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The Role of the Public Partner in Innovation in Transport Infrastructure PPPs: A Qualitative Comparative Analysis of Nine Dutch DBFM Projects

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Abstract

By transferring risks and responsibilities to the private sector, governments hope that public–private partnerships (PPPs) bring about innovations in transport infrastructure development. Taking the position that a PPP is not equal to outsourcing, this article explores the role of the public partner in innovation in infrastructure PPPs. To this purpose, nine Design-Build-Finance-Maintain (DBFM) projects in Dutch transport infrastructure development were systematically analyzed with qualitative comparative analysis (QCA). The results show that the presence of innovation is associated with multiple, nonexclusive combinations of three conditions: the procurement result of the partnership contract, the composition of the private construction consortium, and the project management by the public partner (i.e., stakeholder management, technical management, and contract management). In particular, the public partner's choice to enter into a PPP with a construction consortium consisting of a small number of firms is associated with innovation.

Keywords

public–private partnership (PPP), Design-Build-Finance-Maintain (DBFM), transport infrastructure project, innovation procurement, qualitative comparative analysis (QCA)

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Introduction

Research on public–private partnerships (PPPs) has focused on topics such as the transfer, allocation, and management of risks, the financing models, and the performance of PPPs in terms of efficiency (Cui, Liu, Hope, & Wang, 2018; Tang, Shen, & Cheng, 2010). In recent years, the use of PPPs to stimulate sustainable development and innovation in public infrastructure projects—including transport infrastructure projects such as road and waterway infrastructure—has also been encouraged (Caloffi, Pryke, Sedita, & Siemiatycki, 2017). It is often argued that PPPs may drive creativity and 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 sector (Himmel & Siemiatycki, 2017; Hueskes & Verhoest, 2015; Leiringer, 2006; Rangel & Galende, 2010; e.g., The European PPP Expertise Centre, 2015). Innovations in PPPs are said to lead to increased efficiency of infrastructure development and management (The European PPP Expertise Centre, 2015), result in higher quality infrastructure solutions that are better able to address the social complexity involved in project implementation (Lenferink, Leendertse, Arts, & Tillema, 2014), and contribute to finding solutions for major societal challenges such as climate change and urban sustainability (e.g., Koenen, 2018; Witters, Marom, & Steinert, 2012). These advantages of innovations in PPPs notwithstanding, Leiringer (2006) identified that "the publications that endorse PPP as arenas promoting innovation are based on anecdotal evidence and wishful thinking" (p. 303). To date, the empirical evidence of PPPs' ability to stimulate innovation has remained scarce (Himmel & Siemiatycki, 2017; Hueskes & Verhoest, 2015). Reasons may include that collaborative working in PPPs is challenging (Verweij, 2015) and that private construction consortia are often incentivized to minimize risks in PPPs, which may lead to only incremental innovations (Himmel & Siemiatycki, 2017; Roumboutsos & Saussier, 2014). It thus seems that innovation is not an intrinsic part of PPPs (Rangel & Galende, 2010).

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 (e.g., Akintoye, Hardcastle, Beck, Chinyio, & Asenova, 2003; Rangel & Galende, 2010; Uyarra, Edler, Garcia-Estevez, Georghiou, & Yeow, 2014). These studies, however, focused on the ways in which contracts, or precontract competition, incentivize innovation behavior by the *private* partner. Research has largely neglected the role of the *public* partner in innovation in PPPs (Rangel & Galende, 2010). Although recent work has started to emphasize the public partner's role in innovation (e.g., Roberts & Siemiatycki, 2015), more empirical research is needed into this topic, especially comparative work that goes beyond single cases and anecdotal evidence (Rangel & Galende, 2010). The present article addresses this research gap by conducting a systematic comparison of the role of the public partner in nine Dutch PPP projects.

Innovation is defined in the study as technological product and process (TPP) innovations, which comprise "implemented technologically new products and processes and significant technological improvements in products and processes" (Organisation for Economic Co-operation and Development [OECD] & Eurostat, 1997; in Leiringer, 2006, p. 303). The focus of the study is on proposed innovations that are incorporated in the bids of private consortia in the tender. The innovations are further worked out after the contract award. Contracts are awarded based on both price and quality criteria; hence, the innovations allow the consortia to gain a competitive advantage over the other tenderers because they lead to higher quality transport infrastructure and lower costs, thus potentially increasing the private consortia's profit margins as well as their competitive position in the international market. Three conditions are explored that concern the role of the public partner in innovation in PPPs.

The first is the public partner's choice to award the contract to a bid with a high *procurement result* (Verweij, Van Meerkerk, & Korthagen, 2015). A high procurement result means that the contract value of the partnership is lower than was estimated by the public partner before the bidding process. Provided that the public procurer is able to make a proper design and cost calculation and specify the quality and functionality criteria, a high procurement result may indicate that the private partner has found smarter and more innovative solutions with at least the same quality and functionality. The second condition is the choice for a certain *composition of the private construction consortium* (cf. Spescha, 2018). Literature suggests that consortia consisting of a small number of small firms may have a collaborative advantage over, and lower transaction costs than, consortia with a larger number of firms, thus increasing the potential for innovation. The third condition concerns the *project management by the public partner* (cf. Grotenbreg & Van Buuren, 2018). This condition focuses on the role played by the public partner during the implementation of the project, that is, after the contract award (Verweij, 2015), in particular the stakeholder management, contract management, and technical management by the public partner (Reinking, 2014). Innovations with environmental and technical impact will ask for more management support by the public partner to implement them interactively and effectively in the often-complex stakeholder environments of the projects. As such, increased public technical and stakeholder management may indicate that the private partner is more creative and innovative compared with the design drawings in the tendering documents. At the same time, it means that the public partner facilitates the use of innovations.

This article investigates the role of the public partner in innovation in PPPs by exploring the associations between the three conditions and innovation. The research question is as follows: What are the associations in infrastructure PPPs between procurement result, consortium composition, and public project management on one hand, and innovation by private partners on the other hand?

This article continues in the section "Innovation in Transport Infrastructure PPPs," with further introducing and defining the central concepts of the study: innovation, procurement result, composition of the private construction consortium, and project management by the public partner. Nine Design-Build-Finance-Maintain (DBFM) projects in Dutch transport infrastructure development were analyzed with qualitative comparative analysis (QCA). DBFM projects are a type of PPP where the private partner is integrally responsible for designing, building, maintaining, and (partly) financing the infrastructure development (Lenferink, Tillema, & Arts, 2013). The section "Data and Method" presents and explains the cases, data, and methods used for the QCA-analysis. QCA is a relatively novel method in research on PPPs (e.g., Kort, Verweij, & Klijn, 2016; Soecipto & Verhoest, 2018; Verweij, 2015). It is highly suitable for systematically analyzing a small or medium number of cases and its configurational nature allows the researcher to explore how conditions together are associated with a certain outcome of interest (Berg-Schlosser, De Meur, Rihoux, & Ragin, 2009; Gerrits & Verweij, 2018). The section "Analysis and Results" provides the analysis and the results. The section "Discussion and Conclusion" comprises the discussion of the results, the limitations of the research, and the final conclusions.

Innovation in Transport Infrastructure PPPs

PPPs and Innovation

Project innovation can generally be categorized into product, process, organizational–contractual, and financial innovation (Russell, Tawiah, & De Zoysa, 2006; Tawiah & 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 (Russell et al., 2006). For many years, these have also been the core motivations to develop transport infrastructure through PPPs (Eversdijk & Korsten, 2015; McQuaid & 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 sector (Lenferink et al., 2013) and performance-based payment mechanisms are used to incentivize the private partner to perform well (Reynaers, 2015). With the organizational–contractual and financial innovations now being default in Dutch PPPs, particularly in DBFM, at the beginning of the century the motivation for PPPs shifted toward their ability to stimulate innovation themselves (Eversdijk & Korsten, 2015). PPPs became popular for the "optimal use of available resources and to promote entrepreneurship and innovation" (Rutte & Samsom, 2012, p. 37) and for the realization of "added or surplus value" (Ministerie van Infrastructuur en Milieu, 2012; Rijkswaterstaat, 2014a; Rijkswaterstaat et al., 2016). However, to date, the empirical evidence of PPPs' ability to stimulate innovation has remained scarce (Himmel & Siemiatycki, 2017; Hueskes & Verhoest, 2015), a concern that is also echoed by policy makers (see e.g., Koenen, 2018).

Hence, this article considers product and process innovations in infrastructure projects and focuses on how such innovations can be stimulated through PPPs. Innovations concern "significant technological improvements" in both products and processes (OECD & Eurostat, 1997, p. 31). *Product innovation* includes the development of new products and—because the construction industry is an innovation adopter rather than developer—the use of new products, for example, 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 & Russell, 2008). In PPPs and in DBFM projects in particular, however, the private partner not only delivers products (e.g., tunnel systems or new roads) but also provides services (e.g., the maintenance of tunnels and roads; Yescombe, 2007). Therefore, product innovation includes the *development and use* of innovations in provided *products and services* (OECD & Eurostat, 2005). *Process innovations* concern new or significantly improved methods or skills that are used to construct the product or perform the service (OECD & 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 & Russell, 2008).

In the following subsections, the three conditions of the study are elaborated. The conditions were selected in consultation with managers of Rijkswaterstaat, the executive agency of the Dutch Ministry of Infrastructure and Water Management. Especially these conditions appeared regularly in the discussions about procurement through PPPs as they concern the role of the public partner in innovation in PPPs. Moreover, internal information was available on them.

Procurement Result

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

A measure for gauging the private partner's need for efficiency improvement is the procurement result. The procurement result 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, this could be explained by opportunistic bidding behavior by the contractors (Mohamed, Khoury, & Hafez, 2011). However, a previous study into Dutch transport infrastructure projects found that, although, on average, the concluded contract value was 23.8% lower than estimated by the public procurer prior to the tender, there was no evidence for opportunistic bidding behavior by private partners (Verweij et al., 2015).

An alternative explanation, which is explored in the present article, is that a high procurement result may indicate that private consortia have incorporated creative and innovative ideas in their bids. Because contracts are awarded based on price and quality criteria, the innovations should lead to higher or equal quality at lower costs, which allows tendering consortia to gain a competitive advantage over the other tenderers. Assuming that the public procurer is able to make a proper design and cost calculation and specify the quality and functionality criteria, this translates into a higher procurement result. For this explanation to hold, the development or use of the product or process innovation has to stem from the private partner (market-driven) and not from the project scope defined by the public procurer in the tendering documents (including design drawings) for the DBFM contract (client-driven; cf. Möller, Rajala, & Westerlund, 2008). Through this line of reasoning, a high procurement result may indicate that the private consortium felt an incentive in the tendering to incorporate creative ideas and innovation in its bid (Burger & Hawkesworth, 2011; Himmel & Siemiatycki, 2017).

Composition of the Private Construction Consortium

DBFM contracts are usually applied to large projects (in terms of scope and budget). In the Netherlands, for instance, DBFM is applied in principle only to infrastructure projects with a minimal contract value of €60 million (Ministerie van Financiën, 2013, 2016). As a result, DBFM contracts usually involve bids by firms of sufficient size and/or bids made by multiple firms to share the risks and complement knowledge.

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 & Sexton, 2006; Spescha, 2018). On 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). Moreover, small firms may have stronger creative capacities and a stronger drive to innovate 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 (e.g., Qi, Shen, Zeng, & Jorge, 2010) and that larger firms benefit from larger R&D budgets, driving innovation (Spescha, 2018). Both small and large firm sizes may thus be associated with innovation (Goffin & Mitchell, 2017), although literature seems to be slightly in favor of a small firm size being favorable for innovation (Tidd, Bessant, & Pavitt, 2005).

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

Project Management by the Public Partner

Research on PPPs has shown that, more so than the organizational–contractual characteristics of PPPs, the project management is of pivotal importance for project performance (e.g., Klijn & Koppenjan, 2016; Kort et al., 2016). Typically, in DBFM projects, the public and private partners establish their own project management organizations as separate organizations working together. DBFM projects differ in this respect from, for example, alliances where one integral management team is established. 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, Teisman, & Gerrits, 2017). Because it may complement each other's skill sets and resources and may establish favorable institutional conditions for innovation, the deployment of project management capacities by the public partner may be associated with innovation in PPPs (Grotenbreg & Van Buuren, 2018; Himmel & Siemiatycki, 2017; Rangel & Galende, 2010).

However, the relationship between public project management and innovation is not straightforward (Savini, Majoor, & Salet, 2015). On 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 article sheds further light on the complex relationship between public project management and innovation. In the Netherlands, five different public project 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, analysis, and effect mitigation.

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 focuses on the government's role in managing networks of actors, boundary spanning, bringing actors together, and intermediating between actors (Grotenbreg & Van Buuren, 2018; Lodge & Wegrich, 2014). 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. These actions bring together complementary skills and resources, which is important for innovation (Grotenbreg & Van Buuren, 2018). More important, however, is that the innovative solutions proposed in the private consortia's bids may ask for more intensive stakeholder management by the public partner because novel solutions have to be interactively implemented in the often-complex stakeholder environment of the project, for instance, via living labs (Neef, Verweij, Gugerell, & Moen, 2017).

The technical manager is responsible for the technical input in the project. He or she translates the client's demands into project requirements in the tendering documents 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 & Van Buuren, 2018), he or she contributes to increased knowledge "about future projections and current developments" (Lodge & Wegrich, 2014, p. 16). His or her actions bring "new knowledge into play (. . .) and encourage transformative learning and out of the box thinking" (Sørensen & Torfing, 2012; in Grotenbreg & Van Buuren, 2018, p. S47). By decreasing uncertainty and increasing learning, the riskiness of innovations may be reduced. Because the manager's actions facilitate the implementation and use of innovations, the innovative solutions in private consortia's bids may thus call upon the capacity of technical managers from the public partner.

The contract manager's responsibilities focus on the management of the contractual relationship between the public partner (client) and private partner (contractor) in the project (Wermer, 2012). His or her tasks include determining the procurement need, drafting the tendering documents and the contract dossiers, and contract control during the implementation of the project (Reinking, 2014). Whereas a high deployment of stakeholder and technical management capacities is expected to be associated with innovation, this may be less straightforward for contract management. On one hand, the contract manager may give temporary permissions, accept risks, and adjust or develop rules which facilitate the private partner in the implementation and use of innovations (cf. Grotenbreg & Van Buuren, 2018). On the other hand, contract managers are involved in controlling risks and regulating the project management by the private partner, which may decrease its flexibility and hence possibilities to innovate (Hertogh & Westerveld, 2010). The analysis in this article may shed light on the relationship between contract management by the public partner and innovation.

Data and Method

Data Collection and Cases

The data for the study were collected via questionnaires (for innovation) and from the Project Database of Rijkswaterstaat (for the three conditions). In the Netherlands, Rijkswaterstaat is the procurer of major transportation infrastructure. Since 2010, it integrated all its project data into a single database. Access to the data and publishing about the data was allowed by Rijkswaterstaat, with the provision that the data and results are carefully anonymized and cannot be traced back to specific persons or projects. The data collection took place between April and July 2018. Rijkswaterstaat managers and experts were consulted during the data collection process 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 purposes, this contributed to the practical relevance of the study. The database contained 14 DBFM projects in transport infrastructure (i.e., roads and waterways) that had actually reached their implementation phase (i.e., after the contract award). One project was devoid of data and was excluded from the data set.

All remaining 13 projects are planned to finish their implementation phase (i.e., design and build) before the end of 2020. Their contract values range from approximately €60 million to €1.5 billion. 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. The cases include tunnels, bridges, roads, and waterways/locks. They characterize as complex cases with multiple governmental and nongovernmental stakeholders (cf. De Schepper, Dooms, & Haezendonck, 2014; Hertogh & Westerveld, 2010).

Measurement and Data

The degree of *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 (in Dutch, based on the "baseline innovation measurement") that were completed by the technical managers of the studied projects. Innovation was regarded to be either present or absent. For two projects, the innovation data could not be retrieved and these cases were thus not included in the analysis. Table A1 in the appendix provides some more details on the innovations in the cases.

The innovations in the remaining 11 projects 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., flyovers) and production methods (e.g., recycling concrete or new types of asphalt with longer life spans), 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 11 projects (73%). In one of those eight cases, the innovation was client-driven instead of 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, on one hand, and the actual awarded contract value, on the other hand. 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 Verkeer & Waterstaat, 1997). For both the estimated and the actual contract value, the net present value (NPV) of the project was used. Data were available for 11 of the 13 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 by the firms' sizes. The number of firms in the 13 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 13 cases, it ranged from approximately €75 million to €19,910 million. One firm was an outlier with revenue of approximately €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 12 cases. The management functions (e.g., the stakeholder manager) and the supporting functions (e.g., advisor stakeholder management) were added together. Per management role, the average FTE of the first 3 years of the project's implementation phase was taken. For four of the 12 cases, only one (two projects) or two (two projects) implementation years were available. After the FTEs for the management roles 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 12 projects, the FTE allocated to stakeholder management was on average 22.9%; for technical management this was 29.2%; and for contract management this was 25.6%.

Method: QCA

The data were analyzed with QCA (Gerrits & Verweij, 2018). QCA is a case-based method that helps to systematically and transparently analyze how different configurations of conditions—in the present article: procurement result, consortium composition, and public project management—are associated with the outcome of interest (in this article: innovation). The relationships between the conditions and the outcome are expressed in terms of necessity and sufficiency (Schneider & Wagemann, 2012). The method is also particularly suitable for data sets with a small-to-medium number of cases.

The *first step* in the application of the method is the calibration of the data, for which QCA relies on set theory (Schneider & Wagemann, 2012). 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). Calibration helps to distinguish relevant and irrelevant variation between cases (with cases with the same set membership score having irrelevant variation) and to prepare the data for transparent comparison. 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 & Verweij, 2018). Calibration is an iterative process between theoretical expectations and the empirical data and should hence be discussed in detail (Gerrits & Verweij, 2018); it results in a calibrated data matrix (see the section "Calibration Rules and Calibrated Data").

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; Gerrits & Verweij, 2018). 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. Thereafter, 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 nonexclusive configurations that are associated with the outcome of interest. The mutually nonexclusive configurations (i.e., equifinality) are also called "conjunctions" or "paths" and they express that conditions form conjunctions with other conditions. In this way, QCA helps to shed light on the complex relationships between the conditions and innovation in PPPs and on the different roles that the public partner can assume in PPP projects. Because the size of the truth table increases exponentially with each condition that is added, limited diversity may occur (Schneider & Wagemann, 2012). 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 (see e.g., Gerrits & Verweij, 2018). To curtail limited diversity, analyses were conducted separately for the different management roles (see the section "Analysis and Results"). The analyses were conducted with the fs/QCA software (Ragin, 2017; Ragin & Davey, 2017).

Calibration Rules and Calibrated Data

Regarding the outcome *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 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 (Case-L; see Table 2).

Verweij et al. (2015) found an average *procurement result* of 23.8%. A first calibration attempt using that value 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 almost all the cases having a high procurement result. Therefore, we instead performed a cluster analysis for the calibration, using the QCA software "Tosmana" (Cronqvist, 2011), and identified four clusters: low procurement result (0.00) [7.15%-20.1%], medium procurement result (0.33) [20.2%-29.5%], high procurement result (0.66) [29.6%-37.2%], and very high procurement result (1.00) [37.3%-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 (Rihoux & De Meur, 2009). The calibration thus expresses the expectation that a high procurement result is associated with innovation by the private partner (see the section "Procurement Result").

Regarding the *composition of the private construction consortium*, as discussed in the section "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 a small firm size being

Table 1. Calibration of the Composition of the Construction Consortium.

	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

associated with innovation. Literature is a bit clearer on the fact that smaller numbers of firms are more likely to contribute 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.

After consulting experts from Rijkswaterstaat, the cutoff point for the number of firms was set at three firms, based on the reasoning that in infrastructure construction there are at least three different areas of expertise involved. Regarding firm size, existing classifications derived from the "Economic Institute for the Construction Industry" (Groot, Afrian, Hardeman, & Vrolijk, 2012) did not result in a meaningful distribution of cases because the DBFM projects in the present sample all involve large construction firms. The reason is that small companies cannot bear the relatively high financial risks involved in large DBFM projects. Therefore, a cluster analysis was performed with Tosmana (Cronqvist, 2011), which identified the annual revenue of €9,688 million as the cutoff point. Note that, as an exception, Case-F and Case-G are assigned a calibrated score of 1.00 while 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 (Cronqvist, 2011). The so-called *Normering Kerntaken Aanleg* (in Dutch) 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 for the deployed management FTEs is not perfect (in consultation with Rijkswaterstaat), it was decided to adopt a conservative calibration strategy to avoid faux precision (cf. Gerrits & 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%-25.38%] and 1.00 [25.39%-37.88%], technical management as 0.00 [21.56%-27.32%] and 1.00 [27.33%-37.54%], and contract management as 0.00 [15.90%-23.02%] and 1.00 [23.03%-35.26%]. Table 2 provides the raw data (except for the procurement result, to ensure anonymity of the cases) and the calibrated data of the study. To be included in the truth table 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 the section "Analysis and Results."

Table 2. Raw and Calibrated Data Matrix.

				Public project management							
	Procurement result	Composition consortium		Stakeholder management		Technical management		Contract management		Innovation	
Case ID	Cal.	Raw	Cal.	Raw	Cal.	Raw	Cal.	Raw	Cal.	Raw	Cal.
Case-A	**1.00**	*N* = 2—small only	**1.00**	21.30%	**0**	24.83%	**0**	35.26%	**1**	Yes—client-driven	**1.00**
Case-B	**0.00**	*N* = 1—small only	**1.00**	23.76%	**0**	25.74%	**0**	26.90%	**1**	Yes—market-driven	**1.00**
Case-C	**n/a**	*N* = 4—large also	**0.00**	27.00%	**1**	25.42%	**0**	25.84%	**1**	Yes—market-driven	**1.00**
Case-D	**n/a**	*N* = 7—large also	**0.00**	19.01%	**0**	37.54%	**1**	24.44%	**1**	No	**0.00**
Case-E	**0.66**	*N* = 3—small only	**1.00**	n/a	**n/a**	n/a	**n/a**	n/a	**n/a**	n/a	**n/a**
Case-F	**0.00**	*N* = 4—small only	**1.00**	21.48%	**0**	28.90%	**1**	20.41%	**0**	Yes—market-driven	**1.00**
Case-G	**0.33**	*N* = 4—small only	**1.00**	37.88%	**1**	21.56%	**0**	15.90%	**0**	n/a	**n/a**
Case-H	**0.33**	*N* = 3—large also	**0.66**	29.21%	**1**	22.83%	**0**	20.64%	**0**	Yes—market-driven	**1.00**
Case-I	**0.33**	*N* = 4—large also	**0.00**	21.85%	**0**	30.96%	**1**	27.28%	**1**	No	**0.00**
Case-J	**0.66**	*N* = 2—small only	**1.00**	15.53%	**0**	33.10%	**1**	31.50%	**1**	Yes—market-driven	**1.00**
Case-K	**1.00**	*N* = 7—small only	**0.33**	23.73%	**0**	29.20%	**1**	21.59%	**0**	Yes—market-driven	**1.00**
Case-L	**0.66**	*N* = 4—small only	**0.33**	17.39%	**0**	36.66%	**1**	27.50%	**1**	Partly—market-driven	**0.33**
Case-M	**1.00**	*N* = 3—small only	**1.00**	16.58%	**0**	33.58%	**1**	29.97%	**1**	Yes—market-driven	**1.00**

Note: The boldface numbers refer to the calibrated data values and the non-boldfaced text in the table refers to the raw data values.

Table 3. Truth Table With Stakeholder Management.

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

Note: PRI=Proportional Reduction in Inconsistency.

Analysis and Results

Analysis of Necessity

Prior to the construction and analyses of the truth tables, a necessity test was performed. For a condition to be considered necessary, it must have a consistency of at least 0.9 (Schneider & Wagemann, 2012). Basically, consistency expresses "the degree to which empirical evidence supports the claim that a set-theoretic relation exists" (Rihoux & Ragin, 2009, p. 182). In addition, coverage is a measure that helps to "gauge[s] empirical relevance or importance" (Ragin, 2006, p. 292). The test revealed no necessary conditions. The conditions with the highest consistency scores were a composition of the construction consortium with few firms (CompCons) [consistency: 0.86221] and a low deployment of stakeholder management (~StakMan) [consistency: 0.86357].

Construction of the Truth Tables

The truth table for the analysis with stakeholder management is provided as Table 3. Truth table rows that are devoid of cases are not shown. In addition to the regular raw consistency score, a high PRI-consistency (i.e., Proportional Reduction in Inconsistency) expresses that the truth table row is sufficient for the outcome "presence of innovation" and not simultaneously for the negated outcome (i.e., the absence of innovation; see Schneider & Wagemann, 2012). Innovation occurred in all the cases in the first three truth table rows. The high consistency scores express this; 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). The fourth row is hence a so-called logical contradiction, where the evidence is too ambiguous to assign the configuration an outcome score of 1 and thence include it in the subsequent analysis of the truth table. 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 (see Table 2).

The truth tables with technical management and contract management are provided as Tables 4 and 5, respectively. The assignment of the outcome scores to the truth table

Table 4. Truth Table With Technical Management.

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

Note: PRI=Proportional Reduction in Inconsistency.

Table 5. Truth Table With Contract Management.

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

Note: PRI=Proportional Reduction in Inconsistency.

rows followed the same process as described for Table 3. That is, effectively, only truth table rows with perfect consistency scores (i.e., all cases show innovation) are assigned an outcome score of 1.

Results of the Truth Table Analyses

The results of the truth table analyses (i.e., analyses of sufficiency) are provided in Table 6. All the results meet the standard consistency requirement of 0.75 (Ragin, 2006). Table 6 shows six paths that are associated with innovation. The results of the analysis with stakeholder management indicate that a construction consortium with fewer firms (CompCons $\leq$ 3), combined with either a low-to-medium procurement result (~ProcRes) or a low deployment of stakeholder management (~StakMan), is associated with innovation. The results of the analysis with technical management indicate one path consisting of a single condition that is associated with innovation, namely, a construction consortium with fewer firms (CompCons $\leq$ 3; however, see the section "Robustness Test"). Finally, the truth table analysis with contract management resulted in three sufficient paths for the occurrence of innovation. First, a construction consortium with fewer firms (CompCons $\leq$ 3), combined with either a low-to-medium procurement result (~ProcRes) or a high deployment of contract management (ContMan), is associated with 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).

Table 6. Results From the Three Truth Table Analyses.

		Minimized configuration	Raw coverage	Unique coverage	Consistency	Cases
Results StakMan	Path 3	CompCons*~StakMan	0.77217	0.40791	1.00000	Case-A, Case-J, Case-M; Case-B, Case-F
	Path 2	CompCons*~ProcRes	0.45430	0.09004	1.00000	Case-B, Case-F; Case-H
		Solution consistency/coverage: 1.00000/0.86221				
Results TechMan	Path 1	CompCons	0.86221	0.86221	1.00000	Case-B, Case-H; Case-J, Case-M; Case-A; Case-F
		Solution consistency/coverage: 1.00000/0.86221				
Results ContMan	Path 4	CompCons*ContMan	0.59072	0.36289	1.00000	Case-A, Case-J, Case-M; Case-B
	Path 2	CompCons*~ProcRes	0.45430	0.18145	1.00000	Case-F, Case-H; Case-B
	Path 5	ProcRes*~CompCons*~ContMan	0.13643	0.09141	1.00000	Case-K
		Solution consistency/coverage: 1.00000/0.90860				

In the absence of strong theoretical expectations about the relationships between the conditions and innovation, only the so-called conservative solutions are provided. This effectively means that the truth table rows that are devoid of cases were not included as counterfactuals in the truth table analysis (Gerrits & Verweij, 2018).[1]

Robustness Test

As explained in the section "Calibration Rules and Calibrated Data," we adopted a conservative calibration strategy for the public project management conditions. To check the robustness of the analysis with this calibration (Skaaning, 2011), we also performed the analyses using a four-value fuzzy set calibration scheme, as with the conditions "procurement result" and "consortium composition" (see the section "Calibration Rules and Calibrated Data"). Using the cluster analysis in Tosmana (Cronqvist, 2011), we recalibrated the public project management conditions. Stakeholder management was recalibrated as 0.00 [15.53%-20.16%], 0.33 [20.17%-25.38%], 0.66 [25.39%-33.54%], and 1.00 [33.55%-37.88%]; technical management as 0.00 [21.56%-27.32%], 0.33 [27.33%-32.03%], 0.66 [32.04%-35.12%], and 1.00 [35.13%-37.54%]; and contract management as 0.00 [15.9%-18.16%], 0.33 [18.17%-23.02%], 0.66 [23.03%-33.38%], and 1.00 [33.39%-35.26%].

The test showed that the results of the analysis are robust. The analysis with the recalibrated data again returned no necessary conditions. The results for the truth table analyses with contract management (applying a consistency cutoff of 0.79640) and stakeholder management also remained the same. However, the results for the analysis with technical management changed because Case-F and Case-K moved to different truth table rows. A construction consortium with fewer firms (CompCons $\leq$ 3) remained important, but now in combination with either a high procurement result (ProcRes) or a low deployment of technical management (~TechMan). When lowering the consistency cutoff to 0.75188 to include Case-K, the combination of a high procurement result (ProcRes) with a low deployment of technical management (~TechMan) was additionally also associated with innovation. This means that the results for the analysis with technical management in Table 6 are somewhat robust with CompCons still at the core, but that they do become more complex in the recalibrated analysis.

Discussion and Conclusion

Discussion of the Results

To aid the interpretation of the results, Figure 1 depicts the five solution paths from the results of the analysis. The paths correspond to the minimized configurations (paths) in Table 6.

The results clearly indicate the importance of a *private construction consortium* composed of a few number of firms (CompCons), thereby confirming the theoretical expectation (see the section "Composition of the Private Construction Consortium").

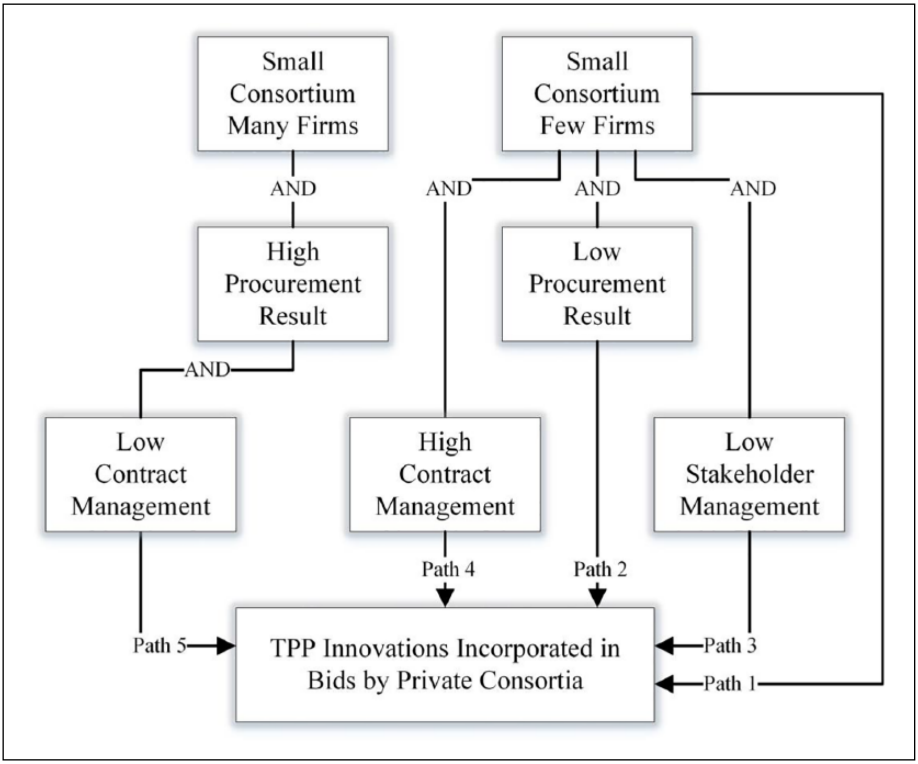

Figure 1. Solution paths from the three truth table analyses.
Note. TPP = technological product and process.

This is indicated by Path 1 in Figure 1. The condition was found to be not quite necessary (see the section "Analysis of Necessity"), which is caused by Case-K that shows that innovation may also occur in a consortium with a larger number of firms. However, the truth table analysis does indicate the association between the composition of the consortium and the occurrence of innovation (see Table 6). This is furthermore supported by all the other minimized configurations also containing the condition CompCons, with the exception of Path 5 (see Figure 1). Based on particularly Path 1, the results suggest 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, and are therefore better conductors for innovation (see the section "Composition of the Private Construction Consortium"). Although important, a consortium consisting of a small number of firms cannot fully explain innovation. This is indicated by Paths 2 to 4 in Figure 1 and supported by the truth table analyses with stakeholder management and contract management (Results StakMan and ContMan; Table 6) and the robustness test (see the section "Robustness Test").

First of all, the results show that a consortium with few firms (CompCons), combined with a low *procurement result* (~ProcRes), is related to the occurrence of innovation. This is indicated by Path 2 in Figure 1. A possible explanation is that fewer private partners make risk allocation and management easier (CompCons), which makes making a more realistic and competitive bid on the contract easier and which, in turn, translates into a lower procurement result (~ProcRes).[2] It can be noted that Path 5 in Figure 1 provides the mirror image, which supports the idea that when more firms are involved, producing a realistic bid may be more challenging, resulting in a higher procurement result.

Second, a consortium with few firms, combined with the deployment of public project management roles, is related to innovation. This is indicated by Paths 3 and 4 in Figure 1. The truth table analysis with *stakeholder management* shows that, when the private consortia consist of few firms (CompCons), they may benefit from a relatively low deployment of stakeholder management by the public partner (~StakMan; Path 3). This result is contrary to the idea that innovative solutions proposed in bids ask for more intensive public stakeholder management to interactively implement the innovation in the complex project's stakeholder environment (see the section "Project Management by the Public Partner"). A possible explanation is that the private consortia, which all consist of few firms—that are also small—are very capable of stakeholder management themselves. In fact, small firms (CompCons) are said to have communication and coordination advantages (cf. Spescha, 2018; see the section "Composition of the Private Construction Consortium") and this may extend to stakeholder management, thus requiring only a low stakeholder management input from the public partner (~StakMan). Small firms are typically involved in innovations that involve interactive processes, which means that they are more likely to possess the required stakeholder management capacities through experience.

It is also noteworthy that the truth table analysis shows that *technical management* is not associated with innovation (see Table 6). The condition is absent in Figure 1. This is contrary to the idea that innovative bids by private consortia call upon the capacity of public technical managers to help in the implementation of the innovations by, for example, supporting actions in grant applications or information supply (see the section "Project Management by the Public Partner"). Possibly, this result is explained by the fact that the innovations, save for one, are all market-driven (see Table 2). The public technical manager may commission studies, supply information, support subsidy and grant applications, investigate possibilities for innovations, and so on (Grotenbreg & Van Buuren, 2018; see the section "Project Management by the Public Partner"). 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 most dominantly in the bidding phase and that their role with respect to innovation has largely been played when the project enters the implementation phase.

Regarding *contract management* by the public partner, the truth table analysis indeed indicates that it can be related to innovation in different ways (ContMan and ~ContMan; see Table 6). This is indicated by Paths 4 and 5 in Figure 1. On 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 & Van Buuren, 2018). On the other hand, he or she may also aim to minimize risk and decrease complexity and stimulate the use of proven technologies instead (Hertogh & Westerveld, 2010). The analyses suggest 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), as indicated by Path 4. In the case of consortia with more firms (~CompCons), public contract management was less present (~ContMan), as indicated by Path 5. These results mirror each other. A possible explanation is that consortia consisting of fewer and smaller firms have a stronger tendency to be competitive through product-oriented innovations, which may lead to contract negotiations and changes, which is the domain of the contract manager (Path 4). The result depicted as Path 5, however, is covered by only case and the low coverage for that path (see Table 6) limits interpretation. Based on the analysis, it is difficult to identify conclusively how the public contract management role was played.

Discussion of Limitations and Further Research

The present study measured the public project management by the amount of allocated FTE. The advantage of this approach is that it is a relatively efficient and objective way of measuring management capacity. The downside is that measurement through FTE obscures the importance of *how* management roles are played. The present study did not analyze how the management roles were performed qualitatively and this may have contributed to its somewhat diffuse findings regarding public project management. Future research may inquire into the ways public project managers can facilitate or constrain innovation in PPP projects. A second measurement issue concerns the composition of the private consortium, which was defined by the number and sizes of the firms (see the section "Measurement and Data"). Data were available on these indicators and they were relatively easy to measure. The downside is that this measurement obscures the importance of the organizational structure of the private consortium and how risks are allocated between the private partners. For instance, certain firms may be more willing to assume certain types or degrees of risks than other firms and this may affect how risks are allocated and what risks are taken by the consortium in the first place (Eaton et al., 2006). Future research may inquire into the relationship between the organizational structure of the consortium and other organizational features, on one hand, and innovation, on the other. A promising approach, for instance, is to use network theory to analyze the organizational structures (see Chowdhury, Chen, & Tiong, 2011) and combine it with QCA to test which structures are associated with innovation.

A third issue stems from the number of cases. Although nine cases is an analyzable number in QCA, it sets a limit to the number of conditions that could be included in the analysis (Gerrits & Verweij, 2018). This problem was addressed by conducting separate analyses for the different public project management roles. However, the idea of the IPM model used in the public management of PPP projects is that the interests and goals related to stakeholder management, technical management, and contract management are implemented and safeguarded in a balanced manner (Reinking, 2014; Rijkswaterstaat, 2014b). This implies that the degree to which innovation is facilitated, or perhaps even stimulated, in PPP projects may rely on how these interests and goals in fact interact and balance out in the IPM model on the project level. Additional configurational analyses may inquire into this balancing but will need more cases. When more cases are available, other conditions such as project sector, project complexity, or contract type (e.g., DBFM vs. Design-and-Construct) may also be included. This would allow a more refined analysis of how innovation occurs less or more in different infrastructure sectors and contract types and of the influence of project complexity on the need or willingness of the tenderers to introduce innovations in their bids.

Fourth, regarding the types of cases, this study focused on innovations incorporated in the bids of private partners and on DBFM projects only. DBFM is the standard PPP option in the Netherlands and it is applied to large, national-level projects (Lenferink et al., 2013). The transfer of risk to the private sector through private project financing—the F in DBFM—is an essential element of this type of PPP. The private partner is stimulated to achieve the project milestones on time; otherwise, it is penalized and payments by the public partner are delayed, which means that it may have to pay additional interest to the financiers that provided the loans to the consortium. This often incentivizes risk-averse strategies. Scholars have hence observed that innovations in these PPPs are often incremental at best (Himmel & Siemiatycki, 2017; Roumboutsos & Saussier, 2014), or that private consortia revert to tried-and-tested strategies to minimize risk. This first raises the question as to whether a higher procurement result may actually be an indication for low-risk project implementation strategies and therefore a low degree of innovation. Future research comparatively analyzing PPPs with little innovation may delve into this. Moreover, it raises questions of the extent to which innovations have actually materialized at the end of the project implementation, of how DBFM contracts can be made more flexible (Demirel, Leendertse, Volker, & Hertogh, 2017) to simulate innovation, and whether other types of PPP are more conducive of innovation (Van den Hurk & Verweij, 2017). For instance, alliances focus on risk sharing instead of risk transfer and this may allow the partners to accept more risk resulting in more innovation (cf. Leendertse, 2015). Future research may focus on comparatively analyzing different types of PPPs and PPP contracts and answer these questions.

Final Conclusion

This article set out to explore the role of the public partner in innovation in infrastructure PPPs. The study focused on three conditions that concern the role of the public partner in innovation: the procurement result, the choice for a certain consortium composition, and public project management. The results especially suggest that bids by private consortia composed of a few firms, generally of smaller size (CompCons), are more innovative. This observation is interesting in light of recent concerns expressed by highly placed policy makers in the Netherlands. They are concerned with the low degree of innovation by the market in the infrastructure sector and argue that innovation processes need to speed up to address pressing societal and technological challenges, such as climate change and big data (Koenen, 2018). The results in this article may instigate policy makers to explore the idea to procure smaller projects instead of the current DBFM megaprojects, thereby attracting bids by smaller consortia with a strong motivation to innovate. This would simultaneously address the recent concerns expressed by construction companies that the DBFM projects are getting too big and too risky, sometimes leading to major financial problems for the companies involved (Koenen, 2019).

The study also addresses the role of public project management in innovation in PPPs. Management by the public partner is associated with innovation, but not in a straightforward way. The results indicate that 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, is associated with innovation. More important, however, is *how* public project managers actually play their role in PPPs. In that respect, because of the strictly separated management responsibilities present in DBFM that are often little conducive of collaborative behavior (Verweij et al., 2017), other forms of PPPs beyond DBFM are interesting to investigate.

Appendix

Table A1. Innovation in the DBFM Projects.

Case ID	Innovation used/ realized?	Innovation market-driven or client-driven?	What are the innovations?
Case-A	Yes	Client-driven	Implementation of pilot circular viaduct
Case-B	Yes	Market-driven	Rejuvenation top layer asphalt
Case-C	Yes	Market-driven	Application new type of asphalt; application prefabricated pillars; implementation new design solutions
Case-D	No	Neither	None
Case-E	n/a	n/a	n/a
Case-F	Yes	Market-driven	Application new process and timing for asphalt repairs
Case-G	n/a	n/a	n/a
Case-H	Yes	Market-driven	Application fiber reinforced, recycled, and low-temperature asphalt; application new process for lifetime extending maintenance; implementation removable markings and LED lightning; application of noise-reducing concrete

(continued)

Table A1. (continued)

Case ID	Innovation used/ realized?	Innovation market-driven or client-driven?	What are the innovations?
Case-I	No	Neither	None
Case-J	Yes	Market-driven	n/a
Case-K	Yes	Market-driven	Development energy-neutral operating locks
Case-L	Partly	Market-driven	Offer to implement solar panels; sustainable concrete; new measures for lock impact protection
Case-M	Yes	Market-driven	Implementation low-weight doors; application of eco-filter measurement tool

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Notes

1. The parsimonious solutions for the analyses with StakMan, TechMan, and ContMan, respectively, are as follows: CompCons → Innovation [cons. 1.00000, cov. 0.86221], CompCons → Innovation [cons. 1.00000, cov. 0.86221], and ~ContMan + CompCons → Innovation [cons. 1.00000, cov. 1.00000]. The intermediate solutions for the analyses with StakMan, TechMan, and ContMan, respectively, are as follows: CompCons → Innovation [cons. 1.00000, cov. 0.86221] (model: all conditions present), CompCons → Innovation [cons. 1.00000, cov. 0.86221] (model: all conditions present), and CompCons + ProcRes*~ContMan → Innovation [cons. 1.00000; cov. 0.95362] (model: ProcRes and CompCons present).
2. This finding, together with the fact that—although the majority of the projects with innovation also had a high procurement result (57%)—nearly half of the projects were considered innovative, given a low procurement result (43%; see Table 2), leads to the conclusion that the analysis provides little evidence for the idea that a high procurement result is associated

with innovation because the private consortium would feel an incentive to include creative and innovative solutions in its bid to maintain a profitable business case (cf. the section "Procurement Result").

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