Governing and Coordinating Large-Scale Societal Assignments in Project-Based Polycentric Systems:

Towards a Participatory and Programmatic Approach for the Dutch Rehabilitation Assignment of Civil Engineering Structures

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Abstract - The Dutch civil engineering sector is facing a large-scale rehabilitation assignment of their civil engineering structures, that consists of complex projects that lead to cost overruns and time delays. As a consequence thereof, the sector as a whole must realise a productivity growth to match the required capacity and complexity. Criteria such as innovation, knowledge dissemination and digitisation have a positive effect on productivity growth. However, barriers such as current rules & regulation, individual interests and short-term competition result in collective action problems. Furthermore, the sector is characterised as a polycentric system that consists of multiple autonomous yet interdependent public and private actors with diverging interest. These aspects the challenges of the rehabilitation assignment. Therefore, there is a need for governance and coordination that is able to facilitate collective action. This article presents a novel conceptual framework of governance and coordination is that is able to address the challenges of the rehabilitation assignment. More specifically, the framework combines programme management, process management, polycentric systems, hybrid organisational structures and participatory systems to facilitate collective action.

Keywords: Civil infrastructures, Governance, Coordination, Programme Management, Design, Organisations, Transition, collective action, polycentric systems

1. Introduction

The Dutch civil engineering sector as a whole is at the forefront of a large-scale rehabilitation assignment of its many civil engineering structures which are distributed across the Netherlands – in particular bridges and viaducts. The purpose of rehabilitation is to ensure that the infrastructure is futureproof and the operational demand is met. More specifically, engineering structures are confronted with deferred maintenance that, if not dealt with, may lead to unexpected downtime. While simultaneously, changing functional and structural requirements as a consequence of changing use conditions and societal demands (Hertogh et al., 2018). Take for example the increasing weight of freight transport, the advance of smart mobility and the circular economy. In a way the infrastructure's operational demand changes over time and the civil infrastructure must adapt – referring to the civil engineering structures themselves as well as their control and management (figure 1).

The Dutch civil engineering sector

The civil engineering sector is responsible for the control and management of the infrastructure and roughly consists of asset owners, asset managers and service providers (Volker et al., 2012). Being a public infrastructure, it is owned and managed by public actors (governments and government agencies) whereas part of the management and work is publicly procured to service providers whom are private actors conform European and Dutch public procurement law resulting in competition and lacking trust (Doree, 2004; Beuter, 2005). Service providers include but are not limited to contractors, engineering consultancies and suppliers – each of which play an important role in the construction supply chain. Furthermore, in the case of the Netherlands, the civil infrastructure is institutionally fragmented across multiple national, regional and local public authorities (also known as contracting authorities) whom share no hierarchical relationship (Huitema et al., 2009) and are thus considered as autonomous actors.

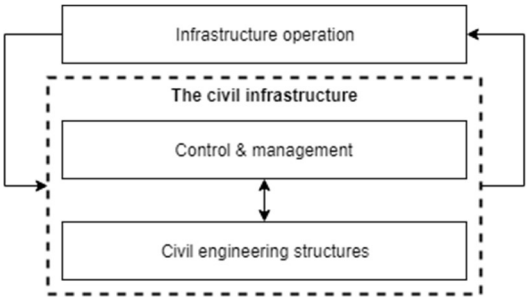

Figure 1: Infrastructure system emphasizing on the relationship between the control and management of civil engineering structures on one hand, and the infrastructure operation on the other. Adopted from Bouwmans & Weijnen (2006)

Complexity of the rehabilitation assignment

The sector is overwhelmed by a large number of complex rehabilitation projects. This is reflected by the schematisation of scenario 1 presented in figure 2. The inability to deal with complexity in projects is attributed to causing cost overruns and time delays (Jalali Sohi et al., 2016). Particularly in the Netherlands, the majority

of construction projects are confronted with cost overruns and time delays (ABN AMRO, 2019). As a consequence thereof, the sector as a whole should become more innovative, develop and share knowledge, realise an overall productivity growth and reduce uncertainties to match the required capacity and complexity associated with the rehabilitation assignment. This desired state is reflected by the schematisation of scenario 2 in figure 2, yet organising for such a scenario requires sector-wide cooperation and coordination. However, this is difficult to accomplish in the Dutch civil engineering sector (CoBouw, 2019c; 2020).

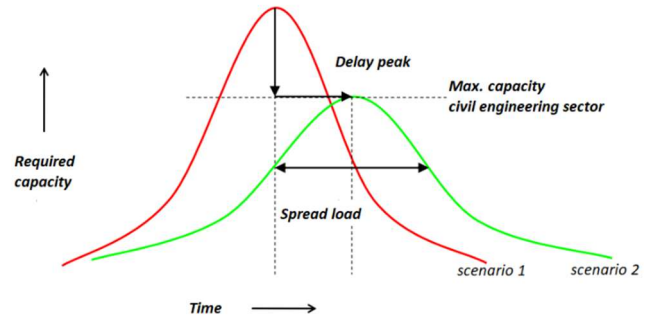

Figure 2: Schematisation of the required capacity of the civil engineering sector for the rehabilitation assignment as a function of time. Two alternative scenarios representing the current situation of (scenario 1) and desired situation (scenario 2) adapted from Molenkamp (2018).

Indeed, societal assignments – such as the rehabilitation assignment – characterised by their social and institutional complexity and uncertainty (Rittel & Webber, 1973; Head, 2008). Furthermore, additional characteristics are associated to this societal challenge (Mertens, 2015) that add to social and institutional complexity and uncertainty:

1. There is a finite and shrinking time horizon within which action is possible.
    - Deferred maintenance needs to be dealt with in time to reduce the risk of structural failure;
    - Needs and desires of infrastructure operation are changing.
2. There are multiple government bodies involved that are responsible for their own infrastructure policy and multiple private actors that act on behalf of their own interests.
    - In the absence of a central authority there is no hierarchical relationship between actors that is able to direct a course of action.

Additionally, the sector's project-based nature hampers across project coordination and multi-actor collaboration. Therefore for the sector to be able to move from scenario 1 to scenario 2, appropriate governance and coordination is desired to overcome such collective action problems and to deal with the project-based nature of the civil engineering sector.

The rehabilitation assignment's challenges

On the basis of the aforementioned information, the following challenges related to the rehabilitation assignment and the characteristics of the Dutch civil engineering sector are identified:

1. Large number of rehabilitation projects due to changing deferred maintenance, and functional and structural requirements;
2. High project complexity;
3. Social and institutional complexity due to short time horizon and decentralised institutional character;
4. Lack of trust and high degree of competition.

1.1 Problem definition

Overcoming these challenges and moving towards the second scenario, good governance and coordination across the civil engineering sector is necessary. Nevertheless, finding a suitable governance and coordination strategy that is compatible with the characteristics of the civil engineering sector is not trivial. That is due to the absence of hierarchical relationships among actors, the existence of diverging interests and the project-based nature of the sector. Therefore, the following research question was formulated:

Can governance and coordination be designed to address the challenges of the rehabilitation assignment? And how?

1.2 Premise of this study

The purpose of this article is on one hand to persuade the Dutch civil engineering sector to rethink their organisational structure and in such a way become more innovative and productive system that transcends contemporary project-based approaches. On the other hand, to contribute to the current knowledge-base by synthesising existing theoretical perspectives into a new system design based on participatory systems thinking principles. As such, this study puts forth the design of a multi-perspective conceptual framework for the development and operationalisation of governance and coordination by taking into account the characteristics and existing trends of the Dutch civil engineering sector. The framework aims to contribute to existing efforts with respect to the rehabilitation assignment. This design fundamentally leverages on the advances in modern Information and Communications Technologies which opens up new opportunities for rethinking organisational structures emphasising on

participation and co-creation instead of delegation and information retention. This article regards the rehabilitation assignment and its challenges as a known problem whereas the contribution put forth in this article an innovative solution. Therefore, in accordance with Gregor & Hevner (2013), the designed artefact is considered to be an improvement to the existing state of knowledge.

Remainder of this article

The remainder of this article is based on the Design Science Research guidelines presented by Gregor & Hevner (2013). More specifically, an overview of the literature that substantiates the framework's design is presented in section 2. The research methodology is presented in section 3. Subsequently, section 4 presents a thorough description of the artefact design; in particular, the conceptual framework of governance and coordination. Then, in section 5 the evaluation and justification of the designed conceptual framework. Finally, in section 6 the article is concluded and the results are discussed accordingly.

2. Literature Review

Prior to elaborating the conceptual framework's design, it is important to explicate the particular characteristics of project-based industries, and existing descriptive and prescriptive theoretical perspectives that comprise the foundation of the framework's design philosophy.

2.1 The civil engineering sector as a project-based industry

The construction industry, within which the civil engineering sector is positioned, is referred to as a production system characterised by its inefficient, fragmented, project-based and demand (pull) driven approach (Vrijhoef & Koskela, 2005). According to the definition of Turner & Muller (2003) a project is defined as *"a temporary organisation to which resources are assigned to undertake a unique, novel and transient endeavour managing the inherent uncertainty and need for integration in order to deliver beneficial objectives of change"*. Consequently, since the construction industry has a strong project focus, projects share few connections with other projects complicating across-project coordination and interorganisational collaboration; thus hampering long-term productivity, innovation and learning (Dubois & Gadde, 2002).

Stimulating these traits is essential to the rehabilitation assignment since the development and diffusion of new codified knowledge leads to (endogenous) productivity growth (Romer, 1990). More specifically, the obtained knowledge and innovations are adopted in other project processes resulting in more variation and selection leading to the evolution of knowledge and innovations (Rip, 2018). Winch (1998) mentions two sources of innovation in projects, both originating from the 'environment'; he suggests that innovation may occur either through adoption and implementation of existing innovations, or as a consequence problem solving and learning (figure 6).

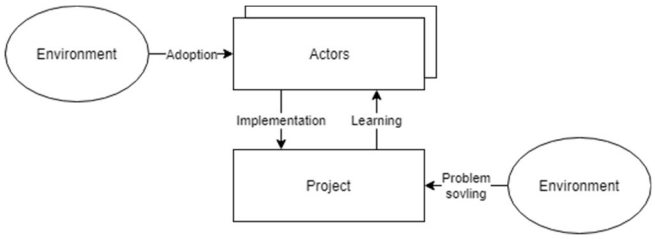

Figure 3: Two innovation mechanisms: innovation adoption and innovation through problem solving. Adopted from Winch (1998)

Problem solving in a project leads to innovation and learning by the project's temporary organisation consisting of the involved actors. The new innovation or obtained knowledge, in turn, leads to adoption and implementation of the innovation by other actors through diffusion. Adoption is the decision of actors to integrate new innovations and knowledge in their organisation and implemented in concurring and future project. Whereas diffusion is the rate with which the innovation and knowledge is adopted by other actors (Rogers, 2010). However, the project-based characteristics of the Dutch civil engineering sector complicates the adoption and diffusion of innovation and knowledge across projects. Therefore, initiatives such as 'de Bouwagenda', 'marktvisie' and 'DigiDealGO' have emerged to increase the shared connections between projects and organisations within the sector with the purpose to stimulate digitisation, standardisation, innovation and knowledge dissemination through cultural, organisational and institutional reform (Bletsis, 2020).

2.2 The civil engineering sector as a polycentric system

The autonomy of the involved actors in the civil is associated with the decentralised institutional character. Thus, the Dutch civil engineering sector is characterised as a polycentric system. Polycentric systems, according to Vincent Ostrom et al. (1961) refer to systems that involve multiple interdependent public and private actors that formally have their own decision-making power; interdependent *"to the extent that they take each other into account in competitive relationships, enter into various contractual and cooperative undertakings or have recourse to central mechanisms to resolve conflicts"*. Consequently, in contrast to hierarchical governance, Elinor Ostrom (2009 p.409) promotes

polycentric governance as a method for governing such systems, since the fitting of institutions to specific settings is crucial for the performance of such systems.

Given that the civil engineering sector consists of both public and private spheres, the rehabilitation assignment requires new approaches that stimulate entrepreneurship and public development respectively such that they may lead to joint outcomes able to solve collective action problems through self-organisation while reducing strategic behaviour (opportunism) (E. Ostrom, 2008). The resolution of such collective action problems requires groups with a shared interest, repeated deliberation across actors to create new rules and norms, and coordination-, monitoring- and conflict resolution mechanisms (Baldwin et al., 2018).

Addressing the challenges associated with the rehabilitation assignment requires collective action within a multi-actor system consisting of diverging interests (van Bueren et al., 2003; Head & Alford, 2015; Chester, 2019). Collective action is defined as the coordinated action taken by a group of actors that benefits their individual and collective interests (Encyclopaedia Britannica, n.d.). However, if it is impossible for the actor's interests to converge, collective action is not feasible. Such a situation is defined as a collective action problem – i.e. the inability for collective action to occur due to the diverging interests of the involved actors (Encyclopaedia Britannica, n.d.; E. Ostrom, 2008).

2.3 A programmatic organisation of the rehabilitation assignment

A programme, according to Turner and Muller (2003), is defined as a *"a temporary organisation in which a group of projects are managed together to deliver higher order strategic objectives not delivered by any of the projects on their own"*.

Rijsdijk et al. (2016) suggests that complex projects should be divided into sub-projects and managed collectively as a programme in order to cope with complexity and continuously evolving contexts. As such, programmes are characterised by their scalability, flexibility and adaptability as they often evolve into maturity over time and not all of the programme's projects are executed synchronously (Lycett et al., 2004). Adaptability and the ability to generate learning effects across projects and organisations are considered to be important benefits of a programme approach (van Herk et al., 2013; Rijke et al., 2014; Hertogh et al., 2018). Both adaptability and learning manifests in the implementation and execution of programme stages while maintaining feedback loops within the programme's organisation (van Herk et al., 2013). The programme's lifecycle stages are initiation, design, delivery and closure (Lycett et al., 2004; Haughey, 2009).

Furthermore, due to their scale, programmes can boost innovation and as such provide standardised solutions and leverage more sophisticated project delivery methods (Hertogh et al., 2018). Interorganisational cooperation across project boundaries and stable interorganisational relationships are drivers for innovation and innovation adoption respectively (Rutten et al., 2009). Similarly, Doree & Holmen (2004) suggest that collaboration between actors and coordination across-projects – between concurring and sequential projects – facilitates innovation. Hence, programmes are facilitators of innovation diffusion and adoption across projects.

Therefore, this article suggest that the rehabilitation assignment should be organised as a programme in as a polycentric system – i.e as a rehabilitation programme; however, in polycentric systems hierarchical governance is ineffective and does not facilitate collective action.

Nevertheless, traditionally, programmes hierarchically governed by a Programme Management Office that facilitates the coordination, support and control of projects within the programme that leads to programme success by means of improving the information, cooperation and allocation quality, and average project success (Unger et al., 2012). Moreover, Programme Management Offices are deeply embedded in its host-organisation and thus also highly influenced by its politics (Hobbs et al., 2008).

Drawing from the Room for the River programme, Rijke et al. (2014) indicate that multi-level governance, involving both central and decentral steering is in the case of a large infrastructural programme in the Dutch civil engineering sector, is more effective than strict top-down (hierarchical) control. Therefore, it is essential for the actors within the programme to agree upon an appropriate mode and levels of governance. Such that a programmatic approaches in a polycentric system lead to collective action and effective programme delivery; while simultaneously retaining sufficient autonomy among the involved public and private actors.

2.4 Alternative organisational structures

Menard (2012), defines three broad categories of organisational structures that govern the interactions among actors dependent on the degree of autonomy the actors wish to retain; namely, market, hybrid and hierarchical structures. Polycentric programmes naturally lean towards a hybrid organisational structure – given that the actors wish to retain their autonomy yet engage in some form of cooperation. In situations where coordination and long-term cooperation is desired, more

long-term oriented relational contracts are preferred over short-term transactional contracts (Menard, 2012).

Especially in situations with diverging or even conflicting interests among a set of diverse autonomous actors, a high degree of coordination is necessary (van Bueren et al., 2003). This way, collective action problems are overcome through participation in the sense that actor networks emerge in which actors forge interdependent (social) relationships leading to innovation and knowledge development and sharing (Dhanaraj & Parkhe, 2006; Menard, 2012). In order to maintain cohesion among participating actors within the hybrid organisational structure, different governance structures may be exploited depending on the characteristics of the system – i.e. the degree to which actors are willing to sacrifice autonomy. For instance a pure network governance structure (Jones et al., 1997) or allocating a certain degree of coordination to a central entity – under the premise that this is mutually agreed upon – such as third-party coordination or a strategic centre (Menard, 2012). In network governance a policy network is formed in which the interdependent and participating actors self-organise into a network in which policies are derived through deliberation (Klein & Koppenjan, 2000).

2.5 Collective action: organising for participation

Participatory systems thinking is a new design paradigm based on the premise that connectivity enabled by technology is causing a transition towards a networked society where participation is becoming an important factor influencing the way actors govern, coordinate and act within systems (Participatory systems, n.d.). Similarly, the Dutch civil engineering sector is experiencing a transition towards the need for connectivity across organisational boundaries and projects to share and adopt knowledge and innovation is becoming increasingly important.

A participatory system is a part of a distributed large-scale and networked sociotechnical system, and enabled by ICT. Such systems consists of interdependent and interwoven social, communications and technical systems (figure 4) that aim to stimulate targeted actors to establish trust and to engage, self-organise and coordinate activities such that the collective mission is achieved with explicit and/or implicit benefits for the larger distributed system it is embedded in (Participatory systems, n.d.; Brazier, 2011; Rezaee et al., 2013; 2015; van Kooten et al., 2018). Therefore, resulting in a manifestation of collective action (table 1).

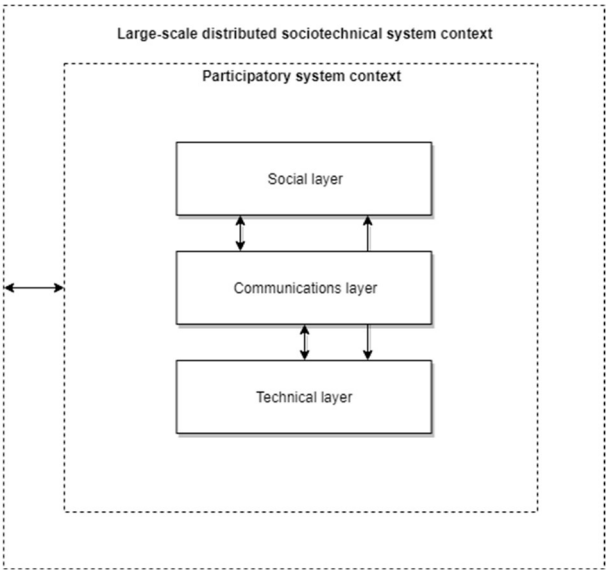

Figure 4: Three-layered architecture of a participatory system and its environment (adopted from Rezaee, 2013)

Effective coordination leads to shared situational awareness, innovation, information availability, collective action and reduces uncertainties (van Bueren et al., 2003; Kurapati et al., 2012; Head & Alford, 2015) that occur in the programme lifecycle stages.

Table 1: Participatory systems are designed for trust, autonomy and interaction. These requirements are mapped onto the rehabilitation programme that is characterised by the theoretical concepts presented in this section. The design requirements are adopted from: the participatory systems initiative (n.d.)) The information is the author's own elaboration.

Mapping of participatory design requirements onto the rehabilitation programme		
Design for:	**Requires:**	**Rehabilitation programme:**
Trust	Social acceptance, transparency & security	The process leading to programme design should be transparent & invoke trust through social acceptance by its participants.
Autonomy	Empowerment, self-management & self-regulation	Actors should be able to remain autonomous, establish rules & self-organise themselves within the programme.
(Inter)-action	Engagement & collaboration	Interdependencies and interoperation among actors should enable them to initiate collaboration & collective action.

Therefore, coordination positively contributes to the programme's performance (Rijke et al., 2014). Recent advancements in ICT facilitate across-project coordination such as virtual organisations (Evaristo & Fenema, 1999) and industry 4.0 technologies (Dallasega et al., 2018). Shared situational awareness leads to better actual contextual information and better collective decision-making within the system; implying the ability to participate in joint corrective actions, and adapt while a problem occurs in the system (Kurapati et al., 2012; Priya Datta & Christopher, 2011).

2.6 Literature synthesis

The abovementioned subsections present a knowledge base that suggests solution directions with which the challenges of the rehabilitation assignment are addressed. First, programmes are hierarchically governed and coordinated by means of a Programme Management Office. Given the polycentric characteristics, an organisational structure is needed that is able to retain a sufficient degree of autonomy and decentralised coordination while facilitating the establishment of long-term collaborative practices. Such structures are hybrid organisational structures of which their embodiment is dependent on the system's characteristics. Second, for collective action to be possible, collective action problems need to be resolved. Thus, also implying that the process leading to the design of the rehabilitation programme needs to facilitate iterative deliberation and participation of the involved actors. This complication is resolved by introducing a process design consisting of multiple decision-making rounds in combination with empowering participation through trust, self-organisation and network governance.

3. Method

Given that the challenges associated with the rehabilitation assignment of civil engineering structures is a contemporary and high profile problem in the civil engineering sector of the Netherlands, there was, and still is, no consensus on a solution. Hence, the 'solution direction' of dealing with these challenges proposed by the civil engineering sector is dynamic and evolving rather than static. Doing research and participating in such a dynamic environment involved constructing and reconstructing knowledge as a consequence of changing perceptions. Therefore, the research approach comprised of multiple iterations; as such by learning about the framework of ideas, methodology and area of concern through action research (Checkland & Holwell, 1997).

Critical systems thinking is used as a research paradigm; where both soft and hard systems thinking approaches are utilised (Jackson, 2001; 2003 p. 301). On the one hand, soft systems thinking for researching and expressing the problematical situation and the design validation by means of Qualitative Data Analysis (Braun & Clarke, 2006). On the other hand hard systems thinking for the design-process of the conceptual framework as an improvement from a functional perspective.

3.1 Design methods

For the design of the conceptual framework, a three-dimensional engineering perspective is adopted that incorporates process, institutional and technical design perspectives (Herder, 2010 p.12). Thus, instead of only focussing on one dimension, it synthesises all three into a coherent design. In the rehabilitation assignment the social dimension in particular plays a crucial role. Therefore, the emphasis is put on the process and institutional design perspectives (figure 5).

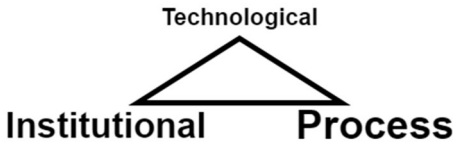

Figure 5: The TIP triangle visualises a three-dimensional engineering perspective and emphasises the design focus of the conceptual framework. In this article the emphasis is on the institutional and process designs and thus the "institutional" and "process" perspectives of the triangles are of a larger font.

As a general design process, systems engineering principles were applied and requirements formulated (Brazier et al., 2018). Regarding the methods used for the design perspectives, first, the process design complies with the literature on process management (de Bruijn et al., 2010). Second, the institutional and technical design complies with an adapted version of the alignment perspective as described in institutional economics literature (Koppenjan & Groenewegen, 2005; Kunneke, 2009; 2013) and principles of participatory systems thinking (Brazier, 2011).

Adapted alignment perspective

The alignment perspective as described by Kunneke (2009; 2013), is a framework with levels of abstraction (access, governance and coordination) that facilitates cohesiveness of institutional and technological designs such that the system's critical functions (control, capacity, interoperation, interconnection) to achieve the system's objectives. As such, the expected system performance is satisfied. In this article, the alignment perspective is adapted to better fit the concepts of programmes and participation (figure 6).

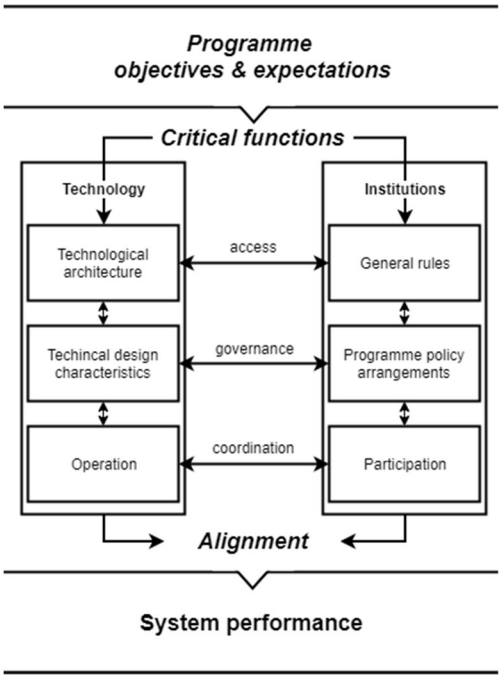

Figure 6: The alignment perspective (Kunneke, 2013) adapted to the context of programmes (author's own deliberation)

4. Artefact Description

The designed conceptual framework of governance and coordination is in part based on the requirements that are drawn from the previous section. The full set of requirements obtained from Bletsis (2020) – the in-depth study on which this article is based. The following mission statement was formulated:

"To engage the civil engineering sector in participative processes for the development and operation of a polycentric approach that stimulates collective action and anticipates uncertainties with the aim of addressing the challenges in the rehabilitation assignment more productively"

The rest of this section will explicate the design in more detail. By briefly touching upon the framework's superstructure and process design and describing the programme's institutional and technological design.

4.1 Superstructure of the programme process

Moreover, the framework consists of a superstructure (figure 7). At the core lies the programme's lifecycle that represents sequential modulations of the programme process – consisting of four stages each with their own rationale and coordination. At first the programme should be initiated by a core coalition, afterwards the programme is developed according to the set objectives and expectations (design). Subsequently the programme is operationalised (delivery) after which it is closed in the final stage (closure). The programme's organisation may continue to evolve when the collective mission is redefined; however, the goal of the programme is to accomplish a set of objectives. The governance element of the superstructure coordinates the lifecycle in its entirety. This design describes governance as a dynamic element, co-evolving with the programme process as they interact and adapt with one another overtime. Furthermore, adaption occurs as a consequence of changing contexts and organisational learning processes.

On a final note on governance, process design guides the development of governance structure and processes by means of network governance. Thus, as the lifecycle continues towards the delivery stage, the governance includes the designed organisational structure(s) and rules-in-use.

4.2 Institutional and technological design

Besides the programme process and development, the institutional and technological designs are provided at all three abstraction levels. The specific design-choices should be interpreted as guidelines informed by the

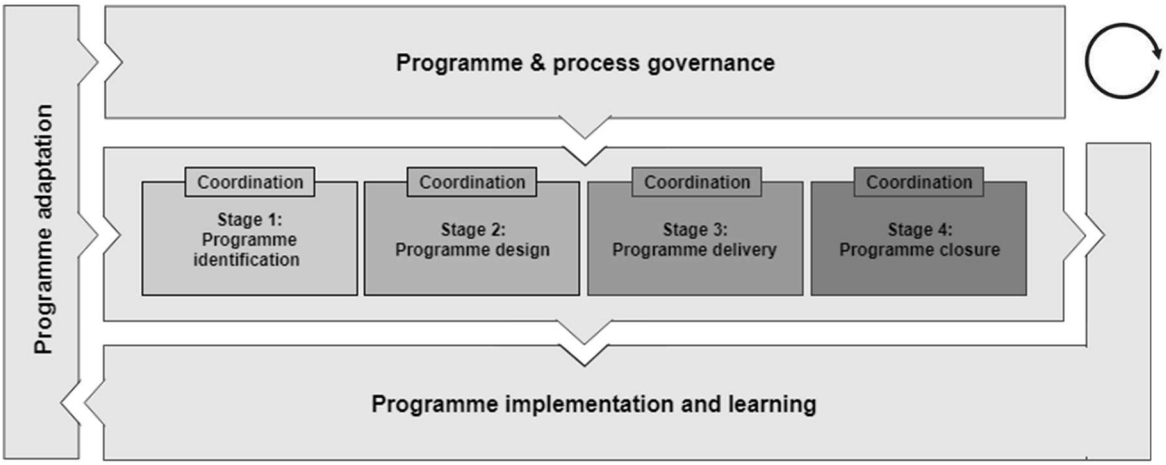

Figure 7: Programme process superstructure consisting of four lifecycle stages and their respective coordination, programme & process governance (aAuthor's own elaboration). Based on Brazier et al. (2018), Lycette et al., (2004) and Rijke et al. (2014)

literature covered in this article. More specifically, according to Gall's law, *"a complex system that works is invariably found to have evolved from a simple system that worked. The inverse proposition also appears to be true: A complex system designed from scratch never works and cannot be made to work. You have to start over, beginning with a working simple system"* (Gall, 1975 p. 71). In line with this law, generating a detailed and complex design does not work. Rather, a 'simple' set of design guidelines should evolve into a detailed and complex design through the programme's participatory programme processes. The key principle of the design is to move towards a network approach facilitated by an ICT infrastructure that is able to support the programme's critical function.

At the highest level of abstraction, the network is facilitated by means of a digital platform accessible to actors with the appropriate credentials and whom comply with the programme's protocols. The particular design-choices on this abstraction level should be taken

Table 2: The institutional and technical design of the conceptual framework at three levels of abstraction. Including the objectives, expectations and critical functions of the rehabilitation programme for the delivery stage. The design-choices are made in the design stage of the programme's lifecycle. (Source: author's own elaboration)

<table>
<tr><th colspan="3">Overview of design-choices for the programme delivery stage</th></tr>
<tr><th colspan="2">Objectives</th><th>Expectations</th></tr>
<tr><td colspan="2">Collective action
Improve overall rehabilitation project performance and success</td><td colspan="1">Actors are able to self-organise
Knowledge and innovations are developed, diffused and adopted across rehabilitation projects and actors</td></tr>
<tr><th colspan="3">Critical functions</th></tr>
<tr><td colspan="3">Actors are able to: self-organise the development, diffusion and adoption of innovation and knowledge across rehabilitation projects and organisational boundaries

System control: Interests of actors are aligned and immaterial resources are accurate & appropriate
Capacity management: Sufficient participating actors and resources are available
Interconnection: Actors are networked and resources are linked
Interoperability: Actors are able to communicate, organise and exchange resources on the basis of rules and standards</td></tr>
<tr><th>Technology</th><th>Alignment</th><th>Institutions</th></tr>
<tr><td>Technological architecture
A digital platform facilitating inter-organisational and cross-project processes.</td><td>Access
Open access to all relevant actors whom are willing and eligible to participate.</td><td>General rules
Certification and conformance to programme protocols and standards while taking into account formal laws (e.g. procurement law) and cultural constraints (e.g. autonomy, opportunistic behaviour).</td></tr>
<tr><td>Tech. design characteristics
Virtual organisation that facilitates the diffusion and adoption of immaterial (strategic) resources across project and organisational boundaries.</td><td>Governance
Network governance based on relational contracts and hybrid organisational structure(s): establish policies and monitor their implementation</td><td>Programme arrangements
Tasks of programme management office, degree of autonomy, roles, incentives, protocols, standards and monitoring that enable long-term collaboration and participation</td></tr>
<tr><td>Operation
Exchange of immaterial resources of specific project processes and bridges and viaducts, and ensuring the integrity of the programme.</td><td>Coordination
Reputation, performance and financial incentives, technical standards and digital technologies that facilitate shared situational awareness</td><td>Participation
Self-organisation, collective action and shared situational awareness</td></tr>
</table>

into consideration in the programme arrangements and technical design characteristics.

On the middle level of abstraction, the organisational structures are in place to ensure (establish and monitor) that the programme arrangements and virtual organisations are able to facilitate the development, diffusion and adoption of innovations and knowledge. Moreover, the embodiment of the (hybrid) organisational structure is dependent on the system's characteristics. For example the exact role of the Programme Management Office might require some degree control and strategic resources depending on previous decisions on roles, standards and degree of autonomy; in this case, third-party coordination in combination with an information network might be a suitable organisational structure.

On the lowest level of abstraction, operation and participation is facilitated through coordination technological and institutional mechanisms, such as technical standards and incentives respectively. In such a way shared situational awareness, col lective action and the self-organisation of groups around specific themes is facilitated.

An overview of the design-choices of the rehabilitation programme for the delivery stage – including the objectives, expectations and critical functions – are presented in table 2.

Final notes

The design process of the institutional and technological designs as described in the previous subsection is occurs in stage 2; whereas the design's functions serves the rationale of stage 3. The system's objectives, expectations and critical function, on the other hand, are in-part determined in the stage 1, and the design's embodiment is dependent on the choices made in policy networks. Therefore, the role of the framework's superstructure should not be forgotten given that programmatic endeavours are highly contextual and evolve over time.

5. Evaluation

Currently, the Dutch civil engineering operates according to a project-centric approach – in line with classic project-based industries. However, there is a desire in the Dutch civil engineering sector for a new, more effective, approach in which the challenges of the rehabilitation assignment are addressed. In the past years, multiple initiatives have emerged each emphasising the need for innovation, standardisation, knowledge sharing, digitisation and collaboration (Bletsis, 2020).

More specifically, in 2018 'De Bouwagenda' first referred to the orchestration of a programmatic approach to tackle the rehabilitation assignment. In particular, to cluster projects based on region and type into a portfolio, and subsequently realise a nation-wide programme of portfolios[ii] (core coalition roadmap 1, 2018). Two years later, in march 2020, three public actors have taken first steps in this regard (Pianoo, 2020). In particular, the province of Noord-Holland, Rijkswaterstaat (public agency that manages the main (national) civil infrastructure) and the municipality of Amsterdam have reached an agreement to orchestrate such a portfolio. In parallel to the recent advancements in 'de Bouwagenda', a platform is being organised based on existing initiatives and specifically for bridges where actors are able to bundle their efforts (de Bouwcampus, 2017; Telder, 2019). The exact institutional and technological design of this platform has yet to be determined. Thus, the conceptual framework presented in this article can assist in this process.

Validity of the described design artefact

The designed artefact described in the previous section was validated by means of conducting semi-structured interviews with experts (Bletsis, 2020). In total seven experts were interviewed.

All experts expressed a desire for a transition towards a networked approach as described in section 4. It has even been expressed to be the sector's *only* remedy for alleviating the challenges of the rehabilitation assignment. Where innovation (5), knowledge development and sharing (4), and digitisation (4) were the top three most important contributors, whereas, individual interests (4) the biggest perceived obstruction for realising productivity growth (Bletsis, 2020).

"I think that the network approach is the only one that is able to solve the problems surrounding the rehabilitation assignment. Especially due to its size, especially in bridges and civil engineering structures. […] I see it increasingly emerging within the market and that it is moving toward that direction." – Dijkhuizen in Bletsis (2020).

However, it is currently not feasible – since it is less familiar and requires systemic changes to be implemented across the sector. Therefore, a stepwise process within which the necessary changes to the sector are realised. A portfolio approach can function as an the in-between step and then to continue by constructing an overarching network that connects portfolios and projects – similar to what is proposed by 'de Bouwagenda'. In such a way, the network approach evolves as combination of the previous approaches thus

maintaining characteristics of both portfolios and projects.

"I really believe the network approach. And this approach, like you have indicated, will have manifestations of 'swarms' with specific portfolios. I believe that this is in line with what we have identified to be important in 'de Bouwagenda': make baskets (a portfolio approach) but do so on a network level. In other words, look where specific approaches (e.g. project processes) are applicable and connect those with one another and engage in contracts spanning multiple years. The approach posited in 'de Bouwagenda' is in between 2 (portfolio) and 3 (network) – has elements of approaches 2 and 3 – and I think that this holds the future." – Molenkamp in Bletsis (2020).

6. Discussion & Conclusion

Considering the aforementioned developments in the Dutch civil engineering sector and the responses of the experts, the need for an approach such as the one presented in this article seems to be necessary. However, programmes are already in use and proven within the sector. Yet, no theoretical perspective was found to support the development of effective solutions that address the challenges of the rehabilitation. More specifically, solutions that take into account the complexity of project-based polycentric systems. The existing solutions relied on a dominant top-down component as a driver for action instead of participation and collective action – i.e. a more bottom-up approach. Therefore, instead of relying on hierarchical and autocratic governance, this article emphasises on processes, participation, networks and the organisational structures that respect the sector's polycentric nature and are able to organise for collective action. As such the contribution of this article is multi-dimensional perspective on the conceptualisation of programming in networks that leverages existing initiatives to maintain continuity.

Furthermore, given the scale of the rehabilitation assignment, an approach is required that is able to evolve and adapt to changing contexts. The perspective of development, diffusion and adaptation of innovation and knowledge through leveraging advancements in ICT is assumed to be the most appropriate resolution to benefit across-project coordination and multi-actor collaboration in project-based systems. On the one hand, codified knowledge can be abstracted has little to no reproduction costs. On the other hand, because innovation and knowledge development allows for self-organisation and participation across project and organisational boundaries; facilitated by shared situational awareness.

For directions for future research the following research trajectories are stipulated: first, an interesting continuation of this research would be to implement the conceptual framework in the real-world rehabilitation assignment of civil engineering structures. More specifically, to implement each step and document progression and important observations that may serve as additional validation or lead to the revision of the framework's design. Furthermore, it would be interesting to add more detail to the framework, more specifically with regards to the institutional and technological design-choices for the programme delivery stage. For example, a higher fidelity and perhaps operational hybrid organisational structure, programme arrangements and digital platform to identify important elements with respect to micro-institutions and technical design.

Conclusion

This article set out to describe how the challenges of the rehabilitation assignment of civil engineering structures and in particular bridges and viaducts can be addressed by means of governance and coordination. The main challenges identified were: the large number of rehabilitation projects due to changing functional and structural requirements and deferred maintenance; the increasing project complexity; the increased social and institutional complexity due to short time horizon and decentralised institutional character; and the lack of trust and high degree of competition in the civil engineering sector.

In this article, the civil engineering sector is defined as a polycentric system consisting of autonomous yet interdependent public and private actors that in the absence of formally hierarchical relationships are subjected to polycentric governance. Furthermore, the civil engineering sector is characterised as a project-based industry and confronted with inefficient cross-project coordination and interorganisational collaboration hampering productivity and innovation. A programme approach, that manages multiple projects in order to achieve higher-order strategic objectives, is found to be an enabler of innovation and standardisation across projects. However, programmes are traditionally governed hierarchically and coordinated centrally through a Programme Management Office. Therefore, for a programme approach to be used in the face of the rehabilitation assignment, collective action is needed and thus different ways of orchestrating governance and coordination are needed to avoid impasses and resolve collective action problems. Hybrid organisational structures and participatory systems thinking are ways to construct programmes in polycentric project-based systems that are enabled by ICT.

Based on the presented methods, a conceptual framework of governance and coordination is presented

that consists of a superstructure with which a self-organising programme is orchestrated in a polycentric system to address the challenges of the rehabilitation assignment. The design leverages process, institutional and technological dimensions; with a particular focus on the process and institutional dimensions to facilitate collective action through participation and self-organisation. The process design consists of four consecutive stages that represent the programme's lifecycle. Where each stage is an aggregate of the previous stages; the purpose of the first two stages is to initiate the negotiation process and design process respectively that facilitates the transition towards an operational programme for which design-choices with regards the accessibility, governance and coordination determines how the institutional and technological designs are aligned. The resulting design-choices suggests that governance and coordination can be designed to facilitate the development, diffusion and adoption of knowledge and innovation across projects and organisational boundaries enabled by ICT.

This in combination with expert validation, suggests that the designed conceptual framework of governance and coordination is indeed able to address the challenges of the rehabilitation assignment and therefore it answers the main research question.

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[ii] Turner & Muller (2003) defined portfolios as: *"an organisation, (temporary or permanent) in which a group of projects are managed together to coordinate interfaces and prioritise resources between them and thereby reduce uncertainty".*