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Leena Pekkinen

INFORMATION PROCESSING VIEW ON COLLABORATIVE RISK MANAGEMENT PRACTICES IN PROJECT NETWORKS

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Abstract

Large engineering projects are executed by a network of heterogeneous organisations. In order to be effective, risk management in large engineering projects needs to take the perspective of the entire project network instead of focusing on risk management practices of single actors. Contextual factors such as complexity of the project network and the challenging institutional environment pose additional challenges to risk management.

The purpose of this study is to increase the understanding of the sources of risks in engineering project networks and the role of risk sources in determining risk management practices. The perspective of information processing theory is used. The role of equivocality and uncertainty as organisations' rationales for processing information is examined to gain new insights into the selection of appropriate risk management practices. Literature introduces relational contracting as a response to the need for collaboration in project networks. In this study collaborative risk management practices in the workshop-type meeting and in the project alliance were studied. A qualitative research method was employed to study the nature of risk sources, the role of risk sources in determining risk management practices and collaborative risk management practices.

The results of this study enhance the understanding of the nature of risks in engineering project networks. The current project risk management literature proposes that contextual factors related to technology, organising projects and environment increase uncertainty in projects. This study shows that it is relevant to categorise risk sources based on their contingency factors related to uncertainty (lack of information) and to equivocality (the existence of multiple interpretations). It is shown how risk sources impact the selection of project risk management practices. Collaborative risk management practices of workshop-type meeting and project alliance are depicted.

Project-based companies and organisations executing investment projects can benefit from the results of this study. This study can guide managers when developing practices to enhance risk management. This study shows how informal risk management practices should be considered in addition to the traditional formal risk management practices, particularly in cases when projects confront situations of equivocality.

Keywords: alliance projects, ambiguity, collaborative risk management, complex projects, equivocality, information processing theory, project alliance, project networks, project risk management, relational contracting, risk categorisation, risk management, risk sources, uncertainty

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Tiivistelmä

Suuria projekteja toteutetaan heterogeenisten organisaatioiden muodostaman projektiverkoston avulla. Projektiverkoston tehokkaaseen riskienhallintaan tarvitaan koko verkoston näkökulma yhden organisaation näkökulman sijaan. Tilannetekijät kuten projektiverkoston monimuotoisuus ja projektin haasteellinen ympäristö asettavat lisää haasteita riskienhallinnalle.

Tämän väitöskirjan tavoitteena on lisätä ymmärrystä siitä, mitkä ovat riskien lähteitä projekteissa ja kuinka riskien lähteet vaikuttavat riskienhallintamenetelmien valintaan. Väitöskirjassa on käytetty teoreettisena viitekehyksenä informaation prosessoinnin näkökulmaa. Erityisesti on tutkittu monimerkityksisyyden ja epävarmuuden roolia organisaatioiden perusteena käsitellä informaatiota. Kirjallisuudessa on esitetty luottamukseen perustuva sopiminen vastauksena projektiverkostojen yhteistoiminnallisuuden tarpeelle. Väitöskirjassa on tutkittu yhteistoiminnallisina riskienhallintamuotoina työpajatyyppistä työskentelyä sekä projektiallianssia.

Tutkimuksessa on tapaustutkimuksen avulla selvitetty projektien riskien lähteitä, riskien lähteiden roolia riskienhallintamenetelmiä määritettäessä, sekä yhteistoiminnallisia riskienhallintakeinoja. Tutkimuksen löydökset lisäävät ymmärrystä projektien riskien lähteistä. Nykyinen projektin riskienhallintakirjallisuus esittää, että projektien tilannetekijät, jotka liittyvät teknologiaan, projektien organisointiin ja ympäristöön kasvattavat epävarmuutta. Tämä tutkimus osoittaa, että on tärkeää jaotella projektien riskit tilannetekijöittäin. Jaottelu tulee tehdä sen mukaan onko vallitseva tilannetekijä epävarmuus eli tiedon puute vai monimerkityksisyys eli tilanne, jossa on paljon keskenään ristiriitaista tietoa. Tässä tutkimuksessa osoitetaan kuinka riskien lähteet vaikuttavat projektiverkoston riskienhallintamenetelmien valintaan. Lisäksi kuvataan yhteistoiminnallisia riskienhallintamenetelmiä projekteissa.

Projektitoimintaa harjoittavat yritykset sekä investointiprojekteja tekevät organisaatiot voivat hyödyntää tämän tutkimuksen tuloksia. Tutkimuksen tulokset ohjaavat riskienhallintamenetelmien muokkaamista erilaiset tilannetekijät huomioon ottaen. Tämä tutkimus osoittaa, kuinka epämuodollisia riskienhallintamenetelmiä tulisi suosia perinteisten muodollisten menetelmien ohessa erityisesti tilanteissa, joissa monimerkityksisyys on vallitseva tilannetekijä.

Asiasanat: allianssiprojekti, epävarmuus, informaationkäsittelyteoria, kompleksinen projekti, luottamukseen perustuva sopiminen, monimerkityksisyys, projektiallianssi, projektin riskienhallinta, projektiverkosto, riskien kategorisointi, riskienhallinta, riskin lähde, yhteistoiminnallinen riskienhallinta

Dedicated to my children, Juho, Aino and Simo
– Never stop learning new things.

Acknowledgements

The six years' journey of this study has been a breathtaking and unforgettable experience. I started as a practitioner who thought that project management is something you learn by doing and implementing the best practices of your colleagues. Studying the topic afforded me new fabulous approaches. I quickly noticed that the phenomena and regularities I perceived in my daily work were also widely studied and experienced in other industries.

I am deeply grateful to my supervisor, Professor Jaakko Kujala, for his encouraging coaching throughout the entire journey. Jaakko guided me to view my profession through theoretical and scientific glasses. I sincerely thank my instructor, Assistant Professor Kirsi Aaltonen, for her untiring constructive comments on my analysis and texts. Jaakko and Kirsi have always believed in me and my capabilities to finalise this journey. I am thankful for Dr Janne Härkönen for his advice on the writing process and his detailed comments on my texts.

I am thankful for directors Tuomo Hulkkonen and Ari Nieminen for giving me opportunities to work on very interesting and challenging projects. I have been privileged to work as a member of many global project teams. With my Finnish colleagues, I have experienced, for example, Chinese business culture, South American working culture and the Latin "mañana" ethos. The experiences and insights obtained through my projects have been of utmost value in my research as I have analysed and made conclusions from the observations.

The research journey has had the same elements as running a marathon: blood, sweat and tears and a happy end – the finish line.

I thank all my nearest for your support and encouragement. I thank you for your patience and love. Without you, this journey would have never happened.

Varkaus, October 2015 Leena Pekkinen

List of abbreviations and definitions

IPD	Integrated project delivery
PA	Project alliance
PMO	Project management office
PP	Project partnering
RQ	Research question

The terms engineering project and investment project have been used as synonyms.

List of original publications

This dissertation is based on the following publications:

I Pekkinen L & Aaltonen K (2015) Risk management in project networks: an information processing view. Technology and Investment 6(1): 52–62.

II Pekkinen. L, Aaltonen K, Kujala J & Härkönen, J (*In Press*) Evaluating sources of risks in large engineering projects – the roles of equivocality and uncertainty. Accepted for publication in the International Journal of Management, Knowledge and Learning.

III Pekkinen L & Kujala J (2014) Collaborative meeting as an integrative mechanism in a multinational investment project. Technology and Investment 5(1): 45–55.

IV Pekkinen L (*In press*) An information processing view on risk management in project alliances. Accepted for publication in the International Journal of Information Technology Project Management.

The author of this dissertation is the primary author of all above listed publications. The author has been responsible for framing the research. She has formulated the research problems, collected the theoretical bases, formulated the research questions, coordinated the collection of empirical data, analysed the data and drawn the conclusions. The role of co-authors includes reviewing and commenting on the manuscripts of the primary author.

Contents

1 Introduction

1.1 Background and research environment

This dissertation investigates project risk management in large engineering projects. Project risk management is recognised as one of the key performance factors for project success or failure (Miller & Lessard 2000, Chapman & Ward 2003). Complexity in projects is caused by project networks consisting of several actors and stakeholders and by challenging project environments (Miller & Lessard 2001). Complexity in international engineering projects has been growing rapidly over the last few decades (Miller & Lessard 2000, Flyvbjerg *et al*. 2003, Grün 2004), creating an increasing need for effective project risk management. Heterogeneous project actors in project networks have oftentimes contradictory and conflicting goals which engender the need for coordination. Therefore, a broader, inter-organisational and collaborative approach on managing the risks involved in the project networks is needed. Increased use of networked project setups in large engineering projects creates pressure to shift the focus from project management practices carried out at the single project actor level to the collaborative project risk management practices at the project network level (Tukiainen *et al.* 2010, Lehtiranta 2014). Furthermore, the increased complexity of large engineering projects in relation to project networks and stakeholders creates a need to understand more thoroughly the nature of risk sources and how project risk management practices vary based on the risk sources.

The current project risk management literature introduces a formal, well-structured risk management process (Chapman & Ward 2003, APM 2012, PMI 2013) with the following steps: risk management planning, risk identification, risk analysis, risk response planning and risk monitoring and control. In the literature, as a part of the risk identification and analysis phases, risks are categorised based on their sources which are mainly founded on the uncertainty inherent in projects. The networked project execution model gives rise to new types of risks (Hallikas *et al.* 2002, Kähkönen & Artto 2008, Pekkinen 2010) and emphasises the importance of understanding the different risk sources, the nature of these sources and the contextual factors behind these sources. According to information processing theory, organisations process information to reduce uncertainty and equivocality (Daft & Lengel 1986). In information processing theory, uncertainty is understood as a lack of information and equivocality is understood as ambiguity

and the existence of multiple and conflicting interpretations. Daft and Lengel (1986) introduce different information processing mechanisms for situations when uncertainty or equivocality is the prevailing attribute of the situation. The underlying philosophy of the current formal project risk management process (Chapman & Ward 2003, APM 2012, PMI 2013) is that at the commencement of a project, a project plan is prepared based on the information available at the current moment and based on the best possible assumptions behind the uncertain issues. During the project execution phase, more information is gathered from the project participants and project environment. Based on the additional information, the project plan is updated. Due to the turbulence in the project environment, the regular updating of risk information is an essential part of the project plan updating and project execution work (Floricel & Miller 2001). This philosophy is based on the assumption that by reducing uncertainty through gathering information, it is possible to provide more accurate and better project plans. Hence, this kind of fundamental thinking in project risk management is akin to the information processing theory, which argues that organisations process information to reduce uncertainty (Galbraith 1974). At the same time, information processing theory has also recognised equivocality as the rationale for organisations to process information (Weick 1979).

There is a gap in the current project risk management literature concerning the awareness of the nature of risk sources, the contextual factors behind risk sources and how risk sources affect the selection of risk management practices in large engineering projects in the global project network context (Lehtiranta 2014). This gap provides the justification for this research. This research also enhances our understanding of risk management practices in relational contracting project delivery arrangements. The author of this dissertation has extensive experience in working in different positions in several project-based companies, and she has acted more than 10 years as a project manager in the industry. She has executed her projects in challenging environments on different continents. Her personal motivation to study project risk management is based on the challenges encountered in various projects. These challenges have raised her interest in understanding the projects' contextual factors and their impact on project management and particularly on project risk management approaches and practices. She has worked in project networks in which collaborative project risk management practices have been applied. Her experiences have raised her interest in understanding how inter-organisational collaboration in large project networks can enhance project risk management and its practical implications.

In this study, project risk management is investigated through the lens of information processing theory to discover the challenges of risk management in large engineering project networks. The heterogeneous project actors of the project network, various project stakeholders and the diversity of the contextual factors such as cultural, political and institutional project environment poses challenges to project risk management and calls for collaborative risk management practices. In particular, the risk sources are examined to obtain new insight into the nature of risk sources. Project risk management practices in collaborative meeting process and in project alliance setup have been examined from the perspective of information processing theory.

1.2 Objectives and scope

The main motive behind this study arises from the challenges of project risk management in complex project networks. There is a clear need to increase the understanding of the sources of risks in large engineering project networks and the role of risk sources in determining risk management practices. Hence, there is a clear need to study risk management practices and risk sources in the context of the project networks where risks are complex and caused by the numerous contextual factors such as the project network actors, external project stakeholders and the cultural, political and institutional project environment. In addition, collaborative risk management practices need to be elaborated as an illustration of risk management practices in the relational contracted project setups.

The research objective of this doctoral dissertation is to understand the nature of risk sources and how risk sources impact risk management practices in large engineering project networks. The diversity of the contextual factors of large engineering project networks poses challenges to risk management practices. The objective of this study is also to examine collaborative project risk management practices as a response to those challenges.

The overall research objective is approached from two perspectives. First, the research objective is studied starting from the challenges perceived in project network level risk management. Then, risk sources with emphasis on the bases of the sources are evaluated. Particular attention has been paid into the attributes of the contextual factors prevailing in risky situations. Secondly, collaborative project risk management practices in two types of project network level execution setups are in the focus. A particular workshop-type of collaborative meeting practice is introduced, and its risk management practices are studied. Moreover, project

alliance as an example of the contractually agreed risk sharing mechanism between project partners is studied, and practices supporting collaboration are elaborated. These collaborative project risk management practices are examined as responses to the need for coordination and collaboration caused by complexity and the diversity of contextual factors in large engineering project networks. In this study, the perspective of information processing theory is used to study the project risk management practices in large engineering project networks. In particular, examining the role of equivocality and uncertainty as organisations' rationales for processing information is examined to gain new insight into the selection of appropriate risk management practices in relation to the risk sources.

There could have been different paths to study this research objective in more detail. For example, organisation theories with different paradigms could have given most interesting approaches to the research objective. The selected perspectives – challenges, risk sources and collaborative risk management practices – were formulated into five research questions (RQs), as presented in Table 1.

Table 1. Research questions.

RQ#	Research question
RQ1	What different types of information processing mechanisms are used for implementing project risk management in large engineering projects?
RQ2	What kinds of challenges are related to the use of information processing mechanisms in large engineering projects?
RQ3	What are the roles of equivocality and uncertainty as bases of risk sources in large engineering projects?
RQ4	How do collaborative meetings enhance integration and coordination by reducing uncertainty and equivocality in the context of multinational investment projects?
RQ5	How do the features of the project alliance support project risk management?

In this dissertation, the research questions are answered in more detail through four journal publications, which are summarised in Table 2. The contributions of these publications are presented in this dissertation in the Chapter 3 Research contribution.

Table 2. Research papers overview.

Publication	RQ#	Title	Journal
I	RQ1 RQ2	Risk management in project networks: an information processing view	Technology and Investment
II	RQ3	Evaluating sources of risks in large engineering projects – the roles of equivocality and uncertainty	International Journal of Management, Knowledge and Learning
III	RQ4	Collaborative meeting as an integrative mechanism in a multinational investment project	Technology and Investment
IV	RQ5	An information processing view on risk management in project alliances	International Journal of Information Technology Project Management

The research questions are related to each other, and each one is focused differently on the research objective. Figure 1 illustrates the overall research objective and the perspective used. Figure 1 shows how the research starts with the evaluation of the challenges of risk management in relation to the evaluation of risk sources and the use of risk management practices. The research then proceeds to the project risk management practices in two collaborative project setups. One collaborative project practice is based on mutually agreed upon non-contractual practice while the other is based on commercial contracts. Throughout, the information processing theory is the theoretical perspective of the research. Each of the four publications provides a different approach to the research objective. These publications complement each other and give partial solutions to the research objective. The research objective has remained the same during the study, but the research questions have been clarified.

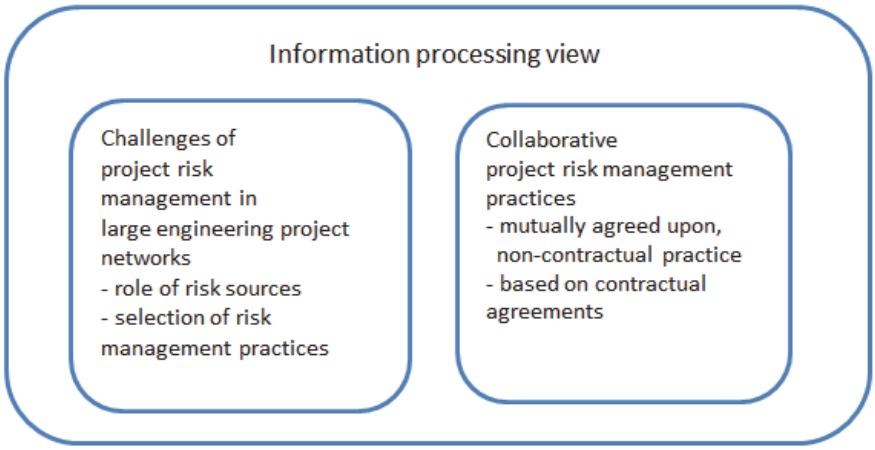

Fig. 1. The research objective and the perspectives used in the research.

The first publication shows the challenges of project risk management at the project network level and, in addition, illustrates how information processing theory can be utilised to distinguish between different kinds of project risk management needs based on the sources of the risks. The first publication identifies the risk management practices of a complex project networked viewed from the perspective of information processing theory. The second publication sheds light on the categorisation of risk sources based on the contextual factors in a large engineering project. The information processing view is utilised to differentiate between situations when uncertainty or equivocality is the prevailing contextual feature. Publications III and IV describe and introduce the risk management practices implemented in two case projects which utilised collaborative risk management differently in each case project. Publication III portrays a detailed description of the practices and features of the particular workshop-type model of collaborative risk management implemented in a large engineering project. The publication gives insight into the atmosphere and spirit of the collaborative meeting, showing how informal measures of information processing theory were used to catalyse common, best-for-project thinking among project participants. In addition, the publication also analyses the sub-processes of the collaborative meeting and depicts their roles and functions as integrative measures in project networks. Publication IV introduces the features characteristic to project alliance that enhance project risk management in the project alliances. The publication shows how inherent

collaborative features of project alliance aside the contractually guided risk sharing mechanism support risk management.

1.3 Research approach

From a philosophical viewpoint, researchers face epistemological, ontological and ethical questions when approaching scientific research. The relevant questions to be considered are, for example, the following: How can one believe and know of reality based on scientific research? How is scientific knowledge obtained, and when is this knowledge scientific? When does the researcher abuse his/her research object or act unethically against the scientific community? (Lancaster 2005).

Ontology determines whether reality is objective or subjective. An ontological view of the phenomena to be studied influences the choice of theory, the concepts and the research method (Eriksson & Kovalainen 2010). Ontology can be roughly divided into objectivism and subjectivism. The topic of this research, project risk management practices and risk sources in complex engineering projects as phenomena, is closer to subjectivism than objectivism. In this research, project risk management is studied as an integrated process of project execution work, and a subjective research approach has been applied. Subjectivism is an ontological position implying that research is based on subjective analysis and interpretations rather than on facts experienced through the senses (Saunders *et al*. 2007, Bryman & Bell 2011). Particularly the identification of risks and contextual factors which may raise risks is a subjective phenomenon where project participant´s experience and capabilities play an important role. Epistemology can be divided into positivism and interpretivism (Saunders *et al.* 2007). This research is closer to interpretivism than positivism. According to interpretivism, knowledge is based on the subjective interpretations of actions and the relationships between actions and actors (Saunders *et al.* 2007). This study utilised the empirical data obtained through interviews. The interviews were semi-structured, and the researcher guided the interviewees to speak – naturally, in their own words and using relevant examples – about the events and situation and the responses to those in the case projects. The empirical information about the risky situations and unexpected events is based on interviewees´ and researcher´s interpretation. The author interpreted the responses and actions perceived in the case project as actual manners of project risk management although not nominated by interviewees as such.

In this research, mainly the inductive approach is followed, and the role of the researcher is to understand the events and the contextual situations experienced and the relationships of those in the studied case projects based on her interpretation and experience gained in project execution work. In publications I, II and IV, the inductive approach was applied when the events and features of the case projects were studied. In publication I, unexpected events, incidents and surprises were analysed and the challenges of risk management in relation to the contextual situations of the unexpected events were examined. Information processing theory is the framework of this study Information processing theory introduces different information processing mechanisms for situations of high uncertainty and high equivocality. In the publication II, an inductive approach was followed, where risk sources were categorised based on their prevailing contextual factors. The categorisation was noticed to follow the main distinguishing of the contextual situations introduced in the information processing theory. And the risk sources were divided into those having the nature of high uncertainty or high equivocality. In publications III and IV, project risk management practices were studied in a collaborative and a relational project delivery setup. The research approach was inductive and based on information processing theory, showing that both formal and informal information processing mechanisms were used as project risk management tools in project networks.

The research questions are answered based on the empirical examples gathered from three single case studies. A single case study approach was selected to gain a better understanding of the risk management practices in large and complex engineering projects. According to Yin (2014), a qualitative method is suitable for investigating phenomena within real-life contexts having different contextual conditions relevant to the phenomena. Hence, a qualitative research method is applied to empirically study the risk management practices and processes in large engineering projects executed by several companies. The selected case projects represent large engineering projects with numerous actors from different cultures. One case study was selected as the empirical basis for publications I and II due its nature as large and complex project setting and environment. In that case project, there were many unexpected events occurring during the project execution phase which had major impacts on project outcomes. Via many unexpected events and their contextual background, it is possible to understand the dominant features of the events. The case projects for publications III and IV were selected due the interesting setups and particular project risk management arrangements implemented in the case projects. The author worked in the case project of

publication III and obtained insights into the collaborative meetings by participating in the meetings and by participating in the preparation for the collaboration meetings. The case project of publication IV is the first public infrastructure project in Finland executed through a project alliance arrangement. The case project of publication IV is national, while the other case projects are global. The focus of the study for publication IV is on how relational contractual arrangements guide project risk management. Hence, the national context is not a limitation of the case study, while the entire research objective has a global project network context.

1.4 Research realisation and dissertation structure

The starting point of the research reported in this dissertation is the need to understand the challenges of project risk management as well as the role of project risk sources, the nature of the sources and the importance of risk sources in the selection of project risk management practices in the context of complex engineering projects. Additionally, collaborative risk management practices as a response to the need for integration and coordination in large engineering projects were elaborated. The perspective adopted in this research is that of information processing theory, and project risk management has been investigated at the project network level. In complex and large engineering projects, contextual factors related to project network actors as well as to the cultural, political and institutional project environment play essential roles in the analysis of the risk sources and are investigated thoroughly. In order to investigate the key factors and issues related to the studied phenomena, several case studies were conducted and four research papers were written. An understanding of the role of risk sources and their relations to risk management practices in the light of information processing theory is gained through the separate studies conducted for the publications. The overall research process of the dissertation is linked to the research process of the individual publications attached to this dissertation. Each publication has a specified research question(s) and a different focus on the challenges of project risk management.

The research process starts with an investigation into the challenges of project risk management in the large, international engineering project context in complex and challenging environments. In the elaboration process, the information processing mechanisms introduced in the literature are utilised when categorising the perceived risk management practices and evaluating the fitness and effectiveness of the practices in the case project. The findings of the first phase of

the research are reported in publication I. The observation that different contextual factors influence the fitness of risk management practices engendered a need to investigate the risk sources in large engineering projects more thoroughly. The focus of the study in publication II is the categorisation of the risk sources based on the dominant contextual factors. Publication II shows the results of a deep analysis concerning the risk sources and their empirical examples and implications in the case project. This study reveals the importance of differentiating between risk sources based on the nature of the relevant contextual factors. Risk sources are categorised based on the prevailing attribute of the situation being uncertainty or equivocality.

Publications I and II reveal how risk sources can be categorised to those having uncertainty or equivocality as the prevailing attribute and therefore the suitability and effectiveness of perceived risk management practices varied. These observations guided the research to discover the risk management practices in large and complex engineering project networks. In one of the selected case projects, a collaborative approach was implemented to enhance project risk management. Publication III elaborates a particular workshop-type meeting; it portrays the collaborative meeting practice as a risk management measure by showing how the collaborative meeting enhanced coordination in the project network. Publication III gives a detailed description of the collaborative meeting practices, features and coordination mechanisms. An information processing perspective is utilised in this study to show how the sub-processes of collaborative meetings serve as coordination mechanisms and reduce uncertainty and equivocality in case projects.

The research was further continued through an elaboration of the risk management practices in the project alliance type of project arrangement. In publication IV, the risk management practices implemented in the project alliance were investigated through the lens of information processing theory, showing how the features of project alliance support risk management. In project alliances, risk sharing is contractually agreed upon to be a common task of the alliance partners. Aside the commercial contract, in project alliances there are particular features that facilitate the use of integrative and collaborative mechanisms and act as risk management practices.

The overall research process consists of four studies which each provided information and understanding leading to the following steps of the research. The research processes of the publications form a logical overall research process, giving a complementary approach to the research. The literature review of project risk management and information processing theory was conducted in tandem with

the empirical case studies. The information processing perspective taken regarding project risk management provided a novel view emphasising the role of risk sources. In publications I and II, the challenges and risk sources in the case engineering projects were studied from the turnkey contractor's point of view, and in publications III and IV, the viewpoint of the entire project network was adopted to investigate the risk management practices in two relational contracting project setups. The research process is illustrated in Figure 2.

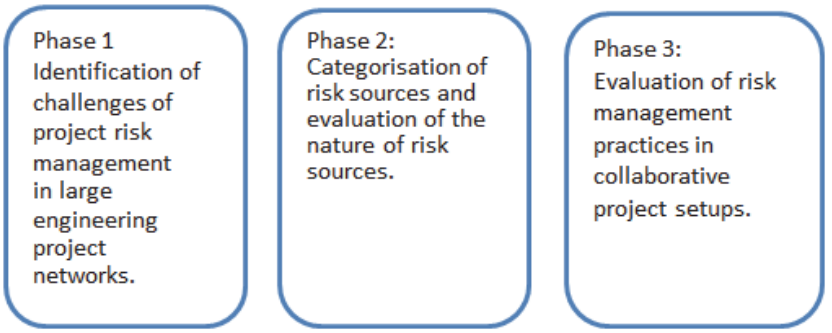

Fig. 2. The research process.

Table 3 summarises the research methods, data collection and data analysis techniques employed in each individual publication. The author of this dissertation had the role of an outside observer in terms of the empirical material for publications I and II. Another researcher was present at the interviews and gave her input in the analysing phase. The conclusions of the interviews for publications I and II were reflected upon and reviewed by the researcher who was present at the interviews. Through this arrangement, the author of this dissertation was ensured the role of an outside observer. Furthermore, the conclusions were verified with the other researcher who was present in the interviews. The empirical data for publication III were collected in relation to the collaborative meeting practice. The author of this dissertation participated in the collaborative meeting as a project manager of the main contractor and participated in the preparation process before the collaborative meeting. She made the analyses and to avoid bias, the analyses and conclusions were reflected upon and discussed with other researchers who were outsiders of the case project. For publication IV, the author of this dissertation participated in the interviews and the project lessons learnt session together with

other researchers. She discussed the topics of the interviews as well as the conclusion with other researchers.

Table 3. Research methods, data collection and data analysis used in individual publications.

Publication	Research method	Case project	Level of collaboration in the case project	Data sources and data collection	Data	Analysis
Publication I	Single case study	Infrastructure project in a former Soviet Union country. The case featured many unexpected events during project execution. The selection logic for the case was its unique nature and the challenging environment.	Traditional project execution model with a supply-chain arrangement.	10 semi-structured face-to-face interviews with project team participants between October 2007 and February 2008. Project documentation such as risk analyses, project status reports and project plans.	Description of the unexpected events and the realised risks. Description of the contextual factors. Background information concerning the project environment and the project participants.	Within case analysis. Classification of the risk management practices. Qualitative content analysis of transcribed interviews emphasising practices for handling unexpected event.

Publication	Research method	Case project	Level of collaboration in the case project	Data sources and data collection	Data	Analysis
Publication II	Single case study	Infrastructure project in a former Soviet Union country. The case featured various realised risks. The selection logic for the case was the various risks and risk sources.	Traditional project execution model with a supply-chain arrangement.	10 semi-structured face-to-face interviews with project team participants between October 2007 and February 2008. Project documentation such as risk analyses, project status reports and project plans.	Description of the realised risks. Description of the contextual factors. Description of the risk sources. Background information concerning the project environment and the project participants.	Within case analysis. Qualitative content analysis of transcribed interviews emphasising the nature of the risk sources. Identification and categorising of the risk sources.

Publication	Research method	Case project	Level of collaboration in the case project	Data sources and data collection	Data	Analysis
Publication III	Single case study	Green field investment project in America. The case featured a collaborative meeting practice for risk management. The selection logic for the case was its unique nature and the collaborative meeting practices applied in it.	Traditional project execution model with supply-chain arrangement. Collaborative practices were applied based on mutual decisions.	15 semi-structured face-to-face interviews with project team participants in September and October of 2011. Project documentation such as project status reports, project plans Observations in the preparation phase of the collaborative meeting. Documentation related to the preparation of the collaborative meeting. Observations during the collaborative meeting	Description of the risk management practices. Project information related to the project plan, progress reporting and risk management. Information concerning the preparation of the collaborative meeting.	Within case analysis. Researcher participated in the collaborative meeting as a project manager of the main contractor, and she also participated in the preparation process before the collaborative meeting.

Publication	Research method	Case project	Level of collaboration in the case project	Data sources and data collection	Data	Analysis
Publication IV	Single case study	Railway renovation project in Finland. The case featured project alliance as the execution model and a challenging environment. The selection logic for the case was that it was the first public project executed with the project alliance model and a challenging environment.	Project alliance project execution model. Collaboration was guided through a commercial contract and by particular project alliance features.	6 semi-structured face-to-face interviews with project team participants in November and December of 2014. Observations in project closing meeting.	Description of the project alliance working methods from the point of view of risk management. Background information concerning the project environment and the project participants.	Within case analysis. Qualitative content analysis of transcribed interviews with an emphasis on practices of risk management.

This dissertation consists of four individual publications and this compilation section. The compiling section is organised as follows: Chapter 2 presents the literature review as the theoretical foundation for the research. Chapter 3 summarises the research contribution of the four publications attached as appendices. In Chapter 4, the overall findings of the research are presented.

2 Literature review

2.1 Background

The literature review provides an overview of the key theoretical perspectives that are salient to this dissertation. The main theoretical background of the dissertation is information processing theory which gives project risk management research the perspectives through which to understand the usability of different kinds of risk management practices based on the contextual factors of project settings. In this dissertation, project risk management is studied in the international project network context. Figure 3 illustrates the theoretical perspectives used in this study.

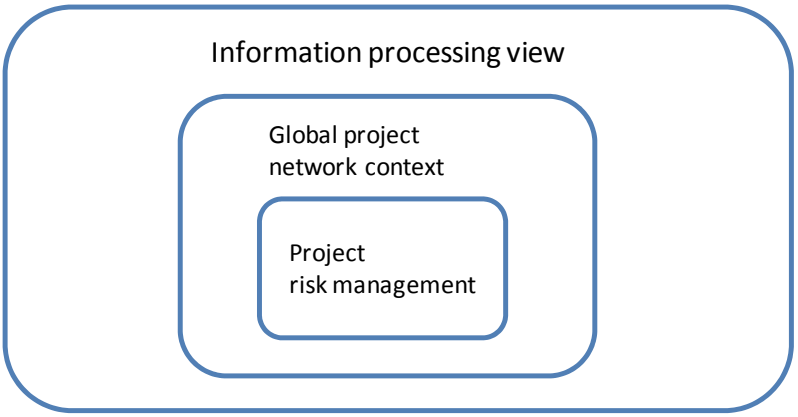

Fig. 3. The theoretical perspectives of the dissertation.

The literature review starts with an introduction of the current project risk management processes, practices and standards (Chapman & Ward 2003, APM 2012, PMI 2013) which typically consist of generic process descriptions including three core project risk management processes: risk identification, risk evaluation and risk response planning (Kähkönen & Artto 2008). The contemporary project risk management as a set of planning oriented steps can be seen as a formal process executed by project organisations to reduce the uncertainty project organisations encounter. Next in the literature review, the focus is on the risks, risk sources and categorisation of the risks. The contemporary project risk management literature introduces risk sources and categorises risks based on the different kinds of uncertainties related to the project environment and setup (Miller & Lessard 2001,

Ward & Chapman 2003). Finally, section 2.2 introduces risk management in project networks as well as risk management in collaborative project arrangements.

In section 2.3, information processing theory and its related concepts are the focus. The section starts with a short introduction of project organisation. The section concentrates on uncertainty and equivocality as key concepts of information processing theory. Ambiguity and how it relates to the concepts of uncertainty and equivocality are also covered. Information processing theory introduces uncertainty and equivocality as the rationale for different kinds of information processing practices used in organisations. In the information processing literature, uncertainty is understood as a lack of information and equivocality is understood as ambiguity and the existence of multiple and conflicting interpretations (Daft and Lengel 1986). Daft and Lengel (1986) have proposed seven structural mechanisms to fit along a continuum with respect to organisations' capability for reducing uncertainty or for reducing equivocality. The structural mechanisms are as follows: (1) group meetings, (2) integrators, (3) direct contact, (4) planning, (5) special reports, (6) formal information systems and (7) rules and regulations.

Section 2.4 summarises the theories and concepts introduced in the literature review to give an overview of the theoretical perspectives applied in this dissertation.

There are a number of other theoretical perspectives that could have been used, such as different organisation theories. The rationale for the selection of information processing theory is that it emphasises the importance of the information and its processing as an essential part of project management. The importance of the information processing in projects stems from the behaviour of a project's internal organisations and project stakeholders. Different kinds of agendas and targets of the stakeholders impact the information processing needed in projects. Risk management generally and risk identification particularly can be seen based on information available and processed in the project organisations.

2.2 Project risk management

Proper and well performed project risk management is proven to have an essential role in achieving project goals (Leung *et al*. 1998, Raz & Michael 2001, Lee *et al*. 2009), and it is a widely researched area in project management research (e.g. Miller & Lessard 2000, Floricel & Miller 2001, Chapman & Ward 2003, Kähkönen & Artto 2008,). The current research on project risk management is primarily focused on the concept of project risk, the identification of risk sources and

effective tools and practices for reducing the consequences of risks in projects (Chapman & Ward 2003, Ward & Chapman 2003, APM 2012, PMI 2013). Several earlier studies have presented classifications of the sources of risks (Floricel & Miller 2001, Ward & Chapman, 2003, Kähkönen & Artto 2008). Whilst most of the studies have focused on the categorisation of project risk sources in a single actor project context, few studies have addressed risk sources in networked multi-actor projects (Ward 1999, Artto *et al*. 2008, Hallikas *et al*. 2002, Kähkönen & Artto 2008, Pekkinen 2010).

The existing project risk management presents predetermined, structural applications and guidelines for project risk management. In an ideal process, risks are identified, their probabilities and impacts are explicitly estimated and plans for appropriate responses are made and monitoring and control principles are documented (Chapman & Ward 2003, APM 2012, PMI 2013). In the Project Management Body of Knowledge (PMBoK) (PMI 2013), one of the most quoted standards of the project management field, the generic risk management process is presented with six different phases.

- *Risk management planning* – Deciding how to approach, plan and execute the risk management activities for a project.
- *Risk identification* – Determining which risks might affect the project and documenting their characteristics.
- *Qualitative risk analysis* – Prioritising risks for subsequent further analysis or action by assessing and combining their probability of occurrence and impact.
- *Quantitative risk analysis* – Numerically analysing the effect on overall project objectives of identified risks.
- *Risk response planning* – Developing options and actions to enhance opportunities and to reduce threats to project objectives.
- *Risk monitoring and control* – Tracking identified risks, monitoring residual risks, identifying new risks, executing risk response plans and evaluating their effectiveness throughout the project life cycle.

The whole planning-oriented project management approach with specific steps can be considered a fundamental approach for reducing uncertainty in projects. Through detailed planning and the use of predefined project management methods and tools, risks and uncertainties in projects are considered to be minimised and better managed (Morris & Hough 1987). Furthermore, within the current view of project management as a lifecycle process, project risk management is seen as an encompassing process, starting at project definition and continuing through the

planning, execution and control phases up to completion and closure (Raz *et al.* 2002). All changes made in the project execution plan and changes in the ambient circumstances are sources of new risks and, therefore, continuous monitoring of the project execution environment is needed.

2.2.1 Risks and unexpected events in projects

According to the current project risk management literature, the origin of risks is the uncertainty inherent within any project (del Caño & de la Cruz 2002, Geraldi *et al*. 2010). In the beginning of the project, a lack of information prevents the preparation of the project plan, which could take into the consideration all possible happenings during the project life span, and, hence, unexpected events will take place and risks will materialise. Risk is mainly related to the negative impacts (Hillson 2002), but recently a broader perspective has been adopted (Miller & Lessard 2001, Hillson 2002, Ward & Chapman 2003, APM 2012, PMI 2013). The most cited project management standards, Association for Project Management (APM 2012) and The Project Management Institute (PMI 2013), define risk in the context of projects as follows:

> *"Project risk is an uncertain event or set of circumstances which, should it occur, will have an effect on achievement of one or more objectives". (APM 2012)*

> *"Project risk can be defined as an uncertain event or condition that, if it occurs, has a positive or a negative effect on at least one project objective, such as time, cost, scope or quality". (PMI 2013)*

Unexpected events besides the materialised risks have been recently studied as an important feature of projects that influence project outcomes (Floricel & Miller 2001, Miller & Lessard 2001, Hällgren 2007, Söderholm 2008, Orr & Scott 2008, Aaltonen *et al*. 2010). Research has revealed that unexpected events are only seldom managed according to formal project management procedures and guidelines. Therefore, the majority of studies on unexpected events and their management in projects tend to focus on informal actions that take place in projects instead of formal project management procedures and processes. The importance of project–environment interaction as a source of unexpected events has also been highlighted in the earlier research on unexpected events (Miller & Lessard 2001, Floricel & Miller 2001, Hällgren & Maaninen-Olsson 2005, Hällgren 2007,

Söderholm 2008). Furthermore, research evidence has also shown that the number of unforeseen events or exceptions is higher in the context of multinational projects than in completely domestic projects (Orr & Scott 2008). The insightful research by Floricel and Miller (2001) on large engineering projects has highlighted the association of complex project systems with the number of emergent unexpected events.

2.2.2 Risk sources and categorisation of risks

In the current project risk management literature, risks are categorised into groups based mainly on common sources or their features (e.g. Ward & Chapman 2003, Atkinson *et al*. 2006, Krane *et al*. 2010, Artto *et al*. 2011). The project risk management literature sees uncertainty as the source of risks which projects confront. Ward and Chapman (2003) and Atkinson *et al*. (2006) have depicted risk sources from the viewpoint of uncertainty. Ward and Chapman (2003) have identified the types of uncertainties as (1) variability associated with estimates, (2) uncertainty about the basis of estimates, (3) uncertainty about design and logistics, (4) uncertainty about objectives and priorities and (5) uncertainty about fundamental relations between the project parties. Atkinson *et al*. (2006) introduce three key areas where projects confront uncertainty: (1) uncertainty associated with estimating, (2) uncertainty associated with project parties and (3) uncertainty associated with stages of the project life cycle.

Several scholars have categorised project risks according to their nature and features. Artto *et al.* (2011) divided risks related to projects into four different risk types: pure risks, business risks, financial risks and area-specific risks. Pure risks include accidents or losses, and financial risks are related to the financing and funding of the project as matters of liquidity, operative cash flow and fluctuating interest rates. Area-specific risks are relevant due to some contextual factors of the area where the project is executed and are usually caused by the political, legislative, national, cultural and natural environment of the area. Business risks in the project context refer to the miscellaneous group of risks that do not fit into any other risk category but that may have an impact on the project and its objectives or benefits. Business risks include those that may relate to the functionality or usability of the end product and also those that are threats or possibilities during project execution (Artto *et al*. 2011). In turn, Miller and Lessard (2001) categorised the sources of risks in large international engineering projects into three categories: market-related risks, completion risks and institutional risks. The categories are further

divided into several risk classes in which the specific risks tend to belong. Market-related risks are divided into demand, financial and supply risks; completion risks are divided into technical, construction and operational risks. Institutional risks, the last category, are divided into regulatory, social-acceptability and sovereign risks. PMBOK (PMI 2013) introduces the risk breakdown structure as a generic categorisation to be applied in different kinds of projects. The structure has four main risk categories: technical, external, organisation and project management. Technical risks include requirements, technology, complexity and interface and performance and reliability as well as quality. PMBOK lists risks related to subcontractors and suppliers, regulatory, market, customer and weather to be included in the group of external risks. Organisational risks are divided into four subcategories: project dependencies, resources, funding and prioritisation. Risk categories as project management-related risks are nominated as concern estimating, planning, controlling and communication. Jafaari (2001) has introduced several risk categories, such as promotion risks, market risks (volume and price), political risks, technical risks, financing risks, environmental risks, cost estimation risks, schedule risks, operating risks, organisational risks, integration risks and force majeure. Krane *et al*. (2010) differentiates between the operational and strategic risks of projects. Operative risks jeopardise the achievement of the predefined results and outputs of projects, and strategic risks threaten the goals and purposes of projects. According to their study, there are short-term strategic risks and long-term strategic risks. Rolstadås *et al*. (2011) introduce contextual risks beside operational and strategic risks as the main category of project risks. The contextual risks are connected to circumstances outside the project that may influence the scope of work and the performance of the organisation. Examples are competing projects, change in ownership and management, legislation and governmental directives, media attention, extreme market conditions, accidents, etc. (Rolstadås & Johansen 2008). Floricel and Miller (2001) include risk categories such as sponsorship/development, market, social acceptability, regulatory and political, financial, execution and operation. Risks in the projects emerge from different risk sources which are typically categorised based on the contextual factors such as technology, project network actors, external project stakeholders and the cultural, political and institutional project environment.

2.2.3 Project risk management in networks

Increasingly, projects are executed by networks of organisations (Hellgren & Stjernberg 1995, Söderlund 2004, Artto *et al*. 2008, Ahola 2009). Even though interrelationships are a new area of interest, there has been very little discussion on the functioning and dynamics of project networks outside the field of project marketing (Cova & Salle 2005). A lack of project risk management research in the project network context is recognised by Lehtiranta (2014) and Tukiainen *et al.* (2010). According to Hellgren and Stjernberg (1995), the studies of collaborative arrangements and networks usually concern long-term inter-organisational arrangements, such as acquisitions and joint ventures.

Project networks consist of the relationships between actors or organisations to establish robust capabilities to perform the tasks of the project to achieve the set targets of the project (Hellgren & Stjernberg 1995). Furthermore, Hellgren and Stjernberg (1995) give three frames for the definition of the project network:

1. The project network is a set of relations where no single actor may act as the legitimate authority for the network as a whole.
2. The project network is open in the sense that there are no definite criteria by which the boundary of the network may be identified and controlled.
3. The project network is temporally limited, dynamically changing and reconstructed from one project to the next.

Project networks are intentionally developed networks formed in order to create capital assets for the buyer over a certain period of time (Skaates & Tikkanen 2003). Project networks can therefore be seen as an instrument for achieving specific, predefined targets. It could be considered that this common target acts as the temporary underlying force which glues the project network actors together and is the *raison d´être* of the project network (Hellgren & Stjernberg 1995). Nevertheless, the individual project participants involved in the temporary project network might have other rationales and motivations for their participation other than completing specific project goals. Consequently, the heterogeneous actors in project networks have oftentimes contradictory and conflicting objectives which pose fundamental coordination and integration challenges in the project network (Morris & Hough 1987, Flyvbjerg *et al*. 2003).

The networked form of organising has many important implications for project risk management. The literature on large projects lists various major challenges and suggestions related to organising and managing a project as a network of several

participating organisations, especially related to analysing risk, uncertainty and success issues (Kharbanda & Stallworthy 1983, Flyvbjerg *et al*. 2003, Klemetti 2006). The multiplicity of the project actors, as well as the interactions and relations between the actors, are a source of uncertainty in the project network possessing risks. Risk in the project network context can be defined as an uncertain event or condition that results from the network form of work having an impact that contradicts the expectations. An event is at least partially related to other actors in a network (Kähkönen & Artto, 2008). The extant literature has addressed to a limited extent the sources of risks in networked project settings (Ward 1999, Hallikas *et al*. 2002, Klemetti 2006, Artto *et al*. 2008, Kähkönen and Artto 2008, Söderholm 2008). However, Ward (1999) states that the involvement of multiple actors in project execution introduces uncertainty arising from the ambiguity related to the following six aspects: specification of responsibilities, perceptions of roles and responsibilities, communication across interfaces, the capability of parties and contractual conditions and their effects.

The networked project execution model encompasses the idea of multiple actors forming one organisational entity established for achieving the predefined targets. Organisational variety beside technological diversity has been recognised as one dimension of the complexity of projects (Baccarini 1996, Bosch-Rekveldt, 2011). Furthermore, Bosch-Rekveldt (2011) also introduces environmental complexity as a relevant feature in the project management context. Uncertainty is linked to the complexity by Williams (1999) when he defines the project complexity as structural complexity relating to the number and interdependences of the elements and uncertainty in goals and methods. Aaltonen and Kujala (2015) introduce complexity as one of the key dimensions of the project stakeholder landscape. Other key dimensions of the project stakeholder landscape are uncertainty, dynamism and institutional context.

The networked project setups highlight the importance of a broader perspective on project risk management. Complex delivery projects are typically networked efforts where the traditional single company-oriented risk management approach can be considered to result merely in solutions which are too limited (Artto *et al.* 2008). In order for risk management to be successful, the focus on risk management should be shifted from single project actors to the project network level (Artto *et al*. 2008, Pekkinen 2010). Particularly, collaboration and integration over organisational boundaries is required in project networks in order to ensure an efficient and effective risk management approach. According to Kähkönen and Artto (2008), continuous risk register updating and scanning of an environment

should be emphasised in the risk management approach in project networks due to the dynamism of the projects. The current risk management literature does not fully appreciate the complexity and dynamism of the whole network of project actors.

2.2.4 Risk management in collaborative project arrangements

The traditional project execution model with tight contractual relationships of the project participants tends to lead to the silo-type operation when all stakeholders optimise their profit, resulting the non-optimal performance of the entire project (Pekkanen 2005, Lahdenperä 2012). The construction industry is oftentimes presented as fragmented and contradictory by its very nature due to the high levels of risks and the growing sizes of the projects and their increasing complexity (Jefferies *et al*. 2014). Relational contracting has been introduced in response to the need for collaboration and coordination of project actors (Dainty *et al.* 2001, Jorgensen & Emmitt 2009) to enhance the achievement of project outcomes. Relational in this context means relationships built on a partnering ethos in order to embrace collaboration, change and innovation in project delivery (Sakal 2005). Walker and Lloyd-Walker (2015) introduce five collaborative arrangements for project delivery teams: (1) partnering (both project and strategic), (2) integrated solutions (competitive dialogue, integrated project delivery and delivery consortia/partner), (3) alliancing (project and program) and (4) early contractor involvement and (5) framework agreements.

Lahdenperä (2012) introduces and compares three project delivery arrangements based on relational contracting: project alliance (PA), project partnering (PP) and integrated project delivery (IPD). In all of those, the final outcome of individual project actors is in the relation to the performance and outcome of the entire project in which they worked. PA, PP and IPD as collaborative, relational contracting forms are based on soft elements of co-operation emphasising a best-for-project mindset, good faith and transparency. The same integrative elements can be found in all three mentioned relational contracting forms, although they are distinguished by different degrees of integration (Lahdenperä 2012). The comparison of PA, PP and IPD by Lahdenperä (2012) and Walker *et al*. (2002) points out the similarities and the differences between the arrangements and the strategies. PA has been found to have the deepest embedding of integration between parties due to the strong contractual elements included (Ross 2003). PP and IPD include shared risk and reward mechanisms that are based on predetermined project outcomes and group performance, while PA has inherent

contractual mechanisms to handle risks and uncertainties mutually in the project phase to minimise the impact of risks. In IPD project setup model the main project partners have an integrated agreement (contract) which describes the relationships that are established among each of the partners of the integrated project delivery. The contract guides partners to work together in the spirit of cooperation, collaboration and mutual respect for the benefit of the project (Lichtig 2006, Darrington *et al.* (2009). The scarcity of research concerning risk management practices in collaborative project arrangements is evident although some literature on collaborative risk management exists. The literature on collaborative risk management emphasises integration (Bresnen & Marshall 2000, Chan & Au 2009), the use of multidisciplinary teams (Lichtenberg 2000) and joint risk management (Rahman & Kumaraswamy 2005). Lehtiranta (2014a) introduces a multi-organisational risk management process based on collaboration as a framework for risk management in large projects. She allocates the phases of generic project risk management practices (AMP 2012, PMI 2013) to key project participants in multi-organisational risk management.

Project alliance

Project alliance has been implemented as a manner of collaborative and relational project arrangement particular to big construction and infrastructure projects. Through contractual measures, PA aims to remove barriers between project participants and to avoid silo-thinking inside the project network. PA is formed between project owners and contractors, which are also called non-owner-participants (Walker *et al*. 2002, Department of Infrastructure and Transport 2011, Lahdenperä 2012). Project alliancing differs from traditional contracting in terms of risk sharing, profit earning, decision making and the handling of disputes and requires a different mindset of the participants, emphasising "best for project thinking", a no-blame culture and the equitable sharing of risks. Risk management in project alliancing is a common effort of project alliancing partners and is formulated and promoted by contractual arrangements. The extant PA research covers several topics, including risk allocation and the commercial model of risk sharing as an inherent part of a commercial agreement (Rahman & Kumaraswamy 2002, Yeung *et al*. 2007, Love *et al*. 2011, Chen *et al*. 2012), the value-for-money concept (MacDonald *et al*. 2013), the success factors of a PA (Love *et al*. 2010, Jefferies *et al*. 2014), partner relationships (Laan *et al*. 2011) and the development

of social capital (Colledge 2005). But the amount of literature showing empirical evidence of practical risk management implications in PAs is limited.

2.3 Information processing in organisations

2.3.1 Project organisations

Complex system deliveries are suggested to be organised most naturally by project organisations (Gann & Salter 1998, Hobday 1998). Hence, most of the technology-based and service-based companies (also called project-based companies) arrange their operations based on customer delivery projects (Morris & Hough 1987, Hobday 2000, Flyvbjerg *et al.* 2003, Artto & Kujala 2005). Furthermore, Hobday (2000) argues that project-based organisations are more effective and efficient for complex system deliveries compared to functional organisations. Those project-based companies exist in many industrial areas such as consulting, professional services, cultural and sports industries and complex products and systems (Sydow *et al*. 2004). Project-based companies provide temporary project organisations to deliver machinery, technology systems or infrastructure systems to their customers. Packendorff (1995) has identified the following characteristics of temporary organisations.

> *"They aim to evoke a non-routine process or deliver a non-routine product, have a finite and pre-defined life-span; they need to be consciously organised, and their performance can be evaluated".*

Project organisations confront changing internal and external environments. According to the contingency theory (Lawrence & Lorsh 1967, Thompson 1967, Galbraith 1973), organisations should be organised based on the contingency factors of the surrounding environment. E.g. in the situations of increased functional specialisation and economics of production organisation should move its model towards a functional organisation. Contingency factors in the context of project organising are related to uncertainties in the project environment and the interdependencies of project actors (Donaldson 2001). Tosi and Slocum (1984) summarise that the contingency theory argues that complex relationships exist among environmental, organisational and individual/group variables. According to Galbraith (1973), increases in project uncertainty, diversity and changing external conditions pose demand of organising by projects. Hereby, uncertainty can be seen

as an underlying concept of contingency factors in relation to the project environment.

2.3.2 Uncertainty, equivocality and ambiguity

Uncertainty

In the contemporary project risk management literature, project risks originate from the uncertainty that is present in all projects (PMI 2013). The recent edition of PMBOK (PMI 2013) defines project risk as "*an uncertain event or condition that if it occurs, has a positive or negative effect on at least one project objective, such as time, costs, scope or quality"*. Projects are seen to confront uncertainty as having its bases in the inaccuracy of different kinds of estimates (Ward & Chapman 2003), in relation to its environment (PMI 2013) and/or in internal organisations (Tushman & Nadler 1978). PMBOK defines risk through the notion of "uncertainty" without specifying what "uncertainty" is.

Perminova (2011) has defined uncertainty in the project management context as follows:

> *"Uncertainty in projects is the individual´s (e.g. the manager´s) lack of knowledge and/or understanding of the relevant project elements, its environment and their interrelationship, so that no conclusion can be made as to if and/or how any of these can impact the project success."*

She differentiates uncertainty management from risk management in projects by introducing three reflective uncertainty management methods to handle uncertainty in projects (Perminova 2011). Those methods are investigation, communication and adaption.

To gain a broader and deeper perspective on the concept of uncertainty, a short introduction is given on how uncertainty is understood in several disciplines near the area of project management. Early works in psychology (Miller & Frick 1949, Shannon & Weaver 1949, Garner 1962) determined uncertainty as the absence of information. Head (1967) introduced a more fundamental definition of uncertainty as

> *"a state of mind characterised by a conscious lack of knowledge about the outcomes of an event"*.

Head's definition gives an idea of the subjective nature of uncertainty with the notion that uncertainty is something you are not able to measure, but you are aware of the possibility that it might be important and relevant.

In organisation theory, organisations are seen as open systems facing both internal and external uncertainty. Milliken (1987) introduces three common interpretations of uncertainty in organisation theory: (1) an inability to assign probability as the likelihood of future events (Duncan 1972, Pfeffer & Salancik 1978), (2) the lack of information about cause-effect relationships (Lawrence & Lorsch 1967, Duncan 1972) and (3) the inability to predict accurately what the outcomes of a decision might be (Duncan 1972, Downey & Slocum 1975).

In information processing theory, uncertainty is seen as the need for organisations to process information (Galbraith, 1973, Galbraith 1974, Tushman & Nadler 1978, Daft & Lengel 1986). Galbraith (1973) defines uncertainty as

> *"the difference between the amount of information required to perform a task and the amount already possessed by the organisation".*

Galbraith (1974), Daft and Lengel (1986), and Martinez and Jarillo (1989) introduce several formal and informal mechanisms with which to process information to reduce the uncertainty encountered by organisations. Daft and Lengel (1986) distinguish organisational situations of high equivocality and their need for special information processing practices in the organisations. Information processing mechanisms are further introduced in section 2.3.3 of this dissertation. Tushman and Nadler (1978) identified sources of uncertainty as (1) the characteristics of a sub-unit task (task complexity and task interdependence), (2) the sub-unit task environment and (3) inter-unit task interdependence.

ISO-standard 31004 Risk Management, Guidelines (2013) determining concepts related to risk management, offers a broad perspective on uncertainty when describing following.

> *"The uncertainty which, together with the objectives, gives rise to risk originates in the internal and external environment in which the organization operates. This can be uncertainty that: (1) is a consequence of underlying sociological, psychological and cultural factors associated with human behaviour, (2) is produced by natural processes that are characterized by inherent variability, e.g. in weather, (3) is a variation between observations in a population, (4) arises from incomplete or inaccurate information, e.g. due to missing, misinterpreted, unreliable, internally contradictory or inaccessible*

data, (5) changes over time, e.g. due to competition, trends, new information, changes in underlying factors, and (6) is produced by the perception of uncertainty which may vary between parts of the organization and its stakeholders".

In Table 4, a summary of the definitions of uncertainty introduced in several disciplines is depicted.

Table 4. Uncertainty in different disciplines.

Researcher	Discipline	Definition of uncertainty
Head (1967)	Psychology	Uncertainty is a state of mind characterised by a conscious lack of knowledge about the outcomes of an event.
Knight (1964)	Economics	Uncertainty is a situation for which is not possible to specify numerical probabilities.
Galbraith (1973)	Information processing	The difference between the amount of information required to perform a task and the amount already possessed by the organisation.
Milliken (1987)	Organisation studies	Uncertainty is an individual´s perceived inability to predict something accurately. An individual experiences uncertainty because he/she perceives himself/herself to be lacking sufficient information to predict accurately or because he/she feels unable to discriminate between relevant data and irrelevant data.
PMI (2013)	Project management	Risk is an uncertain event or condition that, if it occurs, has a positive or negative effect on at least one project objective, such as time, costs, scope or quality.
Atkinson *et al.* (2006)		Uncertainty results from the vagueness, ambiguity and contradictions associated with a lack of clarity because of a lack of data, incomplete and inaccurate details, a lack of structure for considering the issues, the working and framing assumptions being used to consider the issues, known and unknown sources of bias, limited control of relevant project players and ignorance about how much effort it is worth expending to clarify the situation.
Perminova (2011)		Uncertainty in projects is the individual´s (e.g. the manager´s) lack of knowledge and/or understanding of the relevant project elements, its environment and their interrelationships so that no conclusion can be made as to if and/or how any of those can impact the project success.

The definitions of uncertainty put forth by scholars of different disciplines have following general features: Uncertainty (1) is a state of lack of determination of something, (2) it is subjective depending on individuals' perceptions and (3) it is not measurable. In the definitions of uncertainty introduced by Atkinson *et al*. (2006) and Milliken (1987), there are also features of ambiguity and conflicting information and, hence, equivocality is implicitly inside the definition of uncertainty.

Equivocality

Daft and Lengel (1986) stated that organisation process information to reduce both uncertainty and equivocality. This argument was originally based on organisation studies, where Weick (1979) argued that reducing equivocality is a basis for organising. Equivocality means ambiguity and the existence of multiple and conflicting interpretations about the organisational situations (Weick 1979, Daft & Macintosh 1981). Equivocality means ambiguity, confusion and lack of understanding. Equivocality cannot be reduced by asking questions and getting more information. New data may not resolve the situation when equivocality is high. Participants need to reach consensus about the relevant issues and relevant questions to reduce equivocality (Daft and Macintosh 1981). In the case of high equivocality, discussions and direct contact are needed to exchange opinions and approaches and to become aligned with the contextual situation.

Uncertainty and equivocality

According to Daft and Lengel (1986), different conditions of the organisations lead to different information processing procedures. Under conditions of high equivocality, managers have to exchange their subjective deviating views, and they have to define problems and resolve conflicts through the enactment of the shared interpretation. When uncertainty is the prevailing feature of the situation, managers acquire more information to answer a variety of objective questions to solve known problems. Although uncertainty and equivocality are presented by Daft and Lengel (1986) as independent constructs, scholars note that uncertainty and equivocality are related in the real world (Atkinson *et al*. 2006, Milliken 1987). This means that under conditions of high equivocality, some new data, clarifications and agreement may be needed; and under conditions of high uncertainty, demand for new data may generate the need for additional interpretation and definition. Table 5 presents typical organisational situations and managerial responses from the point of view of information processing in the cases of different degrees of equivocality and uncertainty (Daft & Lengel 1986).

Table 5. Prevailing organisational situations and managerial responses according to different degrees of equivocality and uncertainty.

High equivocality	
Low uncertainty:	High uncertainty:
Occasional ambiguous events	Many ambiguous, unclear events
Unclear events	Managers define questions, also seek answers
Managers define questions	Gather objective data and exchange opinions
Develop common grammar and gather opinions	Rich, personal media needed
Rich, personal media needed	
Low equivocality	
Low uncertainty:	High uncertainty:
Clear, well-defined situation	Many, well-defined problems
Managers need few answers and gather routine, objective data.	Managers ask many questions, seek explicit answers and gather new quantitative data.
Media of lower richness needed	Media of lower richness needed

The role of uncertainty and equivocality has been studied from the management point of view (Lewis 2004) in the engineering project context (Chang & Tien 2006) and in the product development context (Park 2011). Stork and Sapienza (1995) state that when the levels of uncertainty and equivocality change, project managers must (1) change the way they communicate, (2) modify team structure, (3) be prepared for different types of conflict, (4) adjust the way decisions are made and (5) vary their own leadership style. Frishammar *et al*. (2011) have studied the role of uncertainty and equivocality in the innovation process. They argue that both uncertainty and equivocality are more effectively reduced in successful front-end projects than in unsuccessful ones and that the negative consequences of equivocality exceed those of uncertainty. It is also proposed that in the construction industry context, differentiating between uncertainty and equivocality will enable a more profound understanding of the sequential order for information processing – that is, that one must define questions (reduce equivocality) before one can find answers to the questions (reduce uncertainty) (Levander *et al.* 2011).

In the contemporary project management literature, the concept of uncertainty is distinguished from the concept of risk, and particular uncertainty management approaches have been introduced (Chapman & Ward 2003, Perminova 2011). Equivocality has been introduced almost as a synonym of uncertainty in the project management literature as a source of complexity and challenge for management. Some scholars have distinguished between situations of high equivocality and high uncertainty, such as Heikkilä (2010), in the coordination of complex operations.

Ambiguity

The concept of ambiguity in social science originates from the tradition of bounded rationality introduced by March and Simon (1958). In the field of sociology, pervasive ambiguity occurs when individuals or collectives are unable to define a social situation (Sandra 1973). In organisation studies, ambiguity is viewed as similar to the term uncertainty when ambiguity is presented as lack of the necessary information available to a given organisational position (Kahn *et al*. 1964). In relation to technical problem solving, Schader *et al*. (1993) define ambiguity as the *"absence of knowledge about functional variables"*. Porter (1985) and Reed and DeFillippi (1990) express causally features of ambiguity in the context of competitiveness, reflecting the relations between actions and outcomes.

In the project management context, Pich *et al*. (2002) link the lack of information and ambiguity when determining situations where a project lacks information. According to Pich *et al.* (2002), the information available in the project is inadequate if (1) too little is known about the states of the world or the causal effects of actions on the project outcomes (ambiguity) or (2) the effect of actions on the project outcomes cannot be analysed because too many parameters interact in the transition of project outcomes (complexity). Pich *et al*. (2002) introduce different project management approaches (instructionism, learning and selectionism) for situations in which inadequate information about the project, its stakeholders and/or environment is available and for situations where lack of information (uncertainty) is the prevailing feature in relation to ambiguity and complexity.

Uncertainty, equivocality and ambiguity

Uncertainty, equivocality and ambiguity are considered in the literature in some contexts almost as synonyms. When distinguishing the concepts, equivocality and ambiguity are seen as the explanatory features of uncertainty. Ambiguity, according to its definitions, is similar the concept of equivocality in that the situation can be characterised as a lack of defining the prevailing situation (Sandra 1973). Table 6 summarises the concepts of uncertainty, equivocality and ambiguity as well as their relations to each other.

Table 6. Summary of concepts: uncertainty, equivocality and ambiguity.

Researcher	Concept	Definition
Atkinson *et al*. (2006)	Uncertainty	Uncertainty results from the vagueness, ambiguity and contradictions associated with a lack of clarity because of a lack of data, incomplete and inaccurate details, a lack of structure for considering the issues, the working and framing assumptions being used to consider the issues, known and unknown sources of bias, limited control of relevant project players and ignorance about how much efforts it is worth expending to clarify the situation.
Weick (1979), Daft and Macintosh (1981)	Equivocality	Equivocality means ambiguity and the existence of multiple and conflicting interpretations about organisational situations.
Sandra (1973)	Ambiguity	The inability to define a social situation.
Pich *et al*. (2002)	Relation of uncertainty, equivocality and ambiguity	The information available in the project is inadequate (lack of information is uncertainty) if (1) too little is known about the state of the world or the causal effects of actions on the project outcomes (ambiguity) or (2) if the effect of actions on the project outcomes cannot be analysed because too many parameters interact in the transition of project outcomes (complexity).

2.3.3 Information processing

Integration techniques and coordination mechanisms have been presented by many scholars (Galbraith, 1973, Galbraith 1974, Tushman & Nadler 1978, Daft and Lengel 1986, Galbraith & Kazanjian 1986, Martinez and Jarillo 1989, Levitt *et al*. 1999, Hobday 2000, Prencipe & Tell 2001 and DeFillippi 2002). Tushman and Nadler (1978) define information processing as follows:

> *"Information processing refers to the gathering, interpreting and synthesis of information in the context of organisational decision making".*

Information processing theories introduce integration and coordination mechanisms for organisations to reduce the uncertainty and equivocality caused by technology, interdepartmental relations and environment (Galbraith 1974, Daft &

Lengel 1986, Martinez & Jarillo 1989). In the information processing literature, uncertainty is understood as a lack of information and equivocality is understood as ambiguity and the existence of multiple and conflicting interpretations. Daft and Lengel (1986) propose seven structural mechanisms to fit along a continuum with respect to organisations' capability for reducing uncertainty or for reducing equivocality. The structural mechanisms include the following: (1) group meetings, (2) integrators, (3) direct contact, (4) planning, (5) special reports, (6) formal information systems and (7) rules and regulations. The first ones are relevant in cases of high equivocality, and the latter ones are relevant in cases where an environment has high uncertainty as a prevailing attribute.

- Group meetings are face-to-face meetings where participants can exchange opinions and managers can converge on the meaning of equivocal cues and are able to enact or define solutions. Group meetings as means of coordination enhance equivocality reduction rather than information processing capability.
- The integrators' role includes the transmission of data, but it is primarily a way to overcome disagreement and thereby reduce equivocality about goals, the interpretation of an issue or a course of action.
- Direct contact is the simplest form of personal information processing. Through discussion and the exchange of viewpoints, equivocality is reduced.
- Planning is a dynamic process with elements of both equivocality and uncertainty reduction. The initial planning reduces equivocality, while plans, schedules and feedback provide data for uncertainty reduction.
- Special reports include studies and surveys whose primary role is to obtain data and interpret the data and thereby reduce uncertainty. Special reports tend to be undertaken related to issues about which objective data are not currently available but can be obtained through systematic investigation and analysis.
- Formal information systems produce periodic reports that make up an organisation's information support system and typically report measurable aspects of the organisation's performance. These reports reduce uncertainty by producing information.
- Rules and regulations as well as procedures and standards provide a fixed, objective knowledge base from which employees can learn to respond to the routine organisation phenomena. Rules and regulations reduce uncertainty, while equivocality is reduced before rules and regulations are written.

In addition, Galbraith (1974) and Martinez and Jarillo (1989) introduce coordination mechanisms. Galbraith (1974) presents a model consisting of three

elements for coordinating the subtasks: (1) coordination by rules and programs, (2) coordination by hierarchy and (3) coordination by targets and goals. Impersonal tools include, for example, a project plan, an organisation intranet, meeting minutes, case writing, project history files and a database of lessons learnt. Martinez and Jarillo (1989) categorise formal coordination mechanisms into the following categories: departmentalisation, centralisation, formalisation, standardisation, planning and output and behavioural control. These categories are akin to Galbraith's coordination mechanisms. Martinez and Jarillo (1989) also introduce three groups of subtle coordination mechanisms: informal communication, lateral or cross-departmental relations and socialisation. It should be noted that some mechanistic, impersonal coordination mechanisms, such as formal meetings, can also have elements of subtle mechanisms. The impersonal and subtle integration mechanisms presented by Daft and Lengel (1986) have many elements similar to the frameworks introduced by Galbraith (1974) and Martinez and Jarillo (1989). The three above-mentioned coordination frameworks are summarised in Table 7. Both the impersonal and subtle mechanisms they have outlined are presented in the table.

Table 7. Summary of integration mechanisms.

Type of integration	Daft and Lengel (1986)	Galbraith (1974)	Martinez and Jarillo (1989)
Impersonal, formal mechanisms	Rules and regulations	Coordination by rules and programs	Departmentalisation
	Formal information systems	Coordination by hierarchy	Centralisation
	Special reports		Formalisation
	Planning		Planning
			Output and behavioural control
Subtle, informal mechanisms	Direct contact	Coordination by targets and goals	Informal communication
	Integrator		Lateral or cross-departmental relations
	Group meeting		Socialisation

The project-based organisation poses diverse challenges to its risk management, one of which is to integrate the differentiated parts of the organisation to work towards the goal of the whole organisation. It is typical that, due to differentiation,

each department and division develops its own functional specialisation, time horizon, operating practices, goals and jargon (Daft & Lengel 1986).

Large engineering projects executed by networked project structures need coordination of the project actors working in challenging complex project environments. Coordination can be achieved through the variety of practices and frameworks introduced by scholars (March & Simon 1958, Thompson 1967, Van de Ven 1976, Mintzberg 1979, Malone & Crowston 1994). Galbraith (1977) argued that coordination mechanisms are used to reduce uncertainty by processing information. Hence, coordination is an information processing activity and is closely related to communication. Goldkuhl and Röstlinger (1998) point out that

> *"A practice is coordinated through communication. Different linguistic actions are necessary in order to coordinate actions so that the intended results can be produced. This is necessary in practices in which several producers cooperate"*

(Taxen 2003). Coordination mechanisms are decisions on how to manage and coordinate the interface processes between organisations. Through the adoption of coordination practices, companies may improve the efficiency and effectiveness of inter-organisational interface processes.

Galbraith (1974, 1977) introduced rules and practices as basic means through which to handle uncertainty. If those measures are not adequate, the organisations have two possibilities for reacting to the increased uncertainty. They can either lower the need for information processing or increase the capacity to process information. Galbraith (1977) introduced three methods for reducing the need for information processing: the creation of slack resources, the creation of self-contained tasks and environment management as well as two methods for increasing the capacity to process information: investment in information systems and the creation of lateral relations. The creation of self-contained tasks in relation to resource sharing and output diversity (Flynn & Flynn 1999, Fairbank *et al*. 2006) and environmental management as means by which to reduce complexity by influencing the demand or by cooperation (Malone *et al*. 1987, Clemons *et al*. 1993, Flynn & Flynn 1999, Fairbank *et al*. 2006) are procedures introduced to reduce the need for information processing. Lateral relations with measures to easily transmit information upward (Mintzberg 1979, Flynn & Flynn 1999, Fairbank *et al*., 2006) and advanced information systems such as electronic conferences, e-mails and knowledge data bases (Clemons *et al*. 1993, Fairbank *et al*., 2006) are practices for increasing the capacity to process information as a coordination mechanism.

In organisation theory, the term coordination is understood as being parallel to collaboration (Trist 1977), cooperation (Pinto *et al*. 1993, Griffin & Hauser 1996, Ettlie 1995) and integration (Lawrence & Lorsch 1967, Gupta *et al*. 1986). Each of these terms, even if labelled differently, share the common idea of joint behaviour towards the same goal or common interest (Pinto *et al*. 1993).

2.4 Theory synthesis

The main key concepts of the literature review with their main references are presented in Table 8.

Table 8. Main key concepts.

Term	Key concept	Definition of term	Main references
Current risk management practices	Formal risk management is a process with following sub-processes: risk management planning, risk identification, risk analysis, risk response planning and risk monitoring and control.		Chapman & Ward (2003), APM (2012), PMI (2013),
Categorisation of risks	Risks are categorised based on common sources and features. Uncertainty is recognised as a basis of risk and, implicitly, equivocality is expressed in the definitions of risk sources of some scholars.		Miller & Lessard (2001), Floricel & Miller (2001), Jafaari (2001), Ward & Chapman (2003), Atkinson *et al*. (2006), Krane *et al*. (2010), Artto *et al*. (2011), PMI (2013)
Project networks	A project network is a temporary, limited and open system where no single actor may act as a legitimate authority for the network as a whole.		Morrison & Hough (1987), Hellgren & Stjernberg (1995), Flyvbjerg *et al*. (2003), Artto *et al*. (2008)

Term	Key concept	Definition of term	Main references
Delivery arrangements based on relational contracting	Project alliance (PA)	**Project alliancing** is a method of delivering major capital assets where the owner and non-owner participants work together as an integrated, collaborative team in good faith, acting with integrity and making unanimous, best-for project decisions, managing all risks of project delivery jointly, and sharing the outcome of the project (Department of Treasury and Finance, 2011)	Walker *et al.* (2002), Walker & Lloyd-Walker (2015), Ross (2003), Department of Infrastructure and Transport (2011), Lahdenperä (2012) Bennett & Jayes (1995), Cohen (2010)
	Integrated project delivery (IPD)	**Integrated project delivery** is a project delivery method distinguished by a contractual agreement between a minimum of the owner, design professional and builder, where risk and reward are shared and stakeholder success is dependent on project success (Cohen, 2010).	
	Project partnering (PP)	**Project partnering** is (a single project application of) a management approach used by two or more organisations to achieve specific business objectives . . . and based on mutual objectives, an agreed method of problem resolution and an active search for continuous improvements (Bennett and Jayes, 1995)	

Term	Key concept	Definition of term	Main references
Information processing in organisations	Organisations process information to reduce uncertainty and equivocality. Some scholars state that the purpose of organisations is to reduce uncertainty.		Tushman & Nadler (1978), Galbraith (1974), Daft and Lengel (1986), Martinez & Jarillo (1989), Jafaari (2001)
Uncertainty		Uncertainty is a lack of information.	Knight (1964), Head (1967), Galbraith (1973), Weick (1979), Daft & Macintosh (1981),
Equivocality		Equivocality is ambiguity and the existence of multiple and conflicting interpretations.	
Ambiguity		The inability to define a social situation.	Millken (1987), Pich *et al*. (2002),Atkinson *et al*. (2006), Perminova (2011), PMI (2013), Sandra (1973)

3 Research contribution

3.1 Information processing mechanisms and challenges in project risk management (Publication I)

The first publication explores information processing mechanisms as risk management measures in a large engineering project and identifies the challenges that relate to the usability of the perceived mechanisms. Risk management practices were studied through the lens of information processing theory, analysing examples concerning how the identified mechanisms reduced uncertainty and equivocality in project networks.

To study the practices for implementing risk management in large engineering project empirically, a qualitative single case study was conducted. The empirical data consist of 10 semi-structured face-to-face interviews. Project documentation such as risk analyses, project status reports and project plans were also utilised when elaborating unexpected events and realised risks and the mechanisms for managing those events. The case project was a large green-field engineering project carried out in an Eastern European country. The project network consisted of several Southern, Eastern and Northern European countries. The project environment was challenging due to the unstable political situation and constant changes in regulation in the host country.

The publication identifies eight formal information processing mechanisms at the network level for implementing risk management by reducing uncertainty: (1) established rules and criteria for the selection of subcontractors at a global level, (2) specification of responsibilities in the contract, (3) formal risk sheet, (4) progress follow-up tool, (5) database for project information, (6) customer reporting system, (7) updated project plan after the project is delayed and 8) country study team. The personal relationships between parties, personal commitment, experienced individuals, and face-to-face meetings are identified as informal information processing mechanisms used as measures of project risk management to reduce equivocality. These identified mechanisms are those introduced by Daft and Lengel (1986) and are presented in Table 9.

Table 9. Identified information processing mechanisms.

Mechanism category	Mechanism	As identified in the case project
Formal information processing mechanisms	Rules and regulations	Established rules and criteria for the selection of subcontractors in a global network
	Rules and regulations	Specification of responsibilities in the contract
	Rules and regulations	Formal risk sheet
	Formal information systems	Progress follow-up tool
	Formal information systems	Database for project information
	Special reports	Customer reporting system
	Planning	Update project plan after project was delayed
	Planning	Start-up team/country study team
Informal information processing mechanisms	Direct contact	Personal relationships
	Integrators	Experienced individuals
	Group meetings	Kick-off meeting
	Group meetings	Face-to-face project follow-up meeting

The identified informal information processing mechanisms implemented as practices of project risk management are based on direct contact between project participants as well as informal encounters. The informal risk management practices – direct contact between project parties and integrators as well as group meetings and the embodiments of those – are presented in Table 10. The identified formal risk management practices are presented accordingly in Publication I.

Table 10. Informal risk management practices, the applications in the case project and fitness with contextual situation.

Mechanisms in the case project	Application of the mechanism in the case project	The implications of the employed mechanism and fitness with the contextual situation
Direct contact		
Personal relationships: the turnkey contractor – the end customer	Personal relationships between the project managers of the turnkey contractor and the end customer; some trustful and some non-trustful relationships.	In consequence of good personal relationships the end customer not required penalties due to the delayed project although entitled to do so. Personal relations important in situations of high equivocality.
Personal relationships: the turnkey contractor – the main contractor	Trustful relationships between the project managers of the turnkey contractor and the main contractor.	Good cooperation between parties. Personal relations important in situations of high equivocality.
Direct contact: the turnkey contractor – subcontractors	Evaluation of new potential subcontractors in the host country before selection.	Immediate feedback on the information received from the subcontractors. A suitable approach and practice for situations of high uncertainty and high equivocality.
Personal commitment of the turnkey contractor´s project manager	Checking personally all sites with the end customer.	Personal participation and commitment important in situations of high equivocality.
Integrator		
Experienced individuals	Utilisation of the experience of the turnkey contractor´s individual employees during the sales phase and project phases.	The experience of individuals not utilised. Some risks materialised due to that fact. Use of the experience of individuals would be a suitable approach to reduce equivocality.
Group meetings		
Kick-off meeting	Lessons learned from previous projects introduced and discussed in a project kick-off meeting.	Experience from previous projects not fully utilised. Lessons learnt sessions would be suitable practice for situations of high equivocality.
Face-to-face project follow-up meeting	Turnkey contractor´s project manager´s visits in regions with the end customer to see the actual progress and status of the sites.	Increasing of mutual awareness of counter partner. Building trustful relationships. Suitable approach for situations of high equivocality.

The presence of the project managers of the turnkey contractor in the host country enabled the formation of tight and embedded personal relationships with their counter partners. The project manager of the turnkey contractor was changed three times during the first two years of the project. The high turnover of the project participants *per se* introduced turbulence in the project setup. Some project managers succeeded in establishing good and trustful relationships with their counter partners of end customer and subcontractors, while some failed to do so – for example, due to dissimilar senses of humour. One indication of the positive impact of embedded and trustful personal relationships was when the end customer did not require penalties for project delays from the turnkey contractor although entitled to do so.

The turnkey contractor had to change several subcontractors during the project execution phase. In the evaluation phase of a potential substitutive new subcontractor, the turnkey contractor used direct contact as a practice to get necessary information to support the subcontractor selection. In face-to-face encounters, equivocality was reduced when the potential subcontractors received immediate feedback on the information required and given. Uncertainty was reduced by gathering information from the subcontractor concerning, for example, the financial situation of the subcontractor. In the organisation of the turnkey contractor, the experience gained from previous projects is transferred to the following projects via integrators and particular meetings. The experienced project participants transfer their knowledge in several kinds of arrangements based on direct person-to-person contact. In cases where these arrangements are lacking, new projects do not profit from the past experience of the organisation.

This study shows that some mechanisms worked very well and enhanced risk management in the entire project network. At the same time, some mechanisms had certain weaknesses as risk management practices in the case project. It was found that the ineffectiveness was, in some instances, caused by not following the predefined practices and procedures, while in other cases it was caused by the unsuitability of the mechanism to the prevailing contextual factors. Some formal mechanisms, established rules and criteria as well as formal risk sheets were perceived to be inefficient in situations of high equivocality. This notification is akin to the arguments of Daft and Lengel (1986) that formal information processing mechanisms are suitable for situations of high uncertainty and informal ones for situations when equivocality is the dominant feature of the situation.

The results of this publication contribute to risk management research in project networks, which has not been widely studied earlier (Tukiainen *et al*. 2010,

Lehtiranta 2014). The formal and informal information processing mechanisms introduced by Galbraith (1974) and Daft and Lengel (1986) as well as by Martinez and Jarillo (1989) were identified as risk management practices at the project network level. The practical implications of this publication include examples of formal and informal information processing mechanisms to be implemented as risk management practices. Practitioners may find useful the observations of the suitability and effectiveness of the different risk management practices depending on the type of risk source. From information processing perspective risk sources were divided to those of high uncertainty or high equivocality as the prevailing feature.

3.2 Role of uncertainty and equivocality as risk sources (Publication II)

Research question 3 is answered by Publication II. Publication II analyses the risk sources perceived in the large engineering project network. The publication examines the roles that both uncertainty and equivocality play as sources of risks. The empirical data are the same qualitative data collected for the research for the Publication I, consisting of 10 semi-structured face-to-face interviews. Project documentation such as risk analyses, project status reports and project plans were also utilised when elaborating unexpected events and realised risks. The case project was conducted in an environment that was institutionally challenging.

Realised risks and unexpected events were analysed and risk sources were categorised based on the prevailing contingency factors. The results of this study indicate that the sources of risks can be divided into those having their basis in uncertainty and those with their basis in equivocality. The risk sources identified in the case project are presented in Table 11.

Table 11. Categorised risk sources of the case project.

Risk sources related to situations of high	
uncertainty	equivocality
High turnover of the project personnel	Cultural differences
Unclear roles of the project participants	Complex network of different actors
Immature inter-organisational relationships between actors	Unstable country environment
Lack of information about the country environment	

A high turnover of project personnel, unclear roles of project participants, undeveloped inter-organisational relationships between actors and the lack of information about the country environment are identified risk sources that have their bases in situations where uncertainty is the predominant attribute. Cultural differences, a complex network of different actors and an unstable country environment are perceived risk sources having their bases in situations of high equivocality. The results of this study indicate that a single risk can have its basis in either uncertainty or equivocality, or both. In the case project the local country environment is the risk source having both high uncertainty and high equivocality related to it.

The slow, ambiguous and non-analysable permitting process was a problem in the case project and caused project delays, resulting in the turnkey contractor exceeding budget. There was a clear deficiency in terms of experience with the local permitting process and lack of information about the local suppliers. Uncertainty about and a lack of information on the local environment was a risk source of the delayed permitting process, but that was not the only reason for the problems related to the permitting process. It was obvious that the permitting process was not based on stable institutional manners and causality. The process was vague and non-analysable even to local project participants. Hence, high equivocality along with high uncertainty were the attributes of the situation. Equivocality related to the local environment was also high in terms of the behaviour of the main contractors. The behaviour was somewhat unexpected and included going on strike to improve their contractual position.

In the case project, risk sources based on high equivocality are related to situations of conflicting information and multiple interpretations. Risk sources originating from high equivocality can be categorised as risks relating to cultural differences, a complex network of different actors and an unstable country environment. The risk sources, the description of the risk sources and their implications for the project are presented in Table 12.

Table 12. Risk sources, empirical examples and the way risks were experienced in the case project.

Risk source related to high equivocality	Description of the risk source	Empirical examples	Implications
Cultural differences	Eastern and Southern European cultures and business cultures not well known to the Northern European project participants of the turnkey contractor.	Managing via personal relationships	For Eastern and Southern European project participants, personal relationships are important in the business culture.
			Strong personal power inside the Eastern and Southern European companies.
		Reacting to conflicts by showing emotions	The end customer shows its disappointment with strong emotions when the progress of the project is falling behind schedule.
		Shadow agenda and shadow agreements	A formal protocol is followed in meetings but important issues are discussed and agreed upon informally before or after the formal meetings.
Complex network of different actors	Conflicting goals	Interest asymmetries between the parties	Opportunistically maximising benefits and not considering long-term relationships.
	Close relationship and similar business cultures	Tendency to agree on issues without contractual relationship	Maximising benefits and income via by-passing contractual relationships.
	Local citizens	Non-rational behaviour	Individuals agitating the public to oppose the project even if required permissions exist.
	Many actors of different cultures and countries		Personal mature business relationships influenced the choice of contractors.
	Deviating interpretations of the contract	Deviating interpretations of contract effectiveness	Advance payment required before starting work.
Unstable country environment	Permitting process	Lack of stable institutions and causality	No awareness of the permitting process and its causality.
	Behaviour of the subcontractor	Opportunistic behaviour	Going on strike to get a larger scope.

Conflicting goals, close relationships and similar business cultures between the main contractor and end customer, local citizens, many actors of different cultures and countries and deviating interpretations of the contract are identified risk sources perceived to be conceived from high equivocality related to the complex network of different actors. This complexity was detected in several matters. For example, the turnkey contractor and the main contractors had interest asymmetries. This materialised when the main contractors opportunistically maximised their benefits in the case project and did not consider long-term relationships with the turnkey contractor. The main contractors had a close relationship with the end customer and had a similar business culture because they were originally from the same home country. Because of this close relationship, the main contractors negotiated and agreed upon releasing some of their obligations with the end customer despite not having a contractual relationship with the end customer. This by-passing of contractual relations confused the turnkey contractor but also resulted in a release of some obligations. When the main contractors were not satisfied with the outcome of a negotiation with the turnkey contractor, a separate mutual agreement was negotiated between the main contractors and the end customer. In addition, different actors with different business cultures understood the contract differently and interpreted it based on their own cultural premises. For example, in the case project, a local contractor did not start the work until receiving an advance payment even though the payment was not stipulated as a precondition for starting the work.

This publication contributes to the extant project risk management literature in relation to the categorisation of risk sources. Project risks are categorised based mainly on the different types of uncertainty in the existing literature (e.g. Ward & Chapman 2003, Atkinson *et al.* 2006). Some scholars have categorised risks by their nature and features (e.g. Artto *et al*. 2011, Krane *et al*. 2010). This publication shows how equivocality, the existence of several and conflicting interpretations, can be the source of risks in large engineering projects. It was also noticed how project risks can have sources in both uncertainty and equivocality. The majority of the project risk management tools are formal and based on information processing suitable for reducing uncertainty. This study complements the project risk management literature by proposing that equivocality along with uncertainty is a relevant source of risks in large engineering projects. Based on information processing theory, informal risk management practices are suitable for reducing equivocality.

Project-based companies and investors can utilise the results of this study by adapting project risk management practices towards informal practices in cases of

high ambiguity and equivocality. Informal practices include direct contact, group meetings and the use of integrators. In person-to-person communication, consensus and common understanding concerning the main issues are obtained and equivocality is reduced.

3.3 Risk management practices in project networks – collaborative arrangement (Publication III)

Research question 4, concerning collaborative project risk management practices in the networked large engineering project, is answered in Publication III. The case project of the study consisted of several subprojects whose goals and targets were aligned with coordination measures. Coordination is understood as the means of reducing uncertainty and equivocality in the project. A large engineering project confronts uncertainty and equivocality which have their origins in the network of project participants and in the project environment. The focus of this publication is on the elaboration of a particular workshop-type meeting (further collaborative meeting) as a coordinating practice of risk management at the project network level. By analysing the practices of the collaborative meeting, the mechanisms to enhance coordination were studied in the context of a multinational engineering project. Coordination in project networks is an essential part of the project management and hence a part of the project risk management.

The qualitative research method was employed to study empirically the practices of the arrangements of the collaborative meeting as project risk management tools in a large engineering project. Fifteen semi-structured face-to-face interviews were conducted. The interviewees came from several organisations. They presented several levels of organisations, from the steering group members to the project coordinators. The author of this dissertation participated in the collaborative meeting as the project manager of the main contractor. She also participated in the preparation of the collaborative meeting. In addition to the transcribed interviews, the empirical data consist of project documentation (e.g. project status reports and project plans), documentation related to the preparation of the collaborative meeting and observations during the collaboration meeting and preparation phase. It should be noted that the dual role of the author of this dissertation may cause bias. To decrease the impact of possible bias, the conclusions were discussed with other researchers.

The case project was established to build a new, green-field production line. The global project network consisted of the builder, the owner, the main contractor,

suppliers, sub-suppliers of the main contractor, the builder's consultant and local citizens, authorities and unions. In the case project, uncertainty was reduced in the following ways: (1) by using the special reports on the main issues and the status of the project and (2) by implementing response actions agreed upon in the project plan. Collaborative meetings as a big group event also employ many informal information processing practices. It was discovered that the role of integrators, group work and informal discussions during the different occasions and events were elements which reduced equivocality in the project. Table 13 presents the objectives, mechanism, type of mechanism and function of the collaborative meeting sub-process.

Table 13. Objectives, mechanism, type of mechanism and the function of the sub-process.

Sub-processes of the collaborative meeting	Objectives/ questions/tasks of the sub-process of the collaborative meeting	Mechanism	Type of mechanism	Function of the sub-process
Pre-work:				
Information gathering via questionnaires	Main concerns of subprojects Critical issues of subprojects	Special reports	Formal mechanism	Reduction of uncertainty by identifying concerns and issues
Pre-selection of issues Intergrators pre-selected main issues and concerns based on questionnaires	Prioritisation of the issues and concerns Relevant for the entire project Need input of many actors	Integrator	Informal mechanism	Reduction of equivocality via prioritisation

Sub-processes of the collaborative meeting	Objectives/ questions/tasks of the sub-process of the collaborative meeting	Mechanism	Type of mechanism	Function of the sub-process
Collaborative meeting:				
Information sharing	Status reports of subprojects	Special reports	Formal mechanism	Reduction of uncertainty via sharing information
Group work "Issues and concerns"	Response actions Responsible	Direct contact	Informal mechanism	Reduction of equivocality via focusing
Group work of issues and concerns in the collaborative meeting	persons Due dates	Group meeting		on specified common agreed actions
Team creation	Common goals	Direct contact	Informal mechanism	Reduction of equivocality via commitment
Social event	Get to know each other	Direct contact	Informal mechanism	Reduction of equivocality via increasing familiarity
Implementation of actions in the project plan	Updating of the project plan	Planning	Formal mechanism	Reduction of uncertainty via proper planning

According to the empirical examples, formal and informal information processing mechanisms as risk management practices are identified. Perceived information processing practices reduce both the uncertainty and equivocality inherent in large engineering projects.

Publication III shows how the sub-processes of the collaborative meeting complement regular project execution work and project risk management work, providing tools for coordination. Figure 4 illustrates the mechanisms introduced by Daft and Lengel (1986), the perceived mechanisms in the case project and the sub-processes of the collaborative meeting. The underlined sub-processes are not a part of the collaborative meeting, but they complement project execution work and utilise the outcomes of the collaborative meeting.

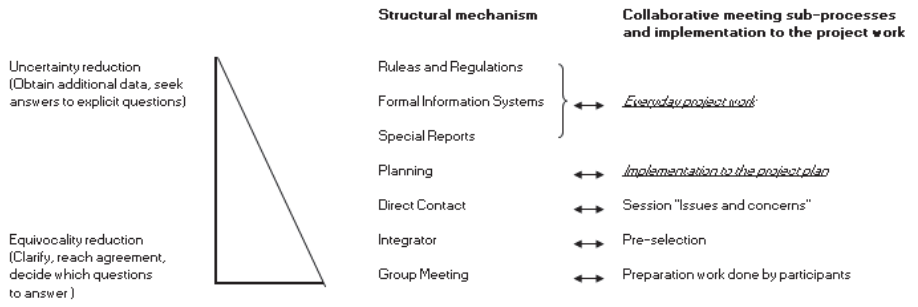

Fig. 4. Sub-processes of the collaborative meeting and implementation of its results in the project work.

Publication III concentrated on giving detailed descriptions of the collaborative meeting practical arrangements and characteristics of the meeting.

This publication contributes the extant literature of project risk management by describing and documenting one particular workshop-type of arrangement as a tool of collaborative project risk management. The coordination mechanisms were seen to act as project risk management practices in project network context. The integration mechanisms – communication, coordination and balance of cohesion introduced by Hoegl and Gemunden (2001) and Gajendra and Brewer (2012) – are substantive in the context of large engineering project networks. The information processing mechanisms introduced in the literature (Galbraith 1974, Daft & Lengel, 1986, Martinez & Jarillo 1989) are found to have a role as practices of project risk management in global project networks.

The practical implications of this publication include the detailed descriptions of the collaborative meeting practices and insights of the participants as guidance in arranging collaborative project risk management practices in large engineering project networks. Based on the interviews, the collaborative meeting was characterised by following terms: information sharing, team creation, prioritisation by pre-selection and social event. These characteristics concretise the formal and informal nature of the collaborative meeting. Furthermore, it is notable that participants of the collaborative meeting have different needs in terms of coordination – for example, project managers need more practical tools to support their daily project execution work, while steering group members benefit from the more general information about the entire project status and main issues.

3.4 Risk management in project alliances (Publication IV)

Research question 5, concerning project risk management practices in the project alliance, is answered in the Publication IV. The focus of this publication is on an illustration of the inherent project alliance features and on how these features support the common risk management of the alliance partners. Risk management practices are studied from the perspective of information processing theory.

The case project was the first public railway renovation project in Finland executed with a project alliance arrangement. In project alliances, project risk management is contractually guided to be a common effort of the alliance partners. Aside the commercial contact, in project alliance there are particular features that facilitate the use of collaborative management practices. Six semi-structured face-to-face interviews were conducted with project team participants. Observations in the project closing meeting were also a part of the empirical information utilised in the study.

The commercial contract with a risk sharing agreement served as one core formal instrument of risk management in the case project. Aside the commercial contract there were several features, typical for PA, which characterise the project management in PAs. Those features include joint-governance structure, integrated risk mitigation strategy, joint communication strategy and substantial co-location (Walker and Lloyd–Walker, 2015). Also, many formal reports and meeting minutes were used as tools of project risk management. The empirical analysis also shows how informal information processing based on personal contact and encounters were widely used as risk management practices in the project alliance. Project alliancing as a contractual instrument with the particular project alliance features supports the collaborative risk management. The empirical examples on how project alliance features enhance risk management in project alliances are depicted in Table 14. The features are classified by information processing mechanisms and the impact on uncertainty and equivocality reduction is distilled from the empirical case examples.

Table 14. PA features to enhance risk management in project alliances.

Information processing mechanisms (Daft and Lengel, 1986)	Features of the project alliance (PA) enhancing risk management	Empirical examples on how the feature was embodied in the case PA.	Manners to reduce uncertainty and equivocality
Rules and regulations	A multi-party commercial contract with risk-sharing mechanisms and joint governance structure.	The commercial contract defines that risk management is the common effort of the alliance partners. The PA has particular project management practices e.g. special workshops.	Uncertainty is reduced with the commercial contract where e.g. risk sharing is defined.
Formal information systems	Joint communication strategy including project information data base.	Project participants have the access to the project information data base which includes also information concerning risks.	Uncertainty is reduced by sharing current and correct information of the project status and relevant issues.
Special reports	Integrated risk mitigation strategy supported by different internal project meetings with corresponding reports available for project participants.	The project participants have the access to the reports and minutes of the meetings with information concerning risks.	Uncertainty is reduced by sharing current and correct information of the project status and relevant issues
Planning	Joint communication strategy; the Last Planner tool for time scheduling, including the identification of obstacles to execution and finalising particular tasks.	Risks are mitigated by identifying the obstacles. Project participants of all disciplines participate in preparing project schedules.	Uncertainty is reduced by planning. Equivocality is reduced by identifying obstacles and obtaining common understanding.

Direct contact	Co-location of project participants who work in the common project facility (the Big Room concept): See Last Planner time schedule Hear all relevant information concerning the project Is available all the time Small Rooms and Micro Rooms also available for smaller working groups and for individuals Personal relationships between PA participants	Alliance partners are aware of the current important contextual factors. This contributes risk management and especially risk identification. When PA confronts some surprising events, project alliance partners will first find out the solution to how to solve the situation and only afterwards think who will bear the costs.	In the direct contacts information and opinions are shared and equivocality is reduced.
Integrator	Joint governance structure including several specialists: PA process specialist Costs estimation specialist Cost controlling specialist Group work specialist Independent observer	Experienced specialists of their own area ensure transparency. They transfer knowledge from earlier projects. The case PA was the first railway infrastructure PA in Finland and the role of PA process specialist was essential particular in the procurement phase and even earlier when the customer selected PA to be a project delivery model.	Integrator transfer information and enhance the forming of consensus. Hence equivocality is reduced.

Group meetings	Joint governance structure includes workshops on the different disciplines: Site activities, different construction disciplines Interfaces with existing facilities (operation and security) Scheduling Risk management Kick-off meetings in the beginning of new period (fiscal year) with some teamwork-building workshops Project meetings Alliance Management Team (AMT) Alliance Leadership Team (ALT) (Steering Group)	In different workshops and meetings risks are on the agenda. Risks are identified and responses are agreed, In the particular risk workshops the management of the risks is more formal. AMT executes the daily project work including risk management. ALT steer the PA. ALT defined the risk sharing in the cases of scope changes that could not lean on the contract.	In the group meetings information and opinions are shared and equivocality is reduced.

In addition to formal risk management practices based on predefined procedures, informal risk management tools are also widely used in the project alliance context. It was found that risks were discussed and handled in several meetings from different disciplines in the case project and information on the results was distributed by the means of the meeting minutes. In addition, a value-for-money report, a typical project alliance-specific report, was also prepared in the case project. The project information including the minutes of the meetings and the reports were stored in the project data base to which the project participants had an access.

Informal mechanisms as tools of risk management were perceived to be widely used in the case project due to the project alliance's nature and collaborative and integrated project execution arrangements. In the project alliance, one core tool was the Big Room working facility, which, as its name implies, was one large room where the main project alliance participants from the alliancing organisations worked together and naturally had much continuous direct contact and many face-to-face encounters. In addition to the common and public working facility, the Big Room, where regular visitors within the project alliance were also welcomed, there were Small Rooms and Micro Rooms as working facilities for small disciplinary meetings and for individuals. The use of these working facilities enabled common risk management via natural and rich communication between project participants. The Last Planner as a scheduling tool is, by its nature, a tool for utilising direct contact and face-to-face meetings. The Last Planner scheduling tool was originally developed for the production planning in 1990s and afterwards its applicability has been expanded to cover also the fields of design and construction (Ballard 2000). With the Last Planner tool obstacles for the performing of the particular, predefined tasks are nominated aiming to ensure the performance. The use of the Last Planner tool is not limited to the project alliance form of project setup but can be utilised in other setups, too.

Project alliance introduces some new roles compared to the traditional project execution mode with supply-chain arrangements. Those roles are the roles of the project alliance process specialist, the costs estimation specialist, the costs controlling specialist and the group work observer. Those persons evaluate the alliance performance as a third party to ensure the equal rights and obligations of the alliancing partners. Specialists use their own experience and competence in the field of industry and guide alliance participants in case they observe deviations from the agreed upon mode of operation. In the case project alliance, the project manager of the customer and the service provider also acted as integrators between

the several disciplinary project groups. The extant literature on project alliances is focused on contractually guided risk allocation (Chen *et al*. 2012, Love *et al*. 2011, Yeung *et al*. 2007), the value-for-money concept (MacDonald *et al*.2013), the success factors of a project alliance (Jefferies *et al*. 2014, Love *et al.* 2010) and partner relationships (Laan *et al*. 2011). This study complements the existing project alliance literature by illustrating the practices of project risk management in the light of information processing theory. This study shows how also project alliance features have an important role in supporting risk management in PAs. The commercial contract and many formal reports and information sharing systems as formal information processing mechanisms are recognised as risk management tools. Direct contact and group meetings as informal information processing mechanisms are utilised as risk management tools. Hence, a project alliance utilises both formal and informal coordinative mechanisms introduced in information processing theory (Daft & Lengel 1986, Galbraith 1974) as risk management practices.

Project-based companies and investors can utilise the practices depicted in the publication in the execution of risk management practices in project alliances. Some practices of the project alliance, such as the Big Room and the Last Planner, could also be applied in other project execution arrangements.

3.5 Research contribution summary

Table 15 provides brief summaries of answers to each of the research questions.

Table 15. Summarised answers to the research questions.

RQ#	Research question	Answers
RQ1	What different types of information processing mechanisms are used for implementing project risk management in large engineering projects?	The mechanisms introduced in information processing theory can be identified as practices of project risk management in large engineering projects.
RQ2	What kinds of challenges are related to the use of information processing mechanisms in large engineering projects?	-The fitness of the applied mechanisms varied in relation to the contingency factors. - Inefficiency can be caused by not following the predefined practices and procedures and/or by the unsuitability of the mechanism to the prevailing contingency factors.
RQ3	What are the roles of equivocality and uncertainty as bases of risk sources in large engineering projects?	Risk sources in large engineering projects can be divided into those having their bases in uncertainty (a lack of information) or in equivocality (the existence of conflicting and multiple interpretations). A risk source can also have its bases in both.
RQ4	How do collaborative meetings enhance integration and coordination by reducing uncertainty and equivocality in the context of multinational investment projects?	The practices of the workshop-type of practice (collaborative meeting) to enhance project risk management are described. Information processing mechanisms as tools of coordination can act as risk management practices to reduce uncertainty and equivocality.
RQ5	How do the features of the project alliance support project risk management?	Contractually set risk and gain sharing mechanisms and particular project alliance features form the foundation for collaborative risk management, implying both formal and informal risk management practices.

The research contribution of this dissertation consists of deepening the understanding of risk management challenges relevant to large engineering project networks. The challenges mainly emerge from contextual factors such as technology, cultural, political and institutional project environments as well as from the hidden agendas and targets of project stakeholders. In this study, it was observed that risk sources can have their bases in uncertainty or equivocality, or in

both. Collaboration in risk management can be seen as a response to the challenges of project management at the project network level. Collaborative risk management practices in two project setups were examined and illustrated in detail.

4 Discussion

This doctoral dissertation studies project risk management in complex engineering projects in a global project network context. The dissertation makes its primary contribution to the project management literature and more specifically to the project risk management research by focusing on project risk management practices and on the selection of appropriate risk management practices based on risk sources. The extant project risk management literature argues that contextual factors related to technology, project organising, the project environment and project stakeholders increase uncertainty in projects. This study shows that it is relevant to categorise risk sources based on their prevailing contingency factors into those of high uncertainty (lack of information) and to those of high equivocality (the existence of multiple and conflicting interpretations). In this study, it is shown how risk sources impact the selection of project risk management practices in large engineering project networks. In addition, a particular workshop-type collaborative meeting practice and project alliance with contractually guided risk management practices were elaborated, and the function of collaborative risk management tools in a large engineering project network context was illustrated.

4.1 Theoretical implications

This dissertation examines project risk management practices from the perspective of information processing theory. This study contributes to the existing project risk management research in two ways. First, it increases the understanding of the nature of risk sources in large engineering projects. Risks emerged from the different contextual factors have uncertainty or equivocality as the prevailing feature. This study indicates how risk management practices need to be adapted based on the nature of the risk sources. Secondly, this study illustrates how collaborative project risk management practices are implied in collaborative meeting process and in project alliance setup.

4.1.1 Contribution to research on project risk management practices

The main objective of this dissertation is to contribute to the project management research by bringing new valuable information and a theoretical understanding of the nature of risk sources in the context of large engineering project networks and how the nature of risk sources affects the selection of risk management practices.

Categorisation of risks

The findings of this study provide new insights into the categorisation of project risks. In the current project risk management literature, risks are categorised into groups based mainly on their common sources or attributes (e.g. Ward & Chapman 2003, Atkinson *et al.* 2006, Krane *et al*. 2010, Artto *et al*. 2011). Uncertainty is seen as a source of risks (Ward & Chapman 2003, Atkinson *et al*. 2006). Scholars introduce how uncertainty can be related to estimation, design, objectives, fundamental relations between project parties etc. (Ward & Chapman 2003). This kind of categorisation does not consider in depth the nature of the contextual factors from which risks arise. In this dissertation, equivocality in addition to uncertainty is introduced as a risk source in large engineering projects. This study distinguishes situations of high uncertainty and high equivocality as different kinds of contingency factors and illustrates that it is relevant to categorise risks based on the nature of their source: uncertainty or equivocality. Some scholars, such as Milliken (1987), Pich *et al*. (2002) and Atkinson *et al*. (2006) have included equivocality and ambiguity in relation to conflicting information in their definitions of uncertainty. Alternatively, some scholars have indicated that the project management approach and style should be adapted based on contingency factors (MacFlarlan 1981, Stork & Sapienza 1995), but less attention has been paid to the need for different kinds of risk management approaches based on contingency factors. Notwithstanding, the role of equivocality as a risk source has been left out of the discussion of risk sources (Ward & Chapman 2003, Krane *et al*. 2010, Artto *et al*. 2011). By providing empirical examples of the unexpected events and realised risks, it is shown in this study how equivocality can play a role as its own type of risk source in complex engineering projects.

Risk management practices in project networks

The findings of this study provide new insight into the selection of risk management practices based on risk sources in a large engineering project network context. The extant project risk management literature recognises the challenges of risk management in the networks of several participants (e.g. Flyvbjerg *et al*. 2003) and also defines risks in the project networks as originating from the network's form of work *per se* (Hallikas *et al*. 2002, Kähkönen & Artto 2008). The findings of this dissertation provide empirical examples of the challenges of project risk management in large engineering projects in relation to the prevailing contingency

factors. Information processing theory is used as the theoretical perspective of this study. Information processing theory holds that formal practices should be used in cases of high uncertainty and informal practices in the cases of high equivocality (Daft & Lengel 1986). Hence, information processing theory proposes rationales for different information processing practices for situations with different contingency factors. In the context of project risk management, this means that different kinds of project risk management practices need to be applied in the cases of high uncertainty and high equivocality. Based on the empirical examples, formal risk management practices – including the use of rules and regulations, formal information systems, and redefined special reports and plans – were seen to be applied and were seen to be suitable for situations of high uncertainty. With formal information processing practices, organisations and the entire project network can obtain more information concerning project actors, the project environment and external project stakeholder so as to be able to prepare and update more accurate project plans. The informal information processing mechanisms were perceived to be applied in large engineering project networks as risk management practices in cases of high equivocality. These informal mechanisms include practices which utilise direct contact in the form of group meetings and integrator roles. In situations when equivocality was the dominant contingency factor, project network actors used informal and subtle tools to reach consensus and decisions on the relevant issues. Atkinson *et al*. (2006) propose soft tools such as conversations and sense making for project management in cases of high ambiguity. In this study, based on empirical analysis, the use of soft tools is brought into the context of project risk management. The selection between formal and informal and hard and soft project risk management practices is based on the risk sources.

The main objective of this dissertation is to contribute to the project management research by bringing new valuable information and a theoretical understanding of how the nature of risk sources impacts the selection of project risk management practices in the context of large engineering project networks. The key contribution of this study with regard to project risk management practices is that informal risk management practices should be emphasised more and utilised in situations of high equivocality – referring to those situations where much information is available but it has many conflicting and contradictory interpretations.

4.1.2 Contribution to research on collaborative project risk management

This study also provides new knowledge on how collaboration in project risk management can be applied in large engineering projects. Collaborative risk management practices were studied from the perspective of information processing theory. Collaboration in project networks can be guided by commercial contracts, or it can be based on the mutually agreed project execution practices. In addition in project alliances the contract guides the use of informal project risk management practices. In collaboration the use of formal and informal information processing mechanisms as risk management tools responds to the challenges of project risk management emerging from uncertainty and equivocality as sources of risks.

This dissertation provides new insight into collaborative practices as a means through which to coordinate the targets of project networks. The extant research on project coordination focuses on general coordination (Galbraith 1973, Galbraith 1974, Tushman & Nadler 1978, Daft & Lengel, 1986, Galbraith & Kazanjian 1986, Martinez & Jarillo 1989, Levitt *et al.* 1999, Hobday 2000, Prencipe & Tell 2001, DeFillippi 2002). Less attention has been paid to coordination in the context of project risk management (Rahman & Kumaraswamy 2002, Janowicz-Panjaitan *et al*. 2009, Lehtiranta 2014). This study provides empirical examples of the use of formal and informal collaborative risk management practices in global project networks. The objectives and the mechanisms of the particular workshop-type of collaborative meeting are elaborated. The applied risk management practices of the collaborative meeting were seen to be akin to the information processing mechanism to reduce the uncertainty and equivocality introduced by Daft and Lengel (1986). Furthermore, this thesis provides new knowledge on collaborative risk management in project alliances based on contractually guided risk sharing mechanism and particular features of project alliances. Project alliancing is introduced in the literature as one form of project execution arrangement based on relational contracting (Walker & Lloyd-Walker, 2015). The extant research on project alliances is mainly focused on contractually guided risk allocation (e.g. Chen *et al.* 2012, Love *et al*. 2011, Yeung *et al.* 2007), the value-for-money concept (MacDonald *et al*. 2013), the success factors of a PA (Love *at al*. 2010, Jefferies *et al.* 2014) and partner relationships (Laan *et al*. 2011), and less attention has been paid to the practices of risk management. This study sheds light on how features characteristic to project alliances enhance risk management in project alliance setups. One of the key contributions of this study to the project alliance literature

is showing how alliance participants work as one team towards common goals in relation to the project risk management supported and guided by a mutual commercial contract. This can be seen as a realisation of Galbraith's (1974) organisational coordination according to targets and goals.

4.1.3 Summary of the theoretical implications

Table 16 summarises the theoretical implications, showing how individual publications increase the knowledge of risk management practices in large engineering projects in a global project network context. Particular workshop-type collaborative meetings and project alliances are examined as practical realisations of collaborative risk management in large project networks.

Table 16. Summary of theoretical implications.

Publication	Title	Implications
I	Risk management in project networks: an information processing view	Documenting challenges of risk management in large, global engineering projects Evaluating fitness of applied risk management practices in relation to contingency factors
II	Evaluating sources of risks in large engineering projects – the roles of equivocality and uncertainty	Categorisation of the risk sources Role of equivocality alongside uncertainty as prevailing feature of risk sources
III	Collaborative meeting as an integrative mechanism in a multinational investment project	Model of workshop-type tool (collaborative meeting) as a coordinative risk management practice
IV	An information processing view on risk management in project alliances	Contractually guided cooperation and particular project alliance features supporting project risk management

4.2 Practical implications

Project-based companies having project deliveries as their main products as well as organisations executing investment projects can benefit from the results of this study. This study can guide the project management offices (PMOs) of project-based companies when developing practices and procedures to enhance risk management by adjusting project risk management approaches based on the nature of risk sources. This study shows how informal risk management practices should

be considered in addition to the traditional formal risk management practices, particularly in cases where the project confronts situations of high equivocality and the existence of multiple and conflicting interpretations of prevailing situation. Based on information processing theory, this study shows the suitability of informal measures of project risk management for cases of high equivocality. Informal practices are based on direct contact and person-to-person information and opinion sharing and exchange. With these kinds of information processing mechanisms, project participants can negotiate and reach consensus on the main issues to be handled and main questions to be answered in the circumstances of high equivocality and ambiguity. In this study, two collaborative approaches of project risk management are studied. These include the particular workshop-type meeting practice (collaborative meeting) and the project alliance as a contractually guided project execution arrangement and special project alliance features. Many practical implications can be drawn from both studied case projects for project-based companies to perform risk management considering the contingencies manifested in different kinds of risk sources. A summary of the practical implications is presented in Table 17.

Table 17. Summary of practical implications.

Publication	Title	Implications
I	Risk management in project networks: an information processing view	Identifying challenges of risk management in large, global engineering projects Fitness of applied risk management practices in relation to contingency factors
II	Evaluating sources of risks in large engineering projects – the roles of equivocality and uncertainty	Categorisation of the risk sources Distinguishing contingency factors between those of high equivocality and those of high uncertainty.
III	Collaborative meeting as an integrative mechanism in a multinational investment project	Detailed description of workshop-type tool (collaborative meeting) as coordinative risk management practice
IV	An information processing view on risk management in project alliances.	Project alliance contract and project alliance features as tools for project risk management

Typically, risk management in project-based companies is based on the standardised and formal risk management practices introduced in the literature and in the handbooks of the field. Risk management is carried out with particular risk management reviews, or risk management is integrated in the other formal practices of project management. Formal risk management practices are based on formal information processing practices. This study shows how informal project management practices and tools have an important role in project risk management, particularly in the cases of high equivocality. The use of integrators, group meetings and direct contact, occasionally also coincidental and ad hoc based, can significantly enhance the cooperation of the project participants. In every day project work, the existence of face-to-face meetings and rich person-to-person contact are facilitated when project participants work in the same location near each other. Particularly, lessons-learnt types of information and experience sharing can be reinforced by transferring information via direct contact and by integrators in addition to through formal reports

This study introduces collaborative meeting practices, which have many practical implications for large engineering projects. Collaborative meeting can be applied in all project network setups independent of the contractual setup of the project network. Through common target setting and aligned goals, common risk management practices enhance the achievement of the predefined project outcomes. Project actors can in risk workshops identify risks and analyse and define risk responses. When many project actors are present in collaborative meetings, the responsible person of a risk can be nominated from the company who has the best possibility and capability of carrying out the risk response. Defining a due date for the risk response is one key task of the risk workshop. When collaborative meeting practice is applied in a project network which is based on the traditional supply-chain contract arrangement, commitment to the agreed upon risk responses and due dates is restricted. In the traditional supply-chain contract model, extra risk response efforts will be restricted to those fulfilling the contractual obligations and cases where good-will is obtained with minor effort. This kind of collaborative meeting can at its best enhance the achievement of project goals through information sharing and providing a broader perspective for the project participants about the entire project. The collaborative meeting can also have implications on a smaller scale in terms of the cooperation between the main contractor and its subcontractors by deepening the understanding of the importance of a common approach and enhancing common risk management.

In project alliances, the project execution work is contractually guided to support the common risk management of the alliance partners. Project alliance contracts include inherent risks and gain sharing, steering alliance partners to integrate risk management into the daily project execution practices. Additionally, in project alliances there are particular features that facilitate the use of collaborative management practices enhancing project risk management. The Big Room as one of the core physical arrangements enhancing the common efforts of the project risk management at the project network level is not exclusive to project alliances but can be utilised in other project arrangements, too. Many face-to-face meetings and encounters during normal work enable the use of informal information processing and enhance risk management measures. The output of common time scheduling tools, such as the Last Planner, can be located in the Big Room. This makes the schedule visible for all working in and visiting the Big Room. The use of Last Planner scheduling as practical project management practice is not bound to the project alliance form of project setup but can be utilised in other setups, too. The practical arrangement introduced in project alliances can be implemented

in the other projects setups and can enhance risk management as is done in project alliances. For example, a project-based company can make office arrangements so that the core team of the project is located near each other like in the Big Room. This arrangement enables natural media-rich communication between project team members, enhancing information transfer and hence general awareness of the project status and contextual factors and provides good preconditions for effective project risk management.

The principles of the project alliance can be applied in the supply-chain contracted project setups, while the main contractor can form project alliances with its suppliers in certain areas, such as where engineering, delivery and installation form an integrated entity but are typically executed by several suppliers. Project alliancing with risk sharing and gain sharing mechanisms could enable the use of new cost-effective ways of delivering in relation to, for example, engineering pre-assembly, logistic, and installation. In the project model with inherent bonus-mechanisms, the atmosphere of the project work could be potentially shifted from the traditional mode of securing own rights and seeking for possibilities of back-charging to the innovative and flexible fit-for-purpose and best-for-project delivery mode. In the long term, the best-for-project thinking inside the field most likely also means best-for-actors.

Over the last decades, the PMOs of project-based companies have formulated predetermined modes of operation to be applied in projects of companies' project portfolios to achieve effectiveness and cost-competitiveness. In light of this study, these structured and formal modes of operation are suitable in the context of easily predictable conditions and when only limited uncertainty is related to the project execution environment. In cases where the project confronts high complexity in relation to project organisation, environment and external project stakeholders possessing high equivocality and ambiguity, PMOs should adopt their mode of operation towards more agility to be able to respond to challenges arising from equivocality and ambiguity. Even though this dissertation does not address the link between selected risk management practices and project performance and success, it offers guidance for project practitioners to consider different risk management practices for different contextual situations.

4.3 Reliability and validity

There are four tests to evaluate the quality of any empirical study being relevant also for case study research: *construct validity, internal validity, external validity and reliability* (Yin 2014).

Construct validity covers two questions. First, the researcher must ensure that specific types of issues are selected to be studied, and, secondly, she/he must demonstrate that the selected measures on these issues actually reflect the specific types of issues that have been selected (Yin 2014). The research problem and issues were formulated with project-based companies from several industry sectors and researchers of project management. Therefore, the research topics are relevant for the companies and researchers in the field. The research problem is based on issues relevant for project-based companies, and it is reflected against the relevant literature. This increases the validity of the research. Publications I, II and IV utilised as empirical data interviews with representatives of the project network participants at different organisational levels and in different positions. Publication III utilised interviews, company documents and observations as evidence. In publications I, II and III, interviews were conducted with individuals from various national backgrounds. In addition, a subset of informants were interviewed twice for publications I and II. In the interviews the interviewees were guided to tell about the project risk management practices used in the risky situations. The interviewees also nominated other managerial practises with which risks were managed. Another principle to follow in assessing construct validity is to establish a chain of evidence, which refers to allowing the reader, the external auditor of the study, to reconstruct how the research proceeded from the research questions to the final conclusions (Yin 2014). The chain of evidence was maintained by focusing on the presentation of the basis for the conclusions. When reporting the results with the publications illustrative quotations and stories were presented to support the empirical findings. The verification of the research and conclusions by giving the participants an opportunity to review and give feedback ensured the validity of the research. The publications have been carefully reviewed by other researchers to eliminate the influence of the single researcher and her preconceptions on the research topic.

The research problem was viewed from three complementary perspectives through four journal publications. Additionally, each perspective was reflected against the existing literature. Should the companies be selected from different industry sectors, the results could vary to some degree. Moreover, should the perspectives and themes be selected differently, this could affect the obtained

results slightly. Hence, it can be claimed that the requirement of construct validity has been met with the applied research methods and setup.

Internal validity is concerned with the extent to which causal relationships and explanatories can be established between events (Yin 2014). This research is more exploratory by its nature when categorising risk sources and evaluating risk management practices in large engineering project networks. Risk sources were categorised to those having emerged of high uncertainty or high equivocality. Degree of uncertainty and equivocality was defined based on interpretations the contextual factors of the risky situations and unexpected events. In the case projects some coordinative and integrative project management measures were interpreted as risk management measures. The selection of the risk management practices based on risk sources was one objective of this study but the fitness of the selected risk management practices was evaluated only in the publication I. Hence, the question concerning internal validity in this study is more focused on making inferences and how correctly the actions, the contextual situations and the circumstances as well as the relations of those were interpreted. The interpretation is influenced by the experience and capability of the interviewed project participants and the researcher. The valid question in this context is how well uncertainty and equivocality as contingency factors were distinguished by the researcher and how distinguishable those contextual factors are in the daily project execution work carried out by the practitioners. The role of the author of this dissertation differs in the research of the individual publications. She was the outside researcher in the publications I, II and IV and in the research of the publications III she had active role in the case project and she had extensive inside knowledge and access to project documentation. In all studies beside the author there were also other researchers analysing the empirical data. Co-authors of the publications reviewed and commented analyses and conclusions. According to Airala and Pekkanen (2002), publicity and critical judgement by the scientific community are integral parts of scientific research. Anyhow, should the scientific publications be sent to different journals, the comments made by the reviewers could vary to some degree, resulting in slightly different conclusions and results. Should the prior knowledge and personal experiences of the researcher be different, the analyses could have provided different results. The way the publications are combined may also have some influence on the obtained results. The capabilities and experience of the researcher may have had an influence on the general conclusions as well. But finally in this research the caterogisation of the risk sources is based on the researcher´ interpretation of either uncertainty or

equivocality was the prevailing feature in studied risky situations and unexpected events.

External validity deals with the problem of knowing whether the research findings can be generalised beyond the context of the study (Yin 2014). The generalisation of the case study can´t be justified by evaluating the amount of samples but the focus is on the forming of the research questions. Conceptualisation of the world using "how" and "what kind of" questions enables the generalisation of the research. The studies in publications I and II are based on a single case studies with a relevant and complex global project network setting. The case project is selected due to its representativeness related to a complex networked project setup, challenging environment, and richly embodied unexpected events during project execution. Some unexpected events were in relation to the nature of the Eastern European institutional culture but still the country context was not the dominant selection criteria. Publication III studies a single case in a business sector different from that in publications I and II. The selection of the case study is based on the same criteria that was used for the selection of the case project for publications I and II. Publication IV portrays a local case study of a public construction project in Finland. Together, the three different case studies of three different business sectors form the bases of this research. Althought the case projects cover a broad range geographically, politically, and culturally, the generalisation in limited. A greater number of case studies would increase the external validity of the research. However, this research provides the risk management research field with analysing measures based on information processing theory. These measures can be implemented in studying different project risk management approaches. This study shows that the information processing theory can be used as a framework in categorisation of risks on project network setups in some business sectors. Hence the framework most likely can be applied in the other sectors too. The objective of reliability is to verify the quality of the research. The purpose is to ensure that other researchers can repeat the research and obtain similar results by following the described procedure (Yin 2014). The researcher is the most critical aspect regarding the reliability of the qualitative research (Airala & Pekkanen 2002). The observations of the researcher are influenced by her biases and values. Qualitative research relies on the interpretations of the interviewees' descriptions and statements. The researchers make their interpretations based on their experience and prior knowledge of the phenomena and events described. Qualitative research focuses on a few cases and aims to analyse them thoroughly.

The criteria for reliability depend on the quality, not on quantity. In addition, the research has been conducted at a certain time and by certain individuals, making the research somewhat unique. The author of this dissertation participated in collaborative meeting, the object of the empirical data for Publication III. She also participated in the preparation for collaborative meeting. Her participation may cause bias in her observations. To minimise the effect of bias, she discussed and reflected on the conclusions with other researchers. The research methodology and process used in this dissertation are documented and described for each individual publication, making it possible to repeat the research and compare the findings. Also, the part of this dissertation presenting the overall conclusions has been documented in the same manner. However, no researcher is perfect, and incorrect conclusions are possible. The reliability of this study is ensured by the accurate documentation of the research, including questionnaires, recorded and transcribed interviews and other material, making it possible to audit the research process and results afterwards.

4.4 Recommendations for further research

Studying the risk management of large engineering projects in a global project network context can be considered to contain several aspects and issues, and the study could have been conducted via several approaches. Many issues worthy of further research have been identified during the research of this dissertation. For practical reasons, those issues have been left out from the scope of this dissertation.

It would be valuable if further studies gathered empirical evidence of the use of formal and informal project risk management practices in different contexts such as R&D projects, inter-organisational development projects and engineering projects in different industrial sectors and in different business cultures. Future research could also include analysing the effectiveness and success of the selected project risk management practices in different contexts such as, again, R&D projects, inter organisational development projects and engineering projects in different industrial sectors and in different business cultures. It would be interesting to investigate the effectiveness and success of the selected project risk management practices in relation to the complexity of the project network, related technology, the political and institutional environment and external project stakeholders leading to situations of high equivocality and ambiguity as prevailing contingency factors. The behaviour of project stakeholders with different and oftentimes hidden agendas

and targets may cause high equivocality in large engineering projects which would be an interesting avenue for future research.

In this study, the project risk management practices in project alliances were studied. Further research could provide empirical information on project risk management practices in other relational contracting project setups. Research could investigate project risk management practices in other relational project delivery arrangements, namely in integrated project teams and in project partnering. Furthermore, the case alliance project was the first public infrastructure project executed with this model in Finland. Hence, the practice was new for all participants. Hence, it would be an interesting topic to study the risk management when project alliance is in a more mature phase and alliance partners have previous experience when starting new alliances.

This study uses information processing theory as a framework for examining risk management practices in large engineering projects at a project network level. Contingency theory and other organisation theories would also offer fruitful models through which to study risk management in large project networks. Research into the identification phase of risk management would particularly benefit from the interpretive paradigms of organisational theories. The identification phase is sensitive to the interpretations of the prevailing situations, and, for example, sense making would be an appropriate approach for investigating the phenomena related to the individual's capabilities to identify potential risks.

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Original publications

I Pekkinen L & Aaltonen K (2015) Risk management in project networks: an information processing view. Technology and Investment 6(1): 52–62. Reprinted with permission from Scientific Research Publishing.

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