Wat kan de Overheid doen om Innovatie in PPS te Stimuleren? Een Systematische Vergelijkende Analyse van DBFM-Infrastructuurprojecten in Nederland[1]

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Samenvatting[2]

Met het overdragen van risico's en verantwoordelijkheden naar de private sector via Publiek-Private Samenwerking (PPS), hopen publieke opdrachtgevers dat innovaties tot stand worden gebracht in de ontwikkeling van transportinfrastructuur. PPS wordt soms gezien als een vergaande vorm van uitbesteding, waarin de private sector de verantwoordelijk draagt voor de ontwikkeling van een stuk infrastructuur. Echter, het idee van 'samenwerking' impliceert juist een meer gedeelde verantwoordelijkheid. In deze bijdrage stellen wij zodoende de vraag: wat kan de overheid doen om innovatie in PPS te stimuleren?

Om deze vraag te beantwoorden, hebben wij systematisch negen Nederlandse Design-Build-Finance-Maintain (DBFM) projecten geanalyseerd met de methode Qualitative Comparative Analysis (QCA). De projecten zijn aanbesteed door Rijkwaterstaat en hebben contractwaarden variërend van €250 tot €1.500 miljoen. We hebben gekeken naar drie verklarende condities voor het optreden van innovaties in DBFM-projecten: het aanbestedingsresultaat, de compositie van het private consortium en het projectmanagement door de publieke opdrachtgever. De analyse laat zien dat het optreden van innovaties wordt verklaard door verschillende combinaties van deze drie condities. De combinaties bieden aanknopingspunten voor publieke opdrachtgevers om innovatie in PPS te stimuleren.

Ten eerste kunnen opdrachtgevers aansturen op innovatie door DBFM-contracten te gunnen aan private consortia die bestaan uit een relatief laag aantal bouwbedrijven (≤ 3) van een relatief kleine omvang (jaaromzet < €9.688 miljoen). Kleinere consortia genieten mogelijk een 'collaborative advantage' doordat het bouwen en onderhouden van onderlinge vertrouwensrelaties en synergie makkelijker is, beiden factoren die bijdragen aan effectieve innovatieprocessen. Een dergelijke compositie van een consortium is echter niet zaligmakend. Het is, ten tweede, aan te bevelen dat publieke opdrachtgevers contracten gunnen die tevens een relatief laag aanbestedingsresultaat kennen. Dat wil zeggen: wanneer het bod van een consortium in de aanbestedingsfase weinig lager is dan wat de opdrachtgever – Rijkswaterstaat in dit geval – had geraamd, dan kan dit betekenen dat het consortium bereid is meer risico's te nemen. Het nemen van meer risico's resulteert in een hoger bod (dus een lager aanbestedingsresultaat), maar laat daarmee ook meer ruimte voor het ontwikkelen of toepassen van innovaties. Het ontwikkelen of toepassen van innovaties is immers risicovoller dan het toepassen van bewezen producten en processen. Ten derde kunnen publieke opdrachtgevers innovatie meer direct faciliteren via projectmanagement. Vooral een relatief beperkte aanwezigheid van publiek stakeholdermanagement, of facilitering via contractmanagement, kunnen bijdragen aan innovaties in PPS.

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[2] Gelieve dit paper niet te kopiëren of verspreiden zonder toestemming van de auteur.

1. Introduction

In recent years, the use of PPPs to stimulate sustainable development and innovation in public infrastructure projects (e.g., roads and waterways) has been encouraged (Caloffi et al., 2017). It is argued that PPPs may drive innovation through factors such as design freedom for the private partner, long-term commitment, competition between bidders, collaborative working, and risk transfer to the private partner (Himmel and Siemiatycki, 2017; Leiringer, 2006; Rangel and Galende, 2010; e.g., EPEC, 2015). However, "the publications that endorse PPP as arenas promoting innovation are based on anecdotal evidence and wishful thinking" (Leiringer, 2006, p. 303). To date, the empirical evidence of PPPs' ability to stimulate innovation remains scarce (Himmel and Siemiatycki, 2017; Hueskes and Verhoest, 2015). Reasons may include that collaborative working in PPPs is challenging (Verweij, 2015) or that private construction consortia are often incentivized to minimize risks in PPPs, which may lead to only incremental innovations (Himmel and Siemiatycki, 2017; Roumboutsos and Saussier, 2014).

This raises the question of how PPPs may be able to bring about innovations in transport infrastructure development effectively. Research has indicated that the aforementioned factors may indeed stimulate innovation (Akintoye et al., 2003; Rangel and Galende, 2010; Uyarra et al., 2014). These studies, however, focused on the ways in which contracts, or pre-contract competition, incentivize innovation behavior by the *private* partner. Research has largely neglected the role the *public* partner can play in stimulating innovation in PPPs (Rangel and Galende, 2010). Although recent work has started to emphasize the public partner's role in innovation (e.g., Roberts and Siemiatycki, 2015), more empirical research is needed into this topic, especially comparative work that goes beyond single cases and anecdotal evidence (Rangel and Galende, 2010). The present paper addresses this research gap by conducting a Qualitative Comparative analysis (QCA) of nine PPP-projects – Design-Build-Finance-Maintain (DBFM) contracts – to answer the following question: what can the public partner do to stimulate innovation in infrastructure PPPs?

Innovation is defined in this study as technological product and process (TPP) innovations, which comprise "implemented technologically new products and processes and significant technological improvements in products and processes. A TPP innovation has been implemented if it has been introduced on the market (product innovation) or used within a production process" (OECD and Eurostat, 1997; in Leiringer, 2006, p. 303). Three possible explanatory conditions for innovation are studied: the public partner's choice to award the contract to a bid with a high procurement result, the choice for a certain composition of the private construction consortium, and the project management by the public partner. In Section 2, innovation and the three conditions are discussed. Section 3 presents and explains the cases, data, and methods used for the QCA-analysis. Section 4 provides the analysis and results. Section 5 comprises the discussion of the results, the limitations of the research, and the final conclusions.

2. Stimulating Innovation in Transport Infrastructure PPPs

2.1 Public-Private Partnerships and Innovation

Project innovation can generally be categorized into product, process, organizational-contractual, and financial innovation (Russell et al., 2006; Tawiah and Russell, 2008).

Organizational-contractual and financial innovations concern, inter alia, the negotiation of risk assignment, contractual terms regarding performance-based payment mechanisms, and off-balance sheet financing. For many years, these have also been the core motivations to develop transport infrastructure through PPPs (McQuaid and Scherrer, 2010). In Dutch DBFM-projects, risks and responsibilities for designing, building, maintaining, and (partly) financing the infrastructure development have been transferred to the private partner (Lenferink et al., 2013) and performance-based payments mechanisms are used to incentivize the private partner to perform well. With the organizational-contractual and financial innovations now being default in Dutch PPPs, in particularly DBFM, at the beginning of the century the motivation for PPP shifted towards the ability of PPPs to stimulate innovation themselves (Eversdijk and Korsten, 2015). PPPs became popular for the "optimal use of available resources and to promote entrepreneurship and innovation" (Rutte and Samsom, 2012, p. 37) and for the realization of "added or surplus value" (e.g., Ministerie van I&M, 2012; Rijkswaterstaat, 2014a). However, to date the empirical evidence of PPPs' ability to stimulate innovation has remained scarce (Himmel and Siemiatycki, 2017; Hueskes and Verhoest, 2015).

Hence, this paper considers product and process innovations in infrastructure projects and focusses on how such innovations can be stimulated through PPPs. Innovations concern "significant technological improvements" in both products and processes (OECD and Eurostat, 1997, p. 31). *Product innovation* includes the development and/or use of new products, e.g., advanced construction equipment and tools, novel product assemblies, novel designs or concepts, the use of advanced technology in the operation and maintenance phase, and new materials (Russell et al., 2006; Tawiah and Russell, 2008). In PPPs and in DBFM-projects in particular, however, the private partner delivers not only products (e.g., tunnel systems or new roads) but also provides services (e.g., the operation and maintenance of tunnels and roads). Hence, product innovation includes the *development and use* of innovations in provided *products and services* (OECD and Eurostat, 2005). *Process innovations* concern new or significantly improved methods or skills that are used to construct the product or perform the service (OECD and Eurostat, 2005). Examples include logistical technologies, site preparation, off-site fabrication and construction methods, assembling technologies, and information technology tools in the processes of project design and management (Russell et al., 2006; Tawiah and Russell, 2008). Next, the three explanatory conditions of the study are elaborated. They were selected in consultation with Rijkswaterstaat managers.

2.2 Procurement Result

By transferring risks and responsibilities for the integral design, build, finance, and maintenance of infrastructure to a private sector partner, a possibility is created for the private partner to find innovative solutions through integrated designs and processes and life-cycle optimization (Himmel and Siemiatycki, 2017; Lenferink et al., 2013). The idea is that the private partner will be able to design products and processes more efficiently, hence stimulating innovative solutions (Burger and Hawkesworth, 2011).

A measure for gauging the private partner's need for efficiency improvement is the procurement result. It is the difference between the value of the contract that the public procurer estimated prior to the tender and the actual value of the contract that was concluded between the public and private partners (Verweij et al., 2015). A high procurement result means that the contract value of the partnership is lower than was estimated by the public procurer. Possibly, a high procurement result may increase the need for private partners to innovate to maintain a profitable business case. This reasoning would require that the product or process innovation stems from the private partner (market-driven) and not from the project scope defined in the DBFM-contract (client-driven) (cf. Möller et al., 2008). Through this line of reasoning, a high procurement result may incentivize the private partner to innovate to increase efficiency (i.e., lower costs) (Burger and Hawkesworth, 2011; Himmel and Siemiatycki, 2017). However, it may also be a condition for the private partner to "invest in incremental, low risk endeavors that have a high probability of success" (Roumboutsos and Saussier, 2014, p. 357) in order to increase efficiency through routine work, avoiding innovative but riskier solutions (e.g., Barlow and Köberle-Gaiser, 2009). This paper will further elaborate this relationship between procurement result and project innovation.

2.3 Composition of the Private Construction Consortium

DBFM-contracts are usually applied to large projects. In the Netherlands, DBFM is applied only to infrastructure projects with a minimal contract value of €60 million (Ministerie van Financiën, 2013). As a result, DBFM-contracts usually involve bids by firms of sufficient size and/or bids made by multiple firms.

Two lines of reasoning pertain to the composition of the construction consortium. The first relates to the size of the firms in the consortium (Lu and Sexton, 2006; Spescha, 2018). On the one hand, small firms are said to have communication and coordination advantages, lower fragility due to small project sizes, and a better self-selection of able researchers (Spescha, 2018). They may also have stronger creative capacities and a stronger drive to innovate in order to gain market share. On the other hand, innovation or the capacity to innovate may also increase with firm size. Reasons may include that larger firms are more prone to governmental and societal pressures to innovate (Qi et al., 2010) and that larger firms benefit from larger R&D-budgets (Spescha, 2018). Both small and large firm sizes may stimulate innovation (Goffin and Mitchell, 2017), although literature seems to be slightly in favor of firms with a small size (Tidd et al., 2005).

The second line of reasoning concerns the number of firms in the construction consortium. A higher number may increase the innovation potential because more and complementary resources are bundled (cf. Himmel and Siemiatycki, 2017). However, larger numbers of firms may require a network of mutual contracts, potentially decreasing flexibility and effective collaboration, leading to less innovation (Russell et al., 2006). Moreover, risk allocation becomes more fragmented, which may divert firms' focus away from developing or using innovations (Barlow and Köberle-Gaiser, 2009). Instead, a small number of firms is conducive of collaborative working and trust building, both driving factors for innovation (Eaton et al., 2006; Weihe, 2008). The literature thus seems to be slightly in favor of a few small firms contributing more to innovation (Tidd et al., 2005). This assumption will be further tested through the analyses in this paper.

2.4 Project Management by the Public Partner

In PPPs, the private partner is largely responsible for actual project management, but project management by the public partner remains important to achieve good outcomes (Verweij et al., 2017). Reasons are that it may complement each other's skillsets and resources and may establish favorable institutional conditions for innovation (Grotenbreg and Van Buuren, 2018; Himmel and Siemiatycki, 2017; Rangel and Galende, 2010).

However, the relationship between public project management and innovation is not straightforward (Savini et al., 2015). On the one hand, project management revolves around controlling the environment and the actions of actors in it, thus possibly constraining innovation. On the other hand, given the dynamic environments of projects and the strict time and budget boundaries, the need for enabling innovation is also recognized. This paper sheds further light on the complex relationship between public project management and innovation.

In the Netherlands, five different public management roles are distinguished in transport infrastructure development, which come together in the Integrated Project Management (IPM) model (Reinking, 2014; Rijkswaterstaat, 2014b): general project management, project control, stakeholder management, technical management, and contract management. The latter three management roles are particularly important when it comes to innovation, as they specifically focus on coordination and analysis.

The stakeholder manager’s responsibilities focus on the general management of project internal-external relationships and the information exchange and communication between the project organization and the stakeholders (Reinking, 2014). His or her tasks are akin to the “coordination capacity” of governments, which focusses on the government’s role in managing networks of actors, boundary spanning, bringing actors together, and intermediating between actors (Grotenbreg and Van Buuren, 2018). Public stakeholder managers may put their coordination capacity to work through actions such as organizing workshops and meetings, involving relevant actors, negotiation and lobbying, and collaboration. In these ways, they may stimulate complementarity of skills and resources, which in turn is conducive of innovation. Moreover, stakeholder management may be needed because novel solutions have to be interactively implemented in the environment of the project (e.g., Neef et al., 2017).

The technical manager is responsible for the technical input in the project. S/he translates the client’s demands into project requirements and uses systems engineering to manage the implementation of the project (Reinking, 2014). The public technical manager’s tasks bear resemblance to the “analytical capacity” of governments. By such actions as commissioning studies, supplying information for permit applications, supporting subsidy/grant applications, investigating possibilities for innovation, and conducting market consultations (Grotenbreg and Van Buuren, 2018), s/he contributes to increased knowledge “about future projections and current developments” (Lodge and Wegrich, 2014, p. 16). His or her actions bring “new knowledge into play (…) and encourage transformative learning and out of the box thinking” (Sørensen and Torfing, 2012; in Grotenbreg and Van Buuren, 2018, p. S47). By decreasing uncertainty and increasing learning, the riskiness of innovations may be reduced, thereby stimulating their development and use.

The contract manager’s responsibilities focus on the management of the contractual relationship between the public and private partner in the project. His or her tasks include determining the procurement need, drafting the contract dossiers, and contract control during the implementation of the project (Reinking, 2014). The relationship between contract management and innovation is not straightforward. On the one hand, the contract manager may give temporary permissions, accept risks, and adjust or develop rules which allow the private partner to pursue innovations (cf. Grotenbreg and Van Buuren, 2018). However, contract managers are also involved in controlling risks and regulating the project management by the private partner, which may decrease its flexibility and hence possibilities to innovate (Hertogh and Westerveld, 2010). The analysis may shed light on the relation between contract management and innovation.

3. Data and Method

3.1 Data Collection and Cases

The data were collected via questionnaires (for innovation) and from the Project Database of Rijkswaterstaat (for the conditions). Data collection took place between April and July 2018. Rijkswaterstaat managers and experts were consulted to increase the reliability of the data and to retrieve missing data where possible. By collecting and analyzing data that are actually used by Rijkswaterstaat for project management and accountability, this contributed to the practical relevance of the study. The database contained thirteen DBFM-projects in transport infrastructure (i.e., roads and waterways) that had actually reached their implementation phase (i.e., after the contract award).

The projects are planned to finish their implementation phase (i.e., design and build) before the end of 2020. Their contract values range from approximately €250 million to €1,500 million. Rijkswaterstaat is the client for each contract. The private partners in the projects are consortia consisting of two to seven firms, with the exception of one project with a private partner consisting of a single firm.

3.2 Measurement and Data

Innovation was measured using the 'baseline innovation measurement' developed by the Department of Innovation and Market of Rijkswaterstaat. The measurement consists of five questions that assess whether and which innovations were developed in the project, whether the innovation was market-driven or client-driven, and whether the innovation was used and diffused. These data were collected through questionnaires (based on the baseline) completed by the technical managers of the studied projects. Innovation was regarded to be present or absent. For two cases, innovation data could not be retrieved.

The innovations include the energy-neutral operation and production of infrastructure (e.g., energy-neutral locks or the installation of solar panels as part of the infrastructure development), circular designs (e.g., fly-overs) and production methods (e.g., recycling concrete; new types of asphalt), maintenance innovations (e.g., removable road linings on asphalt), and new process management tools and pilots (e.g., DuboCalc-software to calculate the environmental impact of materials used). Innovations occurred in eight of the eleven projects (73%). Nearly all the innovations were market-driven.

Following Verweij et al. (2015), the *procurement result* was measured by first calculating the difference between the contract value estimated by the public procurer and the value of the actual awarded contract. This number was then divided by the estimated contract value to retrieve a percentage. For the estimated contract value, the business-economic estimate was used, known in Dutch as the *BE-raming* (Ministerie van V&W, 1997). For both the estimated and the actual contract value, the Net Present Value (NPV) of the project was used. Data were available for eleven of the thirteen cases. The average procurement result is 30.6%.

The *composition of the private construction consortium* was measured by counting the number of construction firms in the consortium and the firms' sizes. The number of firms in the thirteen cases varied from one to seven. Firm size was measured as the revenue of the participating construction firms as published in the companies' annual reports for 2016. Across the thirteen cases, it ranged from approximately €75 million to €19,910 million. One firm was an outlier with a revenue of about €40,000 million.

The *public project management* was measured by the amount of full-time equivalent (FTE) allocated by Rijkswaterstaat to each of the three project management roles. Data were available for twelve cases. The management functions (e.g., the stakeholder manager) and the supporting functions (e.g., advisor stakeholder management) were added. Per management role, the average FTE of the first three years of the project's implementation phase was taken. For four of the twelve cases, only one (two projects) or two (two projects) implementation years were available. After the FTEs were calculated, they were converted to percentages of the total number of FTEs in the respective projects, to account for the fact that larger projects are allocated more FTEs than smaller projects. Across the twelve cases, the FTE allocated to stakeholder management was on average 22.9%; for technical management 29.2%; and for contract management 25.6%.

3.3 Method

QCA is a case-based method that helps to systematically and transparently analyze how different conditions combine in configurations to explain the outcome of interest (Gerrits and Verweij, 2018; Schneider and Wagemann, 2012). The relationships between the conditions and the outcome are expressed in terms of necessity and sufficiency.

The *first step* in the application of the method is the calibration of the data, for which QCA relies on set-theory. Each condition and the outcome are understood as sets and cases have a membership in each set ranging from 0.00 (fully out the set) to 1.00 (fully in the set). Preferably, criteria external to the data at hand are used to determine the set-membership categories. If these are not available, a cluster analysis can be used to distinguish the groups of cases (Gerrits and Verweij, 2018). The calibration results in a calibrated data matrix (see Section 3.4).

The *second step* is the transformation of the calibrated data matrix into the truth table, which sorts the cases across the logically possible combinations of conditions (i.e., the logically possible configurations). Each truth table row represents one logically possible configuration. Based on the calibrated data matrix, each case is assigned to the truth table row to which it belongs. Then, based on the outcome scores of the cases, the truth table row is assessed to show innovation (score of 1) or not (score of 0).

The *third step* is the analysis of the truth table, which involves the pairwise comparison of truth table rows that agree on the outcome (here: presence of innovation) and differ in only one of the conditions. The condition that differs is minimized away. This minimization process leads to a so-called solution formula, which may consist of several "mutually non-exclusive explanations of the same phenomenon" (Schneider and Wagemann, 2012, p. 78). The mutually non-exclusive explanations may consist of combinations of conditions, where conditions explain the outcome in conjunction with other conditions. In this way, QCA helps to shed light on the complex relationships between the conditions and innovation and on the different ways in which innovation can be stimulated by the public partner. Since the size of the truth table increases exponentially with each condition added, limited diversity may occur. Limited diversity is expressed as truth table rows without any cases, which are consequently not included in the minimization, leading to a more complex solution formula. To curtail limited diversity, separate analyses were conducted for the different management roles (see Section 4). The analyses were done with the fs/QCA software (Ragin and Davey, 2017).

3.4 Calibration Rules and Calibrated Data

Regarding *innovation*, projects that clearly showed the development and use of one or more product or process innovations were assigned a set-membership score of 1.00. Projects without any innovation were assigned a score of 0.00. One project (Case-L) showed some innovation, but lower than expected. In that case, multiple innovations were provided by the market, but they were not actually realized in the project. Therefore, the case received a score of 0.33 (see Table 2).

Verweij et al. (2015) found an average *procurement result* of 23.8%. Taking that value as a starting point for the calibration to distinguish cases that are more out the set ($0.0 \leq x < 0.5$) from cases that are more in the set ($0.5 < x \leq 1.0$) resulted in skewed calibration. Therefore, we performed a cluster analysis using the QCA-software 'Tosmana' (Cronqvist, 2011) and identified four clusters: low procurement result (0.00) [7.15 to 20.1%]; medium procurement result (0.33) [20.2 to 29.5%]; high procurement result (0.66) [29.6 to 37.2%]; and very high procurement result (1.00) [37.3 to 55.4%]. In QCA, higher set-membership scores ($0.5 < x \leq 1.0$) are expected to be associated with the presence of the outcome. The calibration thus expresses the expectation that a high procurement result may condition the private partner to innovate (see Section 2.2).

Regarding the *composition of the private construction consortium,* literature does not provide unambiguous expectations regarding the relationship between firm size and innovation, although it seems to be slightly in favor of small firms contributing more to innovation. Literature is clearer about a smaller number of firms contributing to innovation. Given these considerations, more weight is given in the calibration to the number of firms than to firm size, resulting in the calibration scheme depicted in Table 1.

	Many Firms	*Few Firms*
Larger Firms	More than three firms; at least one firm with revenue above €9,688 million **Set-membership: 0.00**	Three firms or less; at least one firm with revenue above €9,688 million **Set-membership: 0.66**
Smaller Firms	More than three firms; all firms with revenue below €9,688 million **Set-membership: 0.33**	Three firms or less; all firms with revenue below €9,688 million **Set-membership: 1.00**

Table 1: Calibration of the Composition of the Construction Consortium

After consulting experts from Rijkswaterstaat, the cut-off point for the number of firms was set at three, based on the reasoning that in infrastructure construction there are at least three different areas of expertise involved. Regarding firm size, existing classifications from the Economic Institute for the Construction Industry (Groot et al., 2012) did not result in a meaningful distribution of the cases because the DBFM-projects all involve large construction firms. Therefore, a cluster analysis was performed with Tosmana, identifying the annual revenue of €9,688 million as the cut-off point. Note that as an exception, Case-F and Case-G are assigned a calibrated score of 1.00 whilst having consortia of four firms; this was decided because in these two projects, although the firms are separate organizational entities, they are from the same parent company.

For the calibration of the *public project management* roles, again a cluster analysis was performed. The so-called *Normering Kerntaken Aanleg* does provide standards for the allocation of FTE in DBFM-projects, but does not specify this to the different management roles. Because the accuracy of the data is not perfect (in consultation with Rijkswaterstaat), it was decided to adopt a conservative calibration strategy to avoid faux precision (cf. Gerrits and Verweij, 2018) and to distinguish between two set-categories only: low and high deployment of FTE. Stakeholder management is calibrated as 0.00 [15.53 to 25.38%] and 1.00 [25.39 to 37.88%]; technical management as 0.00 [21.56 to 27.32%] and 1.00 [27.33 to 37.54%]; and contract management as 0.00 [15.90 to 23.02%] and 1.00 [23.03 to 35.26%]. Table 2 provides the raw and calibrated data. To be included in the analysis, QCA requires that all cases have full data. Therefore, Case-C, Case-D, Case-E, and Case-G are not included in the analysis in Section 4.

Case	*Procurement Result*		*Composition Consortium*		*Public Project Management*						*Innovation*	
					Stakeholder		*Technical*		*Contract*			
	Raw	***Cal.***	*Raw*	***Cal.***	*Raw*	***Cal.***	*Raw*	***Cal.***	*Raw*	***Cal.***	*Raw*	***Cal.***
A	42.02	**1.00**	2, SM	**1.00**	21.30	**0**	24.83	**0**	35.26	**1**	Yes, CD	**1.00**
B	17.08	**0.00**	1, SM	**1.00**	23.76	**0**	25.74	**0**	26.90	**1**	Yes, MD	**1.00**
C	n/a	**n/a**	4, LA	**0.00**	27.00	**1**	25.42	**0**	25.84	**1**	Yes, MD	**1.00**
D	n/a	**n/a**	7, LA	**0.00**	19.01	**0**	37.54	**1**	24.44	**1**	No	**0.00**
E	31.47	**0.66**	3, SM	**1.00**	n/a	**n/a**	n/a	**n/a**	n/a	**n/a**	n/a	**n/a**
F	7.15	**0.00**	4, SM	**1.00**	21.48	**0**	28.90	**1**	20.41	**0**	Yes, MD	**1.00**
G	23.15	**0.33**	4, SM	**1.00**	37.88	**1**	21.56	**0**	15.90	**0**	n/a	**n/a**
H	27.58	**0.33**	3, LA	**0.66**	29.21	**1**	22.83	**0**	20.64	**0**	Yes, MD	**1.00**
I	25.07	**0.33**	4, LA	**0.00**	21.85	**0**	30.96	**1**	27.28	**1**	No	**0.00**
J	32.33	**0.66**	2, SM	**1.00**	15.53	**0**	33.10	**1**	31.50	**1**	Yes, MD	**1.00**
K	43.14	**1.00**	7, SM	**0.33**	23.73	**0**	29.20	**1**	21.59	**0**	Yes, MD	**1.00**
L	32.06	**0.66**	4, SM	**0.33**	17.39	**0**	36.66	**1**	27.50	**1**	Partly, MD	**0.33**
M	55.40	**1.00**	3, SM	**1.00**	16.58	**0**	33.58	**1**	29.97	**1**	Yes, MD	**1.00**

Table 2: Raw and Calibrated Data Matrix
Notes: SM = small firms only; LA = also large firms; CD = client-driven innovation; MD = market-driven innovation

4. Analysis and Results

4.1 Construction of the Truth Tables

The truth table for stakeholder management is provided as Table 3. In addition to the regular raw consistency score, a high PRI-consistency expresses that the truth table row is sufficient for the outcome innovation and not simultaneously for the negated outcome (i.e., the absence of innovation). Innovation occurred in all the cases in the first three rows. The high consistency scores express this and the rows were hence assigned an outcome score of 1. Case-K in the fourth row did show innovation, but Case-L hardly showed any innovation (see Table 2). For this row, the evidence is too ambiguous to assign the configuration an outcome score of 1. The row was therefore assigned an outcome score of 0, effectively excluding it from the analysis. The last row was also assigned an outcome score of 0, because innovation was absent in Case-I. The truth tables with technical management and contract management are provided as Tables 4 and 5. The assignment of the outcome scores followed the same process as for Table 3.

ProcRes	*CompCons*	*StakMan*	*Innovation*	*Cases*	*Raw Cons.*	*PRI Cons.*
1	1	0	1	A, J, M	1.00000	1.00000
0	1	0	1	B, F	1.00000	1.00000
0	1	1	1	H	1.00000	1.00000
1	0	0	0	K, L	0.60241	0.50376
0	0	0	0	I	0.32673	0.00000

Table 3: Truth Table with Stakeholder Management

ProcRes	*CompCons*	*TechMan*	*Innovation*	*Cases*	*Raw Cons.*	*PRI Cons.*
0	1	0	1	B, H	1.00000	1.00000
1	1	1	1	J, M	1.00000	1.00000
1	1	0	1	A	1.00000	1.00000
0	1	1	1	F	1.00000	1.00000

1	0	1	0	K, L	0.60241	0.50376
0	0	1	0	I	0.32673	0.00000

Table 4: Truth Table with Technical Management

ProcRes	*CompCons*	*ContMan*	*Innovation*	*Cases*	*Raw Cons.*	*PRI Cons.*
1	1	1	1	A, J, M	1.00000	1.00000
0	1	0	1	F, H	1.00000	1.00000
1	0	0	1	K	1.00000	1.00000
0	1	1	1	B	1.00000	1.00000
1	0	1	0	L	0.33333	0.00000
0	0	1	0	I	0.32673	0.00000

Table 5: Truth Table with Contract Management

4.2 Results of the Truth Table Analyses

The results are provided in Tables 6 to 8.[3] All the results meet the standard consistency requirement of 0.75 (Ragin, 2006). Consistency expresses "the degree to which empirical evidence supports the claim that a set-theoretic relation exists" (Rihoux and Ragin, 2009, p. 182). Additionally, coverage is a measure that helps to "gauge[s] empirical relevance or importance" (Ragin, 2006, p. 292). Table 6 shows two configurations that are sufficient for innovation to occur. A construction consortium with fewer firms (CompCons ≤ 3) combined with either a low-to-medium procurement result (~ProcRes), or a low deployment of stakeholder management (~StakMan) explains innovation. Table 7 shows one configuration consisting of a single condition that is sufficient for innovation, namely: a construction consortium with fewer firms (CompCons ≤ 3).[4] The truth table analysis with contract management resulted in three sufficient configurations for the occurrence of innovation. Table 8 shows first that a construction consortium with fewer firms (CompCons ≤ 3) combined with either a low-to-medium procurement result (~ProcRes), or a high deployment of contract management (ContMan) explains innovation. Second, innovation can also occur with a consortium with a larger number of firms (~CompCons), when the procurement result is high (ProcRes) and the deployment of contract management is low (~ContMan). Only the conservative solutions are provided here.[5]

Minimized Configuration	*Raw Cov.*	*Unique Cov.*	*Consistency*	*Cases*
CompCons*~StakMan	0.77217	0.40791	1.00000	A, J, M; B, F
CompCons*~ProcRes	0.45430	0.09004	1.00000	B, F; H
Solution consistency / coverage	1.00000 / 0.86221			

Table 6: Results Truth Table Analysis with Stakeholder Management

Minimized Configuration	*Raw Cov.*	*Unique Cov.*	*Consistency*	*Cases*
CompCons	0.86221	0.86221	1.00000	B, H; J, M; A; F
Solution consistency / coverage	1.00000 / 0.86221			

Table 7: Results Truth Table Analysis with Technical Management

Minimized Configuration	*Raw Cov.*	*Unique Cov.*	*Consistency*	*Cases*
CompCons*ContMan	0.59072	0.36289	1.00000	A, J, M; B
CompCons*~ProcRes	0.45430	0.18145	1.00000	F, H; B
ProcRes*~CompCons*~ContMan	0.13643	0.09141	1.00000	K
Solution consistency / coverage	1.00000 / 0.90860			

Table 8: Results Truth Table Analysis with Contract Management

[3] The necessity test of the data revealed no necessary conditions. The conditions with the highest consistency scores were a composition of the construction consortium with few firms (CompCons) [cons. 0.86221] and a low deployment of stakeholder management (~StakMan) [cons. 0.86357].
[4] A robustness check for this analysis is reported elsewhere. It identified that CompCons was not sufficient but INUS.
[5] The parsimonious and intermediate solutions are reported elsewhere.

5. Discussion and Conclusions

5.1 Discussion of the Results

The analysis clearly indicates the importance of a *private construction consortium* composed of a few number of firms, thus confirming the theoretical expectation. Except for one which represents Case-K (see Table 8), all the minimized configurations contain the condition CompCons, indicating it as a sufficient condition (Table 7) or a necessary part of a sufficient configuration (Tables 6 and 8). This suggests that consortia consisting of a small number of firms may benefit from a collaborative advantage; fewer participating firms may make collaboration and trust building easier, have lower transaction costs, thus enabling innovation to occur. Although important, a consortium with a small number of firms cannot explain innovation by itself. Although the results in Table 7 seem to suggest this, the other results provide this important nuance.

First of all, the results show that a consortium with few firms (CompCons) combines with a low *procurement result* (~ProcRes) to explain innovation. A possible reason is that fewer firms make risk allocation and management easier, making a more realistic bid on the contract easier, which in turn translates into a lower procurement result. This result, together with the fact that nearly half of the projects achieved innovation with a low procurement result (43%) (see Table 2), leads to the conclusion that the analysis provides no evidence for the theoretical expectation that a high procurement result may condition partners to innovate to maintain a profitable business case.

Second, a consortium with few firms combines with the deployment of public project management roles to explain innovation. The results for *stakeholder management* show that, when the private consortia consist of few firms (CompCons), they benefit from a relatively low deployment of public stakeholder management (~StakMan). This is contrary to the theoretical expectation. A possible explanation is that the private consortia, which all consist of few firms – that are also small (see Table 2) – are very capable of stakeholder management themselves. In fact, small firms are said to have communication and coordination advantages (cf. Spescha, 2018) and this may extend to stakeholder management, thus requiring only a low public stakeholder management input. Small firms are typically involved in innovations that are more process-focused, which means they are more likely to possess the required stakeholder management capacities through experience.

The truth table analysis with *technical management* indicates that the deployment of public technical management holds little explanatory value. This is contrary to the theoretical expectation. Possibly, this result is explained by the fact that the innovations, save for one, are all market-driven. The public technical manager may commission studies, supply information, support subsidy and grant applications, investigate possibilities for innovations, etc. However, because the innovations were market-driven, this could imply that the public technical manager had no big role to play here. Another explanation is that technical managers are involved mostly in the bidding phase and that their role regarding innovation has been played when the implementation phase starts.

Regarding *contract management*, no clear one-directional theoretical expectations could be formulated. The truth table analysis indeed confirms that contract management by the public partner can contribute to innovation in different ways (ContMan and ~ContMan). On the one hand, the public contract manager can create room for the private partner to innovate by providing permissions, accepting risks, and setting the framework rules (cf. Grotenbreg and Van Buuren, 2018). On the other hand, s/he may also aim to minimize risk and decrease complexity, by stimulating the use of proven technologies instead. The results show a similar duality. In the case of consortia consisting of fewer and smaller firms (CompCons), public contract management had a stronger presence in the projects (ContMan); in the case of consortia with more firms (~CompCons), public contract management was less present (~ContMan). These results mirror each other. A possible explanation is that consortia of fewer and smaller firms have a stronger tendency to be competitive through product-oriented innovations, which often lead to contract negotiations and changes, which is the domain of the contract manager. Based on the analysis, however, it is difficult to identify conclusively how the public contract management role was actually played.

5.2 Discussion of Limitations and Further Research

The study measured the public project management by the amount of allocated full-time equivalent (FTE). This is an efficient way of measuring management capacity and it offers a clear and practical way for public procurers to implement research findings into management policies. However, measurement through FTE obscures the importance of *how* management roles are played. In a PPP-project, many contract managers may strive to create room for innovation, or a few managers may strive to curtail it to minimize risk. We did not analyze how the management roles were actually played and this may have contributed to the diffuse findings regarding public project management. Future research may study the ways public project managers stimulate or constraint innovation in PPPs.

A second issue stems from the number of cases. This study relied on nine cases. Although this is a perfectly acceptable number in QCA, it sets a limit to the number of conditions that could be included in the analysis (Gerrits and Verweij, 2018). This problem was addressed by conducting separate analyses for the different public project management roles. However, the idea of the Integrated Project Management (IPM) model used in the management of PPP-projects, is that the interests and goals related to stakeholder-, technical-, and contract management are implemented and safeguarded in a balanced manner. This implies that the degree to which innovation is stimulated may rely on how these interests and goals in fact interact and balance out in particular PPP-projects. QCA-analyses may inquire into this balancing, but will need more cases.

Third, the study focused on DBFM-projects. The transfer of risk to the private sector through private project financing is an essential element of DBFM. The private partner is incentivized to achieve project milestones on-time; otherwise, he is penalized or payments by the public partner are delayed, meaning that he may have to pay additional interest to his financiers. This organizational structure often incentivizes risk-averse strategies. This may explain why public project management has less explanatory value for the occurrence of innovation than perhaps expected. It also raises questions of how DBFM-contracts can be made more flexible (Demirel et al., 2017) to stimulate innovation, but also whether there are other types of PPP that are more conducive of innovation (Van den Hurk and Verweij, 2017). Future research may focus on comparatively analyzing different types of PPPs and how they are able to stimulate innovation.

5.3 Final Conclusions

This paper set out to answer the question: what can the public partner do to stimulate innovation in infrastructure PPPs? Public procurers can steer, stimulate, and facilitate.

Most evidently, they may *steer* by favoring bids by private consortia composed of a few firms, generally of smaller size (CompCons). This consortium choice can provide a favorable ground for innovation to occur. Second, public procurers can *stimulate* by taking on or allowing certain risks. This means that the procurement result may be lower, but that innovative behavior is stimulated. They may thus want to favor bids by consortia composed of a few firms with a low procurement result (CompCons*~ProcRes). Public procurers may also more directly *facilitate* innovation through public project management. Public project management is important in stimulating innovation in PPPs, but not in a straightforward way. Public procurers can provide an impetus for innovation by the private partner by means of a low deployment of public stakeholder management or a low or high deployment of contract management depending on the composition of the private constructing consortium. More important, however, is *how* public project managers actually play their role. In that respect, because of the strictly separated management responsibilities present in DBFM that are often little conducive of collaborative behavior, other forms of PPPs beyond DBFM are interesting to consider.

References

Akintoye, A., Hardcastle, C., Beck, M., Chinyio, E., Asenova, D., 2003. Achieving best value in private finance initiative project procurement. *Construction Management and Economics* 21, 461–470.

Barlow, J., Köberle-Gaiser, M., 2009. Delivering innovation in hospital construction: Contracts and collaboration in the UK's Private Finance Initiative hospitals program. *California Management Review* 51, 126–143.

Burger, P., Hawkesworth, I., 2011. How to attain value for money: Comparing PPP and traditional infrastructure public procurement. *OECD Journal on Budgeting* 11, 91–146.

Caloffi, A., Pryke, S., Sedita, S.R., Siemiatycki, M., 2017. Public–private partnerships and beyond: Potential for innovation and sustainable development. *Environment and Planning C: Politics and Space* 35, 739–745.

Cronqvist, L., 2011. Tosmana: Tool for small-n analysis. University of Trier, Trier.

Demirel, H.Ç., Leendertse, W., Volker, L., Hertogh, M.J.C.M., 2017. Flexibility in PPP contracts - Dealing with potential change in the pre-contract phase of a construction project. *Construction Management and Economics* 35, 196–206.

Eaton, D., Akbiyikli, R., Dickinson, M., 2006. An evaluation of the stimulants and impediments to innovation within PFI/PPP projects. *Construction Innovation* 6, 63–67.

EPEC, 2015. PPP motivations and challenges for the public sector: Why (not) and how. European Investment Bank, Luxembourg.

Eversdijk, A.W.W., Korsten, A.F.A., 2015. Motieven en overwegingen achter publiek-private samenwerking. *Beleidsonderzoek Online*.

Gerrits, L.M., Verweij, S., 2018. The evaluation of complex infrastructure projects: A guide to qualitative comparative analysis. Edward Elgar, Cheltenham.

Goffin, K., Mitchell, R., 2017. Innovation management: Effective strategy and implementation. Palgrave, London.

Groot, P.J.M., Afrian, K., Hardeman, A.J., Vrolijk, M.H., 2012. Trends en ontwikkelingen in de wegenbouw tot 2017: Markt, rolverdeling en werkgelegenheid. Economisch Instituut voor de Bouw, Amsterdam.

Grotenbreg, S., Van Buuren, A., 2018. Realizing innovative public waterworks: Aligning administrative capacities in collaborative innovation processes. *Journal of Cleaner Production* 171, S45–S55.

Hertogh, M.J.C.M., Westerveld, E., 2010. Playing with complexity: Management and organisation of large infrastructure projects. Erasmus University Rotterdam, Rotterdam.

Himmel, M., Siemiatycki, M., 2017. Infrastructure public-private partnerships as drivers of innovation? Lessons from Ontario, Canada. *Environment and Planning C: Politics and Space* 35, 746–764.

Hueskes, M., Verhoest, K., 2015. Factors influencing innovation in public-private partnerships: A structured review of the empirical evidence. Presented at the NIG Annual Work Conference, Nijmegen.

Leiringer, R., 2006. Technological innovation in PPPs: Incentives, opportunities and actions. *Construction Management and Economics* 24, 301–308.

Lenferink, S., Tillema, T., Arts, J., 2013. Towards sustainable infrastructure development through integrated contracts: Experiences with inclusiveness in Dutch infrastructure projects. *International Journal of Project Management* 31, 615–627.

Lodge, M., Wegrich, K., 2014. Introduction: Governance innovation, administrative capacities, and policy instruments, in: Lodge, M., Wegrich, K. (Eds.), The problem-solving capacity of the modern state: Governance challenges and administrative capacities. Oxford University Press, Oxford, pp. 1–21.

Lu, S.L., Sexton, M., 2006. Innovation in small construction knowledge-intensive professional service firms: A case study of an architectural practice. *Construction Management and Economics* 24, 1269–1282.

McQuaid, R.W., Scherrer, W., 2010. Changing reasons for public-private partnerships (PPPs). *Public Money & Management* 30, 27–34.

Ministerie van Financiën, 2013. Handleiding publiek-private comparator. Ministerie van Financiën, Den Haag.

Ministerie van I&M, 2012. IenM maakt ruimte: Strategische kennis- en innovatieagenda Infrastructuur en Milieu 2012-2016. Ministerie van I&M, Den Haag.

Ministerie van V&W, 1997. Van "BE-raming" tot "marktraming": Een handreiking. Stuurgroep Ondersteuning Opdrachtgeverschap, Utrecht.

Möller, K., Rajala, R., Westerlund, M., 2008. Service innovation myopia? A new recipe for client-provider value creation. *California Management Review* 50, 31–48.

Neef, M.R., Verweij, S., Gugerell, K., Moen, P.L.R., 2017. Wegwijs in living labs in infrastructuur en ruimtelijke planning: Een theoretische en empirische verkenning. Rijksuniversiteit Groningen, Groningen.

OECD, Eurostat, 2005. Oslo manual: Guidelines for collecting and interpreting innovation data. OECD Publishing, Paris.

OECD, Eurostat, 1997. The measurement of scientific and technological activities: Proposed guidelines for collecting and interpreting technological innovation data. Organisation for Economic Co-Operation and Development, Paris.

Qi, G.Y., Shen, L.Y., Zeng, S.X., Jorge, O.J., 2010. The drivers for contractors' green innovation: An industry perspective. *Journal of Cleaner Production* 18, 1358–1365.

Ragin, C.C., 2006. Set relations in social research: Evaluating their consistency and coverage. *Political Analysis* 14, 291–310.

Ragin, C.C., Davey, S., 2017. Fs/QCA. University of California, Irvine.

Rangel, T., Galende, J., 2010. Innovation in public-private partnerships (PPPs): The Spanish case of highway concessions. *Public Money & Management* 30, 49–54.
Reinking, M., 2014. Succesvol samenwerken: De zachte kant van projectmanagement. Rijksprojectacademie, Den Haag.
Rihoux, B., Ragin, C.C. (Eds.), 2009. Configurational comparative methods: Qualitative comparative analysis (QCA) and related techniques. Sage, Thousand Oaks.
Rijkswaterstaat, 2014a. Innovatieagenda 2015-2020. Ministerie van Infrastructuur en Milieu, Den Haag.
Rijkswaterstaat, 2014b. Samenwerken & integraal projectmanagement (IPM): Eén manier van werken voor elk project.
Roberts, D.J., Siemiatycki, M., 2015. Fostering meaningful partnerships in public-private partnerships: Innovations in partnership design and process management to create value. *Environment and Planning C: Government and Policy* 33, 780–793.
Roumboutsos, A., Saussier, S., 2014. Public-private partnerships and investments in innovation: The influence of the contractual arrangement. *Construction Management and Economics* 32, 349–361.
Russell, A.D., Tawiah, P.A., De Zoysa, S., 2006. Project innovation - a function of procurement mode? *Canadian Journal of Civil Engineering* 33, 1519–1537.
Rutte, M., Samsom, D., 2012. Bruggen slaan: Regeerakkoord VVD - PvdA. Den Haag.
Savini, F., Majoor, S., Salet, W., 2015. Dilemmas of planning: Intervention, regulation, and investment. *Planning Theory* 14, 296–315.
Schneider, C.Q., Wagemann, C., 2012. Set-theoretic methods for the social sciences: A guide to qualitative comparative analysis. Cambridge University Press, Cambridge.
Sørensen, E., Torfing, J., 2012. Introduction: Collaborative innovation in the public sector. *The Innovation Journal: The Public Sector Innovation Journal* 17, 1–14.
Spescha, A., 2018. R&D expenditures and firm growth – is small beautiful? *Economics of Innovation and New Technology*.
Tawiah, P.A., Russell, A.D., 2008. Assessing infrastructure project innovation potential as a function of procurement mode. *Journal of Management in Engineering* 24, 173–186.
Tidd, J., Bessant, J., Pavitt, K., 2005. Managing innovation: Integrating technological, market and organizational change. John Wiley & Sons, Hoboken.
Uyarra, E., Edler, J., Garcia-Estevez, J., Georghiou, L., Yeow, J., 2014. Barriers to innovation through public procurement: A supplier perspective. *Technovation* 34, 631–645.
Van den Hurk, M., Verweij, S., 2017. Reflectie op PPS-onderzoek in Nederland. *Rooilijn* 50, 134–139.
Verweij, S., 2015. Achieving satisfaction when implementing PPP transportation infrastructure projects: A qualitative comparative analysis of the A15 highway DBFM project. *International Journal of Project Management* 33, 189–200.
Verweij, S., Teisman, G.R., Gerrits, L.M., 2017. Implementing public-private partnerships: How management responses to events produce (un)satisfactory outcomes. *Public Works Management Policy* 22, 119–139.
Verweij, S., Van Meerkerk, I.F., Korthagen, I.A., 2015. Reasons for contract changes in implementing Dutch transportation infrastructure projects: An empirical exploration. *Transport Policy* 37, 195–202.
Weihe, G., 2008. Public-private partnerships and public-private value trade-offs. *Public Money & Management* 28, 153–158.