What About Coordination, Transparency and Anticipation in Projects? A Systematic Review of "Controlling" of Projects, Especially of Public Infrastructure Projects

Pia Herrmann and Konrad Spang

Abstract Managing infrastructure projects remains challenging, and especially large infrastructure projects are often criticised for cost overruns and time delays. With the help of controlling, a peculiarity of German-speaking countries, project management and thus project performance can be improved since controlling ensures transparency within the project and supports coordination and anticipation. Furthermore, controlling can improve the quality of decision-making, the ability to respond and adapt to internal and external changes. However, research on controlling within German-speaking countries has been almost isolated from international research. Consequently, conducting a literature review is faced with linguistic challenges and requires some preparatory work. Therefore, the purpose of this chapter is to fulfil three ambitions: First, based on an introduction to public infrastructure projects, this chapter suggests requirement categories for the controlling of public infrastructure projects. Second, by specifying the understanding of controlling, a controlling system framework is proposed. Third, based on the categories suggested and the framework developed, this chapter presents a literature review on controlling of (public) infrastructure projects. Thereby, this chapter provides a common basis for developing an integrated controlling system. Furthermore, by structuring the selected articles based on the controlling system framework, initial experiences in applying the framework were gathered and requirements for adjustments were identified.

Keywords Project management · Public infrastructure projects · Controlling · Project control · Management accounting

P. Herrmann (✉) · K. Spang
University of Kassel, Kassel, Germany
e-mail: p.herrmann@uni-kassel.de; spang@uni-kassel.de

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1 Introduction

On the one hand, public construction and infrastructure projects are relevant. On the other hand, the management of these projects remains criticised (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety ed. 2016). Exceeding costs and time delays of large public and infrastructure projects are often criticised—nationally and internationally (Flyvbjerg 2009; Morris and Hough 1987; Federal Ministry of Transport and Digital Infrastructure, ed. 2015; Riemann and Spang 2014; Sözüer and Spang 2014). An analysis of large infrastructure projects in Germany concludes that the absolute additional costs (in addition to the planned costs) are highest in the transportation sector (Kostka and Anzinger 2016).

Therefore, the first question to be answered is how to support project objectives and project success. Referring to project success, project success criteria and project success factors should be distinguished: Project success criteria are used to evaluate success, whereas the consideration of project success factors promotes successful completion of projects (e.g. Albrecht and Spang 2011; Cooke-Davies 2002; Joslin and Müller 2016). With regard to the question mentioned above, success factors are relevant and contribute to the achievement of objectives and the success of those projects.

The literature on project success factors is extensive. According to Fortune and White (2006), success factors sometimes relate to specific project types (examples of success factors in: Federal Ministry of Transport and Digital Infrastructure, ed. 2015; Spang 2016a). In other cases, they may be limited to a specific sector or are generally applicable (e.g. Pinto and Slevin 1987; Cooke-Davies 2002). The analysis of success factors—generally applicable and specific ones—shows that planning, monitoring, anticipation, risk management, control, integration as well as transparency are considered as success factors (e.g. Pinto and Slevin 1987; Cooke-Davies 2002; Federal Ministry of Transport and Digital Infrastructure, ed. 2015; Spang 2016a). The discipline of controlling can be seen as a peculiarity of German-speaking countries (e.g. Küpper et al. 2013). Even though, there is no consensus on what really constitutes the core of controlling (e.g. Binder 2006; Wall 2008), different controlling approaches share common characteristics (Binder 2006): Controlling is about management support, information, anticipation as well as about transparency, coordination and integration.

With regard to the initially formulated question and focusing on the success factors, it is controlling that plays an elementary role in the achievement of objectives and therefore the chance of successful project completion—especially within large and infrastructure projects. Therefore, it is crucial to elaborate how controlling has to be designed. This chapter aims at answering the following research question: What is the current state of international research literature on controlling of (public) infrastructure projects? Therefore, the purpose of this chapter is to provide an overview of the available international research literature on controlling of (public) infrastructure projects.

However, providing an overview of the available literature entails two challenges: First, controlling is a German peculiarity and "the community of Controlling researchers has long been largely isolated from the international community" (Schäffer 2013, p. 294). At the same time, the term controlling can be seen as made-up (Binder 2006). Therefore, it is difficult to simply search the keyword "controlling" (Richter 1987), which becomes apparent by searching for "controlling" for public infrastructure projects in EBSCOHost / Business Source Premier (search fields: title and abstract, limited to academic journals only, search terms: Transport* / Infrastructur* Project* AND Public* / Governm* AND Controlling; July 2018). The search led to only one result, which was irrelevant concerning the research question. Secondly, the discipline of controlling is very broad and partly controversial. Therefore, several search terms seem to be necessary.

In order to achieve the presented purpose and since preparatory work is required, this chapter aims to fulfil three ambitions, processed in sequence: First, this chapter suggests requirement categories for the controlling of public infrastructure projects. Second, it proposes a controlling system framework for public infrastructure projects. Third, the literature review is performed and the selected articles are discussed.

2 Requirements for the Controlling of Public Infrastructure Projects

In order to identify search terms, we specify our understanding of controlling. In order to structure search results, we define requirements for the controlling of public infrastructure projects. For this purpose, we use two perspectives: We define requirements based on controlling and based on public infrastructure projects. By combining these perspectives, we propose an integrated controlling system framework for public infrastructure projects.

2.1 Developing Requirements based on Controlling

2.1.1 Introducing Controlling

Controlling has its roots in the USA and was developed—in its present form—during industrialisation (Gleich et al. 2015). Unlike the USA, "controlling only spread in Germany in the second half of the 1950s" (Gleich et al. 2015, p. 22; Küpper et al. 2013). Today, the German literature on controlling is rich, and controlling is considered to be established in research (Scherm and Pietsch 2004) as well as in practice (Küpper et al. 2013). However, controlling is also characterised by a self-discovery debate (e.g. Binder 2006; Wall 2008), and a common understanding of controlling is still lacking (Binder 2006; Wall 2008). Furthermore, due to many years of research isolation (Schäffer 2013), the German-language literature on

controlling is hardly found in international research and literature (e.g. Küpper et al. 2013). In contrast, its content is discussed internationally under "management accounting", "managerial accounting" or "management control" (e.g. Gleich et al. 2015, pp. 14–15; Küpper et al. 2013, pp. 8–9). Vesper elaborates twelve English terms, which are relevant for the understanding of controlling within German-speaking countries and if the term "controlling" is used, it is more likely to be used as a phase of the management cycle (Vesper 2014).

Today, controlling covers a wide range of processes: It supports, supplements and limits management. In particular, controlling supports management by assuring "economic transparency", by contributing "to rational corporate management" as well as by designing and developing instruments and systems (International Controller Association and International Group of Controlling ed. 2012, p. 6). Because of the linguistic challenges on the one hand, and the covering of a wide range of processes on the other hand, controlling shall be specified.

2.1.2 Specifying Controlling

In German-speaking countries, controlling conceptions play an important role in controlling research (Binder and Schäffer 2005). According to Küpper et al. (2013), those conceptions characterise the function of controlling. In order to specify controlling, we characterised those conceptions based on criteria, e.g. controlling purposes, objectives and stages.

Concerning controlling purposes, the considered controlling conceptions contain two directions: On the one hand, controlling aims for improving management or control; on the other hand, controlling aims for achieving corporate goals. Whether controlling supports achieving all corporate goals, or exclusively financial goals, is the subject of a controversial debate in research (e.g. Küpper et al. 2013; Wall 2008). By combining two older controlling studies (Baumgartner 1980; Harbert 1982) with controlling conceptions and additional controlling literature, the following five controlling objectives were specified: 0) management support, 1) anticipation, responsiveness and adaptability, 2) integration and coordination, 3) ensuring transparency and 4) ensuring rational decisions. Furthermore, the idea of controlling as management support is important but imprecise (Binder 2006). Therefore, the objective of management support serves as a guiding principle within our research.

The defined purposes and objectives of controlling are summarised in Fig. 1.

In order to further specify controlling, the guiding principle "controlling for supporting management" is applied. Since management can be seen as management cycle (Weber 1997), we suggest that controlling supports management by collecting actual data, measurement, monitoring, control, analysis and evaluation as well as processing. Furthermore, we propose controlling as a continuous cycle, as it enhances management permanently. Moreover, controlling findings consistently influence new controlling processes and add to its optimisation. In addition, we propose to supplement the controlling cycle by reporting and continuous learning (idea extracted of Bauer 2002 as well as of ISO 9000:2015 (International

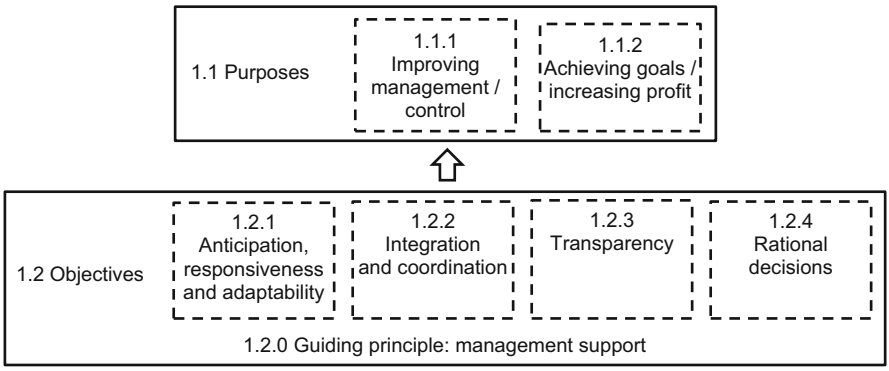

Fig. 1 Purposes and objectives of controlling. **Source:** authors

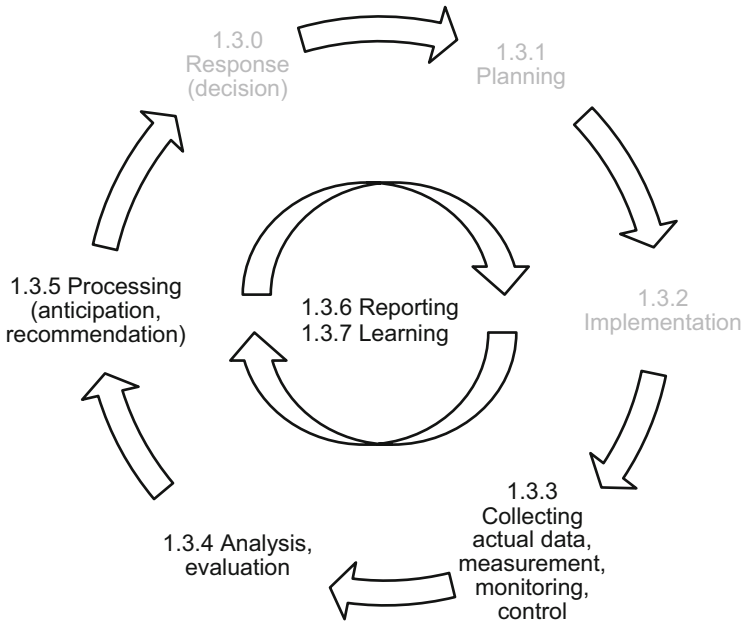

Fig. 2 Controlling cycle. Source: authors based on, e.g., Spang 2016c

Organization for Standardization 2015a), Fig. 2 and ISO 9004:2009 (International Organization for Standardization 2009), Fig. 1). Whereas the stage reporting is based on controlling conceptions, the stage of continuous learning is based on the idea of continually improving controlling itself. The proposed controlling cycle is shown in Fig. 2.

As Fig. 2 shows, the grey stages (1.3.0, 1.3.1, 1.3.2) are not considered as key elements (1.3.1) or elements (1.3.0, 1.3.2) of controlling.

By defining the purposes, objectives and stages of controlling, controlling has been specified. This specification allows identifying search terms for the literature review. Furthermore, in order to develop an integrated controlling system, purposes, objectives and stages of controlling are required. However, developing the integrated controlling system as well as identifying additional research gaps requires more than specifying controlling. It requires defining those elements or perspectives that are necessary for establishing and conducting controlling. We call them the "developing perspectives".

2.1.3 Identifying "Developing Perspectives" of Controlling

Identifying the developing perspectives is based on the idea of controlling as controlling system (for applying the idea to project management, see Herrmann 2016 and Herrmann and Krauss 2017). This idea was inspired by project and quality management: Organisations implement project or quality management systems containing those elements that are required for project or quality management (project management system: Deutsches Institut für Normung (2009); quality management system: International Organization for Standardization (2009; 2015a; 2015b). By transferring this idea to controlling, the controlling system contains those elements, which are required for controlling.

Based on controlling literature, the developing perspectives, named function, structure, people, resources (non-human) as well as partners and context, were derived. Thereby, e.g., the perspective people was based on the relevance of skills, behaviour (e.g. Küpper et al. 1990) and culture and the perspective of partners and context was based on considering controlling as support and cross-divisional function (Weber in Binder 2006), and thus being dependent on its context (e.g. Bauer 2002 with reference to Zünd, 1985 and to Deyhle, 1993).

Furthermore, experiences gained in a master thesis (Herrmann 2016) and structures of management systems served to define the developing perspectives (International Organization for Standardization (2009, 2015b); EFQM® as well as Project Excellence Model® (Westerveld 2003); St. Galler Management-Concept (Bleicher and Abegglen 2017)). Fig. 3 summarises the developing perspectives for an integrated controlling system.

Whereas the developing perspective function describes the content of controlling, the developing perspectives structure, people, resources and partners and context arise from the idea of developing a controlling system. For this reason, it is proposed to call these four perspectives system perspectives. We conclude that developing an integrated controlling system requires establishing the developing perspective function as well as the system perspectives constituting requirements for a controlling system. After having developed requirements based on controlling, we continue by developing requirements based on public infrastructure projects.

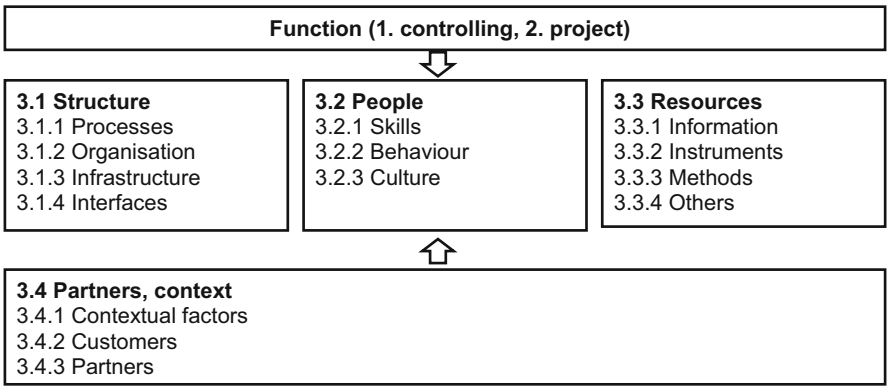

Fig. 3 Developing perspectives of controlling. **Source:** authors

2.2 Developing Requirements Based on Public Infrastructure Projects

Public infrastructure projects are projects. Therefore, we identify project attributes at first. Thereafter, we identify additional attributes by studying the success of projects for developing a controlling system, which supports successful projects. In order to develop initial requirements based on public infrastructure projects, we apply the identified attributes to public infrastructure projects, especially in Germany.

2.2.1 Identifying Project Attributes

The project management literature contains several project definitions, characterising projects as organisation, process or system. By considering the project as process, projects transform input into output (e.g. Shenhar and Dvir 2007; Turner and Keegan 1999). Turner and Cochrane (1993) differentiate "between the objectives of a project (the facility it will produce) and the purpose of a project (the benefit expected from operating that facility after completion of the project)" (p. 93). To fulfil the projects purpose, three types of breakdown structures are required according to Turner and Cochrane (1993): the product breakdown, the organisation breakdown and the work-breakdown structure. Turner (2006a) adds that defining a project requires also defining the outcome, output and required resources, while Xue also adds the definition of the impact (Turner and Xue 2018 with reference to Xue 2009). Furthermore, the product as well as the project process (Project Management Institute ed. 2017) can be divided into stages (Turner 2006b), sometimes being characterised by its own goals and challenges (e.g. de Wit 1988; Jugdev and Müller 2005). Moreover, projects are characterised as being basically unique and novel (representing a sufficient condition according to Spang 2016a) as well as being temporary (e.g. Project Management Institute ed. 2017, representing a necessary

condition according to Spang 2016a). However, in many definitions, it remains open as to when a project starts: does it start after defining the goals (e.g. ICB 4.0 (International Project Management Association ed. 2015); DIN 69901-5:2009-01 (Deutsches Institut für Normung 2009)), or during identifying the problem or need (Samset 2009)? Other typical characteristics of projects are the limitation of allocated resources, the specific project organisation (e.g. Turner and Müller 2003) as well as project stakeholders (e g. Project Management Institute ed. 2017).

2.2.2 Identifying Project Success Attributes

Project success can be defined as "multi-criteria approach" (Dvir et al. 2003, p. 90). Whereas the iron triangle, including time, cost and quality or scope, remains crucial (Pollack et al. 2018), these three factors cannot always explain project success (e.g. de Wit 1988; Dvir et al. 2003; Joslin and Müller 2016; Jugdev and Müller 2005; Spang 2016a). According to de Wit (1988, p. 164), "the most appropriate criteria for success are the project objectives". However, projects are characterised by several stakeholders, sometimes pursuing different objectives. Therefore, project success cannot be evaluated from only one perspective and, in addition, not from only one point in time (e.g. de Wit 1988; Shenhar et al. 1997; Turner and Zolin 2012).

2.2.3 Identifying Attributes of Public Infrastructure Projects

Public infrastructure projects encompass, among others, the construction of roads and railways. These projects are often large scale and result in major interventions. By intervening and disturbing, infrastructure projects influence many people, organisations and the environment. Furthermore, infrastructure projects in Germany are generally financed by public funds, resulting in, among others, public and political interest for these projects (Elbaz and Spang 2018; Spang 2016a).

Furthermore, public infrastructure projects pass several stages (e.g. Spang 2016b), which may vary in terms of stakeholders, success criteria and political responsibilities (Elbaz and Spang, 2018; Spang 2016b). Public infrastructure projects are usually characterised by long and formalised planning stages as well as by public participation or consultation (Riemann and Spang 2014). Due to processing natural building materials, weather conditions and complicated technical solutions, changes and disturbances within infrastructure projects are unavoidable (e.g. Flyvbjerg 2009 and 2014; Sözüer and Spang 2014; Spang 2016a). Furthermore, rising expectations regarding public participation and project disturbances caused by public dissatisfaction can be observed (e.g. the project Stuttgart 21; see Brettschneider and Schuster 2013).

2.3 *Proposing Requirements for the Controlling of Public Infrastructure Projects*

So far, we specified controlling and public infrastructure projects. Now, we are able to initially define project controlling and derive requirements for the controlling of public infrastructure projects afterwards. As initial definition, we propose that project controlling aims to improve project control or management, to achieve project goals and to increase project success. In order to fulfil these purposes, project controlling aims to support management by anticipating, responding and adapting to external and internal changes, by ensuring integration and coordination, by ensuring transparency as well as by supporting rational decisions. To extend the understanding of project controlling, we propose to characterise project controlling as controlling cycle, consisting of collecting actual data, measurement, monitoring and control; analysis and evaluation; processing; and being accompanied by reporting (including information and communication) as well as by learning.

As part of future research, we still have to define controlling tasks. However, since the stages allow identifying differences between definitions of project controlling, considering project controlling as controlling cycle is of great help in structuring and reviewing the existing literature. After all, there are differences between existing definitions: The German project management standard DIN 69901-5:2009-01 (Deutsches Institut für Normung 2009) defines project controlling very similar to our definition. The PMBOK® (Project Management Institute ed. 2017) contains, besides others, the processes "Direct and Manage Project Work", "Perform Integrated Change Control" and "Monitor and Control Project Work". "Monitor and Control Project Work" is defined as "the process of tracking, reviewing, and reporting the overall progress" (p. 105). Furthermore, the PMBOK® explicitly refers to one of its benefits, which is "recogniz[ing] the actions taken to address any performance issues" (p. 105), whereas, e.g., "approving changes" is located in the process "Perform Integrated Change Control" (p. 113). German project management literature sometimes differentiates between planning, directing or control and monitoring, without considering controlling (e.g. Bea et al. 2011 or Burghardt 2018). Based on those few examples—and we have not yet addressed the project management standard ICB 4.0 (International Project Management Association ed. 2015)—it is already obvious that structuring is needed.

After having developed attributes of public infrastructure projects, those attributes were applied to requirements for the controlling of public infrastructure projects. Due to their initial state of development, the requirements were aggregated to requirement categories. Thereby, differentiating between content and process-related requirement categories (founded on Ebert 2014) turned out to be useful: The content requirement categories describe the content of controlling (or controlling objects, what should be controlled), and process-related requirement categories describe how controlling should be executed. In summary, we propose the following requirement categories.

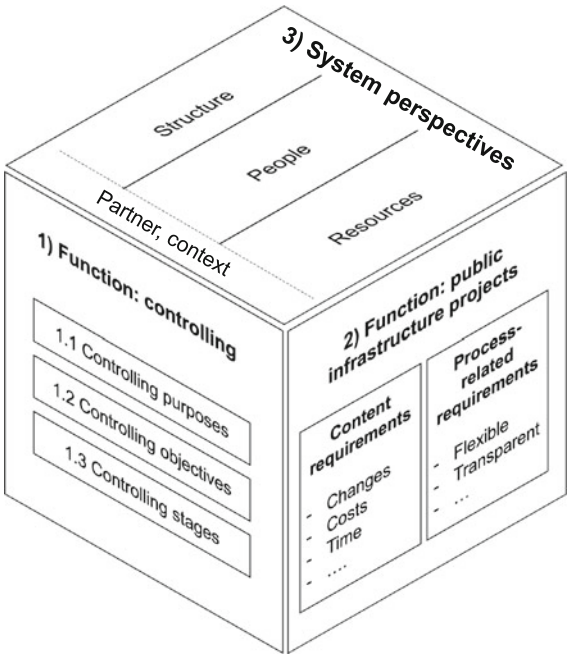

Fig. 4 Controlling system framework for the controlling of public infrastructure projects. **Source:** authors, presentation as cube from Herrmann 2016

Requirement categories, content: 2.c1 dependencies and interactions, 2.c2 changes, 2.c3 special features, 2.c4 success factors, 2.c5 success criteria and objectives, 2.c6 costs and budget, 2.c7 organisation, 2.c8 stages and life cycle, 2.c9 product requirements, 2.c10 resources, 2.c11 risks and opportunities, 2.c12 stakeholders, 2.c13 team, 2.c14 versions, scenarios, 2.c15 contract, 2.c16 work, 2.c17 environment and indirect topics, 2.c18 knowledge, 2.c19 time.

Requirement categories, process-related: 2.p1 flexible, 2.p2 holistic, 2.p3 integrated, 2.p4 comprehensible, 2.p5 scalable, 2.p6 structured, 2.p7 transparent.

Combining the knowledge gained by developing requirements based on controlling and based on public infrastructure projects, we present the following controlling system framework. The framework consists of three perspectives, presented as cube in Fig. 4.

1. Functional perspective, requirements based on controlling
2. Functional perspective, requirements based on public infrastructure projects (draft of requirement categories)
3. System perspectives

These three perspectives serve as a basis for the following literature review as well as for the further development of the integrated controlling system in future research.

3 Literature Review

3.1 Methodology and Approach

To achieve the research goals, a systematic literature review was conducted (following e.g. Geraldi et al. 2011; Petticrew 2001) by using the database EBSCOHost/Business Source Premier. The review focuses on international research literature concerning controlling of (public) infrastructure projects. As the focus was on international research literature, only English articles of the category "academic" were included. Furthermore, the search fields "title" and "abstract" were used. Therefore, the search terms had to be included either in the title or in the abstract.

We verified whether the database contains relevant project management journals (International Journal of Managing Projects in Business: abstracts included since 06.01.2011; International Journal of Project Management: abstracts included since 07.01.1997; Project Management Journal: abstracts included since 06.01.1997).

Due to the challenge of searching for controlling, several search phases, terms and steps were defined and are shown in Table 1.

- *Search phases,* determined by grouping search terms. Search phase 0: Searching for controlling.

Table 1 Search process

Search phase 1	*Search phase 2*	*Search phase 3*
Searching for "*translations*" of controlling, mentioned in German literature.	Searching for controlling *objectives*.	Searching for controlling *stages* (if not already covered by phases 1 or 2)
Search terms: 1. Control* (covers management and managerial control, management control system, controllership) 2. Accounting* (covers management and managerial accounting, management accounting system)	*Search terms:* 1. anticipat* 2. forecast* 3. react* 4. adapt* 5. responsiv* 6. integrat* 7. coordinat* 8. transparen* 9. rational* 10. support AND management OR decision	*Search terms:* 1. monitor* 2. measur* 3. evaluat* 4. report* 5. assess* Searching for monitor* showed the synonymous use of assess. Therefore, assess was integrated into the search.
-	Search term 10: in the evaluation with the consecutive number "0".	Since many irrelevant results are expected, it was not searched for inform*, communicat* and learn*.

As indicated, we used the asterisk wildcard (*) to search for different word endings
Source: authors

- *Search terms,* derived from controlling "translations", controlling objectives and controlling stages as shown in Table 1. Seeming to be too general, the controlling purposes were not used as search terms.
- *Search steps,* based on whether the search refers to public infrastructure projects (search step 1, search for public* OR govern* as well as infrastructure* OR transport*), infrastructure projects (search step 2) or projects (search step 3). Searching separately for public projects was not considered as being useful.

Assuring the identification of each search run, an indicator was created as follows: for phase 1, search term accounting* (term 2), search step public infrastructure projects (step 1), the indicator is 121. This article contains search step 1 as well as partly search step 2 (including phase 1).

3.2 Selection

The identified articles were exported and integrated into a literature management database. A check of doublettes was directly performed. Based on reviewing the abstracts (first check), the sample was refined. If an article seemed to be relevant, its full text served to further refine the sample (second check). If an article covered "only", e.g. stakeholder management, the article was not selected. For two articles, the full text is not yet available. Therefore, these articles are provisionally selected and their subjective relevance is based on their abstracts.

Finally, 35 articles were selected (including two provisionally selected articles); see Table 2.

Since the selected articles differ regarding their relevance to the research question—containing a controlling input or a complete controlling stage—a subjective relevance assessment was integrated, ranging from 1 (little relevant) to 3 (highly relevant). Although being subjective, this assessment serves as initial orientation.

- Relevance of 1, little relevant: Covering a factor (factors) that has to be controlled ("what"), covering relevant aspects
- Relevance of 2, relevant: Covering controlling approaches ("how"), or models that are useful but not controlling-specific
- Relevance of 3, highly relevant: Covering specific controlling instruments, frameworks, specific experiences

Table 2 Overview selected articles

Search term	indi-cator	(1) no. of search res.	(2) thereof doubl.	(3) =(1)-(2)	(4) rel. res. after 2nd check	(5) there-of 1	(6) there-of 2	(7) there-of 3	(8) rel. res. incl. doubl. after 2nd check	(9) prop. of rel. res. after 2nd check - all res.	(10) there-of 1	(11) there-of 2	(12) there-of 3
control*	111	33	0	33	6	2	1	3	6	1.67%	2	1	3
account*	121	5	0	5	0	0	0	0	0	0.00%	0	0	0
Phase 1, step 1		38	0	38	6	2	1	3	-	-	-	-	-
anticipat*	211	9	0	9	1	0	1	0	1	0.28%	0	1	0
forecas*	221	10	1	9	0	0	0	0	0	0.00%	0	0	0
react*	231	10	3	7	1	0	1	0	2	0.56%	0	1	1
adapt*	241	12	3	9	2	0	2	0	2	0.56%	0	2	0
responsiv*	251	0	0	0	0	0	0	0	0	0.00%	0	0	0
integrat*	261	43	6	37	5	1	4	0	6	1.67%	2	4	0
coordinat*	271	16	5	11	1	1	0	0	3	0.83%	1	2	0
transparen*	281	13	3	10	0	0	0	0	0	0.00%	0	0	0
rational*	291	15	6	9	0	0	0	0	2	0.56%	0	1	1
decision OR management support	201	3	2	1	0	0	0	0	0	0.00%	0	0	0
Phase 2, step 1		131	29	102	10	2	8	0	-	-	-	-	-
monitor*	311	17	5	12	1	0	1	0	2	0.56%	0	1	1
measur*	321	52	14	38	5	2	2	1	6	1.67%	2	2	2
evaluat*	331	85	33	52	2	1	1	0	6	1.67%	3	2	1
report*	341	54	19	35	0	0	0	0	2	0.56%	1	0	1
assess*	351	82	49	33	1	1	0	0	4	1.11%	2	1	1
Phase 3, step 1		290	120	170	9	4	4	1	-	-	-	-	-
		-	-	310	25	8	13	4	-	-	-	-	-
control*	112	69	34	35	10	1	4	5	17	4.72%	3	6	8
accounting*	122	20	5	15	0	0	0	0	0	0.00%	0	0	0
Phase 1, step 2		89	39	50	10	1	4	5	-	-	-	-	-
Total		**-**	**-**	**360**	**35**	**9**	**17**	**9**	**35 selected articles correspond to 10 %**				

Abbreviations: doubl. = doublette, no. = number, prop. = proportion, rel. = relevant, res. = results
indicator: search phase II search term II search step --> 291 indicates search phase 1, term 9, step 1

Source: authors

3.3 Findings and Discussion

3.3.1 Overview

Table 2 provides an overview of each search run. In order to identify the most successful search terms, the doublettes are taken into account. Out of 360 identified search results, 35 were selected (corresponds to 10 %; relevance of 3: nine papers; relevance of 2: 17 papers; relevance of 1: nine papers). Most of the selected articles were identified searching for control* in search step 2, followed by searching for control* in search step 1 and searching for integrat*, measure* and evaluat* in search step 1. It is striking that none of the selected articles describes a German case study.

Since a limited number of relevant articles were selected, it is difficult to identify precise research gaps. For this reason, we give an overview of the selected articles, relevance of 3. Following this, the controlling system framework serves the evaluation of review findings and allows the identification of further research questions. For this purpose, the selected articles were assigned to the controlling objectives and stages, to the project content and process-related requirements as well as to the system perspectives.

Within this paper, only identified search results with the subjective relevance of 3 are listed in the references. Please note that our findings are also based on references with the relevance of 2 and 1. However, since we did not quote these papers within this paper, we do not list them in our references. Interested readers can request all identified references from the authors.

3.3.2 Selected Articles, *subjective Relevance of 3 (highly relevant)*

Boersma et al. 2007 (ID 6, indicator 111, full text): By using "the triple paradox" (p. 78) – the cost, control and risk paradox – this paper reflects upon a large Dutch infrastructure project. According to the authors, the project was characterised by the philosophy "decentral unless. . ." (p. 78). This philosophy caused "conflicts between the principal [. . .] and agencies or project-agency managers" (p. 78). As problems increased, the project was reorganised by adapting the philosophy to "central unless" (p. 78). Furthermore, the authors describe quarterly reports, including the topics "time and cost: technical development, risk calculation, human capacity, environmental developments, and communication" (p. 78 and 81). "Although the (quarterly and annual) reports were available from the intranet, only a small group of professionals were able to read and interpret the report results" (p. 82). According to the article, "[p]roject-agency managers 'translated' the results in terms of their own organizational reality and strategically presented the information for their own purposes" (p. 82). The article concludes by discussing the following lessons learned: "Know who is responsible" (p. 81), "Contracting does not solve the issue of

responsibility" (p. 81) and "Separation leads to (a certain amount of) professional 'ivory tower' entrapment" (p. 81).

El-Sabek and McCabe 2017 (ID 317, indicator 112, full text): Based on a case study in Qatar, El-Sabek and McCabe describe, "how the Last Planner® System (LPS®) was used [...] to bring critical project elements back from the brink of failure" (p. 26). The authors conclude that "[t]he introduction of LPS® tools resulted in a rapid learning process with enhanced productivity and efficiency" (p. 42). By applying LPS®, they were able to minimise waste, promote teamwork and improve communication – even with sub-contractors, as well as to improve monitoring and planning.

Kivilä et al. 2017 (ID 323, indicator 112, full text): By conducting a single-case study on a large infrastructure project in Finland (alliance contract), the article aims "to identify the control practices that a project organization uses for sustainable project management" (p. 1167), "especially in the project execution phase" (p. 1169). By analysing the case study, the authors quote that "[t]he interviewees emphasized the importance of the financial incentive model of the alliance contract as a key control mechanism in sustainable project management" (p. 1175). Furthermore, they "described how the main goals of the project were included in the incentive model" (p. 1175) and that measurements and key performance indicators "were finally connected to the financial bonuses and sanctions" (p. 1176). Kivilä et al. conclude by integrating the identified control mechanisms in their proposed initial framework.

Liu et al. 2014 (ID 16, indicator 111, full text): Due to the "poor delivery performance of infrastructure projects" (p. 791), the authors examine control mechanisms. They "investigate through a case study of a complex engineering project [...], how control should be structured" (p. 792). They analyse a nuclear research reactor in Australia based on output, input, clan and behaviour control. The case study "confirms the need to look beyond the application of a single control mode" and "provides insight into how modes can be effectively combined" (p. 800). Based on case findings, the authors conclude, "that input, output and clan control were used as an effective combination along with a conscious decision to avoid behavioral control" (p. 800). Concerning output control, the authors emphasise the ability of verification and that the client "relied extensively on risk management to minimize the potential variance on expected outcomes" (p. 797). Regarding input control, the authors highlight the "rigorous selection process" (p. 800) of staff and prime contractor. Furthermore, the authors identified the significance of clan control. Liu et al. conclude by suggesting a "harmonic use of control modes" (p. 801).

Liu et al. 2014 (ID 177, indicator 321, full text): Liu et al. state that "[i]ncomplete and ineffective performance evaluation" (p. 1) contributes to difficulties of social infrastructure PPP [public private partnership] projects "during construction and operation" (p. 1). Due to limited research in this area, the authors "determine the current nature of PM [performance measurement] in Australian PPPs" (p. 1) by conducting interviews. According to the interviews, the performance measurement relies "on the iron triangle of TCQ [time, cost, quality], though an array of qualitative and quantitative KPIs [key performance indicator] are widely applied and used for

the projects' operations" (p. 7). Agreeing on the simplistic and therefore insufficient nature of the iron triangle, Liu et al. propose "a lifecycle PMF [performance measurement framework]" (p. 6). The framework includes stakeholder orientation in order to improve performance measurement further.

Priemus 2007 (ID 329, indicator 112, full text): The article examines and elaborates inquiry findings, concerning the preparation of two large projects, conducted by the Dutch Parliamentary Commission on Infrastructure Projects. The final report identifies "many shortcomings in the decision-making procedures" (p. 71). "Regarding the proposals by the Parliamentary Commission" (p. 80), the article discusses, among others, the recommendation "to use information on cost and benefits, provided by those stakeholders who will bear the risks [...]" (p. 80). Furthermore, the article outlines the periodic progress reports, their addressed contents and the topic of "quality of information received" (p. 83). Concerning this topic, "a 'rapporteur' for each large project" and "a new knowledge and control centre" (p. 83) are proposed. The paper concludes by presenting five suggestions, addressing "the general flaws in the decision-making processes for large infrastructure projects" (p. 90).

Shaikh 2010 (ID 27, indicator 111, abstract): The article attempts "to show how a particular operation within a large-scale project can be scheduled by LOB method" (LOB = Line-of-Balance as scheduling method)". The method is applied to a bridge construction project. *Since the full text of this article is not yet available (status: requested), the article is not yet assigned to the controlling system framework.*

Stubbs 2013 (ID 334, indicator 112, full text): This article addresses how system engineering principles were used "with the objective to plan, define, deliver, commission, assure and transfer into successful operations and maintenance" (p. 26) and concludes by proposing the use of system engineering in complex projects like the described East London line railway project. They "defined a system architecture which identified systems elements, interfaces and boundaries" (p. 27) for the project and developed the system architecture "in parallel with the technical requirements and interface registers" (p. 27). Stubbs offers "good practices", which "were used and developed on the project" (p. 30).

Wang et al. 2017 (ID 341, indicator 112, full text): This article presents "a detailed case study on the methods and organisational structure used for controlling the time schedule" (p. 862) applied to a "HOPSCA" project, which stands for "hotels (H), office buildings (O), ecological parks (P), shopping malls (S), convention centres (C) and apartment buildings (A)" (p. 862, with reference to Hu et al. 2011) in China. The authors specify, "'Project Controlling' includes [. . .] project monitoring, project assessment, reporting, project steering and initiating project changes" (p. 864). According to Wang et al., "the 'Project Controlling' approach is increasingly being considered as a method that is best undertaken by an independent consulting business" (p. 864, with reference to Jia and Wang 2003 and to Shuai and He 2011) and that time scheduling is "the most important part of 'Project Controlling'" (p. 864). The authors conclude that establishing "a 'Project Controlling Unit' that has no business interest with the various contractors but takes

responsibility for project progress across all the project enables both independent guidance to the client and assistance to other participating organisations" (p. 871).

3.3.3 Evaluation

Although we identified only nine articles with the subjective relevance of 3 (highly relevant), those articles provide a good start into subsequent research. After reviewing and summarising the selected articles, we assigned these articles to the framework perspectives based on the content of the articles. If the full text is not yet available, the article is not assigned. Assigning the articles allowed us to identify at least further research questions. Furthermore, by applying the controlling system framework for the first time, we identified adjustment requirements and questions regarding the framework. In the following, we structure our findings based on the controlling system framework perspectives. Thereby, we address the identified adjustment requirements and questions regarding the framework.

Framework perspective function, controlling requirements, controlling objectives (1.2.1-1.2.4): Whereas the objectives 1.2.1 to 1.2.3 (anticipation and adaptation, integration and coordination, transparency) are often covered by the selected articles, the aspect of rationality (1.2.4) is hardly represented (exceptions are, e.g., Boersma et al. 2007, Priemus 2007). Furthermore, the understanding of transparency has to be specified.

Framework perspective function, controlling requirements, controlling stages (1.3.1-1.3.7): By assigning the selected articles to the controlling stages, the differentiation between the phases 1.3.3 (monitoring) and 1.3.4 (analysis) did not provide any additional value, since the articles usually do not differentiate between those. Furthermore, it should be discussed if integrating collecting actual data and measurement into stage 1.3.2 (implementation) could be useful as the topic of collecting data is rarely discussed. The assignment demonstrates the close relationship between planning and controlling since some selected articles are relevant for planning (1.3.1). Therefore, it should be examined whether the planning stage can still be regarded as not being a key element of controlling. In addition, the assignment shows that stage 1.3.5 (processing) is rarely discussed and therefore requires more research, as does the topic of collecting actual data.

Framework perspective function, requirement categories of public infrastructure projects, content: The most frequently addressed content requirement categories are success criteria and objectives (2.c5), costs and budget (2.c6), organisation (2.c7) and risks and opportunities (2.c11). In contrast, the categories special features (2.c3), team (2.c13), versions, scenarios (2.c14) and environment (2.c17) are documented as covered only once. However, these findings should not be overestimated, as the categories need to be reviewed. Hence, it should be verified if public infrastructure projects have special features (2.c3) that cannot be covered by the other categories and therefore justify a separate category. Furthermore, it is required to distinguish the category environment (2.c17) from organisation (2.c7) and stakeholders (2.c12) as well as the category team (2.c13) from organisation (2.c7). Concerning the

alignment of the framework, it should be discussed whether the categories should refer to only one project type or whether it is conceivable referring to both "purely" public and PPP projects. Finally, it should be examined as to whether the category versions, scenarios (2.c14) is already covered by the process-related requirement flexible (2.p1).

Framework perspective function, requirement categories of public infrastructure projects, process-related: Process-related categories covered the most are integrated (2.p3) and transparent (2.p7). Whereas assigning the selected articles to the controlling objectives demonstrated the need to specify transparency, assigning the selected articles to the process-related categories showed the need to differentiate between transparent and comprehensible (2.p4). Moreover, the process-related categories revealed balancing flexibility and control as a relevant controlling topic. In this context, the article of Walker and Shen (2002) led to the question, if the category "agile" should be added. It is striking that scalable (2.p5) is only addressed once. Concerning holistic (2.p2), it should be discussed whether this requirement is already covered by the multitude of controlling requirements contained in the framework.

System perspectives: Applying the system perspectives showed on the one hand that the sub-perspectives culture (3.2.3) and behaviour (3.2.2) as well as instruments (3.3.2) and methods (3.3.3) should be separated from each other. Due to the lack of conceptual clarity, the sub-perspectives culture and behaviour as well as instruments and methods have not yet been considered separately. The literature review resulted in some articles, e.g. Stubbs (2013), which cover the system perspective structure (3.1). However, due to the importance of good structuring, the research should focus on this system perspective soon by defining requirements for a successful structure of project controlling. Whereas the sub-perspectives instruments and methods (3.3.2, 3.3.3) are often addressed, the sub-perspectives infrastructure (3.1.3) and skills (3.2.1) are rarely mentioned. Regarding the system perspective people (3.2), the principal-agent approach, which is addressed in some of the articles, is of particular interest, as it has numerous principal-agent relationships in public infrastructure projects (e.g. Flyvbjerg et al. 2009). Finally, it should be mentioned that the system perspective partners and context (3.4) is hardly covered at all. With regard to partners, this is of little surprise since articles on stakeholder management or project organisation were not selected.

4 Conclusion

This article aims at identifying the international research literature on controlling of public infrastructure projects. Due to linguistic challenges, preparatory work was necessary in order to specify search terms as well as to structure and evaluate search results. Therefore, a controlling system framework was developed by specifying the understanding of controlling, by defining initial requirement categories for the controlling of public infrastructure projects and by applying the idea of a controlling

system. Finally, the literature review was performed and selected articles were evaluated. Since the controlling system framework served as a basis to structure the selected articles, initial experiences in theoretically applying the framework were gathered and requirements for adjustment were identified.

Since few articles were selected, it is difficult to identify precise research gaps. However, by assigning the selected articles to the controlling system framework perspectives, at least some research questions were identified. However, since the literature review yielded few relevant results, and with regard to the title of this article, we can conclude that there is not that much about coordination, transparency and anticipation in public infrastructure projects—at least not within the international literature analysed in this article.

Regarding the literature review, search step 2 should be completed and it should be discussed whether the most successful search terms should be generalised beyond search step 2, e.g. using the project type construction project. Furthermore, the journals, which are of special relevance for project management (see chapter 3.1), are not completely included in the searched database (older volumes are missing). Therefore, the literature review could be extended to older volumes as well as to German journals and other sources.

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