe South Terminal
Overall Consistency/Coverage	(0.79/0.30)	

Note: A black circle illustrates the presence of the involved condition, a white circle indicates the absence of the involved condition. A large-sized circle denotes a core condition, and a small-sized circle refers to a peripheral condition. Blank spaces refer to no clear results or 'don't care' (Ragin & Fiss, 2008).

5. Discussion of results

The cases that appear the most relevant ones, in the meaning that they are better explained by the strongest solution of the on-cost analysis, are the following four: 1) Larnaca and Paphos International Airports (Cyprus), 2) Deurganckdock Lock (Belgium), 3) Port of Leixoes (Portugal) and 4) E39 Orkdalsvegen Public Road (Norway). It is interesting to observe that three different types of infrastructure projects are explained by the solution path: two seaports, a road and an airport. The path that explains these cases that are on cost, is the following: a good Institutional Context, a high Cost Saving, high Revenue Robustness, high Transport Market Efficiency and Acceptability and a cheap Financing Scheme as core conditions, combined with a good Governance as peripheral condition.

[14] One case was found relevant for the 1st solution of the Table 6 but it is omitted because this case (Piraeus Container Terminal) was contradictory; meaning that while the case was on budget, it appeared to explain the over budget outcome. Similarly for solution 2, two cases were found as relevant but one of the two (Muelle Costa Terminal Barcelona) was contradictory and thus omitted.

The Institutional Context of these cases, at the time of their inauguration, ranges between 0.70 (Port of Leixoes) and 0.82 (E39 Orkdalsvegen Public Road). In general, we see that the Institutional Context of the projects on cost is more than 0.70 with a maximum value of 1. Thus it can be said that projects that are located in developed European countries, like the above, with good Institutional Context have more chances to be on cost.

The values of the Cost Saving indicators for the four transport infrastructure projects are 0.748, 0.467, 0.533, and 0.556 respectively. We should keep in mind that the values that this indicator can take range from -0.333 to 1. Thus we can see that all indicators score a higher value than the 0.333 (50% of the value) and therefore they are considered high value indicators in the solution path. The case with the highest score of the Cost Saving indicator is the Larnaca and Paphos International Airports (Cyprus).

Revenue Robustness for all the projects is the same (0.667), apart from the Deurganckdock lock, whose value equals 0.750. The Transport Market Efficiency and Acceptability of all four projects was the same (0.833), which is a very high value showing that there were no major public acceptability issues about the funding scheme that is used and also that the general perspective about the efficiency of utilization of the transport infrastructure was high (direct benefits of project to funding agent(s)).

The values for the Financing Scheme indicator equal 0.678, 0.655, 1.0 and 0.719 respectively. The project that took the highest and maximum possible value of the indicator (=1) is the Port of Leixoes. The more the value of the indicator goes close to 1, the lower is the capital cost of the project (i.e. the cheaper was the project financed). All the four relevant cases are delivered through PPPs. However, the Port of Leixoes was heavily subsidised by the public sector.

The only non-core condition of this path (peripheral) was the Governance indicator, the values of which were 0.688, 0.625, 0.750 and 0.563, respectively. All the projects showed a value higher than the median value (minimum value 0, maximum 1). When the Governance indicator is equal to 1, this means that 1) the private partner estimates the budget together with the contracting authority, 2) more than one bidder is involved in the procurement process, 3) the design of works is one of the services to be provided in a contract, 4) the contractor is, additionally to carrying the risks of rising costs, obliged to pay a penalty if completion dates are not met, 5) the clauses indicate that guarantees of performance were agreed upon, 6) exploitation, commercial/revenue & financial risk allocation is not concentrated in one party, 7) either or both of the clauses enabling updating of service and price changes are present and 8) clauses indicate that the client has an option to terminate the agreement prematurely without cause (Pantelias et al., 2015).

In general, we conclude that for all four projects, the values of all the indicators are similar and close to each other. Only two indicators out of the six in total show higher variance among the values: the Cost Saving and Financing Scheme indicators.

Under the strongest solution path of the on-cost outcome, we can mention that all our findings are confirmed by the existing literature, except for the high Transport Market Efficiency and Acceptability and the Revenue Robustness factor. Table 7 presents the success factors found in literature that are related with the findings from this paper. However, it should be pointed out that the findings from this paper are not fully comparable with the ones of the literature because there, success is defined generally and the focus is on general construction projects and not transport infrastructure projects and only on PPPs, or on public projects, while this paper tests PPPs and public projects together.

Table 7. Similar success factors found in literature and in our findings

Success factors of the present research	Success factors in literature
Good institutional context	1) External Environment: political & social (including political support & stability & public community support), 2) Less corruption, 3) Effective rule of

	law/Regulatory quality, 4) Favourable legal framework, 5) Institutional quality & 6) Role of political & institutional environment where the projects are sited.
High cost saving	1) Project management factors, 2) Project participants related factors, 3) Suitable/appropriate risk allocation, 4) Good feasibility studies, 5) Detailed project planning, 6) Technology innovation, 7) Pre-project planning & clarity in scope, 8) Effective management control, 9) High level of know-how from both partners, 10) Project-related factors: type, nature, complexity & size, 11) Previous PPP experience, 12) Strong private consortium.
High revenue robustness	X
High transport market efficiency and acceptability	X
Cheap financing scheme	1) Financial capability of private sectors.
Good governance (peripheral condition)	1) Procurement-related factors, 2) Transparent & competitive procurement process, 3) Suitable/appropriate risk allocation, 4) Transparent and adjusted contracts, 5) Clarity of roles and responsibilities among parties.

The case that appears as the most relevant for the over-cost analysis (simplified-second solution) is the Barcelona Europe South Terminal (Spain). A low value of Financial-Economic Context and Financing Scheme as core conditions, combined with a low value Governance as a peripheral condition, explain 29% of the projects over cost. This project is a seaport project that was awarded in 2006 but inaugurated in 2012, after the crisis has arrived. The crisis was more prominent in countries like Greece, Portugal, Italy, and Spain. Thus, it is logic that in 2012, the financial-economic context in Spain is equal to 0.508, while it was equal to 0.700 in 2006 (project award), before the crisis arrived. The Financing Scheme indicator value is equal to 0.438 which is also a low value showing that the capital cost of the project was high. Governance is also low (0.438), showing that either the Governance is not that efficient or/and the contract lacks flexibility.

Regarding the factors found in our research to contribute to the failure of projects, all of them are confirmed by the literature, thus enhancing their importance. Table 8 presents the failure factors found in literature that are related to our findings. The failure factors can be linked and be compared to the literature straightforwardly, because failure is defined in the same way as in this paper (having cost overruns). However, some of the results in literature refer to developing countries' projects, while this paper tests developed European countries' projects.

Table 8. Similar failure factors found in literature and in our findings

Failure factors of the present research	Failure factors in literature
Unfavourable institutional context (peripheral-2nd strongest solution)	1) Political social: public opposition, high service charge to end users, 2) Inappropriate government policies, 3) Bureaucratic indecision, 4) Inappropriate organizational structure, 5) Unconducive regulatory environment, 6) Deliberate cost underestimation, 7) Manipulation of forecasts, 8) Private information, 9) Lack of well-established legal framework.
Unfavourable financial-economic context	1) Currency devaluation, 2) Rises in interest charges, 3) Price fluctuation, 4) Macro-economic factors, 5) Non-conducive financial market, 6) Unstable cost on material.
Inadequate governance (peripheral -1st strongest solution)	1) Cost of unforeseen service and utility, 2) Wrong method of cost estimation, 3) Completion time of project, 4) Misallocation of risk, 5) High transaction cost, 6) Poor contract management, 7) Inaccurate estimates, 8) Cost underestimation, 9) Lack of competition, 10) Lowest bidding procurement, 11) High bidding cost and 12) Length of bidding and negotiation process.
Expensive financing scheme	Poor financing

6. Conclusions

In this section, the strongest solution paths of the initial or simplified models' analysis are presented.

The initial models' analysis of the on-cost outcome (presence) results in the following findings. First of all, a high Financing Scheme is a necessary condition for projects to be on cost (0.90 consistency). High value of Financing Scheme means that the cost of financing is low. This condition appears in both initial solution paths of the sufficiency analysis.

Furthermore, 30% of the projects on cost are explained by a good Institutional Context, a high Cost Saving, high Revenue Robustness, high Transport Market Efficiency and Acceptability and less expensive Financing Scheme as core conditions, combined with a good Governance as a peripheral condition, with 0.78 consistency. This solution is the strongest solution of the initial analysis. It shows that the combination of the following factors explains the projects to be on cost:

- the high ability to save costs in the project, thanks to a high capability to construct, to innovate, to allocate the construction risk optimally;
- a good institutional environment of the country where the project is located, meaning good regulatory framework, political support and policies and government effectiveness;
- a high ability to cover their costs by the revenues generated by or for the projects within a satisfactory revenue risk;
- the political attractiveness of the project funding scheme from the perspective of the efficiency of utilization of the transport infrastructure (allocative efficiency) and the acceptability of the funding scheme for voters;
- a contract with good contractual arrangements.

Projects that are cheaper (low cost of capital) seem to have more chances to be on cost in the above combination, as it was observed in the necessity control as well.

The simplified models' analysis of the over-cost outcome (absence) results in the following findings. First of all, no condition appears to be necessary for the absence of the outcome. The 'over-cost outcome - simplified analysis' of the full sample shows that for projects over cost, less than one third (29%) is explained by an unfavourable Financial-Economic Context and an expensive Financing Scheme as core conditions, combined with inadequate Governance as a peripheral condition, with a consistency of 0.83.

In the on-cost analysis, financing scheme and governance appear to be 'positive', while in the over-cost analysis, they appear to be 'negative', thus acting consistently and showing their importance since they contribute to the achievement or non-achievement of the cost target. This solution shows that a minor share of projects over cost are explained 1) by using an expensive financing scheme (high cost of capital), 2) by being located in a country with unfavourable macro-economic figures, like high unemployment rate, inflation, low GDP per capita or low growth competitiveness index and 3) by inadequate contractual arrangements. It is important to mention that in both the simplified solution and the initial solution, as presented in section 4, the same two conditions of the over-cost analysis (high/low Financial-Economic Context and low value of Financing Scheme) appear as core conditions. Although in the solution path of the initial analysis, Financial-Economic context appears with a positive sign, explaining approximately one third of the projects over cost, in the solution path in the simplified analysis, it appears with a negative sign, as we would expect it to. This finding shows that including 'irrelevant or non-crucial conditions' in the model can affect the solution path itself and not only its consistency, as Legewie (2013) supported.

The selection of the fsQCA method and the development of a framework for conducting the specific type of analysis are considered strengths of this paper. FsQCA allows identifying a combination of factors that affect cost performance of transport infrastructure projects, which is very positive because the transport infrastructure project management is complex and affected by different factors. However, this method has a main limitation. Its paths (combinations of factors) explain a specific percentage of cases that are tested in the sample, and not all cases. Particularly, in this analysis, 30% and 31% of the cases are explained. Regarding the framework that is used, although it is a result of a thorough and long literature review and empirical research, some factors that may affect performance of transport infrastructure projects may not be included in the final indicators: in an attempt to simplify the indicators, the key ones were selected or/and they were aggregated. Using composite indicators does not show to us which exact sub-indicator is the one that mostly affects the cost performance. Also, the results of this analysis depend on the specific sample of projects used and thus do not necessarily reflect cost performance factors for all transport infrastructure projects but may only do so for projects with similar characteristics. Last but not least, we should be careful when interpreting the results because of the low coverage and the not very high consistency, which just surpasses the threshold of 0.75. This means that paths do not always lead to the specific outcome and thus the same path (set of conditions) may lead to another outcome. Therefore it is hard to find a pattern and follow it as a "rule" so as to have transport infrastructure projects that are on the budget that was initially planned.

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Appendix A: Method of calibration of outcomes and typology indicators

ITEMS	SCORING	METHOD TYPE	Scaling
OUTCOME			
Cost	Below budget, On budget, Over budget	INDIRECT	Below budget On budget Over budget
TYPOLOGY INDICATORS			
Institutional Context	Index varies between 0 to 1 (Review index 26 C's from 1996 to 2013)	DIRECT	Threshold for full membership (0.95) Cross over point Threshold for non- full membership (0.05)
Financial-Economic Context	Index varies between 0 to 1 (Review index 26 C's from 2001 to 2014)	DIRECT	Threshold for full membership (0.95) Cross over point Threshold for non- full membership (0.05)
Governance	Index varies between 0 to 1	DIRECT	Threshold for full membership (0.95) Cross over point Threshold for non- full membership (0.05)
Cost Saving	Index varies between -0.333 to 1	DIRECT	Threshold for full membership (0.95) Cross over point Threshold for non- full membership (0.05)
Remuneration Attractiveness	Index varies between 0 to 1	DIRECT	Threshold for full membership (0.95) Cross over point Threshold for non- full membership (0.05)
Revenue Robustness	Index varies between 0 to 1	DIRECT	Threshold for full membership (0.95) Cross over point Threshold for non- full membership (0.05)
Transport Market Efficiency & Acceptability	Index varies between 0 to 1	DIRECT	Threshold for full membership (0.95) Cross over point Threshold for non- full membership (0.05)
Financing Scheme	Index varies between 0 to 1	DIRECT	Threshold for full membership (0.95) Cross over point Threshold for non- full membership (0.05)

Appendix B: Definitions of variables used in the analysis

- The Institutional Indicator refers to political, regulatory and administrative factors ranging related to political stability and capacity, as well as absence of corruption; legal and regulatory framework (in terms of rule of law, regulatory quality), including the liberalization of transport market regulations; and public sector capacity as measured by government effectiveness. For most of these factors, relevant governance indicators of the

World Bank Governance Indicator (WGI) are used, besides the OECD ECTR indicators regarding transport.

- The Financial Economic Indicator measures more than just the macro-economic and macro-financial context of a country, but more broadly the business environment and can be seen as a proxy of the level of productivity of a country. The Global Competitiveness Index of the World Economic Forum was selected to describe this indicator.
- The Governance Indicator refers to factors setting the governance scene within a project. In this respect, it is defined by the contractual conditions and the process leading to them.
- The Cost Saving Indicator is a composite indicator including: Ability to construct (Level of civil works/technical difficulty; Capability to construct; Construction risk allocation as per contractual agreement; Assessment of optimal construction risk allocation based solely on the capability to construct); Ability to monitor/control/plan and provide political support of the respective (public) contracting authority; Adoption of innovation and its successful application; Life cycle planning and operation (Life cycle planning verification; Capability to operate; Operation risk allocation as per contractual agreement; Assessment of optimal operational risk allocation based solely on the capability to operate).
- The Remuneration Attractiveness Indicator represents the various income sources with their assessed risk and potential cost coverage.
- The Revenue Robustness Indicator represents the various revenue sources with their assessed risk and potential cost coverage.
- The Transport Market Efficiency and Acceptability reflects the political attractiveness of the project funding scheme from the perspectives of the efficiency of utilization of the transport infrastructure (allocative efficiency) and the acceptability of the funding scheme for voters.
- The Financing Scheme Indicator reflects an expanded version of the weighted average cost of capital included in the project from both public and private sources (1-WACCad).

Source: Roumboutsos et al. (2016)