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The impact of the private consortium composition on product innovation in DBFM(O) projects

What is the impact of the private consortium composition on product innovation in DBFM(O) projects in the Netherlands?

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Colophon

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Summary

Public-private partnerships are increasingly operated as a tool to spur innovation in infrastructure projects. This thesis studies specifically PPP-projects that are executed with a DBFM(O) contract form. The main research question deals with the impact of the private consortium composition on product innovations in Dutch DBFM(O) projects. The private consortium composition is split into the variables firm size, number of firms (consortium size) and diversity. A distinction is made between real estate and infrastructure DBFM(O) projects. The construction industry is often seen as an adopter of innovation instead of a developer, which results in more incremental innovations. This especially the case in the context of DBFM(O) projects in which a radical innovation could, in the case of failure, lead to a situation in which the output specifications are not met. This could then lead to a penalty or even a delay in the project. The main conclusion is that the private consortium composition has a limited impact on product innovations in DBFM(O) projects. This thesis only found a relationship between the number of firms and product innovations for real estate DBFM(O) projects. Smaller consortia have an advantage over larger consortia in the implementation of product innovations in real estate DBFM(O) projects. This advantage of smaller consortia has not been found in infrastructure projects due to limited variance in consortium size and the number of product innovations in infrastructure projects. This thesis found no relationship between firm size and product innovation. This indicates that both SME and larger firms are to the same extent able to implement product innovations in DBFM(O) projects. No evidence has been found that there is a difference in the number of implemented product innovations between consortia with low and high diversity. However, this thesis shows that internal diversity with traits like experience is important in the implementation of product innovation.

Key definitions: **PPP, DBFM(O), real estate, infrastructure, product innovation, radical innovation, incremental innovation, firm size, diversity, consortium size (number of firms), tender document**

1. Background

The reason for doing this research is that public-private partnerships (PPPs) are increasingly operated as a tool to spur innovation in PPP infrastructure projects (Himmel and Siemiatycki, 2017). However, the construction industry is often seen as conservative with being an adopter of innovation instead of a developer (Russel et al., 2006). This claim can best be proved by studying product innovations. There are also conditions that prevent and steer innovation in PPPs (Russell et al., 2006). This thesis studies condition ''the private consortium composition'' and its impact on product innovation in DBFM(O) projects. DBFM(O) projects are a type of PPP in which the private sector is responsible for the design, construction, finance, management, and eventually operation of the project (Verweij, 2015). The composition of the private consortium can be divided into three sub-variables: firm size, number of firms (consortium size), diversity. There are multiple contradictory views on the impact of the firm size and the number of firms on innovation in PPPs (Carbonara and Pellegrino, 2020; Spescha et al., 2019). What this research sets apart from other studies is that specifically in the context of DBFM(O) projects the impact of the consortium composition on product innovation is investigated. Till today, this has only be done by Verweij et al. (2019). However, the research of Verweij et al. (2019) studied more variables and included confounders. Next to that, this thesis is unique because it includes the sub-variable consortium diversity and studies its impact on product innovation in DBFM(O) projects. This thesis contributes to the discussion about the impact of the private consortium composition on product innovation in PPPs. Next to that, this thesis tries to inform the public sector about how product innovation may be steered by selecting the optimal composition of the private consortium in DBFM(O) projects.

1.1 Research problem

For decades there have been discussions about the impact of firm size and the number of firms on innovation processes (Carbonara and Pellegrino, 2020; Spescha et al., 2019). Multiple contradictory views exist in the scientific literature on the impact of firm size and the number of firms on innovation (Verweij et al., 2019; Spescha et al., 2019). The studies of Schumpeter (1942) and Cabral & Mata (2003) state that larger firms have a greater ability to implement product innovations. However, according to Spescha (2019) and Bolton & Dewatripont (2004), smaller firms have an advantage over larger firms in implementing innovations. For the number of firms, the literature largely agrees on the fact that small consortia are more innovative (Barlow and Köberle-Gaiser, 2009; Carbonara and Pellegrino, 2020). However, empirical evidence has found that larger consortia are also able to implement innovations (Verweij et al, 2019; Himmel and Siemiatycki, 2017). These opposing claims and findings are created by the different purposes of these studies. For example, not all studies did investigate the impact of the private consortium composition on innovation in the context of PPPs. Next to that, confusion remains on the optimal mix of diversity within a private consortium (Russell et al., 2006). Therefore this thesis aims to investigate the impact of the composition of the private sector (size + number + diversity) on product innovation in DBFM(O) projects in the Netherlands by doing quantitative research that collects data by surveying.

Main question: ***What is the impact of the private consortium composition on product innovation in DBFM(O) projects in the Netherlands?***

Sub-questions:

- What sort of product innovations occur in DBFM(O) projects in the Netherlands?
- What is the impact of firm size on product innovation in DBFM(O) projects in the Netherlands?
- What is the impact of the number of firms in a consortium on product innovation in DBFM(O) projects in the Netherlands?

- What is the optimal mix of diversity within the consortia of DBFMO(O) projects in the Netherlands?

2. Theoretical framework

2.1 Introduction

Public-private partnerships (PPPs) can be defined as a governance model or a collaborative arrangement for public service delivery (Hueskes et al., 2019). Public-private partnerships are increasingly operated as a tool to spur innovation in infrastructure projects (Himmel and Siemiatycki, 2017). Innovations in PPPs can lead to increased efficiency and higher-quality infrastructure projects. According to the promoters of PPPs, innovation can best be achieved through PPPs (Rangel and Galende, 2010). This is the case, because the private sector has financial incentives to be cost-efficient and that innovation is an important factor that can enable the private sector to deliver cost-efficient public services (Rangel and Galende, 2010). However, this doesn't indicate that the use of PPPs as procurement mode will lead to innovation. Innovation in PPPs is not an intrinsic part of PPP projects (Rangel and Galende, 2010). Russel et al. (2006) constructed a framework that consists of 22 conditions that determine the innovation potential in PPPs. The study done by Russel et al. (2006) paved the way for other studies that address conditions that make an impact on innovation. Himmel and Siemiatycki (2017) state that the public procurement model and the procurement result influence the degree of innovation. Verweij et al. (2019) similarly studied the association between the public procurement result and innovation but also incorporated the interrelationship with other conditions as private consortium composition and project management. Thus, these other variables may have been confounders. More important, the study of Verweij et al. (2019) is a qualitative research that only studied two sub-variables of the private consortium composition: number of firms and firm size. This thesis contains quantitative research that analyses 32 DBFM(O) projects and will add the variable diversity. Quantitative research allows us to study a greater number of projects and establish statistical relationships. If statistical relationships between the private consortium composition and product innovation exists, than it is possible to design consortia in PPPs that spur innovation.

2.2 Innovation in the construction industry

The construction industry engages in activities involving the creation, repair, or extension of fixed assets like buildings, roads, and dams (OECD, 2013). There are many definitions of innovation in the scientific literature of the construction industry and therefore the exact definition remains somewhat unclear. According to the Civil Engineering Research Foundation (CERF) innovation can be seen as the following: *''the act of introducing and using new ideas, technologies, products and/or processes aimed at solving problems, viewing things differently, improving efficiency and effectiveness, or enhancing standards of living''* (Lu and Sexton, 2006). However, most often the definition of Russel et al. (2006) is applied in construction literature, who split innovation in product innovation, process innovation, organizational innovation, and financial innovation. *Product innovation* involves the use and development of new advanced products, for example, new equipment, tools, novel designs or concepts, and materials. However, the construction industry is not only delivering products but it also delivers services. Therefore, product innovation can be defined as innovations provided in both products and services (OECD, 2005). The construction industry is often an adopter of innovation, instead of a developer of innovation (Russel et al., 2006). To investigate this claim the decision is made to specifically study product innovation. Next to that, a distinction can be made between incremental and radical innovations. Incremental innovations can be seen as small improvements in existing products and widespread innovations (Tawiah and Russell, 2008). This means that incremental innovations are already known and implemented in multiple projects. An example of incremental innovation is the implementation of thermal energy storage in an office building. Radical innovations involve the development of entirely new products and can give rise to major shifts in technical approaches and solutions through research. Radical innovations may affect the nature and efficiency of the construction industry (Tawiah and Russell, 2008). An example of radical innovation is a new type of breakwater (golfbreker). As stated before, the construction industry is often an adopter of innovation (Russel et al., 2006). Thus, we would expect more incremental innovations instead of radical innovations. Spescha et al. (2019) have a more general perspective on innovation and stress the importance of R&D in the creation of innovation. This paper will not provide an in-depth analysis of firm processes and project processes that create innovation. However, this thesis deals with the impact of the private consortium composition on product innovation in DBFM(O) projects in the Netherlands. In order to explain the relationships between the private consortium composition and product innovation, specific firm and project processes are being used.

2.2.1 Innovation in the DBFM(O) context

DBFM(O) projects are PPP projects in which a DBFM(O) contract type is being applied. In DBFM(O) projects the private sector covers all the phases of the project, from the design to the operation and the maintenance. A government will only sign a DBFM(O) contract if it believes that the private sector will provide more efficiency than the public sector (Rangel and Galende, 2010). In DBFM(O) projects private firms, which are responsible for the construction and operation, are already involved in the design phase. This creates the opportunity for those firms to examine the life cycle costs and quality in the early development phases of a project (Straub et al., 2012). In the design phase, this results in the possibility to make decisions about product innovations that will lower the life cycle costs. Next to that, the public sector is often seen as being incapable of introducing innovative solutions in projects (Leiringer, 2006). By making the private sector responsible for all phases in DBFM(O) projects, especially the finance and management, there is a higher probability of the implementation of product innovations that will lead to lower life-cycle costs, higher quality of the end product and shorter construction times (Leiringer, 2006). To motivate and stimulate that the private sector will deliver good work, acceptable quality output specifications are established in the DBFM(O) contract by the public authority. If private firms are not meeting the output specifications, then penalties are given. These penalties can be categorized in design penalties, quality penalties, delays in construction work penalties, and environmental penalties (Rangel and Galende, 2010). The research of Rangel and Galende (2010) indicates that private firms will try to invest in R&D. However, it appears that this will result in more conservative performances instead of radical product innovations. The development and implementation of radical product innovations could, in case of failure, lead to a situation in which the output specifications in the DBFM(O) contract are not being met (Rangel and Galende, 2010). This may result in a penalty and a decrease in the returns on a project.

2.3 Firm size

For decades there have been discussions about the impact of the firm size on the innovation processes in firms and projects. There are several contradictory views on the impact of firm size on innovation. The economist Schumpeter (1942) is one of the scientists who argue that larger firms should have an advantage over smaller firms in the innovation process. According to Schumpeter (1942), larger firms have greater financial resources, and therefore they possess the ability to invest greater amounts of resources in R&D. Next to that, smaller firms suffer from the disability to get sufficient credit, which could be invested in R&D (Cabral and Mata, 2003). Schumpeter (1942) also argues that the innovation ,or R&D process, is a process of increasing returns to scale. The increasing returns of scale to the R&D process are created by the coordinated automatisation of technical advance, which then leads to more efficiency. Thus, again, larger firms would have an advantage over smaller firms in innovation.

Although, larger firms may get more affected by governmental and societal pressure to implement innovation practices (Qi *et al.*, 2010). However, it is as well possible to find literature that elaborates on the advantage of small firms over larger firms in the innovation process. Small firms have usually coordination and communication advantages (Spescha et al., 2019). The horizontal and vertical coordination lines are more outstretched in larger firms and therefore knowledge is spread less effectively (Bolton and Dewatripont, 1994). The efficiency of the innovation process in smaller firms is higher than in larger firms due to a relatively higher marginal productivity of the individual researcher in the smaller firm. An individual researcher in a small firm can make a larger impact on the entire performance of the firm. This will also boost the motivation of the individual researcher in the smaller firm (Baker and Hall, 2004). The studies of Spescha et al. (2019) and Verweij et al. (2019) show that there is little empirical evidence for the claims of Schumpeter (1942) about diseconomies of scale for smaller firms. Their research indicates that smaller firms are more efficient in implementing innovation. However, all studies mentioned above, except Verweij et al. (2019), did not study the impact of firm size on innovation in the context of PPPs. This may be a possible explanation for the different outcomes.

2.4 Number of firms (Consortium size)

The literature agrees to a large extent on the fact that small consortia are more innovative. According to Carbonara and Pellegrini (2020), a higher number of firms in consortia is associated with a lower effort in developing innovation during the implementation phase of the project. In the case of a higher number of firms, the benefits and returns on innovation are more fragmented and cannot be easily appropriated. This lower effort to develop innovation may be prevented by contractual clauses between private firms that regulate the innovation benefits among the higher number of firms (Carbonara and Pellegrino, 2020). A few numbers of firms are associated with trust-building, lower transaction costs, and better collaboration as the result of more openness (Eaton, Akbiyikli and Dickinson, 2006; Verweij et al., 2019). Consortia that consist of fewer firms may benefit from lower stakeholder management by the public partner. Consortia with fewer firms, and in which the firms are small, can do the stakeholder management by themselves. As stated in section 2.3, smaller firms have communication and coordination advantages and are involved in interactive innovative processes. Therefore consortia with fewer firms and smaller firms may already possess the required stakeholder management capacities that stimulate the innovation potential (Spescha et. al, 2019; Verweij et al.,2019). Next to that the allocation of risks is clearer in consortia of fewer firms. This results in PPPs in which the firms are not constantly concerned with minimizing risks and reducing project costs (Barlow and Köberle-Gaiser, 2009). Even though all these arguments are in favor of smaller consortia, nevertheless empirical evidence shows that innovation also may occur in larger consortia (Verweij et al., 2019; Himmel and Siemiatycki, 2017).

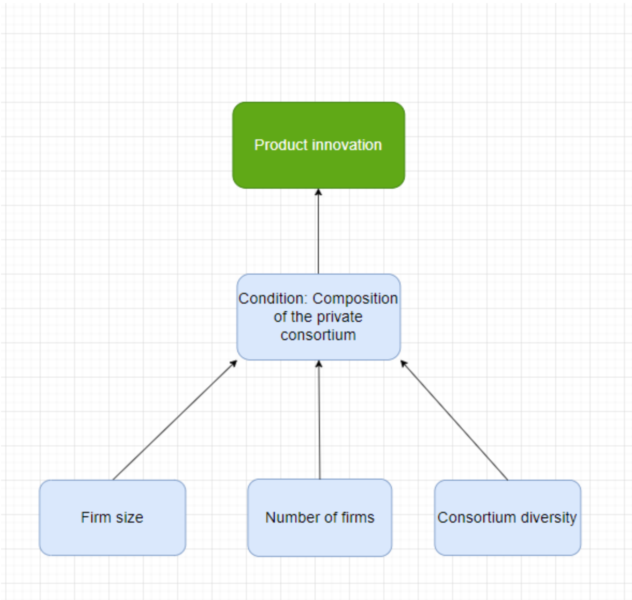
2.5 Diversity

This thesis will focus on diversity within the project team, or better called the consortium. According to Russell et al. (2006), the nature and composition of the consortium drive the innovation potential of a PPP project. A project team or consortium must include innovation champions, which are firms that own specialized resources and have past experiences with implementing innovation in projects. Traits like experience are part of the internal diversity of a company (Hewlett et al., 2013). The consortium should have a structure that creates an environment in which innovation can come from different sources: property owners, designers, consultants, and contractors (Russell et al., 2006). A consortium should consist of an optimum mix of firms that can drive innovation in a project. Diversity is thus seen as the different business categories that occur in a consortium. Due to the fact that Russel et al. (2006) states that innovation should come from different sources, it seems that a consortium with more business categories (higher diversity) would lead to more innovation. However, there is also a chance that the optimal mix of firms has more to do with diversity within firms. This optimal mix of diversity remains unclear in the literature and has never been investigated in the context of PPPs. In table 2.1 the business categories that operate in DBFM(O) construction consortia are mentioned. The business categories were derived from the study of Himmel and Siemiatycki (2017). Himmel and Siemiatycki (2017) introduced these categories indirectly during their data collection. In addition to the business categories mentioned by Himmel and Siemiatycki (2017) four extra categories were added: specialized construction firm, law firm, engineering firm and dredging firm. The business category dredging firm cannot be found in real estate projects and the business category architecture firm cannot be found in infrastructure projects. Thus, in both infrastructure and real estate projects a maximum of 9 business categories can occur.

Business categories	
Construction firm	Engineering firm
Specialized construction firm	Facility management firm
Finance/Investment bank & firms	Architecture firm
Project development company	Consultancy firm
Law firm	Dredging firm

Table 2.1 Business categories

2.6 Conceptual Model and Hypothesis



Figuur 2.1 Conceptual model

Hypotheses	
I.	SMEs are more successful in implementing product innovations than larger firms in DBFM(O) projects.
II.	In DBFM(O) projects smaller consortia are more successful in implementing product innovations than larger consortia.
III.	In DBFM(O) projects consortia with a higher diversity are more successful in implementing product innovations than consortia with lower diversity.

Table 2.2 Hypotheses

3. Methodology

3.1 Data collection and case selection

An overall quantitative survey strategy was used to test the hypotheses (Clifford et al., 2016). A quantitative research survey strategy allows for a greater sample size and generalisation. This in contrast to qualitative research, in which generalisation is problematic. By the use of a quantitative research strategy, we can deliver a serious contribution to the discussions about the impact of the firm size, number of firms, and diversity on product innovation. From all real estate and infrastructure DBFM(O) projects in the Netherlands, 32 DBFM(O) projects were selected. Both real estate and infrastructure projects were chosen to indicate whether there are deviations between the two based on the statistical relationships between variables. The units of analysis are product innovations. The aim is to study the relationships between firm size, number of firms, diversity, and product innovations in these 32 real estate and infrastructure DBFM(O) projects in the Netherlands. The real estate projects that were investigated include schools, government buildings, prisons, hospitals, and courthouses. The infrastructure projects that were investigated include highways, locks, tunnels, and dikes. All projects have a net present value from 5 to 750 million euros and were selected on the availability of information. The reason to chose for this wide range is to include both complex real estate and infrastructure projects in the thesis. Complex infrastructure projects have a higher net present value (± 700 million euros) compared to complex real estate projects (± 250 million euros) (Rijksvastgoedbedrijf, 2019; Rijkswaterstaat, 2018).

The telephone survey and online survey method (Linkedin, email) were used to collect the data (Clifford et al., 2016). Both methods were chosen due to time-efficiency and the allowance of short surveys. The survey was needed to gain information about the product innovations in the DBFM(O) projects. Data on the sub-variables size of firms, number of firms, and consortium diversity were collected by using secondary data in the form of project documents and websites. The project documents were selected on the reliability of the publisher. Only project documents/websites of firms and institutions that participated in the selected DBFM(O)projects were chosen. Project documents/websites were as well used to identify product innovations in DBFM(O) projects. Thus, the triangulation of methods was being used to get a complete overview of the product innovations that were implemented in these projects. However, due to the coronavirus, it was not possible to collect data for each project by using both surveys and project documents. The surveys were filled in by DBFM(O) managers and project managers (unit of observation), who were involved in the DBFM(O) projects. The managers were targeted via email, telephone, LinkedIn by using snowball-sampling. Snowball-sampling indicates that, with the help of surveyed DBFM(O) managers new managers, were targeted (Clifford et al., 2016).

After the data was collected, the data was put in a coding scheme. This was the start of the analysis of the data. The methods of data collection in this research can be seen as both effective and efficient. A short survey that only focuses on product innovations and the use of project documents for the remaining data creates the opportunity to collect data on a greater number of DBFM(O) projects. This was done since it saves the respondents time, which will increase the number of participants.

This thesis makes no distinctions in the degree of innovations within and between projects. It is impossible to determine objectively if one innovation is more innovative than the other. For example, it is impossible to determine whether the use of electric sensors in a hospital is more innovative than the use of geothermal heat in a school. However, it is possible to indicate how many and which sort of product innovations occurred during the construction and operation phase.

3.2 Measurement

The variable firm size was measured by making use of European legislation on firm size. The European legislation is defining the size of firms based on the number of employees. According to this legislation, small-sized firms have less than 50 employees, medium-sized firms between 50 and 250 employees, and large-sized firms above 250 employees (European Commission, 2009). However, DBFM(O) projects are multi-million projects, in our thesis between 5 and 750 million euros, and consortia are most often dominated by larger firms (>250 employees) which are well-funded. There is a low probability that small-sized firms (<50 employees) will dominate a consortium due to insufficient capital and resources. Therefore the categories small-sized firms and medium-sized firms were merged into the category small and medium-sized firms (SME, Dutch: Midden-en kleinbedrijf). A consortium was defined as small and medium-sized if at least three firms or 50% of the firms were small and medium-sized (≤250 employees). A relative cutoff point of 50% was chosen because consortia with less than three firms cannot consist of three SME. A consortium was defined as large when it contained less than three SME or less than 50%. An example of the measurement of diversity in a project is given in table 4. The variable firm size was measured on a nominal scale.

The variable number of firms was measured by counting the number of firms that were involved in the private consortium. However, the variable number of firms was as well categorized based on a cutoff point of >3 firms. The cutoff point was set at >3 because at least three types of expertise are needed within a consortium (Verweij et al., 2019). For this reason, the cutoff point for the variable consortium diversity was set to >3. The consortium diversity was also measured by counting the different types of firms, based on the business categories in table 2.1, within a particular private consortium. To give an example, a consortium with 4 business categories was given a value of 4 (*table 4*).

Product innovation was measured by counting the number of product innovations that occurred during the design, construction, and operation phase of a DBFM(O) project. To give an example, a DBFM(O) project in which 3 product innovations occurred was given a value of 3. This means that product innovation in DBFM(O) projects was measured on a ratio scale. Radical and incremental innovations were measured by counting the number of radical and incremental innovations. But instead of assigning a value for the number of radical and incremental innovations per project, an overall value for all real estate and infrastructure projects was assigned.

3.3 The statistical analysis

Inferential statistics were used to execute the analyses of the data. Before any parametric or nonparametric statistical tests could be executed, a Shapiro-Wilk test needed to be executed to assess the normal distribution of the ratio variable innovation. A Shapiro-Wilk test was chosen because this test is suitable for samples with less than 50 cases (Lewis, 2010). A precondition for executing any parametric test is that the ratio variable innovation is normally distributed. If this is not the case, then each category of the independent categorical variables should at least have 30 cases or in a situation of independent ratio variables more than 30 cases in total (Lewis, 2010). Thus, for executing a parametric test, the ratio variable innovation should be normally distributed or have more than 30 cases. First, multi-linear regression and multiple Mann-Whitney U tests were executed in the context of all DBFM(O) projects. Secondly, multiple Mann-Whitney U tests were executed in the separate context of real estate projects. This to investigate if there is a deviation in the relationships between the variables in the separate context of real estate projects and the overall context. Unfortunately, statistical tests were not executed in the separate context of infrastructure projects. The number of infrastructure projects is not sufficient (11 cases) to execute a statistical test that leads to reliable results. In table 3.1 an overview of all the used variables is given. The hypothesizes in section 2.7 were accepted when the P-value was lower than 0.05%.

Descriptive statistics were used to describe the difference in the number of radical and incremental innovations between real estate and infrastructure DBFM(O) projects.

3.3.1 The assessment of the relationships in the context of all DBFM(O) projects

First, the relationships between the independent variables and product innovations were assessed in the overall context of all selected DBFM(O) projects. This means that both real estate and infrastructure projects were included in the analysis. In this situation, the variables number of firms (3), consortium diversity (5) and product innovation (8) were measured on a ratio scale. To assess the relationship between the independent ratio variables number of firms and consortium diversity and the dependent variable product innovation (8) a multi-linear regression was executed. A multi-linear regression was possible because there were more than 30 cases in total. Non-parametric Mann-Whitney U tests were executed to assess the relationship between the independent variables firm size (2), tender document (7), and the dependent variable product innovation (8). A Mann-Whitney U test was executed because the two categories of the independent variables (2,7) had each less than 30 cases. A Mann-Whitney U test assesses the differences between the medians or mean ranks of two groups.

3.3.2 The assessment of the relationships in the context of real estate DBFM(O) projects

The relationships between the independent variables and product innovation were also assessed in the separate real estate DBFM(O) context. This research looked into 21 real estate DBFM(O) projects. A multi-linear regression could not be performed because there were less than 30 real estate projects and the data was also not normally distributed. Therefore the Mann-Whitney U test was chosen as an alternative. The Mann-Whitney U test requires that the independent variables are nominal or ordinal. Therefore the independent ratio variables number of firms and consortium diversity were turned into ordinal variables. Another precondition for executing a Mann-Whitney U test is that the categories should have similar shapes for the ratio variable product innovation. This was tested by plotting the distribution of the data and the Levene's test of homogeneity of variance. After these steps, a Mann-Whitney test was executed to assess the relationships between the independent categorical variables firm size (2), number of firms (4), consortium diversity (6), tender document (7) and the dependent variable product innovations (8).

Knowledge about the statistical tests was acquired by following statistical courses in the previous years of the bachelor program.

	Variable Name	Code	Definition	Scale
Independent variables				
1	Type of project	0 = Real estate project 1= Infrastructure project	The type of DBFM(O) projects. A distinction can be made between real estate and infrastructure projects.	Nominal
2.	Firm size	0= SME (50% or ≥3) 1= Other	The size of firms. Classifies consortia based on consortia with and without SME.	Nominal
3.	Number of firms Ratio	No code defined	The number of firms in a consortium.	Ratio
4.	Number of firms Specified	0= ≤3 Firms 1= > 3 Firms	The number of firms in a consortium of a real estate DBFM(O) project. Categorized as small consortia (≤3) and large consortia (>3).	Ordinal

5.	Consortium diversity Ratio	No code defined	The number of business categories that can be identified in a consortium.	Ratio
6.	Consortium diversity Specified	0= business categories ≤3 1= >3 business categories	The number of business categories that can be identified in a consortium. Categorized as low diversity (≤3) and high diversity (>3)	Ordinal
7	Tender document	0 = No 1= Yes	Is the innovation specified in the tender document and the contract? Yes or no.	Nominal
		Dependent variable		
8.	Product innovation	No code defined	The number of product innovation.	Ratio

Table 3.1 Overview of all the variables.

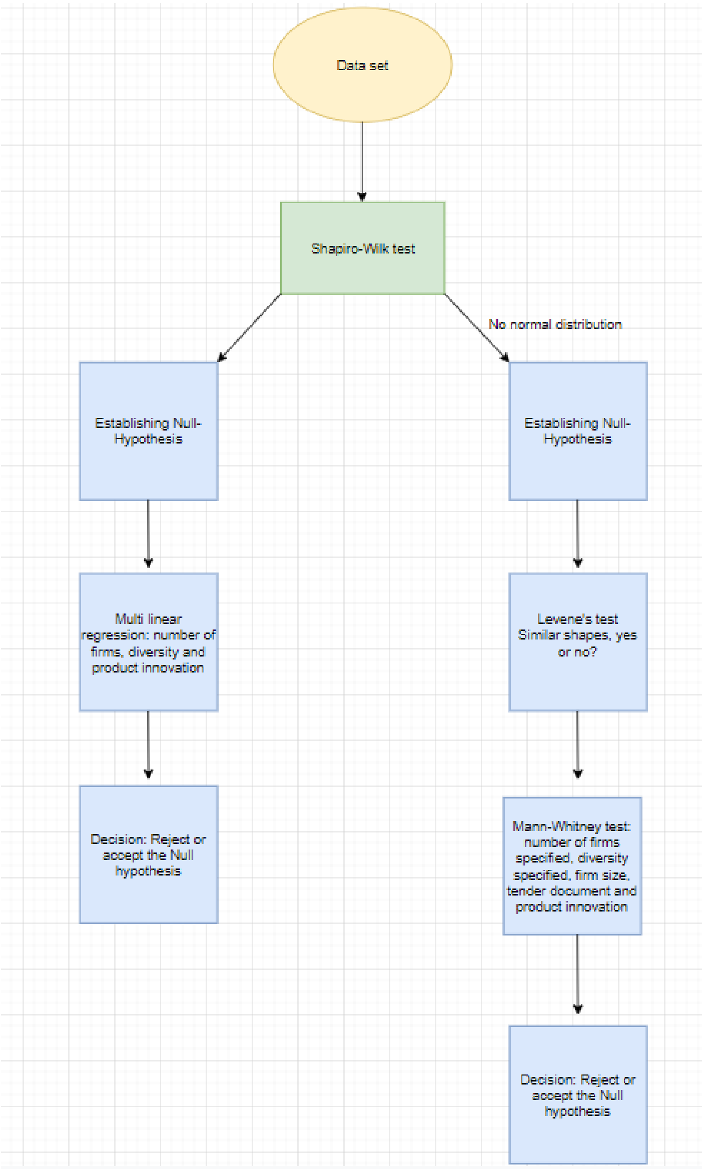


Figure 3.1 Data analysis scheme

4. Results

The DBFM(O) projects that were included in the analysis are presented in table 1 (appendix). Table 1 shows for each project the values for the independent variables. A specification of the number of product innovations per project is not given in table 1. Not all product innovations that were implemented in each project can be published. This because in a few projects the implementation of specific product innovations led to cost reduction and higher efficiency, which resulted in a winning bid for those consortia. By publishing these innovations, rival firms would get helped in the tendering phase of a future project.

Statistical Test	Independent variable	Dependent variable	P-value
		General	
Mann Whitney U test	Firm size	Product innovation	0.836
Multi-linear regression	Number of firms		0.657
	Diversity		0.695
Mann Whitney U test	Tender document		0.425
		Real estate projects	
Mann Whitney U test	Firm size	Product innovation	0.132
	Number of firms Specified		**0.026***
	Diversity Specified		0.095
	Tender document		0.751

Table 4.1 Statistical tests and outcomes

4.1 Product innovations in DBFM(O) projects

First, it is crucial to mention that achieving innovation in the construction industry is never a goal in itself. Product innovation should lead to the fulfillment of a specific goal. Examples of such goals are sustainability, cost reduction, usability, and overall higher quality of the end product. The implementation of product innovations can help to achieve such goals. In all selected DBFM(O) projects product innovations occurred. A large degree of innovations in the DBFM(O) projects focused on energy issues and sustainability. These are product innovations that were copied from the energy sector.

Russel et al. (2006) state that the construction industry is more an adopter of innovation, instead of a developer. The main reason for this is that the implementation of radical innovations could, in case of failure, lead to a situation in which the output specifications in the DBFM(O) contract are not being met (Rangel and Galende, 2010). This could then lead to a penalty, which would decrease the profit margins. Therefore we would expect relatively more incremental innovations compared to radical innovations in the studied DBFM(O) projects (Rangel and Galende, 2010). When we make no distinction between real estate and infrastructure projects the statement of Russel et al. (2006) can be confirmed. In all 32 DBFM(O) projects 23 radical innovations occurred, which comes down to 19.8% of the total number of product innovations. However, when we make a distinction between real estate and infrastructure projects, differences start to occur. 11 out of the 93 product innovations in the studied real estate projects could be classified as radical innovations, which comes down to 11.8%. But for the selected infrastructure projects the claim of Russel et al. (2006) can be put into question. This because 13 out of the 26 product innovations could be classified as radical innovations, which comes down to 50.0%. But what explains the higher percentage of radical innovations in the selected infrastructure projects? A possible explanation for the deviation in the number of radical innovation between real estate and infrastructure projects may be the differences in R&D investments between sub-sectors in the construction industry. The investments in R&D in the total construction industry have always been relatively low compared to other sectors. This has to do with low profitability margins and a lower degree of highly educated people in the construction industry (RWS, 2019). In 2016 R&D investments in the construction industry amounted to 113,926 million euro's and the total gross value added amounted to 29.965 million euros (OECD, 2020; Statista, 2019). This indicates that in the construction industry R&D investments formed 0.38% of the gross added value in 2016 (RWS, 2019). This is relatively low compared to R&D investments in the industrial sector (5.8%) and the agricultural sector (1.7%) (RWS, 2019). The construction industry can be divided into two large sub-sectors: utility or the real estate sector and the excavation, road building, and hydraulic engineering sector to which infrastructure projects belong. For real estate activities, investments in R&D were only 2,113 million euros in 2016 (OECD, 2020). R&D investments in real estate activities formed only 0.0001% of the gross added value of the real estate sector, which amounted to 17.129 million euros in 2016 (Eurostat, 2019). Unfortunately, the OECD and Eurostat do not possess direct data for the subsector of excavation, road building, and hydraulic engineering. But because there are just two large subsectors in the construction industry, the remaining R&D investments that do not belong to the 2,113 million euros of R&D investments of the real estate sector can be assigned to the subsector to which infrastructure projects belong. Thus, in the subsector of excavation, road building and hydraulic engineering R&D investments are in both absolute and relative ways higher than in the real estate sector. Another reason for the relatively low amount of radical innovations in the real estate sector is that real estate projects share a higher degree of variety in construction works and design compared to infrastructure projects (Harvey and Jowsey, 2004). The consequence is that newly developed products and technologies in the real estate sector may not apply to a high number of projects, which makes it not economically viable to develop these new products (Harvey and Jowsey, 2004). To give an example, a new method of circular waste management in an office building may not apply to a wide range of other office buildings. This is in contrast with a newly developed type of asphalt in the infrastructure sector that can be applied to a wide range of road structures.

4.2 Firm size

A Mann-Whitney U test was executed for the variables firm size and product innovation. The Mann-Whitney U test assessed the difference in the number of product innovations between consortia that consist of a large degree of SME (≥3 or 50%) and consortia that consist of a vast majority of large firms. The Levene's test of homogeneity of variance indicated that both groups have homogeneity of variance or in other words similar shapes. The probability value (P-value) of the Mann-Whitney U-test is 0.836. Therefore the variable firm size is not significant (0.836>0.05) and we conclude that there is no difference in the occurrence of product innovations between consortia that consist of for a large degree of SME (≥3 or 50%) and consortia that consist of a vast majority of large firms.

The Mann Whitney U test and Levene's test have, for the same variables also been executed in the context of real estate projects alone. This time with a probability value 0.132. Again an insignificant outcome (0.123>0.05), having no difference in the number of product innovations. All tests can be found in *figures 1 to 4 (appendix).*

In both the overall and the real estate context of DBFM(O) projects the mean number of ranks is higher for consortia that consist of a vast majority of large firms. However, this difference in favor of consortia with larger firms is not significant, and therefore hypothesis I is rejected. Schumpeter (1942) and Cabral

& Mata (2013) state that larger firms have a higher innovative capacity due to more sufficient funds for R&D and the disability of smaller firms to get sufficient credit to develop innovations. This claim can be confirmed for firms in DBFM(O) projects. As already shown, the construction industry, in general, has a low innovative capacity due to low R&D investments (OECD, 2020; Eurostat, 2019). This is valid for both SME and large firms. The claim of Qi et al. (2010), who states that larger firms feel more governmental and societal pressure to implement product innovations can also be rejected for DBFM(O) projects. Next to that, SME may have coordination and communication advantages and the innovation process may be more efficient (Bolton and Dewatripont, 1994; Baker and Hall, 2004). However, this does not lead to an advantage over larger firms in the development and implementation of product innovations in DBFM(O) projects.

4.3 Number of firms and Diversity

The multi-linear regression model in *figure 5 (appendix)* shows that the Beta coefficient for the variable number of firms is negative (B= -0.097). This indicates that each extra firm in a consortium would lead to -0.097 product innovations, which favor smaller consortia in our sample. The Beta coefficient for diversity is positive (B= 0.141), which indicates that each extra business category would lead to 0.141 extra product innovations. Thus consortia with a higher diversity have a benefit in implementing product innovations in our sample. However, for both variables the outcome of the test is insignificant. This means that there are no relationships between the number of firms, diversity, and product innovations. Thus, we are not able to draw to the conclusion that DBFM(O) projects with smaller consortia and a higher diversity would lead to more product innovations. Therefore hypotheses II and III cannot be confirmed in the overall context of DBFM(O) projects.

There is a large probability that these insignificant relationships are created by the selected infrastructure projects, which showed limited variance for the variables number of firms and diversity. Next to that, infrastructure consortia consist of fewer firms and have a lower number of product innovations per project (see section 4.1). Therefore both Levene's test and a Mann-Whitney U test were executed for both variables in the context of real estate projects (*figures 7,9)*. For the variable number of firms specified, the mean rank number for smaller consortia (≤3) is 13.67 and for larger consortia (>3) 7.91. The P-value is 0.026, which means that the result is **significant** (0.026<0.05). Thus, in the context of real estate DBFM(O) projects, smaller consortia have an advantage over larger consortia in implementing product innovations. We accept hypothesis II in the context of real estate DBFM(O) projects. The P-value for the variable diversity specified is 0.091, which indicates an insignificant result. Therefore in real estate DBFM(O) projects, there is no difference in the number of implemented product innovations between consortia with low diversity and high diversity. Thus, hypothesis III is also rejected in the context of real estate DBFM(O) projects.

The advantage of smaller consortia over larger consortia in implementing product innovations in real estate DBFM(O) projects may be explained by trust-building, lower transaction costs, and better collaboration as the result of more openness (Eaton, Akbiyikli and Dickinson, 2006; Verweij et al., 2019). Next to that, in larger consortia, the benefits and returns on innovation are more fragmented and cannot be easily appropriated, which leads to lower effort in developing innovation (Carbonara and Pellegrini, 2020). Related to the benefits and returns are the allocation of the risks. The allocation of the risks is also clearer in smaller consortia. This results in real estate DBFM(O) projects in which the firms are not constantly concerned with minimizing risks and reducing project costs (Barlow and Köberle-Gaiser, 2009).

According to Russel et al. (2006), a consortium should have a structure or mix of firms in which innovation can come from different sources. This diversity of sources has been translated into business categories. However, no significant relationship has been found between diversity and product innovation. This means that both consortia with a low and high number of business categories, or in other words low and high diversity, are to the same degree able to implement product innovations. Russel et al (2006) also state that a consortium must include innovation champions, which are firms that own specialized resources and have past experiences with implementing innovation in projects. This is confirmed by the data. Firms that have the most experience in DBFM(O) projects are also involved in the most innovative DBFM(O)projects. This can be seen in *table 2 (appendix). Table 2* is based on 11 selected DBFM(O) projects with more than 5 product innovations. Traits like experience are part of the internal diversity of a firm (Hewlett et al., 2013). According to Hewlett et al. (2013), firms that consist of a high degree of internal diversity are outperforming other firms in market output and market share (Hewlett et al., 2013). Thus, the high internal diversity (experience with innovation in DBFM(O) projects) of firms in *table 2* led to an outperformance of other firms and may explain why they are involved in multiple DBFM(O) projects. The proposal of product innovations by these firms in the tendering phase probably led to the outperformance of other competing consortia and to the winning bid.

5. Conclusion

Innovation in the construction industry is never a goal in itself. It should lead to the fulfillment of a specific goal, for example, cost reduction, sustainability, and usability. The first sub-question dealt with the sort of product innovations that occurred in DBFM(O) projects. This thesis shows that most product innovations in DBFM(O) can be classified as incremental innovations and are copied from the energy sector. This because the development and implementation of radical innovations could, in case of failure, lead to a situation in which the output specifications in the DBFM(O) contract are not being met. This could then lead to a penalty imposed by the public partner. Relatively, more radical innovations have been identified in infrastructure projects compared to real estate projects. This can be explained by differences in R&D investments between the subsectors of the construction industry but as well by the differences in the nature of these two project types. The three other sub-question dealt with the impact of firm size, number of firms, and diversity on product innovation. This thesis shows that both smaller and larger firms are to the same extent able to implement product innovations in DBFM(O) projects. In the separate context of real estate DBFM(O) projects, evidence has been found that smaller consortia have an advantage over larger consortia in implementing product innovations. No evidence has been found that there is a difference in the implementation of product innovations between consortia with low and high diversity. However, internal diversity with traits like experience has been proven to be important for the successful implementation of product innovations. The main question dealt with the impact of the private consortium on product innovation in DBFM(O) projects. The answer is that the private consortium composition has a limited impact on product innovations in DBFM(O) projects. Only the variable number of firms has an impact on product innovation in the separate context of real estate projects.

Quantitative research on the role of firm size, the number of firms, and diversity on product innovations in the context of Dutch DBFM(O) projects has never been done before. Another strength is that the collected data is detailed and structured, which allows for both inferential and descriptive analysis. A limitation of this research is that the exact product innovations that occurred in the selected DBFM(O) cannot be published due to ethical considerations. However, the publication of the exact product innovations was not necessary to explain the statistical relationships between variables. Next to that, the inclusion of more cases could maybe have led to more significant relationships. However, the inclusion of more cases was not possible due to the coronavirus and resource constraints. Further research could be done on the impact of internal diversity on product innovations in DBFM(O) projects. This with especially the focus on traits like experience, but as well the impact of departments within firms and project leaders on product innovation. A qualitative research strategy would fit to investigate the impact of internal diversity on product innovation.

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Appendix Tables

	Project	Consortium	Firms involved	Diversity (number of categories)	SME (50% or 3)	Start construction phase	Duration operation phase
1.	Rechtbank Amsterdam	NACH	7	7	Yes	2016	30
2.	Rijkskantoor de knoop Utrecht	R Creators	3	2	No	2015	20
3.	Gerechtsgebouw Breda	In Balans	3	3	No	2015	30
4.	Bezuidenhoutseweg 30-B30	Facilicom PPS B30	6	5	Yes	2014	30
5.	Westluidense poort Tiel	-	10	5	Yes	2013	25
6.	Bredeschool Joure	-	4	4	Yes	2013	25
7.	Vernieuwing rijkskantoor Rijnstraat 8 Den Haag	PoortCentraal	7	4	No	2014	25
8.	Zorgacademie Parkstad Limburg	De Huismeesters	4	3	No	2011	25
9.	Nieuwbouw Hoge raad der Nederlanden	Poort van Den Haag	5	4	No	2013	30
10.	Nieuwbouw Nationaal Militair Museum	Heijmans PPP	8	4	Yes	2012	25
11.	Renovatie ministerie van Financien	Consortium Safire	4	3	No	2007	25
12.	Nieuwbouw DUO en Belasting Groningen	DUO²	3	2	No	2009	30
13.	Kromhout Kazerne	Komfort	3	2	No	2009	25
14.	Penitraire inrichting Zaanstad 9	consortium Pi2	10	7	Yes	2014	25
15.	Internationale school Eindhoven	ISE Exploitatie	3	2	Yes	2010	30
16.	Rijksinstituut voor Volksgezondheid en Milieu	MEET	3	1	No	2017	25
17.	Gemeentehuis Westland	De Groene Schakel	3	3	No	2016	25
18.	Provinciehuis Gelderland	In Duma Nova	12	5	Yes	2015	20
19.	Detentiecentrum Rotterdam	DC16	5	4	No	2008	25
20.	Zaans Medisch Centrum	-	2	2	No	2014	25
21.	Montaigne lyceum	Talent Group	3	2	No	2005	30
22.	A1/A6 Diemen - Almere Havendreef	SAAone	4	3	No	2014	30
23.	A12 Wegverbreding Veenendaal - Ede - Grijsoord	Heijmans PPP	1	1	No	2015	16
24.	A27/A1: aanpassing aansluiting Utrecht-Noord – knooppunt Eemnes – aansluiting Bunschoten-Spakenburg	3Angle	3	2	No	2016	25

25.	A9 Holendrecht – Diemen (Gaasperdammerweg)	IXAS Zuid-Oost	3	1	No	2015	20
26.	A6 Almere Havendreef - Almere Buiten-Oost	Parkway6	4	2	Yes	2017	20
27.	N31 Waldwei	Bouwcombinatie Wâldwei v.o.f	3	1	No	2003	20
28.	Verbreding A12 Utrecht Lunetten -Veenendaal	Poort van Bunnik	4	2	No	2011	20
29.	Keersluis Limmel	Keersluis Limmel Company	3	3	No	2015	30
30.	Tweede Sluis Eefde	Lock to Twente	2	2	No	2017	27
31.	Derde kolk beatrixsluis en verbreding Lekkanaal	Sas van Vreeswijk	7	3	No	2016	27
32.	Project Afsluitdijk	Levvel	3	2	Yes	2018	25

Table 1 Selected projects with general information and values for the independent variables number of firms, firm size, diversity

Firms	**How many times involved in consortia of all selected DBFM(O) projects**	**How many times involved in consortia of selected DBFM(O) projects with more than 5 product innovations**
Strukton Worksphere	8	7
Heijmans B.V.	8	2
Ballast Nedam N.V.	7	5
Facilicom Solutions B.V.	6	2
ISS Facility Services	5	3
BAM PPP/BAM PPP-PPGM	4	2
John Liang	3	2
BAM Infra	2	1
BAM Bouw en Techniek	2	1
EGM Architecten	2	2

Table 2 Firms that were involved in DBFM(O) projects with more than 5 product innovations.

	Project	Documents and websites retrieved from
1.	Rechtbank Amsterdam	Heijmans (2017), Groots op de Zuidas. Accessible at: https://www.heijmans.nl/nl/projecten/rechtbank-amsterdam-zuidas/, accessed 30-04-2020
2.	Rijkskantoor de knoop Utrecht	Strukton Worksphere (2019), Van kazerne na duurzaam Rijkskantoor de Knoop. Accessible at: https://strukton.com/nl/projects/2019/07/rijkskantoor-de-knoop, accessed 30-04-2020
3.	Gerechtsgebouw Breda	Jan Kees Verschuure (2016), Een gezagwekkende transparante entree voor de stad. Accessed at: https://www.stedenbouw.nl/artikel/een-gezag-wekkende-transparante-entree-voor-de-stad/, accessed 05-05-2020, accessed 30-04-2020
4.	Bezuidenhoutseweg 30-B30	Rijksvastgoedbedrijf (2018), Den Haag Bezuidenhoutseweg (B30). Accessed at: https://www.rijksvastgoedbedrijf.nl/vastgoed/vastgoed-in-beheer/den-haag-bezuidenhoutseweg-30-b30, accessed 10-05-2020
5.	Westluidense poort Tiel	De Zwarte Hond (2015), Prikkelend cultuurcluster geeft Tiel positieve impuls. Accessed at: https://www.dezwartehond.nl/projecten/zinder, accessed 07-05-2020
6.	Bredeschool Joure	Pellikaan (2014), Brede School Joure Zuid. Accessed at: https://pellikaan.com/projecten/brede-school-joure-zuid/, accessed 04-05-2020
7.	Vernieuwing rijkskantoor Rijnstraat 8 Den Haag	Rijksvastgoedbedrijf (2018), Duurzaamheid en innovatieve oplossingen in het gebouw Rijnstraat 8 in Den Haag. Accessed at: youtube.com/watch?v=ZARJVLP8e98, accessed at 15-05-2020 TU Delft(2011) Bouwhistorische rapportage en waardestelling Rijnstraat 8 Den Haag. Accessed at: https://research.tue.nl/en/publications/bouwhistorische-rapportage-en-waardestelling-rijnstraat-8-te-den-
8.	Zorgacademie Parkstad Limburg	Parkstad Limburg (2010), Regioprogramma Naar een duurzaam en vitale regio. Accessed at: https://parkstad-limburg.lowcdn.com/wp-content/uploads/2017/06/PUB_RAP_2010_DEF-webversie.pdf?x58031
9.	Nieuwbouw Hoge raad der Nederlanden	Bam Bouw en techniek (2015), Nieuwbouw Hoge raad der Nederlanden. Accessed at: https://www.bambouwentechniek.nl/projecten/nieuwbouw-hoge-raad-der-nederlanden-den-haag, accessed 20-05-2020
10.	Nieuwbouw Nationaal Militair Museum	Heijmans (2012), Heijmans gaat nationaal militair museum bouwen. Accessed at: https://www.heijmans.nl/nl/nieuws/heijmans-gaat-nationaal-militair-museum-bouwen/, accessed 02-05-2020
11.	Renovatie ministerie van Financien	Rijksoverheid (2018), Korte voorhout toen en nu https://www.rijksoverheid.nl/ministeries/ministerie-van-financien/organisatie/het-gebouw, accessed 01-05-2020
12.	Nieuwbouw DUO en Belasting Groningen	Strukton Worksphere (2019), Duo2: Duurzaam en efficient cruiseschip. Accessed at: https://strukton.com/nl/projects/2019/11/duo2, accessed 22-04-2020 Strukton Worksphere (2011), Strukton Worksphere: exploitatie, onderhoud en beheer DUO en Belastingdienst Groningen. Accessed at https://www.youtube.com/watch?v=ovEJc6cb6a4,accessed 10-04-2020
13.	Kromhout Kazerne	Ballast Nedam (2014), Kromhout Kazerne Utrecht. Accessed at: https://www.ballast-nedam.nl/projecten/kromhout-kazerne-utrecht/, accessed 16-04-2020 Strukton Worksphere (2014), Duurzaam en eigentijds: de Kromhout Kazerne. Accessed at: https://strukton.com/nl/projects/2019/12/kromhout-kazerne, accessed 17-04-2020
14.	Penitraire inrichting Zaanstad 9	EGM (2016), Justitieel complex Zaanstad Maximale openheid en vrijheid in beslotenheid. Accessed at: https://www.egm.nl/architecten/projecten/justitieel-complex-zaanstad/387, accessed 18-04-2020
15.	Internationale school Eindhoven	Complan (2017), Internationale school. Accessed at: https://com-plan.nl/portfolio/internationale-school/, accessed 10-04-2020
16.	Rijksinstituut voor Volksgezondheid en Milieu	Strukton Worksphere (2019) , Duurzame nieuwbouw en CBG. Accessed at: https://strukton.com/nl/projects/2019/05/rivm, accessed 22-04-2020
17.	Gemeentehuis Westland	HOMIJ (2017), Gemeentehuis Westland. Accessed at:

		https://www.homij.nl/nl/projecten/detail/gemeentehuis-westland, accessed 27-04-2020
18.	Provinciehuis Gelderland	Volkerwessels (2015), Opdrachtverlening Het Gelders Huis. Accessed at: https://www.volkerwessels.com/nl/nieuws/opdrachtverlening-het-gelders-huis, accessed 30-04-2020, accessed 27-04-2020
19.	Detentiecentrum Rotterdam	ANP Pers Support (2008), Ballast Nedam en Strukton winnen PPS Detentiecentrum R'dam. https://www.perssupport.nl/persbericht/13805/ballast-nedam-en-strukton-winnen-pps-nieuwbouw-detentiecentrum-r-dam, accessed 26-04-2020
20.	Zaans Medisch Centrum	-
21.	Montaigne lyceum	SCS (2010), Evaluatie Montaingne Lyceum. https://www.pianoo.nl/sites/default/files/documents/documents/evaluatiemontaignelyceumleerpuntenbouwen3jaarbeheer.pdf, accessed 01-05-2020
22.	A1/A6 Diemen - Almere Havendreef	Cobouw (2017), Grootste SAA-project A1/A6 drie jaar eerder klaar: dubbele wisselstrook open. https://www.cobouw.nl/infra/nieuws/2017/10/grootste-saa-project-a1a6-drie-jaar-eerder-klaar-dubbele-wisselstrook-open-101253241, accessed 20-05-2020
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Table 3: Overview of all the retrieved project documents and pages.

DBFM(O) Project: Keersluis Limmel		
Firms	Number of employees	Diversity (business categories)
1. BESIX	18.000	Construction firm
2. Agidens Infra Automations	650	Engineering firm
3. RebelValley	200	Finance/investment banks & firms
Number of firms: 3	Firm size: Large	Diversity: 3

Table 4: Example of the measurement of the independent variables for one project.

Appendix Figures

1. Firm size

Test of Homogeneity of Variance

		Levene Statistic	df1	df2	Sig.
Product innovations	Based on Mean	4.387	1	29	.045
	Based on Median	2.803	1	29	.105
	Based on Median and with adjusted df	2.803	1	28.733	.105
	Based on trimmed mean	4.408	1	29	.045

Figure 1 Levene's test of homogeneity of Variance for firm size. Overall context

Mann-Whitney Test

Ranks

	Firm size	N	Mean Rank	Sum of Ranks
Product innovations	SME (50% or ≥3)	10	15.60	156.00
	Other	21	16.19	340.00
	Total	31		

Test Statistics[a]

	Product innovations
Mann-Whitney U	101.000
Wilcoxon W	156.000
Z	-.172
Asymp. Sig. (2-tailed)	.863
Exact Sig. [2*(1-tailed Sig.)]	.884[b]

a. Grouping Variable: Firm size

b. Not corrected for ties.

Figure 2 Mann-Whitney U test firm size overall context

Test of Homogeneity of Variance

		Levene Statistic	df1	df2	Sig.
Product innovations	Based on Mean	.282	1	18	.602
	Based on Median	.123	1	18	.730
	Based on Median and with adjusted df	.123	1	17.297	.730
	Based on trimmed mean	.172	1	18	.683

Figure 3 Levene's test of homogeneity of variance for firm size. Context of real estate projects.

Mann-Whitney Test

Ranks

	Firm size	N	Mean Rank	Sum of Ranks
Product innovations	SME (50% or ≥3)	8	8.13	65.00
	Other	12	12.08	145.00
	Total	20		

Test Statistics[a]

	Product innovations
Mann-Whitney U	29.000
Wilcoxon W	65.000
Z	-1.508
Asymp. Sig. (2-tailed)	.132
Exact Sig. [2*(1-tailed Sig.)]	.157[b]

a. Grouping Variable: Firm size

b. Not corrected for ties.

Figure 4 Mann-Whitney U test firm size. Context real estate projects

2. Number of firms and diversity

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.085[a]	.007	-.064	1.860

a. Predictors: (Constant), Diversity, Number of firms

b. Dependent Variable: Product innovations

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.710	2	.355	.103	.903[b]
	Residual	96.838	28	3.459		
	Total	97.548	30			

a. Dependent Variable: Product innovations

b. Predictors: (Constant), Diversity, Number of firms

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3.599	.733		4.907	.000
	Number of firms	-.097	.216	-.141	-.449	.657
	Diversity	.141	.355	.124	.396	.695

a. Dependent Variable: Product innovations

Figure 5 Multi-linear regression number of firms, diversity. Overall context.

Test of Homogeneity of Variance

		Levene Statistic	df1	df2	Sig.
Product innovations	Based on Mean	3.418	1	18	.081
	Based on Median	1.831	1	18	.193
	Based on Median and with adjusted df	1.831	1	17.982	.193
	Based on trimmed mean	3.460	1	18	.079

Figure 6 Levene's test of homogeneity of variance for Number of firms specified. Context of real estate projects.

Mann-Whitney Test

Ranks

	NumberofFirmsSpecified	N	Mean Rank	Sum of Ranks
Product innovations	≤ 3 firms	9	13.67	123.00
	> 3 firms	11	7.91	87.00
	Total	20		

Test Statistics[a]

	Product innovations
Mann-Whitney U	21.000
Wilcoxon W	87.000
Z	-2.227
Asymp. Sig. (2-tailed)	.026
Exact Sig. [2*(1-tailed Sig.)]	.031[b]

a. Grouping Variable: NumberofFirmsSpecified

b. Not corrected for ties.

Figure 7 Mann-Whitney U test number of firms specified. Context of real estate projects.

Test of Homogeneity of Variance

		Levene Statistic	df1	df2	Sig.
Product innovations	Based on Mean	.723	1	18	.406
	Based on Median	.355	1	18	.559
	Based on Median and with adjusted df	.355	1	17.863	.559
	Based on trimmed mean	.831	1	18	.374

Figure 8 Levene's test of homogeneity of variance for Diversity specified. Context of real estate projects.

Mann-Whitney Test

Ranks

	DiversitySpecified	N	Mean Rank	Sum of Ranks
Product innovations	≤ 3 business categories	10	12.65	126.50
	>3 business categories	10	8.35	83.50
	Total	20		

Test Statistics[a]

	Product innovations
Mann-Whitney U	28.500
Wilcoxon W	83.500
Z	-1.672
Asymp. Sig. (2-tailed)	.095
Exact Sig. [2*(1-tailed Sig.)]	.105[b]

a. Grouping Variable: DiversitySpecified

b. Not corrected for ties.

Figure 9 Mann-Whitney U test Diversity specified. Context of real estate projects.

Appendix Data collection

Enquête   Project Naam: ....

Goedendag, ik ben Mehdi Bulthuis, een derdejaars student Technische planologie aan de Rijksuniversiteit Groningen. Voor mijn bachelorscriptie doe ik onderzoek naar innovaties in verscheidene DBFM(O) projecten in de infra- en vastgoedwereld. Hierbij wordt specifiek gekeken naar de invloed van de compositie van het projectteam/consortium op product en proces innovaties in DBFM(O) projecten. De compositie van het consortium bestaat hierbij uit drie onderdelen: bedrijfsgrootte, de hoeveelheid bedrijven binnen een consortium en de diversiteit van bedrijven binnen een consortium. De vragen in de enquête hebben tot doel om de mogelijke relaties tussen de compositie van het project team/consortium en innovatie te onderzoeken. Alvast hartelijk dank voor uw tijd.

1. Is voor dit DBFM(O) project innovatie gespecificeerd als een van de voorwaarden/eisen in de aanbestedingsvoorwaarden?

- o Ja
- o Nee

Optioneel* (Indien nodig) Welke bedrijven zijn onderdeel van het consortium van dit DBFM(O) project? Benoem ze allemaal.

- o Open vraag

2. Wat voor specifieke productinnovaties* zijn/worden er tijdens de constructie- en exploitaitefase van het project geimplementeerd?

- o Open vraag

*Productinnovaties in de vastgoedwereld is het gebruik en/of de ontwikkeling van nieuwe producten die kunnen worden toegepast op vastgoed. Hierbij valt de denken aan het toepassen van nieuwe ontwerpen, het verwerken van nieuwe (duurzame) materialen, vernieuwende apparatuur, elektronische technologieën en snufjes in gebouwen. Maar ook het gebruik van nieuwe machines en gereedschap tijdens de bouw en het gebruik van vernieuwende onderhoudstechnieken tijdens de onderhoudsfase.

Verwerkingstabel antwoorden Enquête

Hulpmiddelen
De tabellen op dit formulier hebben het doel om de door de projectmanager gegeven antwoorden in de verkorte enquête of informatie uit online raadpleegbare bronnen nader uit te werken. Doormiddel van dit formulier kan uiteindelijk de gehele enquête worden ingevuld.

DBFM(O) Project:		
Bedrijven	Aantal medewerkers	Bedrijfstype
1.		
2.		
3.		
4.		
5.		
Aantal bedrijven:	Bedrijfsgrootte:	Diversiteit:

Product innovaties	Proces innovaties
1.	1.
2.	2.
3.	3.
4.	4.
5.	5.
Is innovatie gespecificeerd in de aanbestedingsvoorwaarden/eisen?	

Data verkregen door:	Methode:

Coderingsschema

1. Wat voor project betreft het?

- Vastgoed
- Infrastructuur

2. Is voor dit DBFM(O) project innovatie gespecificeerd als een van de voorwaarden of eisen in de aanbestedingsvoorwaarden?

- Ja
- Nee

3. Wat is de bedrijfsgrootte van de meeste bedrijven binnen het consortium?

- Midden- en kleinbedrijf
- Groot bedrijf

4. Uit hoeveel bedrijven bestaat het consortium?

- Openvraag: invullen cijfer

5. Uit hoeveel verschillende type bedrijven bestaat het consortium?

- Openvraag: invullen cijfer

6. Hoeveel product innovaties hebben er tijdens de implementatiefase van het project plaatsgevonden?

- open vraag; invullen cijfer