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A method to encourage and assess innovations in public tenders for infrastructure and construction projects

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Abstract

Purpose – Stimulating innovation in projects can contribute to achieving policy goals, addressing societal challenges and meeting objectives within programs and projects. Despite their potential, innovations are rarely included in tender assignments and evaluated in the award of civil engineering projects. One explanation for this is the perceived difficulty in triggering and objectively assessing innovations in the awarding of projects. The aim of this paper is to develop, implement and evaluated a method to encourage and assess innovations in the awarding of bridge construction projects to address this problem.

Design/methodology/approach – A design science research (DSR) approach is used to develop, implement and evaluate a method to trigger and assess innovations in tenders for bridge projects. DSR approaches are used to develop "well-tested, well-understood and well documented innovative generic designs, dealing with authentic field problems or opportunities" (van Aken et al., 2016).

Findings – The findings show that the application of the developed method in a bridge project led to the inclusion of a broad range of innovations in the tender offers. Despite the broad support for the defined criteria, there were some differences in the way the criteria were interpreted by the public procurement team and by the tenderers. Despite these differences, no legal claims were filed in court.

Practical implications – Further development and wider adoption of the method is likely to have a positive impact on the application of innovations in bridge projects. With some adjustments, the method would also be appropriate for other civil engineering and construction projects.

Originality/value – This paper contributes to the discussion on how the terms innovation and innovativeness can be operationalized and used in the literature and practice. The developed method provides definitions for assessing the degree as well as the level of innovations in tenders for bridge projects. Further, it provides a way to rank innovations and determine the additional value of the offered innovations in terms of a notional reduction in tender price. Finally, it provides insights into how to encourage innovations through public procurement in civil engineering projects.

Keywords – Procurement, Innovation, Public policy, Infrastructure, Projects, Civil engineering, Civil engineering projects

Paper type – Research paper

Introduction

Public procurement is increasingly seen as an important instrument for contributing to policy goals and in the creation of additional public value (Grandia and Meehan, 2017; Arrowsmith, 2010). Stimulating innovation in civil engineering projects can be an example of the use of public procurement as a strategic tool in innovation policy, targeting national/regional competitiveness and economic growth (OECD, 2010; Edler and Georghiou, 2007). Furthermore, the stimulation of innovation in projects through public procurement can contribute to a wide range of goals and policy objectives on various levels. On the program or organizational level, innovation can be triggered to address societal challenges, such as the increasing effects of climate change (Edquist and Zabala-Iturriagagoitia, 2012) and contribute to organizational objectives, such as the upkeep of public infrastructure and to policy goals, including sustainability and the creation of a circular economy (Witjes and Lozano, 2016; Lember et al., 2014). On a project level, innovation can be triggered to achieve specific objectives within the project and/or to obtain additional value for the money spent with respect to the tender assignment (Yeow and Edler, 2012; Leendertse et al., 2012). An example of such an objective is to design and construct a bridge using bio-based composite materials. Examples of additional value in projects are the reduction of construction-related nuisance and a decrease in the need for maintenance and the lifecycle costs of the procured civil works.

Despite strong policy support and the potential of innovations to contribute to a broad range of goals and policy objectives, innovation is rarely included and stimulated in tender documents for civil engineering and construction projects (Loosemore, 2015; Farmer, 2016; Maghsoudi et al., 2016). This lack of focus on innovation in procurement is reflected in the findings of Lember et al. (2014) who identified a clear implementation gap in innovation-oriented procurement policies in most of the countries they investigated. In addition, they found that, in practice, it was public needs and demands for innovative products and services that often served as the driver for stimulating innovation through public procurement (OECD, 2017; Lember et al., 2014).

So, why is innovation rarely included and stimulated in civil engineering and construction projects and what is needed to stimulate innovation in this kind of projects? To answer these questions a literature review on innovation in construction was first performed. Subsequently, a generic method to assess innovations in the award of bridge construction projects was developed, applied and evaluated within a bridge project in The Netherlands.

This paper is structured as follows. In the next section a review about innovation in construction is presented. This section is followed by the research method section in which the successive research steps are explained. After the research method section, the development of the assessment method in this paper is divided in three parts. First, the development of a generic method to assess innovation in tenders based on the literature review of Garcia and Calantone (2002). Second, the implementation of the assessment method in the project Bridge of Boekelo. Third, the results of the evaluation of the method and the interpretation of these results. The paper concludes with a discussion on the research contributions, the research findings and their implications, limitations and suggestions for future research, which is followed by the main conclusion.

Innovation in construction

The construction industry is often considered as an industry with a lack of innovation (Dorée and Holmen, 2004; Murphy et al., 2015; Loosemore and Richard, 2015; Xue et al., 2014). Yet, there are several studies indicating that this view on innovation in construction is negatively biased because of the way innovation is traditionally measured through R&D expenditure (Gambatese and Hallowell, 2011; Loosemore, 2015) and the exclusion of many innovations developed at the project level in such measurements (Aouad et al., 2010). In addition, the study of Brockmann et al. (2016) indicates that a lot of innovation does occur in megaprojects, which provide plenty opportunities for innovation because of their complexity. As such, they plead for a distinction between different types of projects while reporting on innovation in construction as the innovation potential is strongly affected by the type and size of the project. The relative lack of innovation can also be partly explained by some of the characteristics of the construction industry (Davis et al., 2016):

- The project-based mode of production, producing and integrating products and services in "one-offs or small batches" of final products (Rutten et al., 2009; Gann and Salter, 2000). This limited production volume makes it more difficult to earn back the investments in innovation and seems to favor process – over product – and incremental over more radical innovations from a firms perspective.
- The inter-organizational mode of production in a "loosely coupled system" (Dubois and Gadde, 2002; Dorée and Holmen, 2004), producing and integrating products and services in varying compositions of organizations across projects. As such interorganizational collaboration is considered to be important for innovation. Where suppliers are often seen as an important source of innovations (source) and the main architect/engineer and contractor provide value through the integration of innovations in the design and realization of projects (Winch, 1998).
- The relative complexity, physical scale and expected life span of the final products (Slaughter, 1998), which provide additional requirements for innovations.
- The strong influence of the client on the design and requirements of the final product and provided services (Blayse and Manley, 2004).

Last but not least, construction companies are not always fully aware of the potential benefits of innovation for increasing their technical capabilities and competitiveness as a whole (Pellicer et al., 2014; Winch, 1998). Yet, together with technical problems in projects and client requirements, the stimulation of innovation by senior management is found to be one of the main drivers for innovation in construction companies (Pellicer et al., 2014).

The importance of the role of the client in stimulating innovation has been part of many policy initiatives to improve the performance in the industry over the past decades (Egan, 1998; Latham, 1994; Farmer, 2016; Barbosa et al., 2017; Wolstenholme et al., 2009). Despite these efforts there is still considerable room for improvement, as many clients still award most of their projects based on the lowest price (Loosemore and Richard, 2015), and limit the solution space too much through the use of detailed designs and requirements (Eriksson et al., 2019). Further, they often lack the required knowledge and/or resources to stimulate and assess innovations through public procurement to meet their needs and requirements.

Together with the project- and contextual characteristics, the selection of a procurement strategy has a strong influence on the innovation potential in projects (Tawiah and Russell, 2008; Eriksson et al., 2019). Eriksson et al. (2019) identified four aspects in the procurement strategy to be of particular importance with respect to collaboration, innovation and project performance: (a) the project delivery model, (b) incentives, (c) partner selection and (d) the collaboration model.

Addressing the first of these aspects, Tawiah and Russell (2008) developed an assessment framework to aid civil servants in the selection of a procurement mode/project delivery model to increase the innovation potential in projects. Procurement modes/project delivery models can range from regular design-bid-build, to integrated contracts and public private partnerships. The developed framework is unique in that it provides civil servants a means to assess the innovation potential at the front end of a project, based on 22 project context factors, which can either inhibit or stimulate innovation.

Although the selection of an appropriate project delivery strategy is important with respect to the innovation potential in a project, this research focuses on a different challenge with respect to stimulating innovation in projects from a client perspective: The perceived difficulty in objectively assessing innovation in tenders. This challenge relates to partner selection as well as incentives for stimulating innovation in a procurement strategy.

In fact, a municipality in The Netherlands acting as a client requested two of the authors to develop a method to stimulate and assess innovation for a specific bridge project, whereas this was considered to be a major challenge in the project and the municipality lacked the knowledge to develop this within their own organization. To address this challenge, a design science research (DSR) approach was used to develop and evaluate a generic method for assessing innovations in the tendering phase of bridge projects.

Research method

The aim of DSR is to develop “well-tested, well-understood and well documented innovative generic designs, dealing with authentic field problems or opportunities” (van Aken et al., 2016). DSR investigations are driven by a field problem or an opportunity. In our study, the field problem is the perceived difficulty in objectively assessing innovations in a tendering process for bridge projects. The justification for generic designs as an outcome of DSR is underpinned by their pragmatic validity and/or the production of desired outcomes because of the implementation of the design (van Aken et al., 2016).

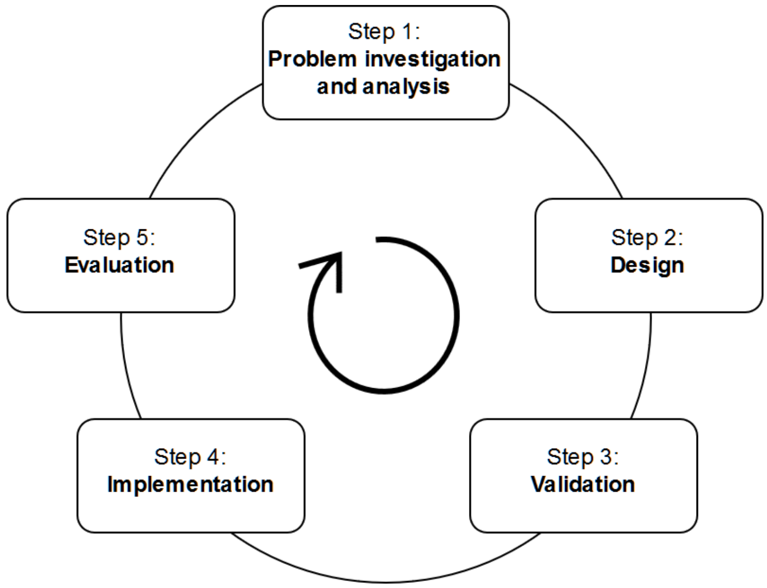

Figure 1. Cyclical design approach for the development of the method, based on (Wieringa, 2014)

A cyclical design approach, as presented in Figure 1, was used in developing a method for triggering and assessing innovations (Van Strien, 1997; Wieringa, 2014; Van Aken and Romme, 2009). The first step in the approach was problem investigation and analysis. During this step, a study was performed on why it is particularly difficult to objectively assess innovations in tender offers. Further, the context of the bridge project was investigated, including its scope, aims and objectives.

In the second step, the design requirements and the initial version of the method for assessing innovations in a tender were developed. For this, the innovation typology of Garcia and Calantone (2002) was tailored to create a method for ranking innovations based on their innovation level as well as the level of the innovation. Subsequently, the developed method was further tailored to fit within the bridge project and the associated procurement strategy.

In the third step, the design was validated through discussions with the public procurement team. This step aimed to assess: (1) if the developed method fitted with the project and procurement strategy and (2) if the developed method provides sufficient incentives for tenderers to offer innovations, which contribute to the design and realization of the bridge.

In steps four and five, the developed method was implemented and evaluated within the bridge project. Specifically, the evaluation assessed:

- the extent to which the method triggered the inclusion of innovations in the tender offers;
- the extent to which the innovations contributed to the design and construction of the bridge; and

- the extent to which the method for assessing the innovations led to differences in interpretation and discussions.

The development and implementation of the method was performed by two researchers who were also part of the assessment committee for the project tender. The data collection and the validation of the developed method was carried out by two other researchers. The analyzed data for the validation of the method consisted of project and tender documents included assessment documents of the tender offers and information notices and recordings of semi-structured interviews with various people involved from the public organizations involved as well as with the tender managers of the five tenderers in the project.

Development of the method for assessing innovations in bridge projects

To provide an operational definition, Garcia and Calantone (2002) delineated the domain of the constructs “innovation” and “innovativeness.” In their literature review, they conclude that the 1991 Organisation for Economic Co-operation and Development (OECD) study on technological innovations best captures the overall essence of innovation: “Innovation is an iterative process initiated by the perception of a new market and/or new service opportunity for a technology-based invention which leads to deployment, production, and marketing tasks striving for the commercial success of the intervention.” As Garcia and Calantone explain, this definition addresses two important aspects. First, the “innovation” process comprises the technological development of an invention combined with the market introduction of that invention to end-users through adoption and diffusion. Second, that the innovation process can be considered iterative and inevitably includes, after the initial introduction of an innovation, a reintroduction of an improved innovation. This iterative process implies there are varying degrees of innovativeness and thus necessitates a typology that can describe different types of innovation.

Garcia and Calantone (2002) propose making distinctions in the degree of newness, ranging from incremental, through really new to radical innovation and in the level of innovation i.e. macro- versus micro-perspectives. These distinctions result in a classification schema consisting of six possible combinations.

We adapted the typology on innovativeness proposed by Garcia and Calantone (2002) to the specific context of bridge projects. For this, definitions for different types of innovations, degrees of innovation and innovation scale levels were tailored to fit within the context of bridge projects.

Types of innovations

Innovation within the bridge project is defined as the development and potentially successful implementation of new ideas, products or processes in the design and realization of bridges. A distinction was made between product and process innovations:

- A product innovation is an innovative solution, which leads to a substantial improvement in the functionality of a bridge, the extension of the functionality of a bridge and/or the improvement of the technical performance of a bridge.
- A process innovation is an innovative solution to increase the efficiency of the construction process.

Examples of process innovations in bridge projects are solutions leading to:

- a substantial reduction in the necessary maintenance during the lifetime of a bridge;
- a substantial reduction in the total lifecycle costs of a bridge;
- a substantial improvement with respect to sustainability (such as a substantial reduction in CO2 emissions or circular design solutions for the materials that are used); and
- the successful application of new technologies such as 3D-printing, robotics, smart materials, self-healing materials, drones and intelligent systems for corrective and predictive maintenance.

The degree of innovation

Innovations can be classified according to the degree of innovation or the innovation level. The literature makes a distinction between radical innovations, these are completely new to the world market and realized using totally new technology; substantial innovations, which are completely new to a specific sector and realized with new technology; and incremental innovations, which are substantial improvements using an existing technology (Song and Montoya-Weiss, 1998; O'Connor, 1998; Garcia and Calantone, 2002). This differentiation of innovations, based on the degree of innovation, is in line with the models of construction innovation as suggested by Slaughter (1998). She indicates that innovation models can be found on a spectrum from incremental to radical innovations.

When applied to the bridge project the following definitions for the different degrees of innovation were used:

- radical innovations are new or only very limitedly applied worldwide solutions, which use new technology;
- substantial innovations are new or only limitedly applied solutions in the Dutch market that use new technology;
- incremental innovations are substantial improvements to existing solutions for bridges or for the bridge construction process;
- creative solutions are original solutions achieved through combining existing solutions for bridges and/or for their construction process; and
- other solutions, which are not regarded as innovations.

In consultation with the public procurement team, it was decided to include creative solutions in the assessment of innovations. This was to provide an incentive for offering original and creative combinations of existing solutions that could provide additional value to the bridge or its realization process.

Innovation scale level

In line with Garcia and Calantone (2002) and Slaughter (1998), we further distinguished three innovation scale levels for product innovations:

- an innovative solution for the bridge as a whole (system innovation);
- an innovative solution for a major part of the bridge (module innovation); and
- an innovative solution for a small part of the bridge (component innovation).

A similar distinction was made for process innovations:

- an innovative solution for multiple work packages (system innovation);
- an innovative solution for one work package (module innovation); and
- an innovative solution for a process requirement within a work package (component innovation).

Ranking the innovativeness of an innovative solution

When assessing the innovativeness of a specific solution for a new bridge one needs to rank the degree of innovation as well as the scale level on which the innovation is applied. A total innovativeness score can be provided by applying weights to both innovation dimensions. For example, the innovation degrees radical innovation, substantial innovation, incremental innovation and creative solution can be given relative weights of 9, 6, 3 and 3, respectively, and a similar weighting formula can be used for the innovation scale levels component, module and system innovation (Table I). Using these values, an incremental innovation on the module level is given an innovativeness score of 3 x 6 = 18 points, a radical innovation on the component level an innovativeness score of 9 x 3 = 27 points and a system-level radical innovation an innovativeness score of 9 x 9 = 81 points. If an offered solution is not considered to be an innovation a score of 0 points can be given.

Table I. A possible classification score of innovations

Weights	Degree of Innovation	Innovation scale level
3 points	Incremental innovation or creative solution	Component level
6 points	Substantial innovation	Module level
9 points	Radical innovation	System level

Implementation of the assessment method in a bridge project

To validate the method, it was applied in the Bridge of Boekelo project. This project consisted of the design and construction of a new bridge to replaces an old bridge on the south side of the city of Hengelo in The Netherlands. First, the context of this bridge project and the approach for encouraging innovation in this project are explained. Second, the innovation assessment method as implemented and the results of the evaluation are discussed.

Context of the bridge project

The project was part of a large area redevelopment on the south side of the city center. This area redevelopment project was carried out under a public–private partnership between the municipality of Hengelo and a real estate developer. However, for this project the municipality acted as a public client on its own. In addition to the municipality, there were several other organizations involved in the client side of the tendering process as follows. The Dutch road and waterway agency Rijkswaterstaat, which is responsible for the management and maintenance of the canal and its infrastructure including the bridges across the canal. The Province of Overijssel, who provided a subsidy to finance a large share of the project. The engineering company SWECO, which managed the tendering process including the development of the tender assignment and the associated requirements and tender documents. In addition, the city architect was involved in designing the spatial guidelines for the bridge. Finally, two researchers, also authors of this paper, were involved to develop the method to be used to trigger and assess the use of innovations in the tender offers.

The main aim of the project was to improve the accessibility, traffic flow and traffic safety of Hengelo within the time and budget restrictions of the project. The main objective in the project was to replace an old bridge with a bridge that would allow more and heavier traffic. This new bridge, with a minimum span of 44 m, should be designed and realized in accordance with the developed requirements and developed design guidelines for the bridge. The second objective in the project was to deliver the southern part of the avenue to the city center in line with design specifications. Within the project, there was a strong focus on realizing an architecturally appealing bridge of high aesthetic quality since the bridge forms the new entrance into the city from the south. Furthermore, there was a strong focus on stimulating the use of product and process innovations to obtain additional value in the design and construction of the bridge.

Triggering innovations in the bridge of Boekelo project

An integrated design and construct contract was adopted to integrate the design and construction phases of the project in a single tender assignment. The contracting authority opted for *a broad solution space* within the boundaries set in the *spatial design guidelines for the bridge*, which were predefined by the municipality. This allowed tenderers to offer a broad range of solutions and innovations with respect to the design and construction of a plate, arch or cable-stayed bridge. Moreover, tenderers were specifically *requested to include* up to three product and/or process *innovations in their tender offer* for the design and realization of the bridge. The solution space for the design and construction of the new avenue was fairly limited and the design of the avenue was not the focus of the project.

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:

- their ability to integrally perform five pre-defined core competences; and
- the extent to which candidates could convincingly prove that innovation is part of their corporate strategy and underpins their relevant achievements in the development and/or application of innovations in projects comparable to this project.

Innovation was one of the award criteria in determining the quality of the tender offers in the award phase. Other criteria in determining the quality of the tender offers were the architectural and aesthetic quality of the bridge design and the time needed to realize the project. In addition, the tender price was used as an award criterion in combination with a maximum allowable tender price of €8.2m.

An overview of the staged tender procedure with the selection and award criteria can be found in Figure 2. The contract was awarded to the tender with the lowest fictional tender price that met all the requirements of the contract. The fictional tender price ($P_{Fictional}$) is determined by subtracting the sum of additional values provided by each of the qualitative award criteria (P $\sum \mathrm{V}_{\mathrm{Additional}}$) from the offered tender price, (P_{Offered}), equations 1 and 2. According to Dreschler (2009) p. 122 and 140, this is one of the most suitable options to determine the most economical advantageous tender in the award of construction projects:

$$P_{Fictional} = P_{Offered} - \sum V_{Additional} \quad (1)$$

$$P_{Fictional} = P_{Offered} - (V_{Architectual\ and\ aesthetic\ quality\ of\ the\ bridge\ design} + V_{Innovation} + V_{Realisation\ time}) \quad (2)$$

The maximum fictional reduction allowed on the tender price was €4.25 million against a maximum allowed tender price of €8.2 million in the tender offer. The innovation award criterion accounted for €1.0 million of this €4.25 million to provide a *strong incentive* for tenderers *to include innovations in their tender offer*. Nevertheless, innovation was not the most important criterion for determining the quality of the tender offers. Rather, the architectural and aesthetic quality award criterion, with a maximum reduction of €3.0 million, was the most important criterion in assessing the quality of the offers. Reducing the realisation time had a maximum value of €0.25 million.

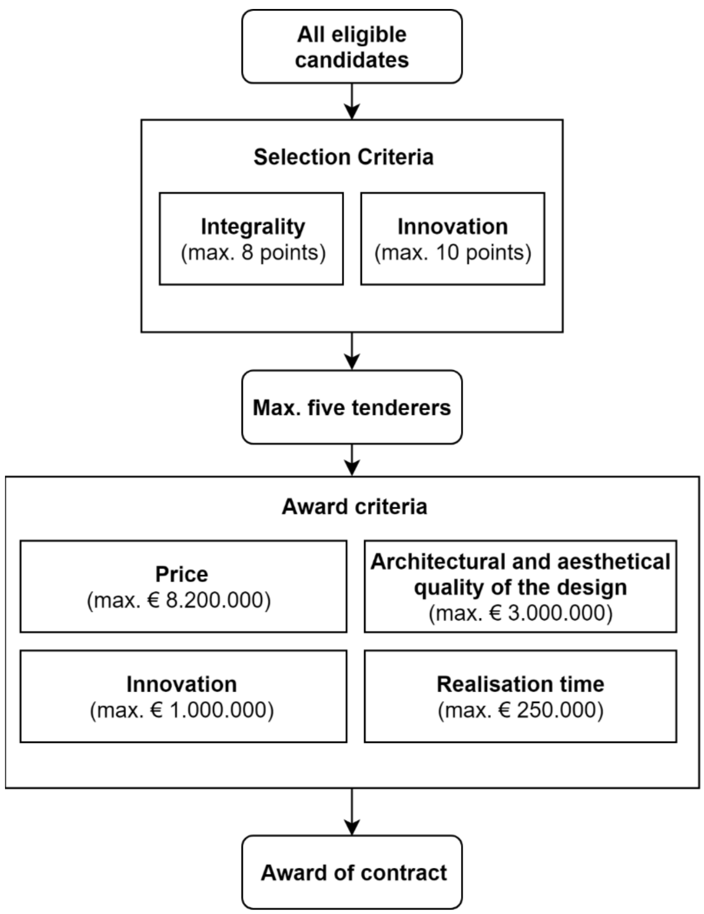

Figure 2. Overview of the tender procedure including selection and award criteria

Assessment method of innovations as implemented in the bridge project

All tenderers were requested to offer up to three innovations in their tender offer for which they could obtain a maximum e1.0m fictional reduction on their tender price. A six-step approach was used to assess the additional value of the proposed solutions offered as innovations in the tender offers:

1. assess if the proposed solutions can be considered as a product or process innovation;
2. assess the degree of innovativeness of the proposed solutions (0; 3; 6; 9 pt.);
3. assess the scale level on which the solutions are implemented (3; 6; 9 pt.);
4. multiply the degree of innovativeness by the scale level on which they are implemented to determine the score for each of offered solutions (e.g. 3*6 = 18 pt.);
5. determine the total score for the provided innovations by summing the individual scores for each innovation (e.g. 18 þ 27 þ 18 = 63 pt.); and
6. determine the added value using equation 3:

$$V_{innovation} = \frac{Total\ score\ (max.\ 90\ pt.)}{90} * \text{€}\ 1.0\ million \quad (3)$$

The possible scores for the different degrees of innovation and innovation scale levels of offered innovations, as well as the total score for individual innovations and combined score for a set of offered innovations are presented in Table II. Note that the total combined score for the three innovations was limited to 90 points for which the maximum reduction on the tender price of €1.0m would be granted.

Evaluation of the assessment method in the bridge project

The call for tenders for the Bridge of Boekelo project led to the enrolment of nine candidates in the selection phase, from which five candidates were invited to submit an offer for the tender in the award phase. All five tenderers who were invited did submit an offer for consideration in the award phase.

Table II. Possible scores for including innovations in the tender offer

Dimensions of innovation/ offered innovations	Innovation 1	Innovation 2	Innovation 3
Degree of innovation	<0;3;6;9>	<0;3;6;9>	<0;3;6;9>
Innovation scale level	<3;6;9>	<3;6;9>	<3;6;9>
Individual innovation	<0-81>	<0-81>	<0-81>
Total score (max. 90 pt.)	<0-90>		

Innovation in the tender offers

The method used to trigger the implementation of innovations in the tender offers resulted in the inclusion of nine product and six process innovations in the tender offers. Hence, each tenderer included the maximum three innovations in their offer. Of the offered innovations, two process and one product innovation were not considered as innovations based on the working definitions of innovation in the project. The reasons for this provided by the assessment committee were: a lack of underpinning of promises and guaranties, a lack of innovativeness in the provided solution and a provided solution that did not fit the working definitions for innovation with respect to the scope/focus of the project.

The average reduction granted on the tender price for the total additional quality offered was €2.45 million compared to the maximum of €4.25 million. The innovation award criterion accounted for €0.58 million of this €2.45 million. At the same time, there was a large spread in the additional value offered through the inclusion of innovations in the tender offers. The associated standard deviation for the innovation award criterion was €0.31 million.

With respect to the degree and level of innovation of the provided solutions, more than half of the solutions were assessed as creative solutions or incremental innovations at the level of a component or module innovation (Table III). Two solutions were assessed as substantial innovations on the module level, one as a substantial innovation on the system level and another as a radical innovation on the component level. Notably, none of the solutions was assessed as a radical innovation on the level of a system or module.

Table III. Assessment of innovativeness of all offered product and process innovations in the tender offers in terms of innovation scale level and degree of innovation

Innovation scale level and degree of innovation **Number of innovations** (product innovations; process innovations) (Score)	System innovation (9pt.)	Module innovation (6 pt.)	Component innovation (3 pt.)
Radical Innovation (9pt.)	**0** (0; 0) (81 pt.)	**0** (0; 0) (54 pt.)	**1** (1; 0) (27 pt.)
Substantial Innovation (6 pt.)	**1** (0; 1) (54 pt.)	**2** (2; 0) (36 pt.)	**0** (0; 0) (18 pt.)
Incremental innovations/ creative solutions (3pt.)	**0** (0; 0) (27 pt.)	**4** (1; 3) (18 pt.)	**4** (4; 0) (9 pt.)
Solution not considered as an innovation	**3** (1; 2) (0 pt.)		

Contribution of innovations to the design and construction of the bridge

Tenderers were specifically requested to include innovations in their tender offers that would contribute to the design and construction of the bridge. Most of the offered innovations contributed to the design and construction of the bridge to some extent. Those that did not were not considered as innovations within the project working definitions for innovation. Subsequently, these proposed solutions were given zero points in the assessment.

The extent and to what element of the design and construction of the bridge the offered innovations contributed to varied from innovation to innovation. Unfortunately, it is not possible to discuss in detail the offered solutions from the unsuccessful tenderers. Nevertheless, some insights into the trends in the contributions of the proposed solutions can be presented.

Overall, there were nine *product innovations* focusing on improving the functionality and technical performance of the bridge or adding additional functionalities and six *process innovations* focusing on the design and construction process. A large proportion of the product innovations included the use of *new materials* or the use of *systems related to energy* in the design of the bridge. Many of the offered process innovations focused on improving *the design process* or *monitoring the need for maintenance* of the bridge.

The tenderer to which the contract was awarded included the use of *mixed reality* as an innovative way to integrate the design and construction processes. More specifically, the bridge is designed in a 3D model and then placed on top of what can be seen in practice through the use of an Engineer and Build in Mixed Reality Solution. Second, the winning tenderer included *high weight resistant solar panels in the road surface of the bridge* to provide the energy for the lights on the bridge. The third innovation was the use of a *low temperature baked powder coating* to extend the lifespan and reduce the maintenance of *the handrails of the bridge*.

In addition, the contracted tenderer offered an innovative plate bridge design integrating the three innovations. This design led to a large reduction in the fictional tender price because of the additional architectural and aesthetic quality it provided. Nevertheless, this innovative design also required the tenderer to develop a new model to calculate the forces and the bearing capacity of the bridge. As the future owner being responsible for the design and maintenance of the bridge, the Dutch road and waterway agency also had to develop a new model to check the calculations. The development of this model caused some delay in the project. The award criterion "reduction in realization time" did not combine well with the implementation of innovations in the project as they increased the chances of delay either caused by the contractor/suppliers or the client. An important conclusion from this is that contractors and suppliers need sufficient time to deal with potential delays related to the implementation of innovations in projects.

Differences in interpretation related to the assessment method

Both the public procurement team and the tenderers indicated that the criteria for the different degrees and levels of innovation were clear and beneficial for assessing the innovations in the tender offers. Originally, the intention had been to score innovations on a continuous level from 0 to 9 but one of the tenderers requested limiting the possible scores to either 0, 3, 6 or 9 (as indicated earlier in the paper). This request was approved and implemented as it made it easier to justify the scores awarded to the proposed innovations.

Despite the broad support for the defined criteria, there were some differences in the way the criteria were interpreted by the public procurement team and the tenderers. As a result of this, there were four occasions where the tenderers indicated that they felt their offered innovations should have been scored more highly. For example, one innovation was expected to be assessed as a system-level radical innovation by the tenderer, whereas the assessment committee assessed the innovation as a substantial innovation on the module level. Even though there were such differences in interpreting the criteria, this did not lead to legal claims and the evaluations of tender offers by the public procurement team were accepted. The fact that most of the potential reduction in the tender price could be obtained

through the architectural and aesthetic quality criterion of the bridge, coupled with the significant difference between the overall scores of the winning and second-placed tenderer, may have contributed to this acceptance of the innovation scores.

Interpretation of the evaluation results

The implementation of the method in the Bridge of Boekelo project led to the inclusion of nine product and six process innovations in the tender offers. Most of these innovations were assessed as creative solutions or incremental innovations on the level of a component or module innovation. Further, the method did not trigger the inclusion of radical innovations on the level of module or system innovations. Further, 3 of the 15 offered solutions were not considered as innovations based on the working definitions.

Several factors may have limited the degree and level of the innovations offered. As expressed by some of the tenderers, the time to develop the tender offer was fairly limited for a project that was focusing on innovation. This limited the time available to assess the value and potential risks of including innovations in the tender offer. In addition, the third qualitative award criterion, focusing on reducing the realization time, increased the time pressures on the project to some extent. Given that radical innovations are more prone to bugs and/or breakdowns compared to conventional solutions and incremental innovations (Klein Katherine, 1996), one could expect time pressures to have a negative effect on the degree and level of the innovations offered.

Setting a higher maximum tender price might well have stimulated tenderers to provide more radical system-level innovations by enabling them to earn a larger return on their investments in innovations in the project. Further, many tenderers stated that the transaction costs for this project were particularly high compared to other projects of this size. According to them, a considerable amount of time and effort was required to submit an offer in the award phase, and only one tenderer would obtain a contract. Two ways to reduce the involved transaction costs for the tenderers would be to:

- limit the number of tenderers who are invited to submit offers; and
- provide reasonable compensation for the work involved in submitting an offer (Hardeman, 2014).

The developed assessment method reduced the subjectivity in the assessment of innovations to a large extent. However, some subjectivity in assessing the degree and the level of innovation in the offered solutions cannot be avoided as it is based on expert judgment. We argue that this should not be considered problematic provided the assessment committee can sufficiently justify how and why they came to their rating. In this respect, evaluation meetings with the tenderers after the tender has been awarded are important in reducing the likelihood of claims being filed in court. The same is true for the assessment, through the use of expert judgment, of designs for civil engineering projects based on predefined spatial design guidelines.

Although most of the offered innovations contributed to the design and construction of the bridge, the extent of the contribution varied from innovation to innovation. This may be explained by the fact that although the contribution of the innovations was included in the working definitions for innovation in the project, it was not used as a separate criterion for assessing the offered innovations. As such, there were no specific incentives to include innovations that made particularly large contributions to the design and construction of the bridge compared to other eligible innovations. Including a four-point scale and definitions for this criterion, similar to those for the degree and level of the innovations, might have encouraged a stronger focus on the contribution of the innovations to these aspects of the project.

Discussion

Research contributions

This study makes three research contributions. First, it contributes to the debate on how to operationalize the terms innovation and innovativeness given that these terms are used in numerous ways in the literature and in practice. The innovativeness typology proposed by Garcia and Calantone (2002) has been adapted to the specific context of innovation in bridge projects. The study provides clear definitions and examples of product and process innovations within the context of bridge projects. Further, it provides definitions to distinguish different degrees of innovativeness and levels on which product and process innovations can be applied within bridge projects.

Second, this study provides a method based on objective criteria to assess and rank innovations in tenders for bridge projects. This method applies the definitions for product and process innovations to assess if the offered solutions should be considered as an innovation within the tender. Further, it uses the definitions of different degrees of innovativeness and levels of the application to determine the additional value of the proposed innovations in terms of a fictional reduction in the tender price.

Third, the study contributes to and supports existing findings in the literature on how to stimulate and trigger innovation through public procurement in civil engineering and construction. This was achieved through explaining how tenderers were triggered to provide innovations as part of their tender offers in the case of a specific bridge project. In short, innovation was triggered in three different ways. First, by providing sufficient incentives to offer innovative solutions (Dreschler, 2009; Edquist and Zabala-Iturriagagoitia, 2012). Second, by providing sufficient solution space to offer innovative solutions (Dalpé, 1994; Uyarra et al., 2014). Third, by using innovation as a selection criterion in shortlisting tendering candidates to go forward and submit a tender offer. Fourth, by providing sufficient time in the project to deal with potential delays related to the implementation of innovations.

Main findings and their policy implications

The findings from this study suggests that it is possible to trigger and assess innovations in tenders for civil engineering projects in line with procurement regulations and their underlying values using the developed method. Inevitably, there will be some subjectivity in the assessment of innovations because of the use of expert judgment to interpret and assess innovations based on the developed working definitions for:

- product/process innovation;
- degree of innovation; and
- level on which an innovation is implemented.

Alternative to using the applied method as a whole, elements of the developed method and applied procurement strategy in the bridge project can be used as components to develop other innovation-oriented procurement strategies. For example, using innovation as a selection criterion and principles such as providing ample incentives and solution space for tenderers to provide innovative solutions could be used as part of other approaches.

The developed method has strong policy implications for procurement practice as it supports the use of public procurement to trigger and assess innovations in tenders for civil engineering projects. Moreover, the use of the proposed method can support public organizations in achieving the intended aims of their projects and in obtaining greater value for money in civil engineering projects.

Further development and wider application of the method is likely to have a positive impact on the adoption of innovations in civil engineering projects since it provides tenderers with the possibility and actively encourages them, to include innovations in their tender offers.

Limitations and future research

The proposed method has been developed, applied and evaluated within one single project in the domain of civil engineering. As such, further development and evaluation are needed to increase the validity of the results, improve the developed method and broaden its applicability. One suggestion for future research is to adapt the definitions to assess innovations in other types of civil engineering projects, such as a sluice construction or a new road project and evaluate the use of assessment method in these types of projects. Further, with some adaptations, the method may also be applicable in other domains, such as in the tendering process for utility buildings or housing projects.

The method is considered most appropriate for civil engineering projects that want to encourage the use of innovations and to offer tenderers an opportunity to test their innovative ideas in practice. In such situations, the underlying rationale is often to stimulate economic development and competitiveness in a region and/or sector. When this aim is coupled with obtaining additional value in terms of the goals of a project, policy and/or organizational level it becomes a win–win situation. However, we admit that this method is only one way to stimulate innovation in civil engineering projects, and that this method will not work for all objectives whereas different goals and objectives require different approaches.

There are at least two situations in which a different approach to stimulating innovation through procurement would be required in civil engineering projects. The first is when the development and/or procurement of one or more innovations is a project on itself (Yeow and Edler, 2012). In this case, the purpose of the project is to develop and/or procure an innovation to address a specific problem. The second is when the development and/or procurement of innovations are required to achieve the aims of the project or to address a specific problem within a project that requires an innovative solution. Since these situations focus on achieving specific aims or addressing specific problems, it would not make sense to insist that tenderers include three innovations as part of their offer and then to assess these innovations with respect to their degree of innovation and the level on which they are applied. In fact, it would make far more sense to focus on the contribution of the proposed solutions to achieve the intended project aims, or to address specific problems, in selecting the successful tender offer.

Conclusion

The relative lack of innovation in civil engineering and construction industry can partly be explained by the way innovation is traditionally measured, the characteristics of the industry as well as the type of products they produce. Moreover, innovation is rarely stimulated and included in the award of infrastructure and construction projects. One important reason for this is the difficulty, as perceived by public clients, to stimulate and objectively assess innovations in tenders for infrastructure and construction projects, often caused by a lack of knowledge and experience.

As a first step to address this challenge, a generic method to encourage and assess innovations in public tenders for infrastructure and construction projects has been developed, implemented and evaluated in a bridge project using a DSR approach. The findings from the evaluation of the developed method suggest that it is possible to encourage and assess innovation in tenders in line with procurement regulations and their underlying values using the developed assessment method. Yet, some subjectivity in the assessment of the innovations cannot be excluded because of the use of expert judgment.

The developed method is most suitable for encouraging and providing tenderers the opportunity to include and test innovations in the project as part of their tender offer. However, in cases where innovations are not ready for application and need more development, and/or in cases where innovation is necessary to address a specific challenge or problem in the project, the developed method is less suitable.

Finally, we want to stress that the use of innovation-oriented procurement strategies to contribute to the policy objectives and objectives and/or challenges within projects is still largely neglected in the literature. Given the major challenges facing us related to sustainability, the exhaustion of resources and the effects of climate change on our public infrastructure, we consider this an important topic with high policy implications that warrants further research.

References

Aouad, G., Ozorhon, B. and Abbott, C. (2010), “Facilitating innovation in construction: directions and implications for research and policy”, Construction Innovation, Vol. 10 No. 4, pp. 374-394.

Arrowsmith, S. (2010), “Horizontal policies in public procurement: a taxonomy”, Journal of Public Procurement, Vol. 10 No. 2, pp. 149-186.

Barbosa, F., Woetzel, J., Mischke, J., Ribeirinho, M.J., Sridhar, M., Parsons, M., Bertram, N. and Brown, S. (2017), Reinventing Construction: A Route to Higher Productivity, McKinsey Global Institute.

Blayse, A.M. and Manley, K. (2004), “Key influences on construction innovation”, Construction Innovation, Vol. 4 No. 3, pp. 143-154.

Brockmann, C., Brezinski, H. and Erbe, A. (2016), “Innovation in construction megaprojects”, Journal of Construction Engineering and Management, Vol. 142 No. 11, pp. 4016059.

Dalpé, R. (1994), “Effects of government procurement on industrial innovation”, Technology in Society, Vol. 16 No. 1, pp. 65-83.

Davis, P., Gajendran, T., Vaughan, J. and Owi, T. (2016), “Assessing construction innovation: theoretical and practical perspectives”, Construction Economics and Building, Vol. 16 No. 3, pp. 104-115.

Dorée, A.G. and Holmen, E. (2004), “Achieving the unlikely: innovating in the loosely coupled construction system”, Construction Management and Economics, Vol. 22 No. 8, pp. 827-838.

Dreschler, M. (2009), Fair competition: how to apply the ‘economically most advantageous tender’(EMAT) award mechanism in the Dutch construction industry, Delft University of Technology, TU Delft.

Dubois, A. and Gadde, L.-E. (2002), “The construction industry as a loosely coupled system: implications for productivity and innovation”, Construction Management and Economics, Vol. 20, pp. 621-631.

Edler, J. and Georghiou, L. (2007), “Public procurement and innovation—resurrecting the demand side”, Research Policy, Vol. 36 No. 7, pp. 949-963.

Edquist, C. and Zabala-Iturriagagoitia, J.M. (2012), “Public procurement for innovation as missionoriented innovation policy”, Research Policy, Vol. 41 No. 10, pp. 1757-1769.

Egan, J. (1998), Rethinking Construction, Construction Task Force Report for Department of the Environment, Transport and the Regions, HMSO, London.

Eriksson, P.E., Leentje, V., Anna, K., Sofia, L., Johan, L. and Lilly, R., (2019), “Collaborative procurement strategies for infrastructure projects: a multiple-case study”, Proceedings of the Institution of Civil Engineers - Management, Procurement and Law, Vol. 172 No. 5, pp. 197-205.

Farmer, M. (2016), Modernise or Die: The Farmer Review of the UK Construction Labour Market, Construction Leadership Council, London.

Gambatese, J.A. and Hallowell, M. (2011), “Factors that influence the development and diffusion of technical innovations in the construction industry”, Construction Management and Economics, Vol. 29 No. 5, pp. 507-517.

Gann, D.M. and Salter, A.J. (2000), “Innovation in project-based, service-enhanced firms: the construction of complex products and systems”, Research Policy, Vol. 29 Nos 7/8, pp. 955-972.

Garcia, R. and Calantone, R. (2002), “A critical look at technological innovation typology and innovativeness terminology: a literature review”, Journal of Product Innovation Management, Vol. 19, pp. 110-132.

Grandia, J. and Meehan, J. (2017), “Public procurement as a policy tool: using procurement to reach desired outcomes in society”, International Journal of Public Sector Management, Vol. 30 No. 4, pp. 302-309.

Hardeman, S. (2014), Transactiekosten aanbesteden: Effecten van aanbestedingswet en marktdynamiek: Economisch instituut voor de Bouw.

Klein Katherine, J. (1996), “The challenge of innovation implementation”, Academy of Management Review, Vol. 21 No. 4, pp. 1055.

Latham, M. (1994), Constructing the Team: final Report of the Government/Industry Review of Procurement and Contractual Arrangements in the UK Construction Industry, HMSO, London.

Leendertse, W., Arts, J. and De Ridder, H. (2012), “How can procurement contribute to network performance? streamlining network, project and procurement objectives”, Procedia - Social and Behavioral Sciences, Vol. 48, pp. 2950-2966.

Lember, V., Kattel, R. and Kalvet, T. (2014), Public Procurement, Innovation and Policy: International Perspectives, Springer Science and Business Media.

Loosemore, M. (2015), “Construction innovation: Fifth generation perspective”, Journal of Management in Engineering, Vol. 31 No. 6, pp. 04015012.

Loosemore, M. and Richard, J. (2015), “Valuing innovation in construction and infrastructure: Getting clients past a lowest price mentality”, Engineering, Construction and Architectural Management, Vol. 22 No. 1, pp. 38-53.

Maghsoudi, S., Duffield, C. and Wilson, D. (2016), “Innovation in infrastructure projects: an Australian perspective”, International Journal of Innovation Science, Vol. 8 No. 2, pp. 113-132.

Murphy, M.E., Perera, S. and Heaney, G. (2015), “Innovation management model: a tool for sustained implementation of product innovation into construction projects”, Construction Management and Economics, Vol. 33 No. 3, pp. 209-232.

O’Connor, G.C. (1998), “Market learning and radical innovation: a cross case comparison of eight radical innovation projects”, Journal of Product Innovation Management: An INTERNATIONAL PUBLICATION oF the PRODUCT DEVELOPMENT and MANAGEMENT ASSOCIATION, Vol. 15, pp. 151-166.

OECD (2010), The OECD Innovation Strategy: Getting a Head Start on Tomorrow, OECD publishing, Paris. OECD (2017), Public Procurement for Innovation.

Pellicer, E., Yepes, V., Correa, C.L. and Alarc on, L.F. (2014), “Model for systematic innovation in construction companies”, Journal of Construction Engineering and Management, Vol. 140, pp. B4014001.

Rutten, M.E., Dorée, A.G. and Halman, J.I. (2009), “Innovation and interorganizational cooperation: a synthesis of literature”, Construction Innovation, Vol. 9 No. 3, pp. 285-297.

Slaughter, E.S. (1998), “Models of construction innovation”, Journal of Construction Engineering and Management, Vol. 124 No. 3, pp. 226-231.

Song, X.M. and Montoya-Weiss, M.M. (1998), “Critical development activities for really new versus incremental products”, Journal of Product Innovation Management, Vol. 15, pp. 124-135.

Tawiah, P.A. and Russell, A.D. (2008), “Assessing infrastructure project innovation potential as a function of procurement mode”, Journal of Management in Engineering, Vol. 24 No. 3, pp. 173-186.

Uyarra, E., Edler, J., Garcia-Estevez, J., Georghiou, L. and Yeow, J. (2014), “Barriers to innovation through public procurement: a supplier perspective”, Technovation, Vol. 34 No. 10, pp. 631-645.

van Aken, J., Chandrasekaran, A. and Halman, J. (2016), "Conducting and publishing design science research: Inaugural essay of the design science department of the journal of operations management", Journal of Operations Management, Vol. 47, pp. 1-8.

Van Aken, J.E. and Romme, G. (2009), "Reinventing the future: adding design science to the repertoire of organization and management studies", Organization Management Journal, Vol. 6 No. 1, pp. 5-12.

Van Strien, P.J. (1997), "Towards a methodology of psychological practice: the regulative cycle", Theory and Psychology, Vol. 7, pp. 683-700.

Wieringa, R.J. (2014), Design Science Methodology for Information Systems and Software Engineering, Springer.

Winch, G. (1998), "Zephyrs of creative destruction: understanding the management of innovation in construction", Building Research and Information, Vol. 26, pp. 268-279.

Witjes, S. and Lozano, R. (2016), "Towards a more circular economy: Proposing a framework linking sustainable public procurement and sustainable business models", Resources, Conservation and Recycling, Vol. 112, pp. 37-44.

Wolstenholme, A., Austin, S.A., Bairstow, M., Blumenthal, A., Lorimer, J., McGuckin, S., Rhys Jones, S., Ward, D., Whysall, D. and Le Grand, Z. (2009), Never waste a good crisis: a review of progress since Rethinking Construction and thoughts for our future.

Xue, X., Zhang, R., Yang, R. and Dai, J. (2014), "Innovation in construction: a critical review and future research", International Journal of Innovation Science, Vol. 6 No. 2, pp. 111-126.

Yeow, J. and Edler, J. (2012), "Innovation procurement as projects", Journal of Public Procurement, Vol. 12 No. 4, pp. 472-504.

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