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Innovation: The European Journal of Social Science Research

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/ciej20

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**To cite this article:** Bart Lenderink, Johan Boes, Johannes I.M. Halman, Hans Voordijk & André G. Dorée (2022): The development of a typology and guideline for selecting innovation-encouraging procurement strategies in civil engineering, Innovation: The European Journal of Social Science Research, DOI: 10.1080/13511610.2022.2094898

**To link to this article:** https://doi.org/10.1080/13511610.2022.2094898

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Published online: 18 Jul 2022.

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*Innovation: The European Journal of Social Science Research*, 2022
https://doi.org/10.1080/13511610.2022.2094898

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# The development of a typology and guideline for selecting innovation-encouraging procurement strategies in civil engineering

Bart Lenderink, Johan Boes, Johannes I.M. Halman*, Hans Voordijk and André G. Dorée

*Department of Civil Engineering and Management, University of Twente, School of Engineering Technology, PO Box 217, Enschede, 7500 AE, The Netherlands*

(*Received 9 April 2021; final version received 29 May 2022*)

Stimulating innovation through public procurement can lead to improved performance, contribute to organizational and policy goals, but can also play a key role in addressing societal challenges that cannot be adequately addressed by conventional solutions. A significant amount of research has been carried out on stimulating innovation through the public procurement of goods and services. However, there is still a lack of knowledge on which procurement strategies and tendering methods can be effectively used to encourage specific types of innovation within larger public initiatives such as civil engineering projects and programmes. The aim of this study is therefore to provide a coherent overview of innovation-encouraging procurement strategies and tendering methods, and to relate their potential effective use to the technology readiness of the targeted innovations, the required level of cooperation between public client and contractor and the willingness of public clients to bear innovation risks, and to provide incentives, budget and solution space for these innovations. Based on a literature review and a multiple case study, an innovation-encouraging procurement typology is developed. In addition, a guideline is provided that can be used by public clients to select an appropriate procurement strategy for their innovation projects and programmes.

**Keywords:** PPI; procurement strategies; tendering methods; civil engineering; typology; innovation procurement; procurement selection guidelines

## Introduction

Public procurement is increasingly used as a policy instrument to achieve horizontal policy goals in addition to its primary objective of obtaining required goods, works and services on the best possible terms (Arrowsmith 2010; Grandia and Meehan 2017). Three such horizontal policy goals are: to reduce long-term unemployment, stimulate small and medium enterprises and to reduce the environmental impact of procured goods, works and services. Furthermore, public procurement can play an important role in addressing societal challenges (Edquist and Zabala-Iturriagagoitia 2012; OECD 2017). As such, public procurement and innovation are recognized as two important elements in the global effort to achieve the Sustainable Development Goals of the

*Corresponding author. Email: j.i.m.halman@utwente.nl

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United Nations (United Nations Environment Programme 2017; United Nations General Assembly 2015).

Over the past two decades, public procurement has again captured the interests of policymakers as a demand-side innovation policy instrument that can complement supply-side policy instruments (Edler and Georghiou 2007; Edquist and Hommen 2000; OECD 2017). With public spending representing 14% of the GDP in the European Union (Grandia 2018), policymakers are becoming increasingly aware of the potential of innovation-friendly procurement to spur economic development and growth (OECD 2011; Uyarra and Flanagan 2010). Furthermore, public organizations can also insist on new solutions that address societal challenges and/or fulfil the needs of the procurement organization (Edler and Yeow 2016; Edquist and Zabala-Iturriagagoitia 2020; Wesseling and Edquist 2018). This trend is also reflected in the European Directive 2014/24/EU for public procurement which gives high priority to innovation as an accelerator of social and economic development. As stated in Recital 95: "It is of utmost importance to fully exploit the potential of public procurement to achieve the objectives of the Europe 2020 strategy for smart, sustainable and inclusive growth".

In part due to the increased interest of policymakers, a significant amount of research has been carried out on the use of public procurement to stimulate and procure innovations over the last two decades. In their review of the different concepts, rationales and approaches to stimulate innovation through public procurement, Lenderink, Halman, and Voordijk (2019) also provide a review of existing typologies of public procurement to induce innovation. The first typology of Public Procurement for Innovation (PPI) was presented by Edquist and Hommen (2000). This typology has two dimensions. The first dimension relates to the end-user of the procured product or service and makes a distinction between the procurer as end-user of the procured product versus procurers as catalysts if the procuring organization primarily acts to satisfy the needs of others, either public or private. The second dimension relates to the level of innovation and makes a distinction between completely newly created products, processes or systems versus products, processes or systems that are not new to the world, but still new to the country of procurement. This first typology was later modified by Hommen and Rolfstam (2005) by extending the first dimension with a third cooperative category, for cases in which the procurer shares the procured product, process or system with other organizations. A somewhat distinctive typology on public procurement in relation to innovation was provided by Uyarra and Flanagan (2010). This typology is based on Kraljic's model (1983) and Storper's categorization (1997). One dimension makes a distinction between standardized versus specialised products while the other dimension distinguishes between products developed for a dedicated versus generic market. Based on the above-mentioned studies and research conducted by Edler (2009), Edquist, Hommen, and Tsipouri (2002), and Hommen and Rolfstam (2009), Edquist and Zabala-Iturriagagoitia (2012) developed a taxonomy that categorizes Public PPI according to three dimensions: (i) the user of the purchased good; (ii) the character of the innovation embedded in the resulting product and (iii) the cooperative or non-cooperative nature of the process.

So far, research on public PPI has dedicated limited attention to the procurement of innovation-oriented civil engineering projects and programmes. In contrast to the procurement of innovative goods and services, the procurement of innovative civil engineering projects and programmes requires a relatively long time frame to develop and realize a specific project or programme (Davies, MacAulay, and Brady 2019). And inherent to the innovation

ambitions of the public client, civil engineering projects and programmes also entail a high risk and uncertainty profile that needs to be allocated and managed by the public client (Lenderink et al. 2022). Further, civil engineering innovation projects and programmes always consist of a large number of interconnected parts, usually produced by different suppliers (Gann and Salter 2000). As a consequence, an effective cooperation between all the supplying parties but also between client and these suppliers is of utmost importance (Eriksson et al. 2019). Considering the typologies that have been developed so far, one may conclude that the dimension that relates to the degree of innovation and also the one that relates to the degree of cooperation among procurers, suppliers are also important to characterize public procurement for innovation of civil engineering projects and programmes. However, they need further refinement and tailoring to the specific context of civil engineering. By contrast, the value of the dimension that relates to the end-user of the procured product or service is negligible. For the specific context of civil engineering, a dimension that relates to the aims, scope and time frame of projects and programmes would be of much more value. In conclusion, there is a need for a typology that captures the different categories and options of public procerement for innovation of civil engineering projects and programmes. And in addition, there is also a lack of knowledge on which type of procurement strategies can be effectively used to stimulate innovation within civil engineering projects and programmes. In order to contribute in closing this gap in literature, the following research question will be answered in this paper:

> How to select an effective innovation-encouraging procurement strategy for specific projects or programmes in the field of civil engineering?

The remainder of the paper is structured as follows. The paper starts with providing a literature background about important topics related to the realization of innovation in the field of civil engineering projects and programmes. This literature section is followed by a section in which the research methodology is explained that was used to collect and analyse the data of eight cases in which the encouragement of innovation played an important role in the procurement strategy. Next, a three-dimensional typology for the classification of innovation procurement in civil engineering projects and programmes is introduced. This is followed by a section in which the eight cases are described in detail. This enabled to classify the cases and to evaluate their positioning in the developed typology. Furthermore, a guideline is provided to assist public clients to select an appropriate procurement strategy for their specific innovation projects and programmes. The paper concludes with a section about the main contributions of this study for literature and practice. Finally, suggestions are made for future research.

## Background literature

In this section, we first provide a general introduction about the characteristics of projects and programmes in the field of civil engineering. This is followed by a definition of innovation in the field of civil engineering and an explanation about the use of Technology Readiness levels (TRL's). Next, we discuss the literature about public procurement strategies and tendering methods to realize innovation in the field of civil engineering. The literature background section ends with a summary of recent insights about the importance of organisational cooperation between public clients and contractors to realise major innovations in civil engineering projects and programmes.

### *Projects and programmes in the field of civil engineering*

As an industry, civil engineering and construction are geared towards the production of Complex Products and Systems (CoPS) (Gann and Salter 2000; Winch 1998). CoPs are seen as high-value capital goods which are designed and produced in one-offs, or small batches, to meet the specific needs and requirements of individual customers (Hobday 1998, 2000). They consist of a large number of interconnected parts, usually produced by different suppliers, that have to be integrated into the final product or system before delivery to the client can take place (Gann and Salter 2000). The low volume production, in comparison to mass-produced goods, allows greater customization and direct involvement of the client in the design and production process. The production of CoPS is usually organized in projects as this organizational form provides an effective way to manage the complexities and uncertainties involved in the design and integration of the many interconnected parts in a final product or system (Hobday 2000). Projects are organized around the achievement of one or more specific objectives within a predefined timeframe (Munns and Bjeirmi 1996). In addition, they may also aim to contribute to secondary objectives such as sustainability, social return or the stimulation of innovation.

With the increasing use of projects over time, programmes and programme management have emerged as ways to improve coordination and balance the interests and priorities between projects, as well as to achieve benefits which cannot be obtained by managing projects individually (Pellegrinelli 2011; Project Management Institute 2017). Programmes can be defined as "a framework for grouping existing projects or defining new projects, and for focusing all the activities required to achieve a set of major benefits" (Pellegrinelli 1997). In comparison to projects, the aims and objectives of programmes tend to be longer term, more abstract and strategic in nature, and are often defined in terms of outcomes rather than outputs. Furthermore, the aims and objectives of programmes are more likely to change as needs change over time, and programmes do not always have a fixed end date as projects tend to do (Pellegrinelli 1997). Programme management is also better able to cope with higher levels of complexity, ambiguity and risk (Office of Government Commerce 2011). Finally, due to their ability to translate strategic policy goals such as climate change adaptation and realising a circular economy into concrete projects (Pellegrinelli 2011), one can expect programmes to become increasingly important as a tool to address these societal challenges (Volker 2019; Vosman 2020) and to develop major innovations through successive innovation projects in a close cooperation between project clients and contractors (Halman 2004, 2018).

### *A characterization of innovation in the field of civil engineering*

The Organisation for Economic Co-operation and Development (OECD) defines innovation as: "the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations" (OECD/Eurostat 2005). In line with this definition, innovation in the field of civil engineering can be defined as the development and successful implementation, of new ideas, products or processes in the design and realization of new civil engineering objects (Lenderink et al. 2020). Innovations in civil engineering projects can be classified according to their degree of innovation. In the literature (e.g. Slaughter (1998); Garcia and Calantone (2002); Lenderink et al. (2020)) the degree of innovation has been placed on a continuum based on the *level of change*: from incremental innovations (i.e. a small change) to fully radical innovations (i.e. completely new to the world, involving

totally new technology). Besides the magnitude of change, innovations can also be classified according to their *degree of complexity*, i.e. the expected linkages of an innovation to other components, modules and the system as a whole (Henderson and Clark 1990; Lenderink et al. 2020; Magnusson, Lindström, and Berggren 2011; Slaughter 1998).

With respect to technological innovations, a distinction is made between *product innovation* and *process innovation* (conform e.g. Schilling 2020; Tidd and Bessant 2018). Product innovation can be characterized as an innovative solution which leads to a substantial improvement in the functionality and/or sustainability of an object, the extension of the functionality of an object or and/or the technical performance of an object. And a process innovation is defined as an innovative solution to increase the efficiency of the construction process (Lenderink, Halman, and Voordijk 2019). To realize technological innovations in the field of civil engineering, a gap between required and acquired technological knowledge needs to be bridged during the development and realization of the project or programme. For radical innovations this knowledge gap – expressed as a technology readiness level (TRL) – will naturally be more significant than for incremental innovations. The concept of TRLs has been developed during the 1970s by NASA for estimating the maturity of a technology (Sadin, Povinelli, and Rosen 1989). Since then, the TRL system has been further developed and has been put into use by many authorities. The European Commission has adopted the TRL system to stimulate specific phases of technology development. TRL as established by the European Commission has adopted the TRL system to stimulate specific phases of technology development. The TRL system as established by the European Commission distinguishes nine levels and four phases. The first three levels (TRL 1, 2, 3) belong to "discovery", followed by TRL 4, 5 and 6 of the "development" phase. TRL 7 and TRL 8 belong to the "demonstration" phase, with TRL 9 "deployment" as the final development phase (EARTO 2014). Typically, the development and realization of incremental innovation projects have a TRL between TRL8 and TRL9 while radical innovation projects have a TRL between TRL4 and TRL6.

### *Procurement strategies and tendering methods to realize innovation in civil engineering*

In the directives for public procurement of the European Union public procurement is defined as:

> The acquisition by means of a public contract of works, supplies or services by one or more contracting authorities from economic operators chosen by those contracting authorities, whether or not the works, supplies or services are intended for a public purpose. (European Parliament and the Council of the European Union 2014)

In adopting this definition, we consider all stages of the process of acquiring works, supplies or services to be part of public procurement. Activities in these stages can range from the identification of needs up to the management of contracts. Further, in line with van Weele (2009) the tendering process is considered to be a specific part of the procurement process that focusses on the selection and contracting of a supplier.

Given the large influence of the project or programme on the procurement strategy in civil engineering, three strategic levels with respect to procurement can be distinguished. The first level is the procurement initiative, which refers to decisions on the level of the civil engineering project or program in which the procurement occurs. This includes

decisions that characterise the initiative, such as scope, budget and duration, as well as, the predetermined aims and objectives which are pursued in the initiative. The second level is the overall strategy, which refers to the plans for how the predetermined aims and objectives can be realized in the procurement process. Examples are to follow a two-stage approach to split the development phase from the realization phase. Or to provide a subsidy to support the needed R&D activities. The third level is tendering methods, which refers to the different procedures that can be followed as part of the procurement strategy. Examples of important elements of tendering methods are the used procurement procedure, selection criteria, award criteria and contractual arrangements.

The most common project delivery model in civil engineering is the design-bid-build model where nearly all of the design activities are performed before a public tender for the realization of the work is published. This delivery model is widely used for straightforward projects of small to medium size where the additional value of involving the main contractor in design activities is expected to be limited. Integrated delivery models, on the other hand, are often used for larger and more complex projects to allow for incremental innovation and optimization between different stages of the project lifecycle (Blayse and Manley 2004; Eriksson et al. 2019). Contracts for Integrated delivery models range from Engineering and Construct (E&C), and Design and Construct (D&C) up to the integration of Design, Build, Finance, Maintenance and Operation (DBFMO) activities in one contract (Lenferink, Tillema, and Arts 2013).

Alongside widely used open, restricted and limited tender procedures, there are several public procurement procedures permitted under the European law which provide additional opportunities for stimulating innovation (Directive 2014/24/EU, 2014; Telles and Butler 2014). The competitive dialogue and the competitive procedure with negotiation both allow greater communication and interaction between the tenderers and the client by including one or more meetings in the tender procedure (Hoezen, Voordijk, and Dewulf 2014). The client can also organize market consultations as part of the market approach to inform and consult the market about the assignment prior to the tender (Lenderink, Halman, and Voordijk 2019; Semple 2015). In comparison to the previous procedures, the design contest, pre-commercial procurement and innovation partnership approaches are mostly geared towards the development of new solutions (Georghiou et al. 2015). Here, one should note that a pre-commercial procurement is a targeted subsidy for the development of new solutions and is not regulated by procurement law (Edquist and Zabala-Iturriagagoitia 2015).

One of the main ways for public clients to stimulate innovation is the use of high-quality standards (Dalpé 1994; Geroski 1990) and innovation-oriented award criteria (Dreschler 2009; Lenderink et al. 2020; Loosemore and Richard 2015). This is to provide incentives to tenderers to offer high-quality and potentially innovative solutions. Public clients can also stimulate innovation in public tenders through the use of functional instead of technical specifications which provide more solution space to tenderers for offering alternative solutions (Edquist, et al., 2015). Lastly, arrangements on intellectual property rights can also provide incentives to tenderers for offering innovations (Edler et al. 2015).

### *The importance of cooperation between public client and contractor*

Interorganisational cooperation is considered an essential aspect of realizing innovation in CoPS where physical and human resources are dispersed among various organisations (Rutten, Dorée, and Halman 2009; Barlow 2000; Gann and Salter 2000). Khalfan et al. (2008) and Caldwell Roehrich, and Davies (2009) concluded in their study that,

through public clients' initiatives, there is great potential to utilize the expertise and knowledge of suppliers and manufacturers in civil engineering and construction projects. In this respect, a public client can act as a catalyst to promote innovative thinking by supporting public client–supplier–manufacturer collaboration.

In his study on procurement effects on coopetition in client-contractor relationships, Eriksson (2008) has positioned cooperation and competition as opposite sides of a continuum. He divides this continuum into a range from: (1) a state of pure competition to; (2) competition-based coopetition to; (3) a state of coopetition; to (4) cooperation-based coopetition and ending with; (5) a state of full cooperation. To realize innovation in civil engineering projects, Eriksson and Westerberg (2011) indicated that a high level of integration between client and contractor should be taken care of resulting in a joint involvement in subcontractor selection and integration; an incentive-based payment on innovation performance criteria and; the usage of collaborative tools such as the usage of joint IT-tools, joint risk management and a joint project office.

Unfortunately, the study of Eriksson (2008) also shows that in the construction industry, clients' procurement procedures often facilitate a focus on competition and not on cooperation. This explains the relatively low level of innovations in the construction industry.

In conclusion, since innovation in the field of civil engineering must take place in project or programme constellations consisting of a public client and supplying firms, these firms are much dependent on public clients to allow for innovation (Ivory 2005; Loosemore 2015; as cited by Lindblad and Guerrero 2020). Public clients can play a central role in supporting innovation by establishing a supportive environment through their willingness to limit the financial innovation risks of the contracted parties and by providing incentives to encourage innovation. In addition, public clients have the power to act as a catalyst to promote innovative thinking through supporting public client-supplier-manufacturer collaboration. And as long-term infrastructure owners, they will benefit from more sustainable processes (Linderoth 2010; Smith 2014; Singh 2014; as cited by Lindblad and Guerrero 2020).

## Research methodology

A multiple case study, involving eight different cases, was conducted to gain insight into the factors that influence the effectivity of innovation-encouraging procurement strategies and tendering methods. Case studies are well suited for understanding the "how and why" of phenomena in their natural settings (Yin 2013). Furthermore, case studies are most suitable when the object under study is difficult to quantify, as in this case. A cross case comparison helped to identify and explain commonalities and differences between the cases in their procurement strategies and tendering methods. This cross case comparison helped to derive a typology of innovation encouragement procurement strategies.

### *Case selection*

In searching for suitable cases, the national expertise centre on public procurement in the Netherlands was contacted, as well as several Dutch provinces and large municipalities who were known for their ambitions with respect to innovation in the field of civil engineering. In the contacts, we asked these organizations to provide us with specific examples of innovations that were realized in the past five years. Further, the online Dutch tendering databases, Tenderned.nl and Aanbestedingskalender.nl, were searched to find innovation-

oriented tenders within the field of civil engineering and construction. Next, we contacted the respective tendering authorities to also obtain additional tender documents. The initial search process resulted in a variety of 25 potential cases in which innovation was explicitly part of the scope, aims and objectives of the project and/or the used Procurement strategy. Next, we made a purposeful selection (Eisenhardt and Graebner 2007) that was based on developing a sample that covered:

- projects as well as programmes;
- incremental as well as radical innovations;
- the identified variety of procurement strategies.

As explained in the literature background section, strategic policy goals such as climate adaption and the realization of a circular economy are defined in long-term innovation programmes which are decomposed into multiple successive and often interrelated innovation-oriented projects with a much shorter time-horizon. However, besides innovation-oriented projects being part of such an innovation programme, there are also innovation-oriented projects that are defined and procured on their own. We therefore decided to include examples of innovation programmes as well as examples of individual innovation projects in our sample of cases.

This case selection resulted in first instance into seven cases that were taken for further study. For comparison reasons, we added at a later stage, one case that did not have a specific focus on innovation, but in which the procurement strategy implicitly facilitated the implementation of innovation. This eventually resulted in a case sample consisting of three examples of innovation-encouraging programmes four examples of innovation-encouraging projects and one project in which innovation was not directly stimulated.

### *Data collection and analysis of the individual cases*

The data collection and individual analysis for each of the cases in the multiple case study were performed in three steps. The first step was to contact the public client of the initiative and request the project/programme, procurement and concept contract documents where these could not be obtained from the public tender database in which the procurement had been published. The second step was to review these documents to identify the scope, aims and objectives of the initiative and to gain an initial grasp of the project and the procurement strategy used in the initiative. This initial document study was also used to prepare questions for the planned semi-structured interviews and to then corroborate findings from these interviews. The third step was to carry out several semi-structured interviews with respondents from the public client side who had managerial roles in the initiative. For example, these could be the project leader, internal client, procurement advisor and, sometimes, external consultants who supported the client. In total, 32 interviews were performed with the clients and supporting external consultants. The questions in the interviews were structured in a chronological order reflecting the different phases of the initiative and dealt with: (a) the development of the scope, aims and objectives of the initiative; (b) the procurement strategy used and why this approach had been adopted and (c) the role of innovation in the initiative as well as in the procurement strategy.

For the selected cases, interviews were also carried out with the contracted organizations and other unsuccessful tenderers. A total of 18 interviews were performed with

contracted organizations and tenderers. These interviews focussed on their incentives to participate in the project as well as their view on the pros and cons of the selected procurement strategy with respect to stimulating innovation. The interviews lasted between 50 min and two hours and were recorded and transcribed. The transcripts were sent to the respondents to verify the content. None of the transcriptions required modification. The cases were analysed from the perspective of public clients who initiated an innovation-encouraging procurement strategy to fulfil the aims and goals of a specific project or programme. This with the aim to increase knowledge on how the use of innovation-encouraging procurement strategies was related to the characteristics of the specific projects and programmes.

### *Development of the typology*

The main strength of typologies is that they can be used to identify and understand relationships between combinations of variables rather than only separate variables, which makes them very suitable for midrange theory development (O'Raghallaigh, Sammon, and Murphy 2010).

The development of the typology as described in this paper was based on the insights on typology development from the literature (Niknazar and Bourgault 2017; Shenhar and Dvir 1996). In developing the typology we followed the steps proposed by O'Raghallaigh, Sammon, and Murphy (2010) in their paper on theory-building using typologies:

1. Define the purpose and limit the domain of the typology.
2. Identify and define the concepts used in the typology:
   (a) Key constructs;
   (b) Ideal types.
3. Describe the logic which explains the relationships between the variable(s).
4. Make predictions and propose suggestions for future research.

### *Guideline development:*

The insights acquired during the literature review, the multiple case study and the typology development were helpful to derive a general guideline for the selection of an innovation-encouraging public procurement strategy. Depending on the type of project or programme a different approach was worked out.

In the remainder of this paper, we will present the results of our research in the order in which it was performed. First, we will introduce the three key constructs that will be used to classify the different ideal types of innovation procurement in civil engineering projects and programmes.

## Classifying innovation procurement in civil engineering projects and programmes

Based on the conducted literature review, a typology has been derived which consists of three dimensions. This typology will be used to classify the cases presented in the next section.

The first dimension refers to the scope, aims and objectives of an initiative and makes a distinction between civil engineering projects and programmes.

The second dimension refers to the degree of innovation that is embedded in the realised project or programme.

The third dimension of the typology refers to the level of cooperation between public clients and contractors.

## Details about the projects and programmes included in this study

This section first provides a brief description of each of the eight cases that were part of our multiple case study. The study includes five procured civil engineering projects and three civil engineering programmes. The characteristics of each of the procurement initiatives and the reasons for the public client in stimulating innovation are listed in Table 1. An overview of the different procurement strategies and the tendering methods that were used can be found in respectively Table 2 (for the procured projects) and Table 3 (for the procured programmes).

Table 4 provides an overview of the type(s) of innovation(s) the public client hoped to achieve in the respective projects and programmes, the innovation degree of the realized innovations, what kind of role the public client played during the whole process, and more specifically, the type of relationship between public client and contractor.

### *Brief case descriptions*

1. Functional barriers

   The municipalities of Amsterdam and Rotterdam and the Ministry of Infrastructure and Water Management published a Small Business Innovation Research (SBIR) procedure for the staged development and initial testing of four functional barriers to fence off construction sites. The SBIR procedure was followed by three pilot projects to test the developed product innovations in practise: (a) a modular barrier (the Wall for All), (b) a barrier which absorbs dust and reflects noise (the Greenbar) and (c) an aesthetically pleasing and strong barrier with benches for the public (the Parkbench).
2. Cycle Bridge Ritsumasyl

   The public client opted for a two-staged client-led approach for the development and realization of a movable cycling bridge of bio-based composite materials. Both the contractor and the supplier of the innovative bridge deck were involved early in the design process. In the first stage, the innovative bridge deck was developed and tested in parallel with the development of the movable bridge design. After most uncertainties in the design and performance of the bridge were mitigated during the first stage, the movable cycle bridge with a swing design was realized under an integrated contract in the second stage with the inclusion of the developed bridge deck of bio-based materials.
3. Boekelo bridge

   The public client requested tenderers to include up to three innovative solutions in their tender offer, for which they could gain a competitive advantage in the award of the tender. To calculate the extent of this competitive advantage the offered innovations were assessed based on their degree of innovativeness, as well as, the scale on which they were applied in the design and realization of the initiative. One process and two product innovations were implemented in the initiative: (a) engineer and build in mixed reality, (b) solar panels on the road surface and (c) low temperature baked powder coating. The bridge design itself was also innovative and made use of fully 3d modelled formworks to cast the abutments.

Table 1. Characteristics of the procurement initiatives and reasons for stimulating innovation.

| | Case | Involved public organizations | Scope of the initiative | Aims and objectives of the initiative | Budget and duration of the initiative | Reasons for stimulating innovation |
|---|---|---|---|---|---|---|
| Project | 1. Functional Barriers | - Municipality of Amsterdam - Municipality of Rotterdam - Rijkswaterstaat | Development and testing of new types of multifunctional physical barriers. | - To reduce construction nuisance and improve the experience of the public near construction sites. | - € 0.55 million - Approx. 18 months | - Contribute to policy goals including the stimulation of private sector innovation |
| | 2. Ritsumasyl Cycle Bridge | - Province of Friesland | Development of a movable bridge deck made of bio-based composite materials. Replacement of a road bridge with the developed bicycle bridge using a movable bridge deck using bio-based composite materials. | - To develop and realize a movable bicycle bridge using bio-based composite materials. - To facilitate the passage of larger Va class ships through the channel. - Use an innovative and sustainable approach in the project. - To Realize the project in collaboration with businesses and educational institutes. | - € 6.6 million - Approx. 12 months for the development and 9 months for the realization of the bicycle bridge. | - Address a project goal which cannot be met by conventional solutions and contribute to innovation and sustainability as policy goals. |
| | 3. Boekelo Bridge | - Municipality of Hengelo - Province of Overijssel - Rijkswaterstaat | Design and construction of a bridge to replace an old bridge. | - To realize an appealing bridge of high. architectural and aesthetical quality - To realize added value through product and process innovations. - To reduce construction hindrance. | - € 8.2 million - approx. 2.5 years | - Stimulate private sector innovation as a policy goal |

(*Continued*)

Table 1. Continued.

| | Case | Involved public organizations | Scope of the initiative | Aims and objectives of the initiative | Budget and duration of the initiative | Reasons for stimulating innovation |
|---|---|---|---|---|---|---|
| | 4. Gemert Northern Ring Road | - Province of Noord-Brabant | Design and construction of a new ring road and restoration of a creek. | - To realize a new traffic connection. - To maintain and improve the flora and fauna network. - Reduction of CO2 emissions in the project. | - Approx. € 4–6 million - 15 months | - Contribute to policy goals including the stimulation of private sector innovation |
| | 5. Vechtdal Connection | - Province of Overijssel | Realization, renovation and improvement of three provincial roads, including junctions, civil engineering works and optimization measures. | - To realize a new traffic connection. - To renovate and improve three provincial roads. - To realize as many optimization measures as possible within the set budget. - To reduce construction nuisance and CO2 emissions. | - € 101.8 million - Approx. 5 years | - Contribute to project objectives and policy goals |
| Programme | 6. Quay Walls Innovation Partnership | - Municipality of Amsterdam | Development and procurement of new solutions for the restoration of quay walls. | - To reduce costs, lead times and construction nuisance in the restoration of quay walls in the inner city. | - € 0.6 million to develop and max. 50% of future quay wall projects in framework contract. - Two-year award and development, and 4 + 2 + 2 year framework contract. | - Address an organizational challenge which cannot be met by conventional solutions. |

| | | | | | |
|---|---|---|---|---|---|
| 7. Urban Lighting Roadmap Implementation | - Municipality of Eindhoven | - Development of the public lighting systems to a smart and open lighting grid. - Maintenance and exploitation of the public lighting grid. | - To create an open smart light grid. - Collaboration in quadruple helix. - Long-term continual innovation process. - To contribute to social and environmental sustainability of the city. - To maintain and enhance the reputation of the city as the "City of Light" and increase the quality of life in the city. | - € 20.5 million - Five-year contract with ten-year extension. | - Contribute to long-term policy goals |
| 8. Smart Way to Sustainable Municipal Buildings | - Municipality of Eindhoven | Renovation, maintenance and exploitation of seven municipal buildings in the city centre. | - To realize sustainable accommodation for civil servants in the city centre based on a solid business case and in the light of the transition to new ways of working. | - € 106 million - Ten-year contract with five-year extension | - Contribute to long-term policy goals |

Table 2. Procurement strategy: Overall strategy and applied tendering methods.

| | | Procurement strategy | | | | | |
|---|---|---|---|---|---|---|---|
| | Case | Overall strategy | Procurement Procedure | Project delivery model | Market approach | Selection criteria | Award criteria |
| Project | 1. Functional Barriers | Targeted subsidies and pilot projects for the development and testing of new solutions. | SBIR procedure (Small Business Innovation Research, targeted R&D subsidy) | - Subsidy contract for R&D. - Small assignment for testing purposes. | - Collaborative call for proposals. - Plenary information session. - Individual sessions during SBIR procedure. | Feasibility research: - Impact on project goals. - Technical feasibility. - Economic perspective. - Price. | R&D phase - Same as selection criteria. - Opportunity to further explain the plan of action. |
| | 2. Ritsumasyl Cycle Bridge | A two-stage approach for the development, testing and implementation of a specific innovation within a bridge project. | Contractor: - European restricted tender Producer: - European open tender | - Construction design team contract for the design and feasibility of the bridge. - Integrated contract for the realisation of the bridge. | Contractor: - Individual information session in award phase. Producer: - Plenary information session. - Individual information session. | Contractor: - Experience with comparable technical works. - Experience with collaborative design processes. - Experience with development of innovations. Not applicable for producer. | Contractor: - Vision on collaboration in construction design team. - Price. Producer: Price and quality (based on plan of action) - Knowledge and expertise on bio-based composite materials. - Collaboration in construction design team. |
| | 3. Boekelo Bridge | Integration of design and construction activities in combination with the application of a specific model for assessing innovation. | - European restricted standard tender procedure | Integrated contract: - Full design for the construction of the bridge. - Execution of the design and construction of a traffic lane. | - Traditional market approach (Publication and written information notices). | - Integration of core competences. - Innovation. | - Price. - Architectural and aesthetical quality of the bridge. - Innovation. - Realization time. |

| | | | | | | |
|---|---|---|---|---|---|---|
| 4. Gemert Northern Ring Road | Integration of design and construction activities, in combination with the assessment of CO2 emissions in the tender. | European public standard tender procedure | Integrated contract: Detailed design and realization of the work. | - Plenary information session. - Opportunity for individual information session in the event of genuine commercial interest. | - Not applicable. | - Price. - Ensured accessibility, safety and traffic flow. - Project management. - Sustainability (CO2-emission, substantiation and innovation). |
| 5. Vechtdal Connection | Integration of design and construction activities in a large contract in combination with an optional optimization measures package as part of the tender offer. | - European restricted tender procedure | Integrated contract: - Design and realization of the work. | - Traditional market approach (Publication and written information notices). - Bus tour. | - Drawing of lots. | - Price. - Offered optimization measures. - Reduced construction nuisance for road users and the environment. - Sustainability in the realization of the project. |

Table 3 Procurement strategy: overall strategy and applied tendering methods.

| | Case | Procurement strategy | | | | | |
|---|---|---|---|---|---|---|---|
| | | Overall strategy | Procurement Procedure | Project delivery model | Market approach | Selection criteria | Award criteria |
| Programme | 6. Quay Walls Innovation Partnership | Targeted subsidies and pilot projects for the development and testing of new solutions followed by a framework contract. | - Innovation partnership (procedure for the development and implementation of innovations) | - Subsidy contract for development and testing of prototypes. - Framework contract with multiple suppliers for the renovation of quay walls in the city. | - Three plenary market consultations. - Request for feedback on concept tender documents through information notices. | - Vision on innovation development and innovativeness with respect to seven topics. | Preliminary award criteria R&D phase: - Scalability of solutions. - Impact on direct environment (time/ nuisance). - Future value with respect to maintenance, sustainability and multi-functionality. - Team, collaboration and plan of action. - Price. |
| | 7. Urban Lighting Roadmap Implementation | Using the flexibility of a large and long-term contract to develop and implement new solutions. | - Competitive dialogue (procedure including dialogue sessions with the tenderers) | - Five-year concession agreement for five pilot areas. - Ten-year concession agreement for entire city. | - Plenary information session. - Several individual consultations. - Two rounds of dialogue sessions. | - Operational management of public lighting installations. - Innovativeness. - Business models for public services. - Anticipation of social needs. - Sustainable business management. | Best value procurement: - Underpinning performance of transformation to smart lighting-grid, quadruple helix, exploitation and sustainability. - Risk dossier. - Opportunities dossier. - Quality of key functionaries. |
| | 8. Smart Way to Sustainable Municipal Buildings | Using the flexibility of a large and long-term contract to develop and implement new solutions. | - Competitive dialogue (procedure including dialogue sessions with the tenderers) | Ten-year contract with option to extend for five years. | - Elaborate market consultation involving five sessions. - Two rounds of dialogue sessions. | - Improvement of energy efficiency. - System-oriented sustainability approach. - Organizational flexibility. | First funnel: - Underpinning collaboration performance. Final award based on best value procurement: - Underpinning sustainability performance and business case. - Risk dossier on collaboration and other subjects - Opportunities dossier. - Quality of key functionaries. |

Table 4. Realization of innovations.

| | Case | Aims of innovation | Targeted technology readiness levels (start/end) | Type of realized innovations | Based on tender documents: Role of public client in innovation process and client-contractor relationship |
|---|---|---|---|---|---|
| Project | 1. Functional barriers | Development and testing of new types of construction fences to reduce construction nuisance and improve and improve the experience of the public around construction sites | TRL 6–7 at the end of the initiative | Three substantial product innovations | Supportive role; Competition based coopetition |
| | 2. Cycle Bridge Ritsumasyl | Development and implementation of a cycle bridge with a openable bridge deck of bio-based materials | TRL 3 at the start of the initiative; TRL 8 at the end of the initiative. | One radical product innovation | Leading role; Cooperation based coopetition |
| | 3. Boekelo bridge | Implementation of product innovations in the bridge and/or process innovations for the realization of the bridge | TRL 6 at the start of the initiative; TRL 8 at the end of the initiative | One incremental product innovation, one radical product innovation and one substantial process innovation. | Limited role; Competition based coopetition |
| | 4. Northern ring road Gemert | Implementation of solutions to reduce CO2 emissions, and improving project management and traffic flow during the realization of the initiative | TRL 6 at the start of the initiative; TRL 8 at the end of the initiative | One substantial product innovation, one substantial process innovation, and one radical process innovation | Limited role: Competition based coopetition |
| | 5. Vechtdal Connection | No specific focus. Potential innovations could improve sustainability and traffic flow during the realization of the initiative | TRL 7–8 at the start of the initiative; TRL 8–9 at the end of the initiative | Process optimisations | Very limited role; Competition |

(*Continued*)

Table 4. Continued.

| | Case | Aims of innovation | Targeted technology readiness levels (start/end) | Type of realized innovations | Based on tender documents: Role of public client in innovation process and client-contractor relationship |
|---|---|---|---|---|---|
| Programme | 6. Quay Walls | Development and implementation of new scalable solutions for increasing the rate at which quay wall renovations can be performed while limiting nuisance to the public | TRL 3–5 at the start of the initiative; TRL 8–9 at the end of the initiative | One radical and two substantial innovations, each including both product and process innovation. | Supportive role; Competition based coopetition |
| | 7. Implementation of the Roadmap Urban Lighting | Implementation of innovations on the lighting grid of the city to increase the quality of life of the citizens in the city. | Targeted TRL levels between 4 and 9 | Innovative collaboration process (quadruple helix). Initiative ended prematurely before product innovations could be implemented | Supportive role; Competition based coopetition |
| | 8. Smart way to Sustainable Municipal Buildings | Implementation of new solutions for the renovation and maintenance of municipal buildings with the aim to make them energy neutral and more sustainable | Targeted TRL levels between 4 and 9 | One substantial process innovation and several incremental product innovations | Supportive, facilitating role; Coopetition; |

4. Northern ring road Gemert

   The project focused on the realization of a new ring road including three roundabouts and a bicycle bridge, along with the restoration of a creek. The public client used an integrated design and construct contract in combination with a European open tender for the project. Furthermore, they included the reduction of CO2 emissions as an award criterion in the tender next to project management and accessibility & traffic flow in the village during the realization of the project. Innovation was included as a sub-criterion of the award criterion reduction of CO2 emissions. The contractor to which the initiative was awarded provided three innovative solutions in their tender offer: (1) a 3d-printed bicycle bridge, (2) the construction of a roundabout next to its final location and (3) the longest composite arch bridge at the time of construction.
5. Vechtdal Connection

   The main challenge for the public client in this project was to realize as much of the scope of the project within a limited available budget. To tackle this challenge the province differentiated the scope of the project into (a) a package of necessary improvements which are a fixed part of the scope of the project and (b) 15 optional optimization measures which could be included by the tenderers in their tender offer to receive a fictional reduction on their tender price as a competitive advantage in the award of the tender. Stimulating innovation was not an explicit goal of this program. Nevertheless, the use of an integrated contract in combination with sufficient design freedom allowed for the implementation of incremental product and process optimisations.
6. Quay Walls programme
7. large share of the quay walls in the city of Amsterdam is in a deteriorated state since their upkeep has not been sufficient to offset their natural decay for many years. The municipality used an innovation partnership procedure for the development and testing of new solutions. So far, the innovation partnership resulted in the development of three new solutions for the renovation of quay walls: (a) renovation of quay walls with the use of prefab elements (EZ-flow), (b) renovation using a self-propelling pile-driven system (GRB system) and (c) circular renovation of quay walls from the water with electric equipment (Save).
8. Implementation of the Roadmap Urban Lighting

   The public client has developed a roadmap for the transition of its urban lighting system into a smart open lighting grid up to 2030 in collaboration with the University of Eindhoven (den Ouden and Valkenburg 2012). For the implementation of the roadmap, the municipality opted for a long-term collaboration with a contractor using a scalable approach for the development and maintenance of the lighting systems. The municipality used the competitive dialogue procedure with elements from best value procurement for the tendering of this assignment. The initiative started with three pilot areas in which a four-step approach was used: (1) replacing the existing light bulbs to lead, (2) mapping the needs and requirements, (3) developing ideas and solutions and (4) realizing the developed solutions. Unfortunately, the client and the consortium jointly decided to terminate the initiative prematurely in 2019 before the realization phase for the innovations started (van Galen, den Ouden, and Valkenburg 2020).
9. Smart way to Sustainable Municipal Buildings

   Similar to case seven, the pubic client used the competitive dialogue procedure with elements from best value procurement for the tendering of the assignment to

make their buildings more energy efficient and sustainable. One of the first results of this project is the circular renovation of the city hall tower in which 95% of the materials were either reused, sold through a purpose build web shop, or recycled. The tower is also used as a living lab to test new technologies such as smart climate systems.

**Positioning of the projects and programmes in the developed typology**

Based on the tender documents, a cross case comparison is made in this section between the characteristics of each of the eight cases with respect to the three dimensions of the innovation-encouraging procurement typology:

- The scope, aims and objectives of the initiative;
- The type and degree of the realized innovation;
- The type of Public client–contractor relationship.

Based on the identified characteristics of each case, it was possible to position each case into one of the cells of the developed typology. The result of this classification is visualised in Table 5. Note, that on the dimension "Public client–contractor relationship" none

Table 5. Typology populated with the cases from the multiple case study.

| | | Degree of innovation | | |
|---|---|---|---|---|
| | | Low | Moderate | High |
| Scope and timeframe | Project (fixed scope and timeframe) | *Regular*<br>5. Vechtdal Connection | *Innovation-oriented*<br>1. Functional Barriers<br>3. Boekelo Bridge<br>4. Gemert Northern Ring Road | *Innovation-driven*<br>2. Ritsumasyl Cycle Bridge |
| | Programme (adjustable scope and timeframe) | *Regular* | *Innovation-oriented*<br>8. Smart Way to Sustainable Municipal Buildings<br>7. Urban Lighting Roadmap Implementation | *Innovation-driven*<br>6. Quay Walls Innovation Partnership |
| Client-contractor relationship | Pure Cooperation | | | |
| | Cooperation based coopetition | | | 2. Ritsumasyl Cycle Bridge |
| | Coopetition | | 8. Smart Way to Sustainable Municipal Buildings | |
| | Competition based coopetition | | 1. Functional Barriers<br>3. Boekelo Bridge<br>4. Gemert Northern Ring Road<br>7. Urban Lighting Roadmap Implementation | 6. Quay Walls Innovation |
| | Pure Competition | 5. Vechtdal Connection | | |

of the cases were classified as "pure cooperation". This is not strange, since the tender regulations prescribe at least a minimum level of competition.

***The scope, aims and objectives of the projects and programmes***

With respect to the scope, aims and objectives, a distinction is made between projects and programmes. As explained in the brief case descriptions and in Tables 2–5, cases 1–5 were classified as civil engineering projects. They are characterized by a narrowly defined scope that focusses on achieving specific objectives and performing specific tasks within a short to medium time frame. In contrast, cases 6–8 could be classified as civil engineering programmes due to their broadly defined scope and the multiple projects to realize the aims and objectives in relative long to very long timeframe.

***The type and degree of the realised innovations***

Table 4 provides an overview of the type and TRL levels of the realized innovations in the eight cases. Case 2 (the Ritsumasyl bridge project) and case 6 (the Quay walls programme) are characterised by a low TRL level (3) and are therefore classified as a high degree of innovation. Case 1 (the Functional Barriers project), Case 3 (the Boekelo bridge project) and case 4 (Gemert Northern Ring project), case 7 (Urban Lighting Roadmap Implementation programme) and case 8 (Smart way to sustainable Municipal Buildings programme) are characterised by a moderate TRL level (4–6) and are therefore classified as having a Moderate degree of innovation. Finally, case 5 (Vechtdal Connection project) is characterised by a high TRL level (7–8) and has there been classified as a Low degree of innovation.

Note that all three civil engineering programmes (cases 6–8) also include projects with a lower degree of innovation. However, we have classified these cases according to their lowest TRL level, since the successful realisation of the projects with a low TRL Level, will ultimately also determine the successful completion of the programme.

***The type of public client–contractor relationship***

Table 4 provides an overview of the type of public client–contractor relationships for each of the eight cases. The public client–contractor relationships varied, according to Eriksson's (2008) continuum for client–contractor relationships, from "Cooperation based coopetition" to "Pure competition". In case 5 (Vechtdal connection project), the role of the public client in the innovation process was the most limited. It only consisted of providing solution space by providing a list of alternatives in the tender requirements from which the tenderers could select one alternative to implement. The public client-contractor relationship was purely based on competition. In cases 3 (Boekelo bridge project) and 4 (Gemert Northern ring road project), the role of the public client in the innovation process was also fairly limited. In both cases, the public client–contractor relationship can be characterised as a "competition based coopetition", although case 3 was slightly more focused on competition compared to case 4. This was due to the inclusion in case 4 of a market consultation and the option for individual information sessions. In both cases, the public client actively stimulated the implementation of innovations in the tender, but played a limited role in the innovation process. The main role of the public client was to assess if the proposed solutions could be realized within the tender requirements. For case 3 this required the development of a new assessment method for assessing the innovative design of the

bridge. In cases 7 (Implementation of the Urban Lighting programme) and 8 (Smart way to sustainable municipal buildings programme) the public client played a more supportive role in the innovation process. For example by allowing for optimizations in the scope during the tender for the proposed business cases. Later, in the realization phase of the cases the public client discussed the potential of the proposed solutions with the contractor and assisted in providing the needed boundary conditions for the implementation of these innovations. However, if compared to case 8, case 7 can also better be classified as a "Competition based cooperation" while case 8 fits with a "Coopetition" based relationship. One of the main differences between the two cases was a stronger focus in case 8 on collaboration in the selection and assessment criteria, as well as the market approach.

In cases 1 (Functional Barriers project) and 6 (Quay walls programme) the public client also played a supportive role in the innovation process. However, there were two major differences between these two cases in comparison to cases 7 and 8, which effected the role of the public clients. First, the development of innovations played a more prominent role in both cases 1 and 6. Second, it was much clearer which innovations needed to be developed and tested in cases 1 and 6 at the time of the tender contract closure. Within the innovation process the tenderers provided their client perspective and expertise on the feasibility and desirability of the proposed innovations on a regular basis. Furthermore, multiple information sessions were organized as part of the market approach. As such, the public client-contractor relationship can be characterized as a "competition based coopetition".

Case 2 (Ritsumasyl bridge project) clearly stands out from the other cases. Prior to the tender phase the public client stated the ambition to develop and implement a specific radical innovation. To this end, the public client used a two-stage approach for the development and realization of the engineering work with the inclusion of the innovation. The first part consisted of collaborative development and testing of the innovation, and the development of the design of the civil engineering work including the innovation. Only after extensive testing, the public client signed the design and construct contract for realizing the civil engineering work including the developed innovation. The public client also significantly reduced the financial liability for the contractor and the producer of the innovation and strongly collaborated with both parties during the development and realization of this bridge project. As such, the public client-contractor relationship can be classified as a "Cooperation based coopetition".

## The cases and their selected procurement strategy

The scope, aims and objectives of the cases and the degree of innovation were found to have a major influence on the selection of a procurement strategy with respect to innovation in several ways.

### *Case 2: A project characterised by a high degree of innovation*

In case 2 (Cycle bridge Ritsumasyl project) the development and testing of radical innovation was a major part of the scope of the project. For this reason, the public client developed a procurement strategy that was specifically geared towards the development of this innovation. The *standard open and restricted procurement procedures* used in case 2 seem to suggest the stimulation of innovations with higher TRL levels. However, these procedures were used within a two-staged approach that enabled the development and realization of the intended innovation, which makes the use of these procedures suitable for the developed innovations.

***Case 1, 3 and 4: Three projects characterised by a moderate degree of innovation***

In Case 1 (Functional barriers project) the public organizations included a small assignment for testing purposes in addition to the *SBIR procedure.* This with the aim to provide tenderers the opportunity to test their developed innovations in a real-life situation.

Case 3 (Boekelo bridge project) and 4 (Northern Ring Road Gemert) were similar in terms of scope, aims and objectives in the sense that they both aimed to stimulate the implementation of innovations in a project for the design and realization of public infrastructure with a budget under 10 million euro and a planned duration of less than three years. Due to the relatively short duration of these cases the public organizations could only stimulate innovations which required limited time for development and testing prior to implementation. The procurement strategies were similar in that they allowed for design freedom through the use of *integrated contracts* and they both used *standard tendering procedures*. Despite this, the reasons for stimulating innovation and the used tendering methods for stimulating innovation differed significantly. In case 3, innovation played a strong role in the selection as well as the award phases of the restricted tender procedure used in the project. In the selection phase, the number of candidates was reduced based on: (a) their ability to integrally perform five pre-defined core competences and (b) the extent to which candidates could convincingly prove that innovation is not only part of their corporate strategy but had also resulted into the development and application of innovations in projects comparable to case 3. In addition, innovation was chosen in the award phase as one of the award criteria in determining the quality of the tender offers. In case 4, innovation was primarily stimulated to reduce $CO_2$ emissions in the realization of the work. To achieve this, innovation was introduced as a sub-criterion of the award criterion for reducing $CO_2$ emissions. In addition, innovative solutions with respect to project management, accessibility and traffic flow during the realization of the work were indirectly stimulated as well since these subjects were included as the other award criteria.

***Case 5: A project characterised by a low degree of innovation***

With a budget of more than 100 million case 5 (Vechtdal Connection project) is expected to be completed within five years. The public client decided to combine a number of projects in the tender of case 5. This was done with the underlying assumption that this could lead to possible optimizations. Innovation was considered of minor importance in case 5 and was therefore not explicitly part of the procurement strategy. An integrated contract and standard tender procedure were used for this project. Despite this selection, innovations that contributed to sustainability improvement and toward a limitation of construction nuances could still be implemented. But it was fully left to the tenderers if they saw sufficient benefits in proposing alternative solutions to reduce construction nuance and improve sustainability in the realization of the Vechtdal Connection project.

***Case 6: A programme characterised by a high degree of innovation***

In Case 6 (Quay wall programme) new scalable solutions for the restoration of quay walls had to be developed and implemented. This required one radical and two substantial innovations, each including both product and process innovations. To this end, the *Innovation Partnership procedure* was chosen. An approach that is specifically suitable for the development of new solutions.

### *Case 7 and 8: Two programmes characterised by a moderate degree of innovation*

Cases 7 (Implementation of the Roadmap Urban Lighting) and 8 (Smart way to sustainable Municipal Buildings programme) are two long-term programmes of considerable size in which the implementation of innovations was important for reaching the aims and objectives of the programmes. The large size and long duration of these cases allowed for the use of economies of scale and provided a significant amount of time which could be used to recoup investments in innovative solutions. In both cases, the public client decided to not fully determine the scope of the case before the tender to allow for optimizations in the scope based on the input of the tenderers. As a result, tenderers were able to optimize their business case with respect to the development and implementation of innovations. To make the optimizations in the scope possible, in both cases the client consulted the market before the tender and used a *competitive dialogue in combination with elements of best value procurement* in both cases. The use of the competitive dialogue allowed for more negotiation and communication with respect to the scope of the assignment in comparison to traditional tender procedures.

## A theory-based reflection on the positioning of the cases in the typology

Based on what is known in literature, we hereby evaluate the positioning of the respective cases in the typology. We also reflect on the suitability of the different configurations of the typology to encourage innovation.

### *Case 1 (Functional barriers): a project classified as a moderate degree of innovation and with a competition based coopetition*

The innovation risks that are involved in the development of multifunctional construction fences such as in case 1, are relatively low (The Ministry of Infrastructure and Water management reports a TRL 6). These types of developing products are pre-eminently assignments that can be asked out to the market in competition. However, from the public client, a supporting role is still required to harmonize the requirements and to formally approve the designs to be installed on roadways. The SBIR procedure that was chosen in case 1, has specifically been designed to facilitate these types of pre-commercial developments (Rugby 2016).

### *Case 2 (Ritsumasyl project): a project classified as a high degree of innovation and with a cooperation based coopetition*

For radical innovations, such as the Ritsumasyl project, the unilateral allocation of innovation risks to the main contractor is undesirable since most of the associated innovation risks are difficult to assess and manage due to the inherent uncertainties. A study conducted by Lenderink et al. (2022) showed that a proactive participation of the public client in the initiation, development and implementation of the project and the willingness to bear innovation risks were essential to successfully realise this innovation project. In addition, Khalfan et al. (2008), concluded that a public client can act as a catalyst to promote innovative thinking through supporting public client–supplier–manufacturer collaboration. Hence, a separate tender – as happened in Case 2 – to include the knowledge and expertise of a key subcontractor in the project team, was also considered an important stimulus for realizing the intended radical green innovation.

### *Case 3 (Boekelo bridge) & Case 4 (Gemert northern ring road): Two projects classified as a moderate degree of innovation and with a competition based coopetition*

Lenderink et al. (2020) conducted a study about the procurement of the Boekelo bridge project and the way how the project client encouraged innovation in this specific project. Their findings show that the public client triggered innovation by providing sufficient financial incentives for innovation and by using innovation awarding selection criteria. The results show that with respect to the innovation degree of the provided solutions, all solutions were assessed as incremental or moderate innovations on the module or system level of the bridge project. This is not surprising given the limited time frame in which the tenderers were expected to develop and implement their innovative solutions (Klein and Sorra 1996). The general conclusion that may be drawn here is that in tenders such as in cases 3 and 4, one may not expect radical innovations. An important reason for this is that the development risks are perceived as too high by the contracting parties and that they do not outweigh any returns. To gain tender advantages, contractors will therefore primarily focus on process innovations. Public clients are expected to have a supporting and testing role in cases such as the Boekelo Bridge project and the Gemert Northern Ring project.

### *Case 6 (Quay Walls): A programme classified as a high degree of innovation and with a competition based cooperation*

In this case, the public client requested an innovative approach for renewing the quay walls in Amsterdam. For this approach, both product and process innovations were needed. The innovative approach had to be developed from TRL 1 to TRL9. Consequently, the programme entailed a great deal of uncertainty for the market parties involved. Besides technological uncertainty, market parties were also unsure if their investment would result profitable. The public client decided to use the Innovation Partnership procedure as an instrument to develop, together with market parties, the required innovations. Agreements regarding the available fixed budget and Intellectual Property were made in a phase in which the TRL was still on a 2–3 level. Given the uncertainties and related high innovation risks the fixed budget understandably led to tensions between public client and contracting parties. In a comparative study between the Quay walls programme and the "Sterke Lekdijk" programme, Heming (2021) concluded, that an open budget during the development and engineering phase, followed by a fixed budget in the construction phase such as in the "Sterke Lekdijk" programme, are to be preferred for cases characterized by a High degree of innovation. The arrangement that was followed in the "Sterke Lekdijk" programme considerably decreased the uncertainty and innovation risks for the market parties. In conclusion, for projects and programmes characterized by a high degree of innovation, a Cooperation based coopetition (such as in the Ritsumasyl project) or at least a Coopetition based public client–contractor relationship is required.

### *Case 7 (Urban lighting roadmap implementation) & Case 8 (Smart way to sustainable municipal buildings): Two programmes classified as a moderate degree of innovation and with competition based coopetition (Case 7) and a coopetition based cooperation (Case 8)*

Dubois and Gadde (2002) view learning as the sine qua non of technological innovation. From a learning perspective, a programme offers the opportunity to co-ordinate, re-use

and progressively develop technology across projects over time. Dorée and Holmen (2004) have convincingly illustrated the successive development of an offshore assembly technology for large bridges across five large projects. Similarly, the technology development process in cases 7 and 8 can be characterised as a process that was designed to successively develop, implement and further upgrade incremental innovations across projects. To realise a successful business case in a long-term programme such as in cases 7 and 8, it must be possible to adjust, if necessary, the requirements and the wishes of the involved stakeholders. From a risk management perspective, a Coopetition based relationship between public client and contractor is by far preferred above a Competition based coopetition (as was applied in case 7).

Note, that some of the configurations along the three dimensions of the typology do not meet the requirements to serve as ideal types for innovation-encouraging procurements. As earlier mentioned, "Pure cooperation" on the dimension "Public client–contractor relationship", is an "empty set", since the tender regulations prescribe at least a minimum level of competition. Also, "Pure competition" on the dimension "Public client–contractor relationship" can be characterised as an empty set, since at least a minimum of coopetition between public client and contractor is required to realize innovation in civil engineering projects and programmes (Eriksson 2008). This explains why the procurement strategy for Case 5 (Vechtdal connection project) – not having any innovation-encouraging awarding procurement criteria – could be classified as "Pure competition". In case the focus on innovation is missing or less relevant, public clients may apply standard procedures and fulfil their testing role. With an increase in scope, through the merging of projects, or in case a project has a long duration, there will be room for incremental innovations and optimisations. In such cases, a public client may also support the implementation of incremental innovations that do not correspond to the standards that are used. Another configuration which may be considered as an "empty set" is the projects or programmes with a low degree of innovation and with a "Cooperation based coopetition" type of cooperation. These low-risk type of projects or programmes do not require such an intense involvement from the public client and can be realised with traditional competitive procurement procedures (Eriksson and Westerberg 2011). And, as concluded for case 6 (Quay walls programme), from an effective innovation procurement strategy perspective, also the configuration with a High degree of innovation and Competition based coopetition should be treated as an "empty set". In Table 5 a dotted line has been drawn in the cells which are considered as "empty sets".

**Guideline for selecting an innovation-encouraging procurement strategy**

This section provides a general guideline for the selection of an innovation-encouraging public procurement strategy. Depending on the type of project or programme, a different procurement strategy is suggested. Table 6 (project perspective) and 6 (programme perspective) provide an integral picture of three different Procurement Strategies: Regular procurement (Low degree of Innovation, particularly product and process improvements); Innovation oriented procurement (Moderate degree of Innovation); and Innovation driven procurement (High degree of Innovation).

Based on the conducted literature review and analysis of the case results, the most important characteristics for procurement projects (Table 6) and procurement programmes

Table 6. A general guideline for the selection of an innovation-encouraging procurement strategy for civil engineering projects.

| Project | | | | |
|---|---|---|---|---|
| | | | Procurement strategy | |
| **Initiative** | **Characteristics** | **Regular project** | **Innovation oriented project** | **Innovation driven project** |
| | Aim & objectives (project goals) | Product & process Improvements | Product & process Development | Product & process Innovation |
| | Scope | Optimizations in general | Inventory of possibilities, to develop specific parts | Focussed at specific topic/part of the project |
| | TRL level | High TRL level, Deployment phase | Moderate TRL Level, Demonstration Phase | Low TRL level, Development Phase |
| | Budget for innovation | Not Applicable | Direct or indirect (through criteria) | Separate Development budget |
| **Tendering Methods** | Procedure | Restricted/open bid procedure | Restricted bid procedure | Two staged bid procedure, special procedures (SBIR) |
| | Project delivery model | Integrated Contract | Integrated or Two staged contract | Two staged contract |
| | Awarding criteria | Quality of suggested improvements/ price ratio | Quality of suggested innovative solutions/ price ratio and Collaboration | Quality of Collaboration & Innovation competencies |
| | Pricing | In competition | In competition or fixed | Negotiated |
| **Public Client-contractor relationship** | Client–Contractor Relationship | Competition based, with separated responsibility | Competition based coopetition or Coopetition with separated responsibilities | Collaboration based coopetition with joined responsibilities |
| | Role of the Client | Supporting | Supporting or Facilitating | Participating, bearing a significant part of the risk |

(Table 7) are included. Depending on the degree of Innovation, the changes per characteristic and the steps that are required to take are specified in respectively Tables 6 and 7. Both Tables 6 and 7 show that with a higher degree of innovation and consequently higher innovation risks, public clients should be open to bear at least a part of the innovation risks. And due to the inherent uncertainties in the development process, a more intense collaboration between public client and contracting parties is required. Rather than impose conditions unilaterally in the tender contract, the aim should be to arrive at jointly supported agreements. The public client should also create sufficient space for adaptation after tendering. This is to prevent that promising solutions are excluded in advance.

As stated, Tables 6 and 7 provide a general guideline. Depending on the specific project or programme, further details need to be elaborated.

Table 7. A general guideline for the selection of an innovation-encouraging procurement strategy for civil engineering programmes.

| Programme | | | | |
|---|---|---|---|---|
| | | | Procurement strategy | |
| **Initiative** | **Characteristics** | **Regular programme** | **Innovation oriented programme** | **Innovation driven programme** |
| | Aim & objectives (long term goals) | Product & process Improvements in multiple projects | Product & process Development through subsequent projects | Product & process Innovation through subsequent projects |
| | Scope | Continuous Improvements & Optimizations | Development and implementation of promising possibilities | Innovation focussed at a specific topic |
| | TRL level | High TRL level, To be realised by projects with demonstrated technology | Moderate TRL Level, Technology developed, but still to be demonstrated in subsequent projects | Low TRL level, Technology still to be developed and demonstrated in subsequent projects |
| | Budget for innovation | Not Applicable | Integrated in total programme budget | Dedicated in total program budget |
| **Tendering Methods** | Procedure | Competitive Dialogue | Competitive Dialogue (Best Value) | Innovation Partnership, SBIR |
| | Project delivery model | Concession, DBFM | Two staged contract (Development/ Frame-work Agreement) | Two staged contract (Development/ Framework Agreement) |
| | Awarding criteria | Quality/price ratio | Quality achieving programme goals/ price ratio and Collaboration | Quality of Collaboration & Innovation Competencies, Achieving programme goals |
| | Pricing | In competition | Negotiated as business case (adjustable scope) | Negotiated as business case (adjustable scope) |
| **Public Client-contractor relationship** | Client–Contractor Relationship | Competition based, with separated responsibilities | Coopetition with separated responsibilities | Collaboration based coopetition with partly shared responsibilities |
| | Role of the Client | Supporting | Supporting and Facilitating | Pro-active, shared risk bearing of additional developments |

## Contributions and recommendations for future research

The role of demand, as an enabler and source of innovation has been a topic in innovation studies and innovation policy for quite some time (Edquist et al. 2015). Both public procurement and innovation are nowadays well-established research themes in contemporary

social science and are recognized as two essential elements in the global effort to achieve the Sustainable Development Goals of the United Nations (United Nations Environment Programme 2017; United Nations General Assembly 2015; Rolfstam 2015). In the wake of the Lisbon strategy in 2000, also EU heads of state and government identified public procurement and innovation as instruments for qualitative change, for example, to develop and implement green sustainable or energy-efficient technologies (Rolfstam 2015). However, in their review of the different streams of literature, dichotomies and typologies on public procurement with respect to inducing innovation, Lenderink, Halman, and Voordijk (2019) concluded that the various innovation approaches provided little insight into the suitability of these approaches in specific situations that are encountered in procurement practice. In line with the conclusions drawn by Lenderink, Halman, and Voordijk (2019) we have pointed out in the Introduction section of this article on the lack of a systematic overview of innovation-stimulating procurement strategies from which, depending on the specific goals and aims of a public civil engineering project or programme, an effective public procurement strategy could be selected.

The conducted multiple-case study, as described in this article, is among the first to classify the different types of innovation-encouraging procurement strategies in the field of civil engineering. Based on an extensive literature review and the multiple-case study, we were able to deduce that the selection of an effective innovation-encouraging procurement strategy, particularly depends on three important factors. These are The scope and time frame of the intended project or programme; The degree of innovation to be realized in the specific project or programme; and The level of cooperation that is required between public client and contractor(s) to realize the envisioned project or programme. Based on these three distinguished factors we were able to compose a typology consisting respectively of 15 configurations of innovation-encouraging procurement projects and 15 configurations of innovation-encouraging programmes. After a closer analysis of the configurations, the cases positioned in the typology and relevant literature, we dropped 8 of the 15 configurations of innovation-encouraging procurement projects and also 8 of the 15 configurations of innovation-encouraging programmes.

The developed typology combines and integrates the insights from three streams of research: the management of product and process innovation in the field of civil engineering (Schilling 2020; Tidd and Bessant 2018; Slaughter 1998; Lenderink et al. 2020); the insights about public client–contractor collaboration in the field of civil engineering (Love, Skitmore, and Earl 1998; Eriksson 2008; Pesämaa, Eriksson, and Hair 2009; Osipova and Eriksson 2011); and the available knowledge about the management of scope, aims and objectives to realize civil engineering projects and programmes (Morris and Hough 1987; Winch 1998; Gann and Salter 2000; Pellegrinelli 2011; Project Management Institute 2017).

The multiple case study and the literature review also helped us to design (cfm. Aken 2005; Van Aken, Chandrasekaran, and Halman 2016) a corresponding guideline for selecting a specific procurement strategy. When considering new initiatives, public clients can benefit from the developed guideline as a tool to select the most appropriate procurement strategy considering the aims, goals and objectives of their intended new project or programme.

To a large extent, civil engineering firms depend on public clients to create a market/demand for innovations (Loosemore (2015); Caerteling, Halman, and Dorée (2008); Caerteling et al. (2013); Lenderink et al. (2022)). However, Loosemore (2015) and Loosemore and Richard (2015) have also pointed out that many public clients are unwilling to pay for

innovations or lack the tools to assess and drive innovation in projects. The results of this paper indicate that to realise innovation in the field of civil engineering, an active role of the public client is essential. To encourage innovation in civil engineering projects and programmes, public clients should at least be willing to limit the financial innovation risks of the contracted parties, and to provide additional incentives, solution space and time for developing and implementing the required innovations.

Naturally, this paper is not without its limitations. First, the case study findings and the developed typology with its corresponding guideline, are based on a multiple case study consisting of eight cases in the field of civil engineering. As such, further case studies are required to establish the external validity of the findings, the developed typology and guideline. Second, the developed typology and the corresponding guideline to select an appropriate innovation-encouraging procurement strategy, provide a general direction for a procurement strategy. More detailed information on the exact scope, timeframe, goals and context of the initiatives will be required to further define and tailor an appropriate and effective procurement strategy. Addressing the research opportunities of the findings of this study in future research, could make important contributions to the understanding of the determining factors and mechanisms that influence the successful development and implementation of innovations in civil engineering projects. This will also open up opportunities to find solutions for the grand challenges our physical environment is facing.

## Acknowledgements

We thank the associate editor and two anonymous reviewers whose most valuable comments have helped us to improve the earlier versions of this manuscript.

## Disclosure statement

No potential conflict of interest was reported by the author(s).

## Funding

This work was supported by the Municipality of Eindhoven and Amsterdam in the Netherlands.

## Notes on contributors

***Bart Lenderink*** has an MSc in Construction Engineering and Management from the University of Twente, Enschede, the Netherlands. His research interest focusses on public procurement and innovation, in particular within the context of civil engineering and construction. He is a PhD-student at the University of Twente in the faculty of Engineering Technology.

***Hans Boes*** has an MSc in Public management and a BSc in civil engineering. Hans Boes is Assistant Professor at the Department of Construction Management and Engineering at the University of Twente. His research, consultancy and lecturing are in the field of public procurement, with a primary focus on the client-contractor relationship. He has advised and supported various public clients in the establishment of tender strategies on innovation and cooperation.

***Dr. Johannes I.M. Halman*** is a professor at the University of Twente in the Faculty of Engineering Technology in The Netherlands. He has an MSc in Construction Engineering from Delft University of Technology and a MSc from the Rotterdam School of Management based at Erasmus University. His PhD is in technology management and innovation was awarded by Eindhoven University of Technology. His research interests are in the field of innovation management, with a primary focus on program and project management. He has specialized in the area of risk management and has advised various multinationals on risk management within innovation processes.

***Dr. Hans Voordijk*** is Associate Professor at the Department of Construction Management and Engineering of Twente University. His expertise is in the field of supply chain management and ICT in the construction industry. He is in particular interested in adoption and diffusion of IT and VR tools in construction supply chains. Hans started his career as research assistant at Maastricht Economic Research Institute on Innovation and Technology (MERIT). He also worked as Lecturer on Production Management and International Marketing at the University of Asmara, Eritrea. Before he joined Twente University, he worked as project manager at the TNO Institute of Infrastructure, Transport and Regional Development and as Assistant Professor Organization and Strategy at Tilburg University.

***Dr. André G. Dorée*** is a Professor at the University of Twente in the Department of Construction Management and Engineering. He studied industrial engineering and management at the University of Twente and also earned his PhD in public procurement from the University of Twente. Current research interests include public procurement methods, project delivery methods, the management of innovation processes and the transition towards sustainable energy. André Dorée has been the initiator in the Netherlands of ZoARG, a program to streamline inner-city infrastructure projects with resect to subsurface utilities and also the initiator of the ASPARI (Asphalt Paving Research & Innovation) research program. He has published several articles in the fields of procurement and innovation management.

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