Customisable framework for project risk management

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Abstract

Purpose – The purpose of this paper is to emphasise on the need for efficient and effective project risk management practices and to support project managers in increasing the cost certainty of projects by proposing a new framework for project risk management.

Design/methodology/approach – The author adopts a "constructivist" methodology, drawing on practices common in construction management sciences and new institutional economics.

Findings – The author presents a holistic and customisable project risk management framework that is grounded in both practice and academia. The framework is holistic because, amongst others, all steps of the typical risk management process are addressed. The framework is customisable, because it allows for alternative ways of implementing the project risk management steps depending on the project-specific circumstances.

Research limitations/implications – The framework does not address the potential unwillingness of the project players to set up a project risk management process, at all. The proposed framework has not yet been tested empirically. Future research will seek to validate the framework.

Originality/value – The framework is designed to account for the difficult circumstances of a complex construction project. It is intended to support decision makers in customising a practical yet comprehensive project risk management concept to the characteristics of the unique project. Although many other project risk management concepts are designed based on the assumption that actors are perfectly rational and informed, this framework's design is based on the opposite assumption. The framework is dynamic and should adapt over time.

Keywords Knowledge management, Infrastructure, Construction management, Risk management, Project management, Risk assessment, Planning management

Paper type Conceptual paper

Introduction

Construction projects are unique, multi-player, technically demanding, capital-intensive and therefore complex ventures. Because of this complexity, the success of construction projects is usually highly dependent on the quality of preparation and planning prior to execution. Every plan for a construction project is exposed to uncertainty. In this context, risk is understood to be a combination of the quantifiable likelihood that a risk event will take place and the extent of a deviation between the actual outcome and the original plan (Schnorrenberg *et al.*, 1997, Girmscheid and Bush, 2008). Project risk management is a process intended to help project players identify, assess and minimise risks to the project while maximising cost certainty.

Project risk management is relevant for all project phases, tasks and players. There are player(s) that set the process up and take responsibility for it, players that conduct the project risk management steps and players that make decisions and take actions. This framework is designed to support the project player(s) that set the project risk management process up and take responsibility for it, namely, the project manager(s); however, the framework takes the whole project into account and, therefore, all project players.

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The purpose of this paper is to emphasise on the need for efficient and effective project risk management and to support project managers in using risk management to increase cost certainty. The focus of this research is the construction industry practice. This paper seeks to identify potential for improvement in practice and to provide a practical solution for addressing project risks and cost uncertainty.

Research methodology

This conceptual paper deals with project risk management in the construction industry. The domain of research is "construction management sciences" (Girmscheid, 2007). This field of applied sciences aims to develop scientific solutions for "practice problems" in the construction industry. The focus of this branch of research is on the practical relevance and applicability of scientific results. Depending on the research focus, construction management sciences make use of natural sciences, management sciences and/or social sciences. This paper draws on both management sciences and social sciences. Management sciences are relevant because project risk management is one element of project management. The social sciences are relevant because the subjects applying project risk management are opportunistic, subjective individuals with bounded rationality that are sensitive to group dynamics. New institutional economics provides the theoretical background to consider bounded rationality.

The research solution was developed using a constructivist approach. Constructivist research aims to use logical thinking to create a research solution (i.e. the research result) for a problem that has been identified by determining whether there is a research gap between the literature intended to provide guidance or solutions to industry and what occurs in practice. According to Popper (1987), constructivist research requires active design of the socio-technical environment. The research solution/result can and should be used to solve the practice problem.

To identify the research gap, this paper considers two types of literature on project risk management:

(1) literature that describes project risk management in practice; and

(2) literature that describes alternative approaches to project risk management.

In both cases, potential opportunities to improve the cost certainty of construction projects are the focus. The research gap is determined by comparing the practical problem to the proposed solutions and identifying where they are not aligned.

Within this research methodology, the originality of the proposed framework is intended to close the project risk management research gap. The value of the research is that it can produce academically supported, implementable solutions. The solution proposed has not yet been tested empirically. Future research will seek to validate the proposed concept through case study analysis, among other methods.

Literature review

Flyvbjerg *et al.* (2003) cites a study from Aalborg University in Denmark which finds that cost overruns for transport infrastructure projects are a global and timeless phenomenon after studying 258 transportation infrastructure projects of various types completed between 1927 and 1998 from 20 countries in five continents. In total, these projects were worth approximately US$90bn (1995 prices). The findings paint a grim picture of cost certainty in practice. For example, in nine out of ten transport infrastructure projects of all types, costs were consistently underestimated, resulting in cost overruns of about 28 per cent in comparison to estimated costs, on average. Specifically, rail project costs were 45 per cent higher than estimated costs, on average. Costs for fixed links (tunnels and bridges) were 34 per cent higher than estimated costs, on average. Road project costs, on average, were 20 per cent higher than estimated costs. To make matters worse, the Aalborg team finds that cost underestimation and cost overruns have not decreased over the past 70 years.

Flyvbjerg *et al.* (2003) analyses the performance of mega projects and identified group interests and resulting opportunistic behaviour as the main causes of flawed project preparation. If project costs are underestimated, the project is likely to be subject to cost pressure throughout. Cost pressure forces project managers to economise cost factors, such as the human resources needed to execute effective project risk management. This situation shows how cost underestimation could have multiple negative effects on the cost certainty of a construction project.

Alfen *et al.* (2010) conduct a survey among public-private partnership (PPP) project players in Germany to understand their risk management competence and the project risk management processes implemented. First, regarding risk management competence, 20 per cent of the contractors and planners considered themselves experts, 26.7 per cent considered themselves advanced and 46.7 per cent said that they only had basic knowledge. Second, 17.6 per cent of the clients considered themselves experts regarding risk management competence, 35.5 per cent considered themselves advanced, 29.4 per cent said that they only had basic knowledge and 5.9 per cent said that they had no expertise at all. Third, equity providers and lenders considered their project risk management knowledge to be at the advanced or expert level. Fourth, a little more than 70 per cent of contractors and planners and less than 40 per cent of public clients had ever implemented project risk management processes. By contrast, all equity providers and nearly 90 per cent of lenders had implemented project risk management processes.

If we assume that each player's self-assessment is correct, these results support the assumption that project risk management is a lot more common and more sophisticated among equity providers and lenders than clients, contractors and planners. In comparison to players in the financial industry, the players most heavily involved in the planning and construction phase have potential for improvement regarding risk management competence.

From a methodological perspective, project risk management is mostly based on individual risk estimations. As no two projects are the same, it is difficult to collect sufficient data to enable a statistical analysis of project risk. Lessons derived from experience can be useful if they are based on standard or common project variables. The uniqueness of every project, however, always requires individual expert assessment to consider project-specific situations when estimating risk. This process of individual risk estimation is vulnerable to opportunism, bounded rationality and subjectivity (Firmenich, 2014).

Bazermann and Moore (2009, p. 50) argue that bounded rationality can influence not only individual but also group decision-making. They discuss advantages and disadvantages of group managerial decision-making, which is particularly relevant for risk estimation. Parkin (1996) develops a descriptive model to explain why project managers experience a lack of rationality in the decision-making process, pointing to power, argument and social values as causes.

The findings in literature so far show that construction projects are still subject to cost uncertainty arising from opportunistic behaviour that results in cost underestimation, cost underestimation that results in cost pressure and cost pressure that results in ineffective project risk management practice, potential competence issues and threats to rational decision-making.

The following paragraphs discuss the literature on guidelines and reports from public institutions and academia. This portion of the literature review is mainly focussed on publications dealing with project risk management of PPP projects to focus on one particularly complicated type of project amidst a huge body of literature. PPP projects are usually complex construction projects with substantial volume. Project risk management is particularly important for PPP projects because of the private equity involvement. In this paper, it is assumed that the findings about project risk management for PPP projects can be transferred to other complex construction projects with substantial volume.

The most mature European PPP market can be found in the UK. Because of the implementation of the Private Finance Initiative in 1992, more than 700 PPP projects worth more than £55bn have been implemented as of 2012 (HM Treasury, 2012, p. 5ff). Several UK institutions with an interest in project risk management have published guidelines or reports to facilitate the growth of this market. These publications address risk transfer or risk allocation in the context of the Public Finance Initiative to support public clients dealing with private contractors. Unfortunately, failing to consider the other risk management steps hinders the implementation of an effective and efficient project risk management (HM Treasury, 1995; Treasury Task Force, 1997, 1999; HM Treasury, 2004; The Treasury Committee, 2011; HM Treasury, 2012). Only HM Treasury (1995) approaches project risk management on a broader level (risk identification, risk assessment and risk allocation but without risk classification and risk controlling), but the authors present just one alternative for implementing these project risk management steps. If only one approach is presented though, the project manager cannot customize the project risk management process to project-specific requirements.

Guidelines and reports from public institutions in Germany (advanced PPP market) usually take a more holistic but very high-level approach to risk management in comparison to the UK. The German Federal Ministry for Traffic, Construction and Housing (BMVBW, 2003) addresses most project risk management steps and presents alternatives to conduct these steps offering a holistic vision of the process. The authors discuss the project-specific selection of alternatives; however, their discussion is based on the importance of risks and not on the project-specific circumstances, such as cost pressure and competence of the players. Furthermore, although they acknowledge the subjectivity of risk estimation, they recommend using objective empirical evidence to estimate risk, if possible, even though such evidence is hardly ever available.

The Glasgow Caledonian University and the University of Manchester are the academic institutions with the strongest track record of researchers and publications dealing with the subject of risk management and PPP projects in the UK. Akintoye *et al.* (2003b) applied interviews and case studies to identify the key factors for "best value" according to different stakeholders in UK PPP projects. The concept of "best value" includes cost certainty as well. The results show the importance of detailed risk analysis and appropriate risk allocation for best value, amongst others. Akintoye *et al.* (2003a) discusses the subject of risk management and PPP projects holistically by addressing all risk management steps. The typical risks are identified and checklists are provided (risk identification). Furthermore, they show how different stakeholders in a PPP project prioritise risks (risk classification). In particular, the researchers contextualize risk within the broader issues of communication and perception, acknowledging the relevance of group dynamics and subjectivity, though without embedding it in the process. Merna and Owen (1998) and Merna and Nijru (2002) discuss typical risks and methods and alternatives for risk identification, risk assessment and risk mitigation in the context of financing infrastructure. They mention that risk management competence and risk perception of players are relevant but, like Akintoye *et al.* (2003a, 2003b), fail to embed these issues in the project risk management process. Smith (2006) focuses on risk management for construction projects. Many methods and alternatives for the typical risk management steps are discussed, and therefore, the publication can be classified as holistic. Again, though the authors identify the relevance of "human aspects" as central to risk management, they (along with many other publications) do not embed these "irrational" aspects in the project risk management process directly (e.g. as customizing criteria).

Bauhaus-Universität Weimar, Technische Universität Berlin and ETH Zurich are the academic institutions with the strongest track record of researchers and publications dealing with the subject of risk management and PPP projects in German-speaking Europe. Elbing (2006) and Alfen *et al.* (2010) present a holistic approach to risk management with alternatives and methods for every risk management step. Girmscheid (2013) discusses all risk management steps, focusing on a rational and, if possible, quantitative approach but neglects to discuss alternatives. All three publications are holistic but fail to explicitly embed cost pressure, potential competence issues or threats to rational decision-making into the project risk management process.

There are other publications that tend to propose complex solutions, often without embedding those solutions in a practical context. Specifically, a substantial body of literature demonstrates how sophisticated concepts such as real options (Miksch, 2007), artificial neuronal networks (Jin, 2010; Jin and Zhang, 2011), fuzzy logic (Yun and Wei, 2008; Jin and Doloi, 2009; Jin, 2010), stochastic processes (Schetter, 2010), Bayesian networks, portfolio theory or game theory could help improve project risk management. These contributions, however, will not find application in practice if the project players lack the risk management competence to use them.

To the best of the author's knowledge, there is no literature which has explicitly proposed a holistic project risk management solution to improve cost certainty for complex construction projects with substantial volume under consideration of cost pressure, potential competence issues and threats to rational decision-making within the project risk management process. The major threats to rational decision-making are as follows:

- *Opportunism*: Project players might have hidden interests that are not in line with the project goals (Flyvbjerg *et al.*, 2003).
- *Bounded rationality*: Project players might suffer from cognitive limitations when estimating risks (Bazermann and Moore, 2009).
- *Subjectivity*: The estimating experts are characterised by subjectivity because of factors such as their experience, values or perception of risk (Parkin, 1996).

In particular, it is assumed that project players apply project risk management practices only reluctantly if it is not possible to manage required resources actively.

Research gap and problem definition

The following paragraph summarises the four potential causes for cost uncertainty based on observation in practice. First, the project players potentially lack the willingness to set up a realistic project plan and/or project risk management to achieve cost certainty at all. For example, clients might try to ignore the real cost of a project because it is easier to promote a cheap project (Flyvbjerg *et al.*, 2003). This practice results in cost underestimation and cost overruns and, thus, cost uncertainty. Second, according to the Swiss Builder Organisation (Schweizerischer Baumeisterverband (SBV), 2013), the average earnings before income and taxes (EBIT) of contractors in Switzerland is only 1.3 per cent of total revenue. The SBV stated that the long-term survival of Swiss contractors would require an EBIT of 4-6 per cent. This lower EBIT results in situations where contractors have limited resources for project risk management unless the client is willing to pay for it. Third, according to Alfen *et al.* (2010), project players not related to the financial industry might have insufficient risk management competence to tackle the project complexity and the difficulties of risk analysis with structured project risk management procedures. Fourth, even if costs were not underestimated, there was no cost pressure, and if all project players executed adequate project risk management with the necessary competence, there would still be threats to rational decision-making such as opportunism, bounded rationality and subjectivity.

As mentioned in the literature review, project risk management is a well-published topic. Despite the existing body of research, construction projects are still characterised by cost uncertainty in practice, possibly because project risk management approaches from academia are not necessarily easily applicable in practice. First, proposed holistic solutions were typically very general and/or had the character of an encyclopaedia without offering customizing options and criteria to project managers according to project-specific circumstances. Second, many publications were focussed on only one or just a few selected aspects of project risk management. They were not embedded in a more comprehensive context and therefore were not practical. Third, proposed solutions that made use of sophisticated methods without ensuring applicability might be useless in practice. If complex solutions are presented, the solution provider needs to demonstrate:

- what competences are needed or how they can be developed; and
- how this solution works in the context of cost pressure to ensure applicability.

Fourth, much of the existing literature ignored the fact that subjects that conduct project risk management are not necessarily perfectly informed or perfectly rational. Risk analysis is based on individual risk estimation. Although this process should be dispassionate, the subjects who perform these assessments are neither perfectly rational nor completely informed. They may be characterised by opportunism, bounded rationality and/or subjectivity. These variables have consequences for the process of project risk management and need to be addressed to ensure practicability.

The paper, therefore, addresses project risk management, not as an explicitly defined series of tasks in a perfect environment conducted by perfectly rational and perfectly informed subjects but instead as a flexible support process that adapts to the challenging constraints of an imperfect project environment and to irrational subjects with imperfect information.

Given this research gap, this paper asks the following question:

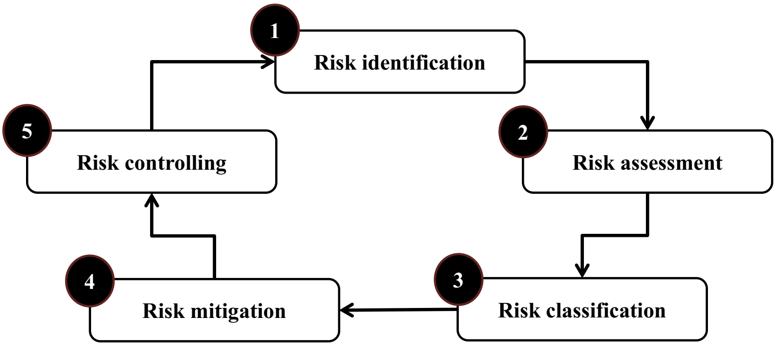
Q1. How can players in complex construction projects with substantial volume improve the cost certainty using project risk management under considerations of cost pressure, potential competence issues and threats to rational decision-making?

To tackle the practice problem specified above, this paper presents a holistic and customisable project risk management framework.

Proposed project risk management framework

Project risk management process

The risk management process, as displayed in Figure 1, typically consists of five steps that, ideally, are periodically repeated over the project's lifecycle: planning phase, comparison of alternatives, execution, operation and major changes such as transactions, renovation or liquidation. The first and most crucial step is cause-oriented risk identification. Only the risks identified can be managed. The second step, ideally, is the monetary effect assessment of the risks identified. The third step is risk classification, which aims to prioritise the risks identified and assessed. The fourth step, risk mitigation, analyses what mitigation alternatives are applicable for each risk identified and which combinations of actions minimise the project risk situation overall. The fifth, and last, step is risk controlling, which requires a player to compare the actual project situation with the original project plan to control the effectiveness of the risk mitigation actions.



Source: Adapted from Girmscheid (2013)

Figure 1.
Risk management process

These project risk management steps should be conducted at as detailed a level as necessary and should be kept as simple as possible. This suggestion reflects the typical conflict of aims to characterise project risk management. For effectiveness, the output quality should be maximised, whereas for efficiency, the resources required should be minimised.

The risk management steps are evaluated and labelled as "required", "optional" and/or "reasonable" (Table I). Risk identification is required and reasonable for every complex project. Proper risk identification is a precondition for all subsequent steps. The risk identification corresponds to a cause analysis. Understanding the cause of a risk event is a precondition to understanding the effects of the event, and understanding both the cause and effects is a precondition to determining the best risk mitigation actions. Likewise, risk assessment is required and reasonable for every complex project. Risk assessment could be considered an effect analysis and allows the evaluator to put a "price tag" on the identified risks. The risk classification, in contrast, is an optional step that is reasonable if the risks need to be prioritised for further treatment because of limited resources. Risk mitigation is a

Table I.
Evaluation of the project risk management steps

Risk management steps	Description	Output	Recommendation
Risk identification	Analysis of cause	List of risks related to project phases, players and tasks	Required and reasonable for every complex project
Risk assessment	Analysis of effect	Qualitative or quantitative monetary assessment of risks identified	Required and reasonable for every complex project; qualitative in case of limited resources
Risk classification	Prioritisation	Clarification of what risks are first priority and what risks can be neglected	Only reasonable if prioritisation is inevitable because of limited resources
Risk mitigation	Actions for risk minimisation	Recommendations to eliminate, reduce, insure, transfer or accept risks	Reasonable for project optimisation based on previous analysis
Risk controlling	Actual/plan comparison	Control of the actions' effectiveness, ideally long-term repetitiveness	Only reasonable for long-term quantitative risk management with continuous improvement

very reasonable and highly recommended step, because most benefits to the project can be generated. Although all previous steps analyse the situation, risk mitigation serves to derive actions for project risk minimisation. The alternatives of risk mitigation are risk reduction, risk elimination, risk insurance, risk transfer and risk acceptance. Risk controlling is another optional step that is reasonable if long-term quantitative risk management is intended. It controls the actions' effectiveness and serves as a mechanism for continuous improvement.

Risk analysis approaches

Risk identification and risk assessment are the most crucial risk management steps and form the analytical basis for the rest of the risk management process. Depending on the context, the risk analysis can typically be approached with a statistical foundation, data from previous project experiences or estimations (Table II). In the context of unique construction projects, a statistical foundation for risk analysis is usually not available. Exceptions occur for certain risks, such as the risk of changing interest rates. Project experience data are information that has been collected on past projects and has an indicative value, but does not suffice for statistical appraisal. These kinds of data are available for risk identification if at least one of the players has documentation, but it is not typically useful for risk assessment because the monetary evaluation depends more heavily on the project circumstances. Regardless, it is crucial to conduct a project-specific analysis to capture the uniqueness and the complexity of the project. The most common approach for unique construction projects that lack a statistical foundation and experience data is estimation by experts. The expert risk estimation is the part of the risk analysis that is most sensitive to flaws because of potential competence issues, opportunism, bounded rationality and subjectivity of the experts. Avoiding these threats to rational decision-making requires additional resources.

Galton (1907), List and Pettit (2002), Surowiecki (2004), Solomon (2006), Wagner *et al.* (2010) and Lorenz *et al.* (2011) have discussed group dynamics in decision-making based on subjective estimations in collectives and how certain team constellations may improve or jeopardise decision-making. Although an internal, interdisciplinary group of experts draws from the most know-how of the project directly, potential problems may arise because of internal conflicts and dynamics. An external group of experts has the benefit of an independent, outside view and additional expertise, but might be insufficient because of lack of internal knowledge of the project. An iterative approach between an internal and an external group of experts would combine the advantages and eliminate the disadvantages of having just one of the two groups do the expert estimations. This would most likely produce the best results but would require the most resources.

Statistical foundation	Experienced data	Estimation External group	Estimation internal group	Estimation individual
Usually not available for unique projects with some exceptions (e.g. interest risk)	Risk identification: • Usually available Risk assessment: • Usually not available with exceptions possible	Reasonable for an independent outside view • Insufficient because of unconsidered internal information	Reasonable because of the best know-how basis • Potential problems because of internal conflicts and dynamics	Usually insufficient because of potential competence issues, opportunism, bounded rationality and subjectivity

Table II. Risk analysis approaches for risk identification and risk assessment

Risk identification (1)

The ultimate precondition for successful risk identification is a proper understanding of the project. The development of this understanding can be challenging for a complex project. The challenge can be tackled using a structured approach that includes the three project dimensions: phases, players and tasks (see Figure 2). The objective is to have a thorough overview of which player is doing what task in what phase. This organisation is achieved with a player-task (PT) analysis for every phase as shown in Table III with an example template. Y is the variable for the project-specific number of tasks. Once the project is understood and described, the actual risk identification can take place.

Risk identification can be structured with help of the project's phases, players and tasks, on the one hand, and the typical project risk types, on the other hand, to ensure output quality. The cause-oriented risk types, according to Girmscheid (2013), are legal risks, technical risks, schedule risks, financial risks, management risks and/or environmental risks.

The application of any of various methods of risk identification is intended to detect the single risks for every risk type in every phase, for every player and for every task (see Table IV for an example template, R is the variable for the project specific number of risks).

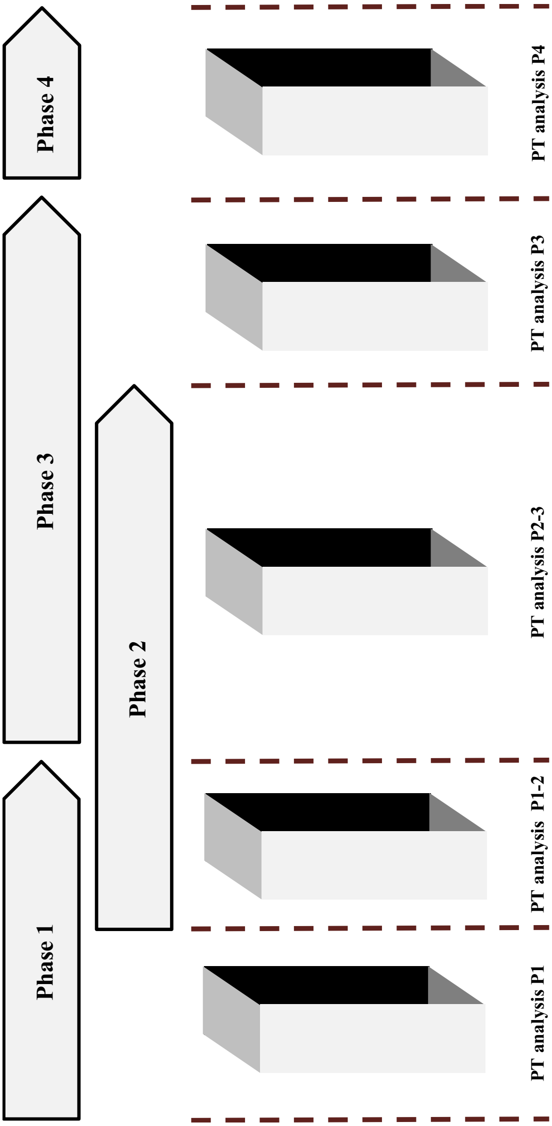
Alfen *et al.* (2010) recommended using a mix of methods to achieve the best results for risk identification. Typical methods that might be applied comprise analysis of project documentation, brainstorming, pondering, mind-mapping, checklist and/or workshop. The project manager selects the methods depending on the resource availability and the risk competence. If several experts are involved in the estimation, the application of the methods selected can be distributed among the experts for efficiency. This applies to risk assessment as well. Table V shows an example in which a group of internal experts and a group of external experts are involved.

A workshop can be a particularly powerful method of risk identification and risk assessment as long as it is structured and goal-oriented, because it uses the know-how of many people. The Delphi method is an established moderation technique that allows for different set-up scenarios. First, Delphi participants could participate in the workshop anonymously. Second, Delphi can structure the workshop in round-based risk estimation (at least two rounds) or in a real-time risk estimation. Third, the workshop could take place with actors who are physically present or with actors participating online. This approach can be used for risk assessment as well.

Risk assessment (2)

The first step of risk assessment is to finalise an effect-oriented risk list based on the same structure as the cause-oriented risk list that came out of the risk identification step (see Table VI for an example template). The purpose of the effect-oriented risk list is to understand which phases, players and tasks will experience the effect of the risk. This information is helpful when estimating the monetary values for each risk identified.

The major customisation option for risk assessment is the selection of the particular risk assessment approach (Figure 3). For example, the *traffic light logic* (A) is a three-level visual scale that evaluates risks as a whole or differentiates the risks based on probability of occurrence and potential impact. If a risk is labelled "green", it is considered to be "under control". If a risk is labelled "yellow", it is considered a "potential danger". A risk with a "red" label is considered an "immediate danger". On the one hand, this practitioner approach is very fuzzy and imprecise as the evaluation scale is usually not defined clearly and the results depend on the estimator's individual assessment. Additionally, this approach limits the possibility of further analysis. On the other hand, it is easy to understand and easy to apply.



Source: Firmenich (2014)

Figure 2.
Understanding the players and tasks (player-task analysis) for every project phase

Table III. Example player-task analysis for every project phase as template

Phase P	Player 1	Player 2	Player 3	Player X
Task 1	X	X	X	X
Task 2	X			
Task 3		X	X	
Task 4		X		X
Task 5			X	X
Task 6		X		
Task 7	X		X	X
Task 8				X
Task Y			X	

Table IV. Example cause-oriented risk list as template

Risks	Phases Phase 1	Phase 2	Phase P	Players Player1	Player2	Player X	Tasks Task 1	Task 2	Task Y
Legal risks									
Risk 1	X	X			X				X
Risk 2	X			X	X			X	
Technical risks									
Risk 3	X	X	X			X	X		
Risk 4		X				X		X	X
Schedule risks									
Risk 5	X	X	X	X			X		
Risk 6		X		X				X	
Financial risks									
Risk 7		X	X		X		X		
Risk 8			X			X		X	
Management risks									
Risk 9	X			X			X		
Risk 10		X			X			X	
Environmental risks									
Risk 11			X			X			X
Risk R	X					X	X	X	

Table V. Example distribution of risk identification methods among experts for estimation

Risk identification methods	External experts: initial analysis	Internal and external experts: workshop	External experts: wrap-up
Documentation analysis	X		
Brainstorming	X		
Pondering	X		
Mind-mapping	X		X
Checklist	X		X
Workshop		X	

Risks	Phases Phase 1	Phase 2	Phase P	Players Player 1	Player 2	Player X	Tasks Task 1	Task 2	Task Y
Risk 1			X	X	X	X			X
Risk 2			X		X				X
Risk 3	X	X	X		X			X	X
Risk 4			X			X			X
Risk 5		X	X	X			X	X	
Risk 6		X	X	X				X	
Risk 7			x		X		X		
Risk 8			X	X	X	X			X
Risk 9	X				X			X	
Risk 10			X		X				X
Risk 11			X			X			X
Risk R		X				X			X

Table VI. Example effect-oriented risk list as template

This ease of use makes the traffic light logic a common approach in practice. Importantly, a higher level of detail can be achieved with the traffic light logic if the two major elements of risk – probability of occurrence and impact – are evaluated separately.

Qualitative evaluation with words or numbers (B) can be applied like the traffic light logic as a scale with an arbitrary number of levels to describe risks as a whole or can be used to differentiate risks based on the probability of occurrence and impact.

The *evaluation of risk cost as percentage* (C) has an assumed risk-free target value as a basis. Each risk's "risk cost" can be estimated as a percentage of this risk-free target value.

In the *quantitative deterministic* approach (D), each risk's "risk cost" is quantified by multiplying the risk's probability of occurrence (percentage) with the estimated monetary value of the risk's impact. To evaluate the total project risk cost, these single risk costs need to be aggregated.

The *quantitative description of risk as a spread* (E) is based on the minimum and maximum potential monetary value of a risk. When each risk's "risk cost" is described as a range, the total project risk cost can be assessed using a scenario analysis.

The *quantitative probabilistic* approach (F) works with the distribution function of each risk's impact as a monetary value. The experts need to estimate the minimal, modal and maximal impact value. The distribution functions can be derived from these three estimated values with the help of software (e.g. ModelRisk, @Risk or Crystal Ball). The single risk's distribution functions can be input into a Monte Carlo simulation using the same software to calculate total project risk cost.

The least complex and laborious approach is the traffic light logic (A). At the same time, it has the least useful output with regards to understanding the monetary value of the project risk and preparing for risk mitigation. The most complex and laborious approach is the quantitative probabilistic risk estimation (F); but this approach provides the most useful output and the best means by which to prepare for risk mitigation. In the case of limited resources, the qualitative risk assessment approaches are particularly useful for developing a general overview of the project's risk situation, at least. Approach (C) is the least complex and laborious way to calculate a monetary value of the project risk. In contrast to the other quantitative approaches (D, E, F), it lacks the cause-oriented aspect, as it is not based on single risks that need to be aggregated. Instead, this approach is usually applied to the total project cost and is therefore rather effect-oriented. This feature limits the understanding of the project's risk situation and the potential for risk mitigation.

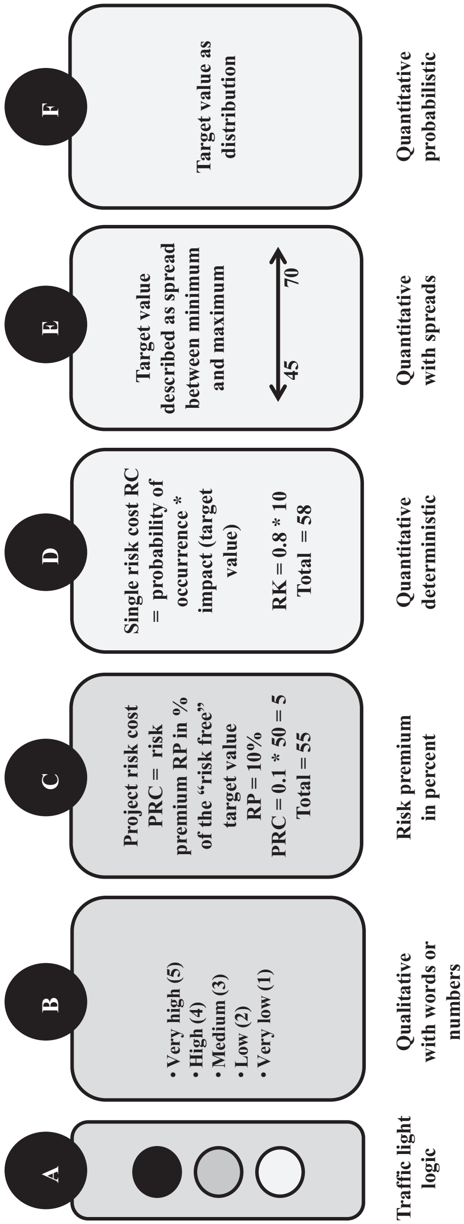


Figure 3.
Risk assessment approaches

The following example compares the cause-oriented risk assessment approaches D, E and F (Tables VII-IX and Figure 4). The starting point is a fictional project α. This project's schedule has a duration of 24 months and costs CHF 100m. It is assumed that any delay will be compensated with an extra CHF 1m per month of delay beyond the scheduled deadline, and that this option will always be used if necessary. For simplification, it is assumed that risk identification will identify three risks to be assessed:

(1) delay of the project start (in months);

(2) variation of project duration (in months); and

(3) variation of project costs (in CHF million).

Approaches D, E and F were applied to assess single risks and the total risk of project α. Table VII presents the overview of the different quantitative risk assessment approaches in the example provided. The overview is followed by Table VIII, Table IX and Figure 4, which provide the details of every quantitative risk assessment approach.

	D) Quantitative deterministic	E) Quantitative with spreads	F) Quantitative probabilistic
Input single risk assessment	Two parameters per risk: • Probability of occurrence • Impact	Three parameters per risk: • Minimum • Mode/mean • Maximum	Three parameters per risk: • Minimum • Mode/mean • Maximum
Aggregation project risk	• One multiplication per risk • One addition for total	• Three scenarios at least (best, normal and worst) • One addition per scenario for totals	• One distribution per risk • One simulation for total • One data analysis for total
Output added value	The estimated deterministic project risk cost amount to CHF 11.6m	The project risk cost lies between CHF 13m (best case) and CHF 68m (worst case). The expected project risk cost amounts to CHF 23m (normal case)	The simulated project risk cost lies between CHF 10.82 and 59.31m. The expected project risk cost amounts to CHF 27.83m. With a probability of 90%, the project risk cost will not be higher than CHF 41.09m

Table VII. Example (1/4) – overview of quantitative risk assessment approaches

Single risk and project risk characteristics	1) Delay of project start	2) Variation of project duration	3) Variation of project cost
Probability of occurrence PO	PO1 = 20%	PO2 = 40%	PO3 = 60%
Impact I mean/mode	I1 = 3 months → CHF 3m	I2 = 5 months → CHF 5m	I3 = CHF 15m
Single risk cost RC = PO × I	RC1 = PO1 × I1 RC1 = 0.2 × 3 RC1 = CHF 0.6m	RC2 = PO2 × I2 RC2 = 0.4 × 5 RC2 = CHF 2m	RC3 = PO3 × I3 RC3 = 0.6 × 15 RC3 = CHF 9m
Project risk cost PRC	PRC = RC1 + RC2 + RC3 PRC = CHF 0.6m + CHF 2m + CHF 9m PRC = CHF 11.6m		
Output	The estimated deterministic project risk cost amounts to CHF 11.6m		

Table VIII. Example (2/4) – details of the quantitative deterministic risk assessment approach

Single risk and project risk characteristics	1) Delay of project start	2) Variation of project duration	3) Variation of project cost
Impact I minimal value	0 months → CHF 0m	−3 months → CHF −3m	CHF −10m
Impact I mean/mode	I1 = 3 months → CHF 3m	I2 = 5 months → CHF 5m	I3 = CHF 15m
Impact I maximal value	6 months → CHF 6m	12 months → CHF 12m	CHF 50m
Project risk cost (best case scenario)	PRC-Best = RC1-Best + RC2-Best + RC3-Best PRC-Best = CHF 0m + CHF −3m + CHF −10m PRC-Best = CHF −13m		
Project risk cost (normal case scenario)	PRC-Normal = RC1-Normal + RC2-Normal + RC3-Normal PRC-Normal = CHF 3m + CHF 5m + CHF 15m PRC-Normal = MCHF 23		
Project risk cost (worst case scenario)	PRC-Worst = RC1-Worst + RC2-Worst + RC3-Worst PRC-Worst = CHF 6m + CHF 12m + CHF 50m PRC-Worst = CHF 68m		
Further scenarios as required	. . .		
Output	The project risk cost lies between CHF −13m (best case) and CHF 68m (worst case). The expected project risk cost amounts to CHF 23m (normal case)		

Table IX. Example (3/4) – details of the quantitative risk assessment approach with spreads

Approach D (quantitative deterministic, Table VIII) is the least complex and laborious regarding the single risk assessment and the calculation of total project risk. At the same time, the added value of the output is the lowest compared to approaches E and F. Every single risk needs to be assessed regarding its probability of occurrence and its impact. The aggregation is done by multiplying each risk and adding the resulting products. The result is one value equal to the estimated project risk cost.

Approach E (quantitative with spreads, Table IX) is somewhat complex and laborious regarding the single risk assessment, aggregation and the output's added value. In total, three parameters need to be estimated for every risk – one parameter more than Approach D. Both approaches require the mean or the mode of every risk's impact. Additionally, Approach E requires the minimal and maximal potential impact for every risk. The aggregation for Approach E requires a scenario analysis using different combinations of impact values for every risk within the risk's spread. The added value of the output is higher for Approach E compared to Approach D, because it produces the minimal and maximal project risk, in addition to the expected project risk.

Approach F (quantitative probabilistic, Figure 4) is also somewhat complex and laborious regarding the single risk assessment and highly complex and laborious regarding the aggregation. At the same time, the added value of the output is the highest compared to Approaches D and E. Approach F requires the same risk assessment for single risks as Approach E. The three parameters (minimum, mode and maximum) are transformed with the help of software (i.e. @Risk) to derive the probability distribution of every single risk's impact. The only further information needed is the type of distribution to be used on the three parameters (i.e. triangle or Pert). These probability distributions are used as input to a Monte Carlo simulation that simulates the aggregated project risk probability distribution. This distribution contains all of the information that can be provided with Approaches D and E. Additionally, the value at risk can be applied, and statements such as "with a probability of x% the project cost will not exceed CHF y million" can be made.

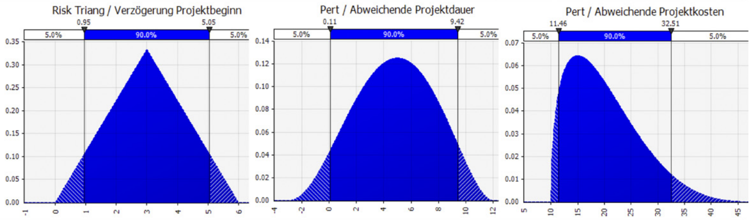
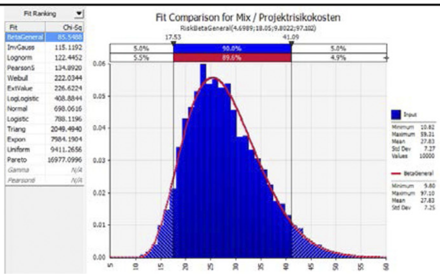
Single risk and project risk characteristics	1) Delay of project start	2) Variation of project duration	3) Variation of project cost
Impact I minimal value	0 months → CHF 0 million	-3 months → CHF -3 million	CHF -10 million
Impact I mean/mode	I1 = 3 months → CHF 3 million	I2 = 5 months → CHF 5 million	I3 = CHF 15 million
Impact I maximal value	6 months → CHF 6 million	12 months → CHF 12 million	CHF 50 million
Probability distributions of the impact (derived from the 3 input parameters with software			
Simulated probability distribution of the project risk cost (Monte Carlo Simulation)			
Output	The simulated project risk cost lies between CHF 10.82 million and CHF 59.31 million. The expected project risk cost amounts to CHF 27.83 million. With a probability of 90%, the project risk cost will not be higher than CHF 41.09 million.		

Figure 4.
Example (4/4) – details for the quantitative probabilistic risk assessment approach

As is shown in the previous tables, the value for the expected project risk and the quality of the output differs substantially depending on the approach and/or aggregation method.

Risk classification (4)

Risk classification is a customisation option directly embedded in the typical project risk management process. It is a step that is intended to prioritise the risks identified and assessed. On the one hand, this step is useful for reducing the amount of resources needed. On the other hand, it can be disadvantageous to neglect certain risks when developing a holistic risk mitigation concept. If some risks are not considered because they have been given a lower priority, potential consequences of risk mitigation actions for these risks cannot be considered, too. Therefore, it is recommended to select risks for risk mitigation only if limited resources absolutely require it or if the construction project is characterised by a low level of complexity.

Risk mitigation (5)

Risk analysis (consisting of risk identification and risk assessment) is the basis for ideal risk mitigation and project risk minimisation. There are several ways to mitigate risk: risk reduction, risk elimination, risk insurance, risk transfer and risk acceptance. Understanding the causes (Table IV) and effects (Table VI) of risk is essential to determine the risk reduction and risk elimination actions needed to address project risks. The quantitative risk assessment puts a "price tag" on the risk identified (Table VII). This is critical information for those who seek to evaluate if potential risk mitigation actions pay off in comparison to the risk reduced or eliminated and those who seek to evaluate if the risk premium to be paid for risk insurance or risk transfer to another project player is appropriate. Any additional risk mitigation actions that alter the original project plan should be challenged with regard to the potential new risks these actions could create.

Table X shows an example outline of risk mitigation alternatives for risks identified and assessed. With this template, all risk mitigation alternatives are considered for each project risk. Furthermore, one risk mitigation alternative might point to different possible actions to ameliorate one risk. Once all risk mitigation alternatives and their respective action options are identified, they can be evaluated to determine a holistic project risk mitigation concept.

Risk controlling

Risk controlling is the last step in the project risk management process. Risk controlling compares the actual project situation with the original project plan to control the effectiveness of risk mitigation actions (e.g. on a weekly or monthly basis). It accounts for the fact that project risk identification, risk assessment and risk mitigation occur at a point in time, whereas complex construction projects of substantial volume are long-term processes.

There are three main advantages of risk controlling. First, immediate actions can be taken if a strong deviation between the actual project situation and the original project plan develops. Second, the project risk management steps that form the basis for risk controlling can be evaluated regarding their effectiveness. A long-term optimisation of the project risk management framework can be initialised based on the resulting insights. The project risk management framework is holistic in that it shows all options and is customisable in that

Risks	Risk reduction	Risk elimination	Risk insurance	Risk transfer	Risk acceptance
Risk 1	Action r1a Action r1b	Not possible	Action i1a	Action t1a Action t1b	Possible
Risk 2	Not possible	Not possible	Action i2a	Not possible	Never
Risk 3	Action r3a Action r3b Action r3c	Action e3a	Not possible	Action t3a	Not reasonable
Risk 4	Action r4a Action r4b	Action e4a	Action i4a	Not possible	Possible
Risk 5	Not possible	Action e5a Action e5b	Action i5a	Action t5a	Possible
Risk 6	Action r6a	Action e6a	Not possible	Action t6a	Possible
Risk 7	Action r7a	Action e7a	Not possible	Not possible	Possible
Risk 8	Action r8a Action r8b	Not possible	Not possible	Action t8a Action t8b	Not reasonable
Risk 9	Not possible	Action e9a Action e9b	Action i9a	Action t9a	Never
Risk 10	Action r10a	Action e10a	Action e10a Action e10b	Action t10a	Possible
Risk 11	Action r11a	Action e11a Action e11b	Action e11a	Not possible	Never
Risk R	Action rRa Action rRb	Not possible	Not possible	Action tRa	Not reasonable

Table X.
Example outline of risk mitigation alternatives for risks identified and assessed as template

players are able to select the option most suitable for the project-specific circumstances. Still, the framework is never final. It is not static but dynamic. In fact, the framework can and should develop over time throughout the course of one project and be adapted for use in future projects. Every utilisation of the framework might identify new customisation opportunities or new evaluation criteria. Third, a database for the next project risk evaluation can be developed. Risk controlling serves as a link that changes the nature of the project risk management process from linear to cyclical by creating a suitable space for periodic re-evaluation of the project. This re-evaluation should be based on risk controlling and repeat the risk identification, risk assessment, risk classification and risk mitigation steps (i.e. on a quarterly, semi-annual or annual basis).

Research findings

The project risk management framework proposed in this paper was developed using a constructivist research approach. Constructivist research makes use of logical thinking to create a solution (the research result) for the practice problem based on the research gap within a given research framework.

Construction management sciences, with a focus on management sciences and social sciences, as well as new institutional economics (Research methodology), was the theoretical foundation of this paper. A comparison between the solutions proposed in literature and the problems that occur in practice revealed an important research gap. The research gap showed that a project risk management framework that can successfully reduce cost uncertainty should be holistic and customisable under considerations of cost pressure and potential competence issues and threats to rational decision-making of the subjects involved.

The proposed project risk management framework is holistic, because it addresses all steps of the typical risk management process (Figure 1) and applies a three-dimensional project analysis concept (Firmenich, 2014; Figure 2). Furthermore, the framework is customisable, because it allows for alternative ways of implementing the project risk management steps to allow project managers to choose options that are relevant to the project-specific circumstances, such as considerations of cost pressure, potential competence issues and threats to rational decision-making. The ability to customise the project risk management process to the project-specific circumstances ensures practical applicability and thus improves project cost certainty. The logical process is as follows:

- Identify the customisation options for project risk management.
- Identify the alternatives for every customisation option.
- Evaluate the alternatives for every customisation option (e.g. Tables I and II).

The provision of example templates that could be used at different project risk management steps (Tables III, IV, VI, and X) supports the applicability of this framework. Finally, the advantages and disadvantages of risk assessment alternatives (Figure 3) are illustrated with an example (Tables VII, VIII, IX, and Figure 4). The selection of the risk assessment method(s) is crucial for the quality of the project risk management and thus for ensuring project cost certainty.

Specifically, the proposed framework stresses that every complex construction project could and should, at least, have more than one expert conduct risk identification and a qualitative risk assessment. In cases where projects have limited resources, risk classification can help to prioritise the identified and assessed risks. Risk identification and a quantitative risk assessment with spreads conducted by an interdisciplinary group of project experts would improve the output quality significantly compared to the same assessment conducted by just one expert. Risk mitigation is the step that requires determining and taking action to improve the project based on the previous risk analysis. Risk controlling closes the loop and compares the actual project situation with the original project plan to control the effectiveness of the risk mitigation actions.

To ensure ideal output quality, all project risk management steps should be processed in the context of risk identification and a quantitative probabilistic risk assessment done by both an internal and external group of experts in an iterative process in which a many-sided method mix for risk analysis is applied.

The proposed framework extends the existing body of research beyond risk management as an explicitly defined series of tasks in a perfect environment conducted by perfectly rational and perfectly informed subjects. Unlike the general high-level holistic publications, the proposed framework includes specific templates along with the general solutions to increase practicability and applicability. In contrast to an encyclopaedia of possibilities, this framework distinguishes "must have" and "nice to have" aspects depending on the project-specific circumstances. The proposed project risk management framework furthermore acknowledges cost pressure, potential competence issues and threats to rational decision-making, as few publications do, and also embeds these aspects as customizing criteria in the project risk management process.

Publications that are focussed on specific elements of risk management might not be applicable in practice because of the missing context and the mentioned cost pressure and potential competence issues. If research is conducted in the context of applied sciences, it is not enough to describe the practice empirically or to prove feasibility of one theoretical element. Academia needs to develop a way to apply innovation to practice as well to solve real problems and improve practice.

Conclusion

The purpose of this paper is to emphasise on the need for efficient and effective project risk management and to support project managers in increasing cost certainty. The existing need for efficient and effective project risk management is underlined by studies that document cost uncertainty for construction projects and the potential competence issues of project players.

The practical aim of this paper is to support project managers in increasing cost certainty by adopting improved project risk management practices. The customisable project risk management framework presented addresses three of the four causes of cost uncertainty that occur in practical situations: cost pressure, potential competence issues and threats to rational decision-making (research gap and problem definition). Three major benefits for project managers emerge. First, the framework offers customisation options and flexibility in setting up a process for project risk management. Throughout the risk management process, all customisation alternatives are described and evaluated. The main customisation options are:

- the selection of the requisite project risk management steps to be performed;
- the number and mix of people involved in each step; and
- the selection and mix of methods applied throughout the process.

These options allow the project manager to determine the best solution for every construction project, despite cost pressure and potential competence issues among the players conducting the project risk management. Second, the risk competence level of the project players conducting the project risk management can be addressed by the availability of different methods. This variety of options ensures that the project manager can control project risks despite variability amongst his or her team members. Furthermore, the framework offers a holistic set of guidelines for project managers by explaining the typical project risk management steps and illustrating how they can be processed successfully. This part supports the project manager in developing his own risk competence. Third, the framework outlines where and how threats to rational decision-making can jeopardise the output quality of project risk analysis and what countermeasures are available. The framework explicitly addresses the disadvantages of individual risk estimation, including opportunism, bounded rationality and subjectivity. Risk estimation by experts is crucial for risk analysis. The number and composition of an expert group, as well as the method mix, can reduce or avoid threats to rational decision-making. The avoidance of such threats requires resources. If the project managers can optimise resources, then they can optimise output quality and, therefore, efficiency and effectiveness of the project risk management.

Importantly, the proposed framework is dynamic, whereas most existing frameworks are static. In fact, the framework can and should develop over time throughout the course of one project and over the course of future projects. Those implementing this framework should make use of further theoretical knowledge and practical experience to achieve the best long-term results.

Furthermore, the framework presented here accommodates the project-specific circumstances of every complex construction project and allows decision makers to customise a practical yet holistically reasonable and useful project risk management concept that fits the difficult characteristics of the unique project. In particular, the subjects involved are acknowledged as not being perfectly rational or perfectly informed.

The impact of this work contributes to both theory and practice. The added value of this new framework, with regards to practice and the existing literature is that it is comprehensive yet specific enough to be applied in practice. It explicitly considers cost pressure by allowing for customisation depending on the judgement of the project manager. The framework enables a range of approaches, from simple to sophisticated. The selection of a given approach depends on the resources available and the risk competence level of the project players conducting risk management. Instead of having no or an ineffective project risk management approach, the result of applying the customisable project risk management framework is an implementable, project-specific risk management process that provides the best output with the quantity and quality of resources available.

Improved project risk management can lead to major benefits for complex construction projects with substantial volume: maximisation of cost and planning certainty; minimisation of risk cost; optimisation of the planning phase; reduction of opportunism and other threats to rational decision-making; acknowledgement of uncertainty; improved project coordination; and project optimisation regarding financing, investor search and due diligence.

With regard to the applicability of the framework, it is assumed that the additional resources needed to set up a project-specific risk management with this customisable framework are compensated, and that the compensation is based either on resources saved as a result of implementing the framework or on the improved cost-benefit ratio in comparison with project-unspecific risk management. The framework does not address the potential unwillingness of the project players to set up a project risk management process, at all.

This conceptual paper developed a holistic and customisable project risk management framework with constructivist research in the context of construction management sciences and new institutional economics. The proposed framework solves the practice problem theoretically. The research solution proposed has not yet been tested empirically. It is part of future research to validate the research result with a case study.

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