APPLICATION OF PAY-OFF METHOD IN PROJECT ALLIANCE RISK CONTINGENCY RESERVE MANAGEMENT

Lappeenranta–Lahti University of Technology LUT
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ABSTRACT

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Examiners: Associate Professor Jan Stoklasa and Tomas Talasek Ph.D.

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Risk management is important in project alliances. Complex projects and project organizations attract more uncertainty. Integrating project delivery methods were developed to tackle these issues efficiently. When it comes to costs, alliances risk reserve is the part of risk management that can be seen in alliance's target cost. Aim of this thesis to apply fuzzy Pay-off method to calculation of alliance's risk reserve. Currently, risk reserve calculations are either result of complex simulations or its calculations are too subjective. By applying Pay-off method, thesis tries to find middle ground solution in possibilistic setting. Additionally, choosing of risks in risk reserve and valuating risks are discussed.

Data was gathered from three large public infrastructure projects. Results indicate that Pay-off method is a viable option in risk reserve calculations. Results do not vary significantly among different methods. When compared to simulation models Fuzzy pay-off method is faster, simpler to apply, requires less computational power, runs in a spreadsheet software and is visually easy to interpret. Since each method gives reliable results, the quality and availability of data becomes important. Being able to identify, analyze and choose risks relevant to project systemically and standardizing practices across the industry are key topics in successful development of risk management.

TIIVISTELMÄ

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Samppa Roimela

TUOTTOJAKAUMAMENETELMÄN SOVELLUTUS PROJEKTIALLIANSSIN RISKIRESERVIN LASKENTAAN

Kauppatieteiden Pro gradu -tutkielma
2022

53 sivua, 8 kuvaa, 11 taulukkoa and xx liitettä
Tarkastajat: Associate Professor Jan Stoklasa ja Tomas Talasek Ph.D.

Avainsanat: riskienhallinta, riskireservi, Tuottojakaumamenetelmä, sumea numero, allianssi

Moninaisissa ja useita eri sidosryhmiä sisältävissä projektialliansseissa riskienhallinta on tärkeä osa projektijohtamista. Monimutkaiset projektit ja projektiorganisaatiot tuovat enemmän epävarmuutta projekteihin. Näitä ongelmia ratkomaan kehitettiin integroivia projektitoimitusmenetelmiä. Riskienhallinnan osa, joka näkyy allianssin tavoitekustannuksessa, on riskireservi. Tämän työn tavoitteena on soveltaa onnistuneesti tuottojakaumamenetelmää allianssin riskireservin laskentaan. Nykytilassa riskireservin laskenta on monimutkaisten simulaatioiden tulos tai se on liian subjektiivista. Tuottojakaumamenetelmää soveltamalla työssä yritetään löytää välimaasto nykyisten vaihtoehtojen välillä. Lisäksi tutkitaan mitä riskejä riskireserviin tulisi valita ja kuinka riskejä tulisi arvioida.

Data kerättiin kolmesta eri julkisesta infrastruktuuriprojektista. Tulosten mukaan tuottojakaumamenetelmä on varteenotettava vaihtoehto allianssin riskireservin laskentaan. Tulokset ovat samankaltaisia kaikkien testattujen menetelmien välillä. Simulaatioihin verrattaessa tuottojakaumamenetelmä on nopeampi, vaatii vähemmän laskentatehoa, toimii taulukkolaskentaohjelmassa sekä on helppo tulkita visuaalisesti. Koska menetelmien välillä ei ole suurta eroa, nousee suurempaan rooliin riskidatan laatu ja saatavuus. Projektin kannalta relevanttien riskien tunnistaminen, analyysi ja valitseminen riskireserviin systemaattisesti sekä prosessien standardointi koko toimialalla ovat avainasemassa riskienhallinnan kehittämisessä.

ACKNOWLEDGEMENTS

I would like to thank all case companies and interviewees for their cooperation and patience during the process of writing this thesis. Special thanks to every colleague of mine at Vison Oy for offering their guidance and expertise to this thesis and to my supervisor for his guidance during this process. Most importantly I would like to thank my family for supporting me through my studies.

ABSTRACT

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Contents

1. Introduction

Construction industry is changing, and the change is driven by megatrends like urbanization, digitalization, and climate change. Construction projects are developed in more dense urban areas and in more challenging environments. (Peisa, 2019) Construction projects are traditionally fractal in nature as the developer procures the services needed from multiple subcontractors. This results in more complexity in process. Together with the ongoing change different solutions are needed.

Typical behavior in construction risk management is risk-aversion, which leads to shifting risk through contractual obligations to party with least bargaining power. Usually, this tendency of risk transfer is towards the primary contractor who in turn shifts risk to lower tier parties of the contract. As a result, parties with least amount of influence over the project's risk factors, carry most of the risk. (Hanna, Thomas & Swanson, 2013) This leads to inflated project costs, division, disagreement, and lack of trust between project stakeholders. To tackle these issues, collaborative forms of project delivery have been ana are being developed. Most advanced forms of these collaborative delivery methods are Project alliancing and Integrated project delivery (IPD). (Lahdenperä, 2012)

Origins of IPD-models are in oil platform projects in 1990s. They were developed to mitigate elevated level of risk and uncertainty in these projects. Collaborative project delivery methods are rather new in construction industry and many of the current issues that arise from new circumstances, are continuously being solved. Joint organization and risk sharing, and other features related to project alliancing require openness, trust, commitment and cooperation from alliance stakeholders. Further developing both structural and cultural features of project alliancing will be vital in future success of collaborative forms of project management. (Lahdenperä, 2009)

Managing risks and uncertainty is an essential part of management of construction project. Modern construction projects are complex and involve multiple parties with different desired outcomes and liabilities. Size and complexity of the projects are difficult in scope of project cost and schedule management. Same challenges make the project risk management difficult. Only the phrase “risk” means different matters for each stakeholder. In finance, risk is uncertainty but in engineering and decision-theory risk can be defined as a set of undesirable outcomes.

Wide range of stakeholders with different goals is a challenge to navigate through for project owners. Modern implementation models such as Integrated Project Delivery and project alliance try to manage these issues by sharing liability and creating common incentives for all parties in the project. Essential part of these integration methods is common target cost derived during design phase of the alliance. Project alliance is the most advanced form of integration in construction project.

1.1. Research questions

Topic of this thesis is to create framework for modern risk reserve estimation in project alliance project by answering following research questions:

Table 1: Research questions of the thesis

RQ1	How to categorize risks in project alliancing?
RQ2	What risks should be identified and valuated in risk reserve calculation process?
RQ3	How the pay-off method performs in relation to project alliance risk reserve calculation methods?

Research questions are answered in scope of construction industry and project alliancing. RQ1 aims to find usable standard practice for risk classification. In current state there is no accepted standard or “best practice” method for risk classification which can lead to lengthy process in design phase where lots of resources are used to agree on risk classification. Answers are found through literature, expert interviews and project comparisons.

RQ2 discusses, what risks should be identified and valuated to risk reserve. Risk reserve is a part of alliance’s target cost. Target cost is the soft capped budget of the project. the underrun or overrun of the target cost is the basis for alliance’s compensation model. This leads to situations where some alliance stakeholders may have incentive to boost risk reserve to drive target cost up. Finding answers helps to standardize and streamline this process.

RQ3 is a continuation of RQ2. Largest projects have the means and expertise to do complex simulations to set risk contingency, that smaller alliances do not have. Creating a model based on pay-off method could be the answer to set more accurate and reasoned risk contingency reserve for implementation phase of the project, without having to rely on Monte Carlo Simulation models or other complex simulations. Creating a consistent model without relying on simulation models, would be valuable to smaller alliance owners, since they do not either have capacity, knowhow or funds to invest in such software needed.

1.2. Scope

This thesis is limited to collaborative project delivery methods and risk management in collaborative project delivery context. Furthermore, calculations in this thesis are considered in scope of risk contingency reserve calculations in alliance target cost.

Project alliance is a collaborative project delivery method where parties assume joint responsibility in design and implementation of the project. Joint responsibility is based on joint agreement (Alliance agreement). Parties in project alliance create a joint organization where they share both positive and negative risks of the project and work in close cooperation. (Lahdenperä, 2009) Integration is in heart of alliance model. Joint organization utilize designers and builders to plan ways execution as early as possible to reach better commitment and more accurate budgeting. As of 2020, the total value of alliance projects in Finland is 4,9 billion Euros. (Vison, 2020a) Project alliances are best suitable for projects where risks related are multidimensional and hard to define and manage. (Lahdenperä, 2009)

Calculating risk contingency reserve is one of the main things slowing down negotiations of target cost of the project. Different goals between alliance stakeholders and imprecise information leads to situation where risk contingency reserve estimation is highly subjective or dependent on complex simulations and too large in general. Goal of this thesis is to tackle this problem by using real option logic and Fuzzy Pay-Off Method to estimate risk impact and to compute risk reserve for project.

Figure 1 depicts the composition of alliance target cost. It consists of project-costs, risk reserve, overhead expenses and margin of service providers. The reward amount is the subtraction is target cost subtracted by margin and overhead expenses. In other words, completing the project under target cost leads to extra profit for alliance service providers.

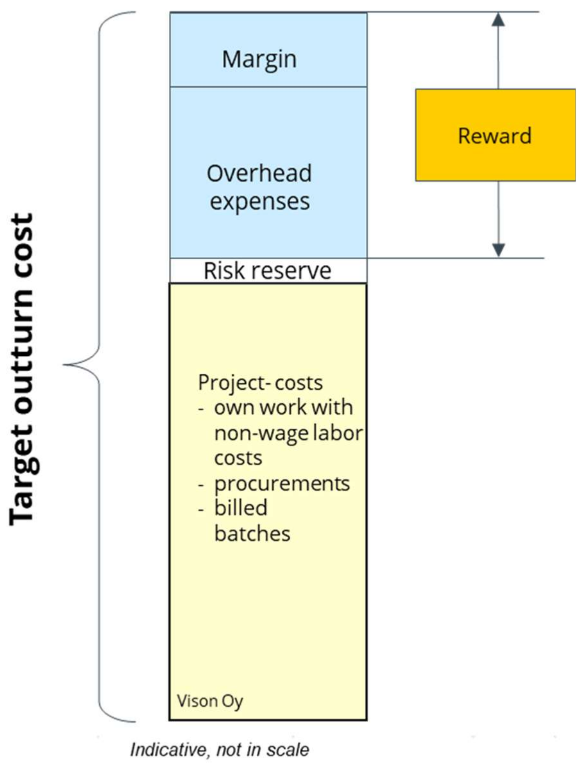

Figure 1: Composition of Alliance target cost (Vison 2020b)

Construction industry, whether building real estate or infrastructure, is usually uncertain, project durations are long, and decisions are based on subjective information or even intuition. Real option theory is one way to bring more rational decision making through financial theory.

This thesis is funded by and done in cooperation with Vison Oy. Vison is a management consultancy firm based in Helsinki. Vison's objective is to improve Finnish project delivery, lean construction, and make Finnish real estate development and construction best in the world. (Vison, 2021) Theoretical background consists of literature review that investigates Integrated Project Delivery and project alliance, risk management in project management, risk contingency reserve calculation methods and Fuzzy Pay-Off Method.

2. Theoretical Background

This theoretical background section gives a brief look into risk management in Project Management with special focus on risk identification and risk assessment. This section also introduces collaborative project models such as Integrated Project Delivery and Project Alliance and the current state of risk identification and assessment in Finnish project alliances. To round up the theoretical background, the theory of Pay-off method and its applications are discussed.

2.1. Risk identification and assessment in Project Management

The general definition for risk is probability distribution of loss (Munier, 2014). It can be also defined as uncertain event or condition that if it occurs, it has a positive or negative effect on project's objectives. Anything that contains uncertainty, contains risk, whether the risk is negative or positive. Positive risks are also known as opportunities. Risk Management is one of the most essential functions of the project owner in making any project successful. Owner initially owns all the risks in a project. (Damnjanovic & Reinschmidt, 2020)

Risk management can be defined as controlling uncertainty of a project. Project of any kind faces some amount of uncertainty and risk management principles should be considered in any stage of a project. (Munier 2014) Typical behavior in construction risk management is risk-aversion, which leads to shifting risk through contractual obligations to party with least bargaining power. Usually, this tendency of risk transfer is towards the primary contractor who in turn shifts risk to lower tier parties of the contract. As a result, parties with least amount of influence over the project's risk factors, carry most of the risk. (Hanna, Thomas & Swanson, 2013)

Risk identification and assessment procedures are vital part of project risk management. Purpose of risk identification is to identify risks to the extent, which is relevant and practical for scope of risk management. The emergent nature of risk requires the repetitiveness of risk identification practices to find risk that were not evident previously. To further analyze the risks associated with project, they must be identified, assessed, and documented. (Project Management Institute, 2019)

2.1.1. Risk identification

Risk identification process starts with finding appropriate inputs for risk identification. According to Project Management Institute's (2017) PMBOK Guide these inputs include project management plans, project documentation, agreements, procurement documentation, enterprise environmental factors and organizational process assets. In other words: Every document regarding project should be included in risk identification inputs. These inputs should be updated through the life cycle of the project. For further data gathering brainstorming, checklists and interviews should be used together with expert judgments to collect as much information as is possible. Best practices suggest using multiple techniques to identify risks since every method has their own shortcomings. Finding techniques that fit the project team's needs and expertise help the project to prosper.

The goal of risk identification process is to find and document risks, prepare preliminary responses for them, and identify risk owners for each risk to monitor and select appropriate risk responses through risk management process. To succeed in this mission, there are several key factors that influence the success of risk identification and the whole risk management life cycle. (PMBOK, 2017)

At project level, risk identification is built on operational and contextual inputs. Operational inputs come from the actions of the project. Project scope statement, life cycle, activity lists, backlogs and work breakdown structures connect project to number of different risks. Contextual risks rise from enterprise environmental factors and other strategic or organizational attributes influencing the environment of the project. Historical data is also important in risk identification process. Past experiences help to identify systemic risks regarding projects.

There is a plethora of different risk identification techniques available. Whatever method is chosen, it is important that identified risk are described explicitly to ensure that emphasis is on actual risks and to diluted or distracted by nonrisks. Using metalanguage and structured risk descriptions help ensuring clarity and distinguishing risk form its causes and effects. Using three-part statement to define each risk (cause-risk-effect) is an example of using such tools. (Project Management Institute, 2019)

One of these methods is creating a Risk Breakdown Structure (RBS). Usually a hierarchical structure, RBS allows to divide risks into groups where they can be identified and assessed efficiently. RBS breaks risk down into categories where further risk groups and individual risks can be assigned. Groups or categories where risks are assigned can be individual for each project's needs.

Table 2: Example of Risk Breakdown Structure

<table>
<tr><th>Level 1</th><th>Level 2</th><th>Level 3</th></tr>
<tr><td rowspan="9">Risk 1</td><td rowspan="3">Risk 1.1</td><td>Risk 1.1.1</td></tr>
<tr><td>Risk 1.1.2</td></tr>
<tr><td>Risk 1.1.3</td></tr>
<tr><td rowspan="3">Risk 1.2</td><td>Risk 1.2.1</td></tr>
<tr><td>Risk 1.2.2</td></tr>
<tr><td>Risk 1.2.3</td></tr>
<tr><td rowspan="3">Risk 1.3</td><td>Risk 1.3.1</td></tr>
<tr><td>Risk 1.3.2</td></tr>
<tr><td>Risk 1.3.3</td></tr>
<tr><td rowspan="7">Risk 2</td><td rowspan="2">Risk 2.1</td><td>Risk 2.1.1</td></tr>
<tr><td>Risk 2.1.2</td></tr>
<tr><td rowspan="2">Risk 2.2</td><td>Risk 2.2.1</td></tr>
<tr><td>Risk 2.2.2</td></tr>
<tr><td rowspan="2">Risk 2.3</td><td>Risk 2.3.1</td></tr>
<tr><td>Risk 2.3.2</td></tr>
<tr><td>Risk 2.4</td><td>Risk 2.4.1</td></tr>
<tr><td rowspan="6">Risk 3</td><td rowspan="3">Risk 3.1</td><td>Risk 3.1.1</td></tr>
<tr><td>Risk 3.1.2</td></tr>
<tr><td>Risk 3.1.3</td></tr>
<tr><td rowspan="3">Risk 3.2.</td><td>Risk 3.2.1</td></tr>
<tr><td>Risk 3.2.2</td></tr>
<tr><td>Risk 3.2.3</td></tr>
</table>

Risk Breakdown Structure links scope and budgeting hierarchically from the risk point of view. It allows to clarify and understand relationship between risks. Finding factors to group risks and determining levels for RBS allow to identify risks efficiently and provides visual documentation of risks in easily understandable manner. RBS can be prepared individually for each project and so allowing for flexibility needed for each project. Additionally, factors that trigger risks can also be integrated into RBS. (Munier, 2014)

Another way to identify risk is Risk-Linking Matrix. It is a square matrix that has twelve areas of the project for both columns and rows. Opposed to Risk Breakdown Structure, Risk-Linking Matrix has set areas that are implemented in any Risk-Linking Matrix and should cover the whole project. It allows for determining potential relationships between different areas of the project. These twelve areas are: Technical, Performance, Planning/Schedule, Cost, Economy and Finances, Environment, Social, Quality, Communication, Legal, Closures and External factors. Illustrated in Table 3 is an example of Risk-Linking Matrix. This can help to visualize links between different project areas and discovering new risks. (Munier 2014).

Table 3: Example of Risk-Linking Matrix (Munier, 2014)

	Tech.	Perf.	Plan/Sch.	Cost	Eco./Fin.	Env.	Social	Qual	Comm.	Legal	Clos.	Ext.Fact.
Tech.	1			1					1			1
Perf.	1	1	1	1				1	1		1	1
Plan/Sch.			1	1								1
Cost		1	1	1	1	1	1	1	1		1	1
Eco./Fin.					1	1	1	1	1			
Env.				1	1	1						
Social				1	1	1	1			1		
Qual								1				
Comm.	1								1			1
Legal			1	1			1	1		1		
Clos.											1	
Ext.Fact.		1							1			1

The structure alone is not enough for good risk identification process. Risk identification needs different perspectives from different stakeholders. Structured approaches give good foundation to risk identification, but the proper work is done by experts from variety of project stakeholders. Reviewing documents and historical information help to identify risks. Uncertainties considering planning and other parts of the project are considered risks at this phase of the project. Historical data points out, what has been identified as a risk in prior projects. Analyzing this information helps to identify risks early and planning response.

Brainstorming, facilitation, interviewing and Delphi technique are examples of bringing expert and stakeholder judgment and views into risk identification process. Brainstorming is a technique where group of people get together to freely discuss ideas and accept and refine or decline the ideas based on discussion. Delphi technique is an iterative method where experts anonymously identify risks in their area of expertise. The answers are gathered and circulated to participants to revise based on other people's contributions. (Project Management Institute, 2019)

Identified risks should be further focused by data analysis. Qualitative analysis methods such as root cause analysis, assumption and constraint analysis and SWOT analysis can be helpful in discovering potential causes and effects of the risk. Inaccuracy, inconsistency and incompleteness of assumptions is uncertainty, but further analysis may help to find more refined definitions for these uncertainties. Identifying internal strengths, weaknesses, opportunities and threats is helpful also in project risk identification. (PMBOK, 2017 p. 130-135)

In the end the result of risk identification process should be a risk register where risks are documented and well prepared for further assessment, reporting and analysis. At this point at least each risk should have a unique identification, causes and effects distinguished, potential risk owners identified, and potential responses identified and documented.

2.1.2. Risk assessment and categorization

Once risks are identified they need to be assessed and analyzed. Assessing risk can be defined as assigning value to a threat or opportunity. Probability of an uncertainty realizing is computed to be included in value of the risk at this step. However, complete valuation of a risk is hard or impossible because uncertainty comes with imprecise or missing information. Because risks effect costs, quality, schedule and so on and the result could be several outcomes it is important to not to assign single value to a risk, but rather a distribution to consider range of outcomes. Also, the number of risks is generally high, which makes assessing every individual risk impossible or wasteful. (Munier, 2014)

Risk analysis is divided to qualitative and quantitative risk analysis. Qualitative techniques are used to prioritize and categorize individual risks for later evaluation. They offer more understanding of manageability, impact, timing, relationships, common causes, and effects of the individual risks. Qualitative risk analysis gives a further classification for risks for project's requirements. Quantitative risk analysis aims to quantify risks and their impact to project cost, schedule or other measurable variables. (PMBOK, 2017 p. 33-34)

Qualitative risk analysis can be done and should be done in different ways to ensure analysis is robust enough to be reliable. Successful qualitative risk analysis relies on using agreed approach, using agreed definitions and terms, collecting credible information about risks and having an iterative analysis process (PMBOK, 2017 p. 34). Qualitative risk analysis aims to separate high priority risks from low priority risks to apply resources optimally. In addition, likelihood of occurrence or probability should be applied to each risk as precisely as possible (Damjanovic & Reinschmidt, 2020). There is a number Qualitative risk analysis options. Probability and impact matrices are one of the more common ways to assess high priority risks from lower priorities. (PMBOK, 2017 p. 136-139)

	5	**MH**	**MH**	**MH**	**H**	**H**
	4	**M**	**M**	**MH**	**MH**	**H**
Impact	3	**M**	**M**	**M**	**MH**	**MH**
	2	**L**	**L**	**L**	**M**	**MH**
	1	**L**	**L**	**L**	**M**	**MH**
		1	2	3	4	5
				Probability		

Risk categories:
1. Low (L)
2. Medium (M)
3. Medium High (MH)
4. High (H)

Impact categories
1. negligible
2. low
3. moderate
4. high
5. catastrophic

Probability categories
1. very low
2. low
3. moderate
4. high
5. very high

Figure 2: Risk matrix with linguistic scales

Quantitative risk analysis should be done to reveal overall risk in project. Using quantitative techniques provides more realistic estimate on overall risk level than approach that only considers risk individually. This process should consider correlation between risks, interdependency and feedback loops. Damjanovic & Reinschmidt (2020) argue that quantitative risk analysis should be different for distinct groups of risks in project. They divide the risks by their impact and probability. Low impact and low probability risks are irrelevant and do not need further assessment. High impact and high probability risks must be mitigated and eliminated and possess threat to project completion. Risks that have low impact, but high probability are usually covered by contingency or by change of process. These risks relate to uncertainties such as material cost, labour cost and other variability that is normal for project. High impact and low probability risks are rare occurrences and are difficult to assign probability to. Rarity of events mean data is not available or biased. Hence, the object should be to mitigate and manage these risks to a plausible level at least.

Subjective information, high level of uncertainty and difficulty of ranking and quantifying risks have created need for different approaches to risk assessment and analysis. One of the methods developed is using linguistic scales for assessing risk impact and probability. Creating risk matrix from these two dimensions can be fuzzified. Fuzzy methods for risk assessment include Fuzzy AHP (Analytic Hierarchy Process), Fuzzy Interference Systems and Fuzzy Risk Matrix.

In project management risks can be categorized by their area, type (Independent, Dependent, Conditional, Correlated) (Munier, 2014) and in terms of frequency (Systematic risk, Specific risk) (Szymanski, 2017). Furthermore, risks can be categorized by phase they occur in. Some risks are specific to design stage of a project, and some happen only in construction stage of a project. Risks should be identified from the preliminary design stage to complete project and the financing of that project. Dividing, classifying and categorizing risks should be conceptualized as part of qualitative risk assessment. Categories should be well defined and refined through the project to be able to monitor risks in a more detailed level. (Szymanski, 2017)

2.2. Risk contingency reserve estimation methods

In alliance model, risk contingency reserve is the part of target cost estimation (Figure 1), where risk management is turned into a cost variable. Deciding on risk contingency reserve is a managerial decision or even a political decision for the decision makers to make. It is yet important to be able to base this decision on data. Therefore, multiple methods for calculation of risk contingency reserve are developed.

According to Moselhi (1997), risk contingency reserve is an inverse function of risk that project management accepts at a related probability of cost overrun happening. In other words, what level of risk the management is willing to take. Higher the contingency, lower the accepted risk level. At the same time, contingency reserve should not be too high because, too high estimates bloat the project budget.

Risk contingency calculation should be done by evaluating uncertainty regarding the project and computing the expected value of risks realizing However the precise risk can be hard to evaluate since information is scarce, not available or hard to quantify. (Project Management Institute, 2019). Thus, there are several ways to tackle these issues from expert judgment to simulation approaches. In any approach that is chosen, the risk contingency reserve should be allocated towards the identified “known unknowns” of the project (Shrivastava, 2014). Project Management Institute (2019) states that reserve analysis is a technique to establish reserves for schedule, budget, estimated costs, or funds. Reserve analysis involves tracking the development during project and reviewing reserve to assess whether it still provides agreed level of confidence. Contingency calculation methods can be broken down to three main methodological groups: Deterministic, probabilistic and modern mathematical methods. (Bakhshi & Touran, 2014) Most methods used today, are probabilistic, non-simulation methods. They are easy to understand and usually older methods so expertise of using them is higher.

Using deterministic methods is the simplest approach to risk contingency reserve is applying predefined of percentage of contingency for whole project or separately to different project stages. Each agency has their own preferred approach to this method. Extension to this method is adding a group of experts to define the contingency percentage to project in hand. These methods do not provide reliability or any risk assessment process and should not be used. (Bakhshi & Touran, 2014)

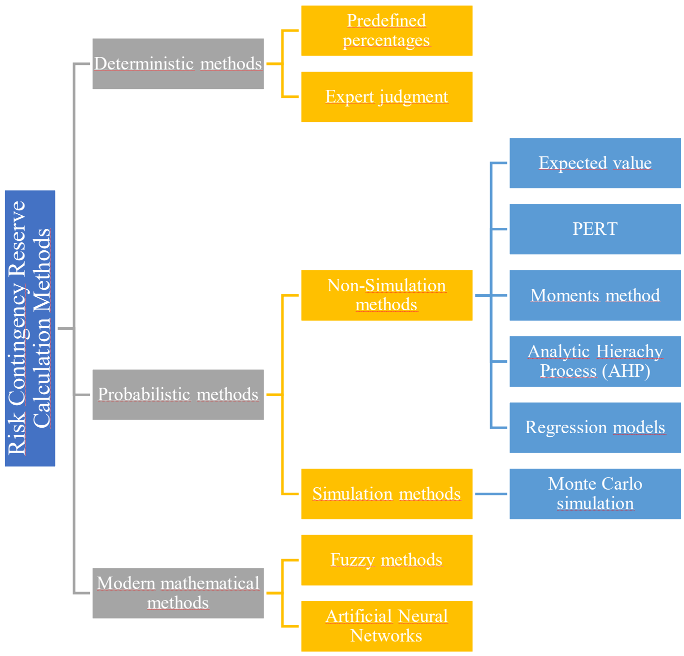

Figure 3: Risk contingency reserve calculation methods

Probabilistic methods use statistical distributions to model uncertainty. Risks arises from uncertainty in project cost estimates to probability of disasters etc. Due to all uncertainty, finding the exact level of contingency needed is impossible. Therefore, a range or distribution is preferred to give a more realistic presentation of project risk. Probabilistic non-simulation models do not require any software packages but can have difficulty catching complexity of projects. Because of this these methods are suitable for large and complex projects. (Bakhshi & Touran, 2014)

Damnjanovic and Reinschmidt (2020) say that contingency levels should be set for each project based on acceptable risk, degree of uncertainty and confidence levels for meeting baseline requirements. The process includes assessment of risks and probabilistic estimating techniques. They argue that defining equation for contingency should be:

$$B = \mu + a\sigma$$

B = Budget for a project or a work package
μ = Expected value of the project or WP cost
σ = Standard deviation of the project or WP cost
a = Contingency factor
$a\sigma$ = Contingency allowance

Contingency should be added to expected value of the cost. Contingency allowance itself consists of contingency factor and standard deviation of the project or work package cost. Setting of contingency factors is done by estimates. There can be a bias to overestimate rather than underestimate since underestimates are more criticized if realized. Imprecise information is also a factor. It can lead to errors in estimates that are covered by adding contingency. (Damnjanovic & Reinschmidt, 2020)

Shrivastava (2014) proposes method based on Expected Monetary Value (EMV). This simple method computes expected value for risk from multiplication of probability and monetary impact of risk realizing. Even if this method is simple, it requires all risks to be independently identified. Furthermore, if risks have high probability, contingency becomes bloated because of high expected value of high probability risks.

Espinoza (2011) implemented option pricing theory to contingency calculation. He used linear stochastic process to model nonlinear random variation with time of the technical and market uncertainty. This simplification allows for use of closed-form solution or use of binomial model to calculate contingency. This technique only takes two types of uncertainty into account: Technical uncertainty and market uncertainty. In other words, uncertainty considering time and material required and price fluctuation of labour and material over time, which are high probability, low impact events. According to Espinoza next extension for this model would be applications for high impact, low probability events.

One interesting approach to risk management and contingency calculation is phasing of the project. From initial planning to project completion, the uncertainty in project diminishes. This especially true for project’s cost estimates and should incorporated to risk management process. (McGraw Hill Construction, 2014) This comes back to iterative approach to risk management. This model introduces a percentage that is released from contingency reserved for grouped risks, by phases of the project.

One of the more popular choices for using simulation to calculate contingency is using Monte Carlo simulation. In Monte Carlo simulation a random variable is inserted into risk function. The simulator makes a predefined number of random draws from specified probability distributions over the population. To build a Monte Carlo simulation model, at least minimum and maximum values for critical risk items are needed. In the end, cumulative distribution function (CDF) is calculated. The CDF is used to determine acceptable level of confidence that contingency reserve will cover all realized risks. @Risk and Cristal Ball are examples of software dedicated to applying Monte Carlo simulation. (Bakhshi & Touran, 2014) Monte Carlo models rely on high number of draws that should be in tens of thousands for results to be reliable. (Damnjanovic and Reinschmidt, 2020) This means that these models require high computing power and time to process.

Eldosouky et al. (2014) propose method based on Earned Value Management. They argue that contingencies exist to minimize threats and maximize opportunities. This method is based on Monte Carlo simulation but takes steps to mitigate and prioritize risks. First step is to obtain preliminary contingency reserve from usual process of risk management: identify, assess risks to risk register etc. Second step is to carry out new simulation after risk responses are applied.

Using fuzzy techniques for risk contingency reserve calculation becomes an option where reliable statistical data is not available. When this is the case, opinion of experts and managers becomes more valuable. Most fuzzy models apply fuzzy logic to convert qualitative statements to quantitative ones.

Fateminia et al. (2020a) have proposed Fuzzy Arithmetic Based Risk Analysis Method for contingency reserve calculation. Method incorporates linguistic terms and fuzzy numbers to determine membership functions for each risk event impact and probability. Contingency reserve is then computed from net severity of events as chosen defuzzied value.

Fateminia et al. (2020b) have developed method called Interval Type-2 Fuzzy Risk Analysis Model (IT2FRAM) for contingency reserve calculation. It is an extension of model by Fateminia et al. (2020a). New model allows for opinion of experts from several subjects in developing of membership function. IT2FRAM also reduces effect of outlier opinions and allows for aggregation of non-linear membership functions into trapezoidal membership functions.

2.3. Fuzzy Pay-off Method

Fuzzy pay-off method is a method for profitability analysis that uses managerially generated cash-flow scenarios as a basis for creating possibilistic pay-off distribution for an investment (Collan, Fedrizzi & Luukka, 2017). It includes calculation of a central measure such as possibilistic mean or center of gravity of future pay-off distribution discounted to a present value. Projects that can take advantage of project alliance, have usually similar characteristics to projects that could profit from implementation of fuzzy methods. Projects that are complex and long lasting in nature and have non-stochastic, subjective, and imprecise information available to them. (Luukka & Collan, 2015)

2.3.1. Fuzzy set theory and fuzzy numbers

Fuzzy sets were established to accept objects to have degree of membership where in an ordinary set an object would either belong or not belong to it (Lake, 1976). Every day one encounters situations where something does not have defined criteria of membership. For example: average human is tall in relation to shorter person but short when compared to a tall person. Is the average person then tall, short, both or neither? This vagueness regarding membership has created need to continuum of grades in membership (Zadeh, 1965). The history of fuzzy sets begins in pattern recognition by Zadeh in 1965. Fuzzy set consists of fuzzy numbers. Zadeh explains fuzzy set as “A fuzzy set is a class of objects with a continuum of grades of membership. Such a set is characterized by membership function which assigns to each object a grade of membership ranging between zero and one.” Membership function depicts the shape of fuzzy set. Most common classes for membership functions are triangular, trapezoidal, Gaussian and generalized Bell. (Shapiro & Koissi, 2015)

A fuzzy number is a special case of fuzzy set that is convex, normalized fuzzy set consisting of real numbers. There are several types of fuzzy numbers, but for sake of this thesis, only triangular fuzzy numbers are examined. Triangular fuzzy numbers (Figure 4) are one the most used fuzzy numbers, due to its simple membership function. (Hanss, 2005) Related to fuzzy numbers, concept of α-cut is useful. It depicts level of membership of crisp set of elements of fuzzy number. α-cut limits the fuzzy number to its set of elements that have membership of at least α. (Shapiro & Koissi, 2015)

2.3.2. Pay-off method

The Pay Off method is part of real option analysis. Real options analysis aims to capture and understand value of real-world optionality in investments. Typical case for real option analysis is in investments comparison where the value and potential of real-investment needs to be investigated and where studying flexibility in investment's cost-benefit analysis is appropriate. Real options, opposed to traditional financial options are usually non-contracted managerial possibilities that are set in illiquid markets and are physical investments. Real option valuation methods include simulation models that require reliable datasets and fuzzy logic -based methods where the data consists of subjective managerial estimates. Pay-off method focuses on valuation of the latter cases. (Stoklasa et al., 2021)

Pay Off Method uses triangular fuzzy number. It is a normal convex fuzzy set with a bounded support. Triangular fuzzy number A [r, s] ⊂R is a fuzzy number, which has following form:

$$A(x) = \begin{cases} 0 & \text{for } r \leq x \leq x_1 - \Delta L \\ A_L(\mathrm{x}) = 1 - \dfrac{x_1 - x}{\Delta L} & \text{for } x_1 - \Delta L \leq x \leq x_1 \\ A_R(x) = 1 - \dfrac{x - x_1}{\Delta R} & \text{for } x_1 \leq x \leq x_1 + \Delta R \\ 0 & \text{for } x_1 + \Delta R \leq x \leq s \end{cases}$$

where ΔR, ΔL > 0. A triangular fuzzy number A can be presented by using α-cut notation as $\{[a_l(\alpha), a_u(\alpha)]\}$, where $a_l(\alpha) = \alpha\Delta_L - \Delta_L + x_1$ and $a_u(\alpha) = x_1 + \Delta_R - \alpha\Delta_R$.

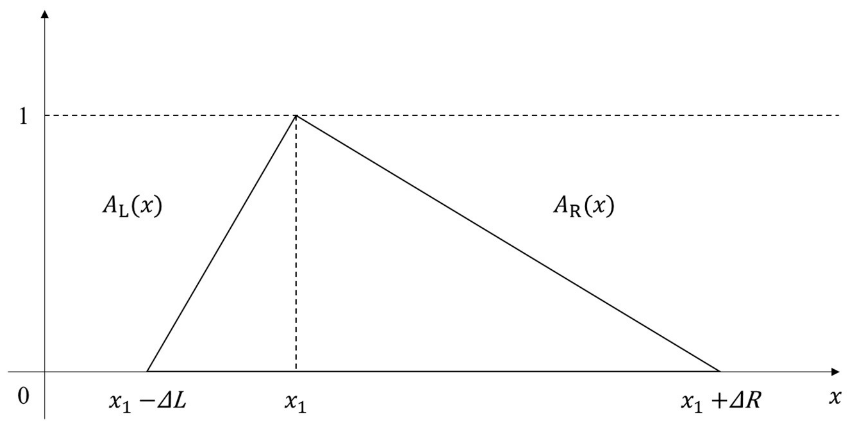

Figure 4: Triangular fuzzy number

Pay off method creates a triangular fuzzy number from three-point approximation where experts give their opinion on minimum, most likely and maximum values on investment cost and returns. This fuzzy number is also known as “Pay-off distribution.” Pay-off distribution aims to catch every possible case for net present value for investment or as in this case: risk. (Collan, 2012)

Earlier variants of Pay-off method have had different ways to calculate real option value from fuzzy NPV. Real option value is the fuzzy mean value for the positive outcomes of the fuzzy NPV. The definition of fuzzy real option value is:

$$ROV = \frac{\int_0^\infty A(x)dx}{\int_{-\infty}^\infty A(x)dx} * E(A_+)$$

Where *A* stands for fuzzy NPV, $E(A_+)$ possibilistic mean of the positive side of the NPV. The integrals compute the ratio of positive part of area of *A* to whole area of *A*. It is simple to see that, when the whole fuzzy number is positive, real option value is equal to possibilistic mean of the positive side of the NPV. (Collan et al. 2009). However, this method has probabilistic components to it (Calculating ratio of two areas).

More use cases have been found in insurance pricing for giga-investment project insurance (Luukka & Collan, 2015; Collan et al., 2017). Other notable use cases include application to oilfield abandonment by Borges et al. (2018), that uses center of gravity approach to calculate real option value.

Stoklasa et al. (2021) have developed a new more possibilistic variant for real option value computation. It uses a center of gravity (COG) -based variant from Borges et al. (2018) as staring point and uses transformation introduced by Luukka et al. (2019) to go fully possibilistic in fuzzy pay-off method for real option valuation. For triangular fuzzy number $A = (x_1, \Delta_L, \Delta_R)$ there are four cases to obtain COG-based fully possibilistic real option value, which are introduced later in the thesis. (Stoklasa et al. 2021)

2.4. Integrated Project Delivery and Project Alliance

Project of any kind faces some amount of uncertainty and risk management principles should be considered in any stage of a project. (Munier 2014) Typical behavior in construction risk management is risk-aversion, which leads to shifting risk through contractual obligations to party with least bargaining power. Usually, this tendency of risk transfer is towards the primary contractor who in turn shifts risk to lower tier parties of the contract. As a result, parties with least amount of influence over the project's risk factors, carry most of the risk. (Hanna, Thomas & Swanson, 2013) This leads to inflated project costs, division, disagreement, and lack of trust between project stakeholders.

Integrated Project Delivery methods are most suitable for projects that face high level of complexity. If risks can be allocated clearly and separated without undue interference by the contracting parties, then alliances advantages might be overshadowed by cost associated with establishing and maintaining the alliance. However, when project faces numerous complex threats considering stakeholder issues, tight timeframes, need for owner interference and value-adding input by the owner or risks that can only be effectively managed collectively, alliancing and other IPD methods should be an option. (Ross, 2009)

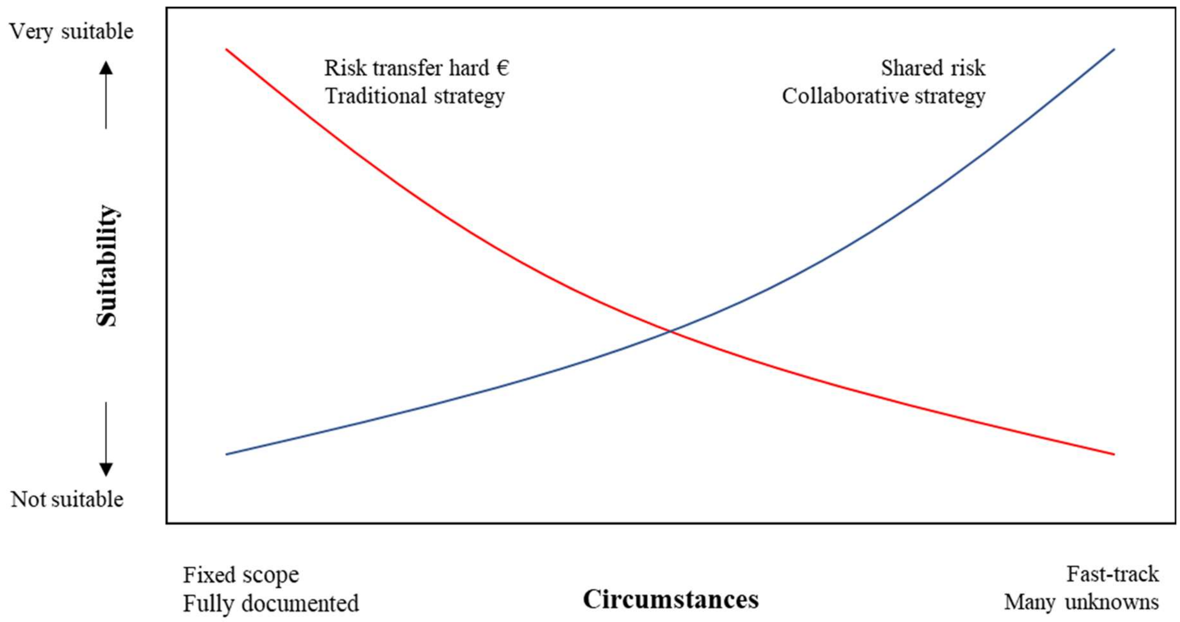

Figure 5: Suitability of IPD methods (Ross, 2009)

Figure 5 visualizes the relationship between suitability of IPD-methods and project complexity. Ross (2009) also states that in the end owners tend to choose alliance as delivery method, when they believe that alliance presents the best chance of achieving their project objectives.

Howell and Matthews (2005) outline four major systemic problems that are prominent in traditional contractual approaches. These problems are that innovative ideas are held back, contracting limits cooperation and innovation, inability to coordinate and the pressure for local optimization. First problem, *good ideas are held back,* is related to fact that key stakeholders are not considered enough in design development phase of project. Even though for example trades are consulted in design development phase, there is no commitment to or from them because participation in project is uncertain. Trade contractors tend to save their ideas for bidding process to gain competitive edge. At that time best ideas are impossible to fully implement to design.

A less obvious problem is the *limiting nature of contracting in traditional contracting*. Hierarchical structures and long tedious subcontracts aim to outline precisely what each subcontractor is to provide and what not to provide. Noncompliance penalties and other remedies make it hard deviate from contract. As a result, innovation is suffocated because there is simply no space for innovation or cooperation. Linked to second problem, subcontracts and hierarchical nature of organization leads to *inability to coordinate* stakeholders from project level. The amount subcontractors at site are unable to coordinate with each other and end up being at each other's way. Fourth and last systemic problem according to Howell & Matthews (2005) in traditional contracting is *the pressure for local optimization.* Each subcontractor focuses to optimize their own performance, which is not necessarily good for the project. Their stance in the project matters tend to be very litigious and legalistic because of the nature of the subcontract they are tied to. Solution to these problems can be found in integration and collaboration. Multi-party contract that gives each stakeholders similar incentives to complete the project are more likely to innovate and work for the good of the project in hand. (Howell & Matthews, 2005)

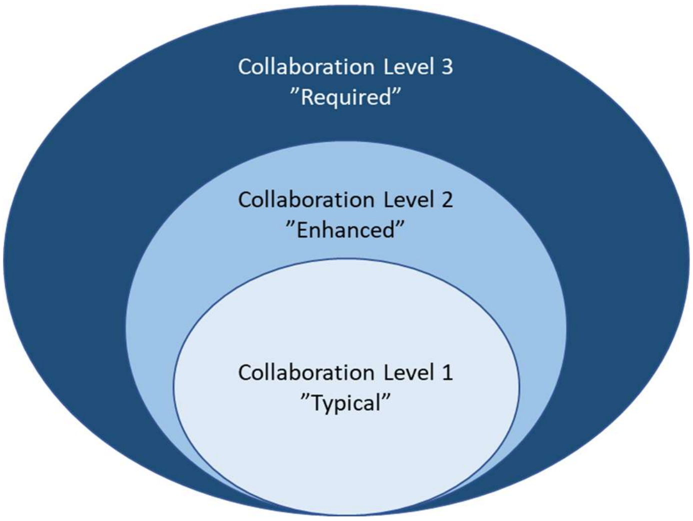

Figure 6: Levels of collaboration (Integrated Project Delivery for Public and Private Owners, 2010)

Integrated Project Delivery methods at varying degrees can be implemented to remove said problems. Level of integration or collaboration in project is determined and driven by owners, more than any other stakeholder, since it is the owner's decision to engage in collaborative project delivery. Figure 6 depicts three levels where collaboration in projects is achieved. Level 1 is the level where owners are used to working in for many years. Owners understand the concepts at least to a level where they can determine whether to apply concept or not. Contractually collaboration is not required. Level 2 of collaboration has some collaboration requirements such as early participation of stakeholders, use of Building Information Modeling (BIM) and sharing of models. At these levels most common delivery approaches are Design-Build models and construction management at risk. The required collaboration or level 3 of collaboration is achieved when owners and stakeholders participate in multi-party contracts and open book concepts with shared financial risk-reward schemes. (Integrated Project Delivery for Public and Private Owners, 2010)

Collaboration Level 3 is reached in Integrated Project Delivery schemes. Desired level of collaboration requires multiple contractual and behavioral principles that are beneficial for the success of the project. Depending on project, not all of them are possible to be implemented but objective is to comply by as many of them as possible to gain most benefit from IPD. Collaboration and integration are not new concepts, but more proactive approach must be taken to establish desired level of integration. (Integrated Project Delivery for Public and Private Owners, 2010) Table 4 depicts key differences between traditional contracting and Integrated Project Delivery in various aspects of project.

Table 4: Differences between traditional contracting and IPD (Integrated Project Delivery for Public and Private Owners, 2010)

Traditional Project Delivery		Integrated Project Delivery
Fragmented, assembled on "just-as-needed" or "minimum-necessary" basis, strongly hierarchical, controlled	**Teams**	*An integrated team entity composed of key project stakeholders, assembled early in the process, open, collaborative*
Linear, distinct, segregated; knowledge gathered "just-as-needed;" information hoarded; silos of knowledge and expertise	**Process**	*Concurrent and multi-level; early contributions of knowledge and expertise; information openly shared; stakeholder trust and respect*
Individually managed, transferred to the greatest extent possible	**Risk**	*Collectively managed, appropriately shared*
Individually pursued; minimum effort for maximum return; (usually) first cost based	**Compensation / Reward**	*Team success tied to project success; value-based*
Paper-based, 2 dimensional; analog	**Communications / Technology**	*Digitally based, virtual, Building Information Modeling (3, 4 and 5 dimensional)*
Encourage unilateral effort; allocate and transfer risk; no sharing	**Agreements**	*Encourage, foster, promote and support multi-lateral open sharing and collaboration; risk sharing*

Integrated project deliveries focus on early sharing knowledge and expertise by integrating stakeholders to work for the project rather than themselves. In traditional contracting, focus of stakeholders is in maximizing their own profit and minimizing their risk. This usually happens by risk-transferring and holding information. It can lead to errors in design and implementation that the project owner ultimately pays for. IPD also encourages innovation from the beginning of the project. As part of collaborative and open process latest ideas can be refined to contemporary design alternatives, better processes and many more.

Project Alliance is one of the most used IPD schemes in construction. It is a project delivery method based on joint contract between key parties. This contract states that parties assume joint responsibility for the design and construction of the project in a joint organization and shared risk-reward schemes. Shared contract and project objectives lead to incentives to share information between alliance parties and better cooperation. As a result, the project should be better prepared to meet its goals related costs, schedule, quality and so on. (Lahdenperä, 2009) Modern alliancing has been pioneered and refined in Australia to meet today's demands (Ross, 2009).

One of the most visible methods of integrating mechanisms is the risk-reward compensation model of project alliance. the generic model consists of directly reimbursable costs, alliance reward and penalty or bonus dependent on project performance. Directly reimbursable costs include any mutually agreed costs or expenses and are always paid to alliance parties. Alliance reward consists of project margin that does not include any bonus or penalty and non-project specific corporate overheads. Bonus or penalty based on project performance, or the incentive model, is a bonus system based on key result areas (KRA) and achievement of project target cost. KRAs are always non-cost-based incentives that encourage working towards owner's objectives for the project. KRAs should be measured with key performance indicators (KPI) that score the performance in each KRA from -100 to +100, where zero is a neutral score and +100 a score for outstanding performance. (Love et al., 2011)

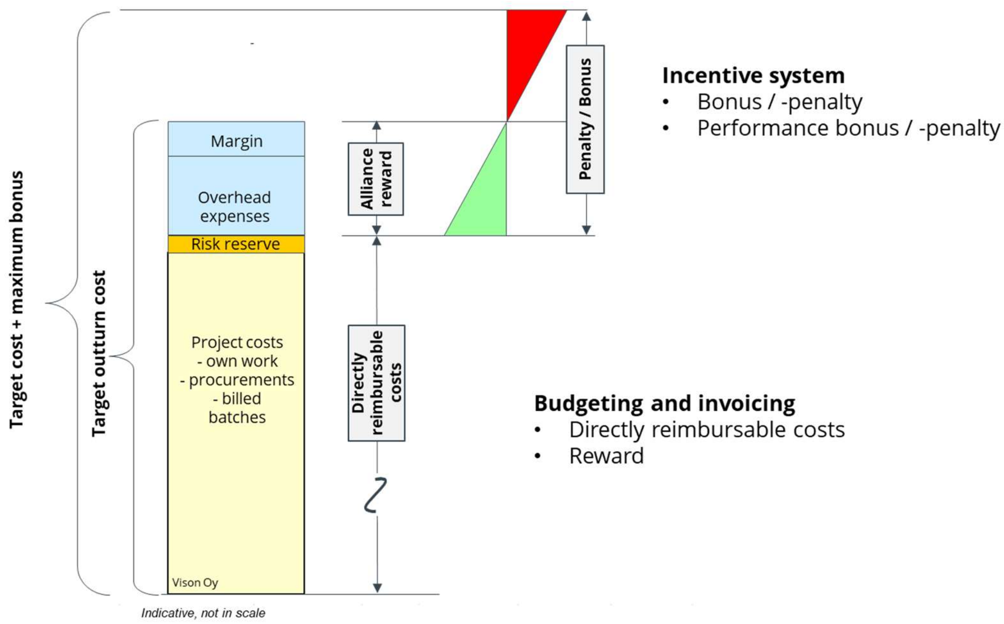

Figure 7: Simplified Alliance compensation model (Vison, 2020b)

Incentive system caps the penalty to alliance reward and bonus to contractually pre-defined level. This kind of incentive model encourages to attain best practices for the project instead of doing the bare minimum to save cost. (Love et al. 2011)

Alliance model has four phases: Alliance formation phase, where key participants are selected, Design stage or Project development phase, where project scope is developed and project targets are agreed, Implementation phase, where project is delivered according to agreed scope and targets and Warranty period, where alliance remains collectively responsible for any defects in project delivery. (Ross, 2009)

Selection of alliance partners is one of more important tasks of owner in alliance. Since cooperation and integration are desired, the selected partners should be committed and willing to participate in contractual and behavioral principles of IPD. Partners selection should not be done based on cost alone. There should be con-cost criteria implemented to selection process. (Ross, 2009) The tender process is ideally thorough and includes informative meetings, interviews, workshops and finally submitted tenders. Based on tenders, best alternative is selected based on weighted scoring assigned to best overall economic solution and non-cost criteria. (Lahdenperä, 2009)

Table 5 outlines the contractual principles for IPD-projects. Contractual principles are principles that can be written into agreements. Table 5 shows that these principles encourage equal status, better relationships between parties and transparency of decision making to do better collaboration on projects. This kind of project delivery and management requires key participants and ideally every participant in project’s lifecycle to adopt the IPD philosophy and mindset to succeed. As a result, the selection process and tendering for participants becomes key stage in project.

Table 5: Contractual principles in Integrated Project Deliveries (Integrated Project Delivery for Public and Private Owners, 2010)

Contractual Principles for IPD	
Key Participants Bound Together as Equals	*Whether it is a minimum of Owner, Architect and Contractor, or a broader group including all project participants essential to project success, a contractually defined relationship as equals supports collaboration and consensus-based decisions.*
Shared Financial Risk and Reward Based on Project Outcome	*Tying fiscal risk and reward to overall project outcomes rather than individual contribution encourages participants to engage in "best for project" behavior rather than best for stakeholder thinking.*
Liability Waivers between Key Participants	*When project participants agree not to sue one another, they are motivated to seek solutions to problems rather than assigning blame.*
Fiscal Transparency between Key Participants	*Requiring and maintaining an open book environment increases trust and keeps contingencies visible—and controllable.*
Early Involvement of Key Participants	*Projects have become increasingly complex. Requiring all participants essential to project success to be at the table early allows greater access to pools of expertise and better understanding of probable implications of design decisions.*
Intensified Design	*The cost of changes to projects increases in relation to time. Greater team investment in design efforts prior to construction allows greater opportunities for cost control as well as enhanced ability to achieve all desired project outcomes.*
Jointly Developed Project Target Criteria	*Carefully defining project performance criteria with the input, support and buy-in of all key participants ensures maximum attention will be paid to the project in all dimensions deemed important.*
Collaborative Decision-Making	*Requiring key project participants to work together on important decisions leverages pools of expertise and encourages joint accountability.*

Contractual principles alone are not enough to implement culture of trust and collaboration to project team. Behavioral principles are also needed to guide actions of alliance parties and its key stakeholders. Behavioral principles encourage to make choices that require collaboration and open communications at every level of project from management to every individual worker at site. These principles are based on choice, and they are further described in Table 6.

Table 6: Behavioral principles in Integrated Project Deliveries (Integrated Project Delivery for Public and Private Owners, 2010)

Behavioral Principles for IPD	
Mutual Respect and Trust	*Nurturing a positive environment requires deep appreciation for the motivations of all project participants: if they do not operate in an environment of mutual respect and trust, performance erodes, and participants retreat to "best for stakeholder" behaviors.*
Willingness to Collaborate	*Collaboration is a behavioral choice. It is important to nurture an environment that supports and encourages participants to choose to collaborate.*
Open Communication	*Collaboration requires open, honest communication: if project participants are reluctant to share ideas or opinions, opportunities for innovation and improvement may be missed.*

Embracing both contractual and behavioral principles boost collaboration on project and leads to realizing IPD from philosophy to delivery method. These principles can also be implemented to other project delivery methods and result in improved project delivery. Goal of project alliancing is to embrace these principles in their full potential to guide every project stakeholder towards objectives of the project.

3. Risk management in IPD and Alliance projects

Early integration of key parties allows for early start of risk management process and early start for risk identification. Risk management is a crucial part of design stage of alliance. During design stage, iterative risk management approach should be able to identify most of the uncertainty regarding the project, plan responses and further mitigate risks. However, all risks cannot be foreseen at design stage. Therefore, risks cannot be allocated effectively through contractual conditions. (Rahman & Kumaraswamy, 2005).

Joint risk management of alliance model and alliance contract aims to tackle this disturbance. In alliance model, the owner pays service providers for better management of risks and opportunities. Alliance contract states that all risks are described and classified in the phase of confirmation of implementation plan and the target cost as follows:

a) the owner's risks (money does not pass through the service provider)
b) risks that, when realized, change objectives (treated as changes in the scope)
c) risks under Alliance's responsibility related to target cost and its implementation.

Table 7: Classification risks in project alliance by responsibility

Risks	Budgeting	Principles	For example,
Owner's risks	Owner's financing decision	Tasks / reserves for which the Owner is responsible. If the owner outsources risk-related tasks to the alliance's service providers, the owner pays direct costs + a fee in accordance with the alliance's commercial terms.	Polluted soil/plots Owner's special tasks Depot, equipment, etc.
Scope changes	Owner's financing decision	When approving the implementation plan, the scope-related reserves remain the responsibility of the owner. The owner decides on the project scope change on its own or on the proposal of the alliance. Target cost / objectives are changed accordingly. Changes will be decided jointly by the parties	Related projects New stop or power supply station, etc.
Alliance risks (Risk reserve)	Risk reserve included in the target cost	Risks are collectively identified and priced and included in the target cost risk reserve as agreed. The realization of risks is covered by the funding reserved in the target cost. A bonus of 38,75 % - 68,75 % is paid for the underrun of the target cost. The overrun of the target cost is shared between the parties 50-50 %	All tasks for which the Alliance is responsible. Planning changes Mistakes and damages Increase / decrease in cost level

Table 7 shows the classification of risks and expands on above classification of risks. Here it shows which risks are included in alliance risk reserve. The take here is that it is strictly defined what risks are considered as Alliance risks and thus included in risk contingency and target cost. For clarity, this classification is noted as A to C where A are Owner’s risks, B Scope changes and C Alliance risks.

In alliance model, owner chooses to pay service providers for better risk management. Aim of integration and collaboration between owner and service providers is to discourage transferring risk to owner by masking uncertainty to extra and modification work. Alliance model creates incentive for all parties to share their risks and opportunities to collectively influence and control them and responses to them. In alliance’s risk management risk contingency is funded by owner, but should some party not be ready to take collective responsibility for the risk, the cost associated should be deducted from risk contingency reserve. (Vison, 2020b)

The foundation for risk management in IPD-project is collective process that starts early and develops through the project. Risks are identified and managed jointly, and goal is that every key stakeholder has mutual understanding about risk management. Mutual understanding requires transparency and open-book basis in financials. Early integration of key parties allows for early start of risk management process and early start for risk identification. Lehtiranta (2014) identified three constructs for joint risk management: Risk workshops, contractor risk integration and performance feedback. Lehtiranta states that an effective time for risk workshopping is in early phases of a project when key participants are selected but works have not begun. Aim of these workshops should be to share information on project’s critical success factors, on any special management processes and to increase general level of risk knowledge, communication, motivation and opportunity.

Modern way to look at construction project is complexity thinking. Complexity in construction project refers to complex organizational structures and technical complexity. To be more specific, Geraldi et al. (2010) identified five dimensions of complexity: Structural, uncertainty, dynamic, pace and socio-political complexity. Structural complexity refers to numerous distinct and interdependent elements. Uncertainty emerges as a complexity dimension from the gap between information on hand and information required to make optimal decisions. Dynamics refer to changes in project goals or scope and are usually linked to uncertainty in project. Dynamic complexity might also be an advantage because dynamism brings adaptability needed for complex projects. Pace or “speed of” project delivery is an important type of complexity. Tighter timeframes lead to more interdependency and therefore intensifying structural complexity. Socio-political complexity is complexity in human interaction. (Geraldi et al., 2010) Differing opinions and personalities are source of this complexity. The challenge is to manage this complexity. Finding the best delivery method for the project, understanding roles of different stakeholders and formal and informal structures of the multi-organization are the ways to manage project complexities. (Lehtiranta, 2014)

Complexity based risk management requires communication and trustful links between project stakeholders in multi-organization environment. Socializing rather than delegating is advised. In multi-organization construction projects, roles of participants must be addressed. Project owners were more concerned about risk related to the investment, collaboration and politics than other participants. Owners tend to care more about risks regarding collaboration rather than risks related to any technical solutions. Main contractor sees their role in risk management within terms of schedule and safety management. Schedule is a baseline for their expectations and the foundation of their risk management process. Architects and other design and engineering parties is to act as owner’s advisor in their field of expertise. they are not expected to be an active part of systematic risk management processes but contribute when asked to do so. Lastly consultants see their role as drivers for integration of other parties. In risk management they are the gathering and sharing risk information and supervising performance according to the owner’s project goals. (Lehtiranta, 2014)

4. Data and Methodology

Empirical part of the thesis introduces case data and methodology used in thesis. First, overview of case project's risk classification, valuation and contingency estimation methods is given. "Data" -part of thesis further introduces data used and presents summary of statistics. Choice of data, its reliability and quality are also discussed. Methodology part discusses the proposed methods for conducting this research, their limitations and applications.

Proposed methodology to achieve this is implementing fuzzy pay-off method to calculate appropriate risk reserve. According to Collan & Luukka (2015) using triangular NPV pay-off distribution for project investment allows to compute payout distribution for the project and finding downside of the project to insure and compute insurance pay-off. Since then, the fully possibilistic real option value computation by Stoklasa et al. (2021) has been released. Estimating cost of project risk is usually based on subjective information, which makes fuzzy logic and pay off method a viable choice of method.

4.1. Data

Data used is case data from Finnish tram alliances. Data of each project is managed separately. Datasets are internal to the case projects and not publicly available. Acquisition of data was done by email inquiries and took few months from first contact to gaining possession of last dataset. There are three case projects, and each project is unidentified and denoted by projects 1-3. Data is managed in common spreadsheet software as well as Business Intelligence software and statistical computing software if appropriate. Datasets obtained from case projects consists of risk data that is collected during the lifespan of the project so far. If the project has already started its implementation phase, data is from the end of the development phase, where the contingency for target cost is set. All datasets have at least id and multiple categorizations. Cost variables in datasets have at least minimum, likely and maximum estimates.

All case projects have detailed risk evaluation techniques. Risk registers of each project have information on qualitative features such as team responsible for risk, geographic areas they occur in, phases and allocation. Expected cost for risks are computed in case of project 1-2 from frequency and consequence of risk realizing. In most cases frequency and consequence are given to a risk matrix. Matrix has values from 1 to 5 for both variables and each value has been given description of consequence of risk and frequency as percentage. Project 3 has multiple cost variables for each risk. Risk can have cost related directly to realization but in addition it has different cost for schedule, work safety etc. Project 3 also uses three-point estimation to value each risk.

The initial look at the data shows that there are hundreds or even thousands of risks identified for each project. Table 8 summarizes risk register of each case project. Risks are handled in tens of columns that contain information of each risk. Columns contain information about categorization, value, probability and identifiers for each risk. Number of risks in Table 8 also include opportunities for all rows.

Table 8: Overview of risk registers

	Project 1	Project 2	Project 3
Number of categories	23	25	29
Number of risks	1244	806	646
Risks included in risk contingency calculation	357	134	182
Expected value of all risks (M€)	78,197	23,807	22,432
Expected value of risks in alliance contingency reserve (M€)	11,047	8,640	4,652
Actual Risk Reserve (M€)	11,000	7,700	4,880

The case projects are huge infrastructure projects, which are valued in hundreds of millions. This means that their area of construction is spread out, which brings more uncertainty to the projects. However, through the risk management process risks are prioritized, mitigated and eliminated to bring down the number of risks to be included in risks contingency reserve calculation. While comparing projects to each other, it is important to remember that each project is in different phase. This naturally mirrors into number of risks considered. Risks that are included in risk contingency calculation are risks that are alliance's risks and relevant in implementation phase.

The value of risks is presented as sum of expected values of all risks and expected value of risks in contingency reserve. Values include both risks and opportunities. From these values can be assumed that Project 1 has been very thorough with their risk management practices. While they have identified high number of risks, they have also eliminated lot of them both in numbers and in value. Other projects have reached similar values of total expected risk. While comparing projects to each other, it needs to be remembered that projects are in separate phases and in different situations in their risk management process.

4.2. Methodology

Proposed methodology consists of qualitative part and quantitative part. In qualitative part, risk management experts or managers of each project are interviewed regarding risk management process and risk classification in their respective project. The quantitative part studies if fully possibilistic method of pay-off method is fit for valuation of risk contingency in alliance project.

Risk management is an iterative process that should cycle and evolve through project's lifecycle. Finding a relevant way to classify risks and developing the risk register is crucial in setting proper contingencies to alliance target cost. What risks should be considered for contingency reserve then? Should I valuate every risk individually or group them for more clarity? These are the questions that need answering in interviews for this thesis.

4.2.1. Interviews

Interviews are conducted as semi-structured interviews, where questions are prepared in advance, but answers are open, and discussion is encouraged. It is suitable for situations where topics of the study are well defined, but still leaves space for participants add new meanings to the study focus. The questions were prepared in advance and sent in advance to interviewees. There was a total of ten questions.

The objective of the interviews is to find more in-depth perspective on risk management process of case projects. This includes the risk management process as well as risk identification and categorization. One of the more important topics is the decision making on risk contingency reserve. What factors influenced the decision and how data supported the decision. What risks are considered and how are these risks valued, are the main questions that need answering. What will be especially interesting is, what similarities and differences can be found between case projects.

4.2.2. Model

Alliance risks or type C risks are risks that include changes in plans, increase or decrease of cost level and so on. When the effect of risk to project cost is unclear, experts and managers need to give their subjective view on risk frequency and impact. Because of the subjective information regarding risk valuation and construction projects and especially infrastructure like trams being irreversible investments, real options approach and namely fuzzy pay-off method is suitable method to model risk contingency reserve estimation. This model aims to emulate results that simulation software can estimate through their rigorous process.

Earlier variants of Pay-off method have had different ways to calculate real option value from fuzzy NPV. Real option value is the fuzzy mean value for the positive outcomes of the fuzzy NPV. The definition of fuzzy real option value is (Collan et al. 2009):

$$ROV = \frac{\int_0^\infty A(x)dx}{\int_{-\infty}^\infty A(x)dx} * E(A_+)$$

Where A stands for fuzzy NPV, $E(A_+)$ possibilistic mean of the positive side of the NPV. The integrals compute the ratio of positive part of area of A to whole area of A. It is simple to see that, when the whole fuzzy number is positive, real option value is equal to possibilistic mean of the positive side of the NPV. (Collan et al. 2009). However, this method has probabilistic components to it (Calculating ratio of two areas).

New fully possibilistic setting for Pay Off method introduced by Stoklasa et al. (2021) is used to compute possibilistic risk contingency reserve. This application needs to take a different approach to project than investment profitability calculation, since the goal is to find appropriate protection for risk, the costs are on the positive side of the distribution (threats) and savings are on the negative side (opportunities). There are four cases to obtain COG-based fully possibilistic real option value, which are introduced below. (Stoklasa et al. 2021)

Case 1, when $x_1 + \Delta_R \leq 0$

$$POSROV_1(A) = \frac{\int_0^0 0\, d\alpha}{\int_0^1 \alpha d\alpha + \int_0^1 \alpha d\alpha} = 0$$

Case 2, when $x_1 \leq 0$ and $x_1 + \Delta_R > 0$

$$POSROV_2(A) = \frac{\int_0^{A_R(0)} \alpha a_u(\alpha)\, d\alpha}{\int_0^1 \alpha d\alpha + \int_0^1 \alpha d\alpha} = \int_0^{A_R(0)} \alpha a_u(\alpha)\, d\alpha$$

that has a fast computation formula that is form of:

$$POSROV_2(A) = \frac{x_1^3}{6\Delta_R^2} + \frac{x_1^2}{2\Delta_R} + \frac{x_1}{2} + \frac{\Delta_R}{6}$$

Case 3, when $x_1 > 0$ and $x_1 - \Delta_L < 0$

$$POSROV_3(A) = \frac{\int_{A_L(0)}^1 \alpha a_l(\alpha)\, d\alpha + \int_0^1 \alpha a_u(\alpha)\, d\alpha}{\int_0^1 \alpha d\alpha + \int_0^1 \alpha d\alpha} = \int_{A_L(0)}^1 \alpha a_l(\alpha)\, d\alpha + \int_0^1 \alpha a_u(\alpha)\, d\alpha$$

that has a fast computation formula that is form of:

$$POSROV_3(A) = \frac{x_1^3}{6\Delta_L^2} + \frac{x_1^2}{2\Delta_L} + \frac{x_1}{2} + \frac{\Delta_R}{6}$$

Case 4, when $x_1 - \Delta_L \geq 0$

$$POSROV_4(A) = \frac{\int_0^1 \alpha a_u(\alpha)\, d\alpha + \int_0^1 \alpha a_u(\alpha)\, d\alpha}{\int_0^1 \alpha d\alpha + \int_0^1 \alpha d\alpha} = \int_{A_L(0)}^1 \alpha a_l(\alpha)\, d\alpha + \alpha a_u(\alpha)\, d\alpha = \bar{M}(A)$$

that has a fast computation formula that is form of:

$$POSROV_4(A) = \bar{M}(A) = x_1 + \frac{\Delta_R - \Delta_L}{6}$$

In addition, possibilistic variant for likelihood of positive outcome of NPV is presented. In original formula it is presented as $\frac{\int_0^\infty A(x)dx}{\int_{-\infty}^\infty A(x)dx}$. Since in Case 1 this there are no possible positive outcomes, and in Case 4 every possible outcome is positive (0 and 1 respectively), computations are necessary only for cases 2 and 3. Below are presented their fact computation formulas. (Stoklasa et al. 2021)

Case 2, when $x_1 \leq 0$ and $x_1 + \Delta_R > 0$

$$\frac{x_1^2}{2\Delta_R^2} + \frac{x_1}{\Delta_R} + \frac{1}{2}$$

Case 3, when $x_1 > 0$ and $x_1 - \Delta_L < 0$

$$\frac{x_1}{\Delta_L} - \frac{x_1^2}{2\Delta_L^2} + \frac{1}{2}$$

For model to be successful, three values are required. Minimum value of total risk present for alliance, most likely value and maximum value. To achieve maximum level of uncertainty, minimum value should be sum of maximum values of opportunities, sum of negative values of minimum risk value or zero in case that there are not any opportunities present. Maximum value in other hand should be sum of maximum value of all risks without opportunities in the calculation. Most likely scenario should be the sum of most likely risks relevant to calculation. For clarity opportunities will be denoted as negative risks.

Using fully possibilistic setting, this model is in theory able to catch the uncertainty in risk contingency reserve calculations. In risk management, risk register includes both threats and opportunities. So, in theory, it is possible that the minimum risk can be on the negative side of the distribution because savings from opportunities are larger than costs from threats in some scenarios. Scenarios where zero risk realize and all opportunities do realize are highly unlikely but are still possible. These scenarios must be considered when computing risk distributions in possibilistic setting.

In practice the calculations can be done in any spreadsheet software or computing environment. To be easily understandable and available to use, Microsoft Excel is used to perform computations. Below (Figure 8) the proposed model is presented. In this sheet user inserts the minimum, most likely and maximum total risks and as a result gets the possibilistic real option value for distribution (POSROV). Sheet shows the value of all possible cases and highlights the correct one. Additionally, the risk distribution and POSROV are given as a graph to visually present the results.

min	- 1 000 000,00 €	
med	4 000 000,00 €	
max	12 000 000,00 €	

min	med	max
- 1 000 000,00 €	4 000 000,00 €	12 000 000,00 €

ΔL	X_1	ΔR
5 000 000,00 €	4 000 000,00 €	8 000 000,00 €

Case 1	- €	0,00
Case 2	4 500 000,00 €	1,13
Case 3	4 506 666,67 €	0,98
Case 4	4 500 000,00 €	1,00

POSROV	4 506 666,67 €

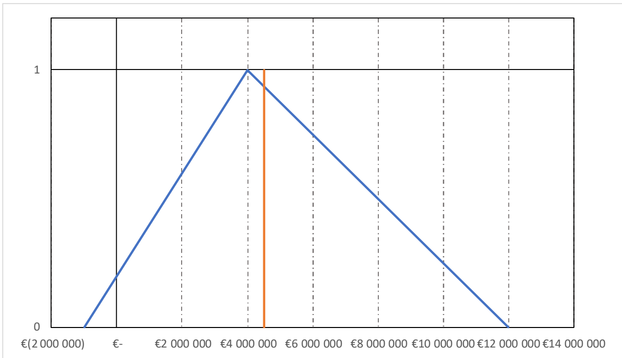

Figure 8: Example of proposed model

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The user of this sheet can paste it into any workbook. User can also create a connection to risk register from where they can compute the right values for risk and connect them to this model with formulas.

Results from this model are compared to two separate Monte Carlo simulation models. Other uses normal distribution and other uses beta distribution to distribute the random variable used in simulations. For simplicity each generated random variate is considered independent. Simulation models take risk values from risk register and simulate each risk independently and summarize value of each risk for final risk reserve value for one simulation. For normally distributed model Excel formula NORM.INV() requires probability, mean, and standard deviation. (Microsoft, 2022a) Beta distributed model uses BETA.INV() -formula and requires probability, alpha, beta, lower boundary and upper boundary. Alpha and beta are parameters of distribution. (Microsoft, 2022b) Lower boundary is the minimum value and upper boundary is the maximum value. Beta model is based on Beta-PERT method developed by Malcolm et al. (1959). Parameterizations are done by formulating alpha and beta according to Davis (2008) when [a, m, b] is the risk distribution in question:

$$\alpha = \left(\frac{2(b + 4m - 5a)}{3(b - a)}\right)[1 + 4\left(\frac{(m - a)(b - m)}{(b - a)^2}\right)]$$

$$\beta = \left(\frac{2(5b - 4m - a)}{3(b - a)}\right)[1 + 4\left(\frac{(m - a)(b - m)}{(b - a)^2}\right)]$$

These equations are simplified from alpha and beta equations that require mean and variance of distribution. By substituting equations for mean variance, equations above can be written.

Both Monte Carlo -models compute minimum, most likely and maximum values for from probabilities and cost impacts from risk register. Minimum value for risk is calculated from multiplication of minimum cost and probability. Most likely value is calculated from most likely cost and probability and same is done for maximum value. Opportunities considered are switched to negative values for risk. Maximal opportunity is considered minimum risk and minimal opportunity maximal risk for each opportunity. For example, opportunity distribution [min, med, max] of [10, 50, 100] is switched as [-100, -50, -10].

5. Results

This section presents results of this thesis. It investigates risk management process and especially risk identification and categorization practices. After that pay-off method-based models are applied to risk contingency reserve calculation of projects and compared to projects' own estimates. Results indicate that project categorize and classify risks based on areas of expertise in project teams, by area and by risk responsibility (alliance, owner). Results from application of pay-off method are consistent and like results of simulations from projects' own models.

5.1. Risk management in alliances

Risk identification in case projects is based on expert groups who identify risks and opportunities workshops and meetings with the said group. Projects identified risks through checklists, keyword lists and utilizing previous experiences of group members. Case projects categorize risks and opportunities based on owner groups, subject areas, KPA metrics, basic project or related project, risk sharing and geographical area for instance.

Risk management in alliances is considered a part of change management. Changes can be both planned and unplanned. Planned changes usually relate to change in scale or quality of the project. Realized risks are unplanned changes that need to be mitigated appropriately.

5.1.1. Risk management process

Base of the risk management process in each case has been systematic review and discussions about risks and opportunities and their attributes. Main attributes for risks were their impact and categorization. Defining the impact of risk, how to mitigate them and deciding who is responsible for risk were integral factors for all case projects. However, the process how these conclusions were reached in projects was quite different.

Project 1 has done extensive workshopping in owner groups to identify, evaluate and categorize risks. Each meeting has had risks and opportunities on their meeting agenda and has led to systematic review of risks on project. This systematic process was placed during development phase of the project and one of the main challenges and need for improvement was identified in earlier identification of risks. Other points for development have been found in giving up risks if they seem irrelevant and sharing of risks between owner groups.

Project 2 started with a process where groups discussed risks and they were documented to risk register. At certain point, there was a realization that risk register was not coherent and not up to date. To solve this, they moved to system where there is one administrator for risk register who is responsible of documenting risks to risk register. Risks were discussed in monthly meetings. These meetings took advantage of keyword lists to identify new risks and opportunities.

Project 3's decisions in risk management were separated in two main groups: project risks and technical uncertainty. Technical uncertainty refers to uncertainty in prices and amounts of material or working hours needed in separate phases of the project. Project planners, designers and contractors discussed project risks in regular meetings. Openness was the main principle of anything done regarding risk management. Openness was challenging and it was needed the most when it came to pricing risks in stakeholders' own processes and finding acceptable level of risk in them. This case project was the only case project that has documented interdependency of risks in risk register and visually represented it in reporting.

The common way to manage risk management process seems to be similar in all case projects. Risks were discussed, identified and reviewed in different expert groups. From there the identified risks were transferred to risk register with all relevant and available information about them. Opportunities were present in all risk discussions, but they do not transfer to risk contingency reserve calculation as often since they are usually priced into target cost directly.

One of the most defining parts of risk management process is the sharing of risks between owner and alliance. The main principle of who owns the risk, pays for it holds true. Case projects budget risks according to who owns them. All cases use the common concept of risk sharing in alliances (Table 7). How projects approached the division, was different. One project discussed these matters regularly in risk meetings and tried to find solutions. Other project left this matter to side until it became relevant and found solutions that suited each alliance party. Third project took example from prior projects and used their division as much they could.

Biggest challenge in risk management process seems to be tracking the costs and other factors of risk realizing. All case projects have faced challenges in verifying risk realizing and verifying whether risk is still open or closed. Cost factor in this problem relates to level of realization. How can project managers find the actual cost of risk realization especially in case that risk could realize multiple times?

Overall, the risk management process in each case was clear and thorough. Risk management process have similarities with each other, but also notable differences. What project sees important and what is their focus in separate phases of the project differs from project to project. They relied heavily on expert judgment in risk identification, valuation and categorization. Projects have found that the best way to transfer risks to risk register is to have a facilitator who leads risk meetings, collects and documents risks.

5.1.2. Risk categorization

Risk categorization practices were similar in each case project. Each project has categorized risks by geographical area, responsibility, cost responsibility, project phase and risk status. Projects have differences in how they treat these categories. Risk categorization gives projects tools to manage their risks from different perspectives.

Project 1's main categories for risks were owner group and distinction between basic project and related project. Other categories included area and subproject categorization as well as separating risks of alliance and owner. For them, the purpose of risk categorization was to help to manage risks in meetings and give them clarity and perspective for example in fiscal management. Project 1 manages and categorizes risks by their impact. Impact can be cost or qualitative factor such as schedule, safety, public image or environment. Project have also created a category whether risk belongs or does not belong to alliance's risk contingency reserve and target cost calculation.

Project 2 categorized their risks based on their KPI-metrics, main project and related projects, geographically, risk sharing between owner and alliance and technologies. Interview answers revealed that project two bases their risk categorization on reporting and monitoring purposes. Being able to distinguish where and what kind of risks realize is deemed to be important for this project's risk and project management. Categorization also helps them with reviewing of risks in risk group meetings. They have also considered realized risks in risk categorization and whether risk is still active or not.

Project 3 based their risk categorization from the angle of being able to present, what the risk consists of and developing understanding about the nature, severity and other capabilities of the risk. This includes defining the area of impact whether it is cost or qualitative impact. Other categorization includes management-based categories such as technical groups who own the risk, whether risk is open or closed, in what phases of the project is the risk relevant and who is responsible for the cost of risk realizing. Risk responsibility defines to whose budget and contingency reserve the risk is placed. As other projects do, Project 3 also has geographic categories to help monitoring and reporting.

Risk categorization is similar in nature in all projects. Risks are categorized by their impact, responsibility, technical group, phase or time and geographical factors. All case projects stated reporting and monitoring purposes as a reason for categorizing risks as they do. Other important reason for risk categorization was defining risk responsibility and budgeting of risks. Separating impacts that risk can have from each other is also key factor in process of categorizing risks. According to interviews case project do not divide risk between whether the risk is systematic or independent as Szymanski (2017) suggests.

Risk categorization should also encourage lean practices and actions that boost the culture of cooperation and collaboration in alliances. Main objective of risk management is to control, mitigate and manage risks, but not share them between stakeholders. This is particularly a worry of project owners as Lehtiranta (2014) states. Politics and collaboration are part of any project with prominent level of complexity. Clear outlines in risk categorization can help to guide the risk management process to a right direction to fulfil its objectives.

5.1.3. Risk valuation

One the more challenging parts of risk management in all case projects is determining the value of risk realizing. Impacts of realized risk are not limited to cost directly caused by the risk. Other impacts such as environmental impact or impact to project schedule can cause additional costs indirectly that need to be budgeted accordingly.

All case projects have taken the approach to value risks by determining minimum, middle and maximum values for risk realizing. Projects 1 and 2 also have probabilities for each of three values and project three has one probability for each risk. These values are used to run Monte Carlo -simulations to determine the distribution of risks for decisions on risk contingency reserve.

Project 1 aimed to determine the value of risk by identifying areas of impact of risk realizing. The valuation process started by identifying impact areas that risk could affect. After these areas were identified, work begun with assessing of impact in different areas and overall. Project 1 approached risk valuation from the standpoint where experts were asked to give minimum and maximum monetary values for risk or impact rating from risk matrix. After the range of risk's value was determined, the middle value was given as consensus of most likely value among experts in that technical group. Risks were also valued on "present" and "net" levels where present level is the initial distribution of risk value and net is the distribution of values after risk has after measures had been done to mitigate risk. Qualitative risks were valued by assessing impact in risk matrix.

Project 2 took an approach where risks were valued on metrics that were connected to KPI indicators of the project. Most risks were related to either cost or schedule. However, project did not want to use many resources to determine the best possible estimate of risk values. Cost estimates were more accurate than other indicators. Project deemed that estimates based on information available on hand were good enough. How they approached the valuation was like project one. Cost estimates were either taken from risk matrix or given as exact values for minimum, most likely and maximum values.

Project 3 executed their risk valuation also with three-point estimates as the other case projects did. They state that their numbers are based on estimates. Whether estimates are acceptable, is decided by project managers. Project 3 has done things in differently in this context by separating the cost effect of qualitative risk impact from direct cost impact. One of the challenges rises from the pricing of unknown risks. How to value something unknown and should it be valued?

All case projects estimated value of their risks as a three-point distribution. The important part for these cases was establishing minimum and maximum values for risk realizing before estimating the middle or most likely value. There is however inaccuracy and subjectivity in estimates since value distribution is either chosen from risk matrix, which has pre-determined ranges for distribution or value is estimated by experts in risk meetings.

There is not a best practice procedure for assessing a monetary value for risk impact. More important is to establish which risks have high impact and thus are a large threat to a project. Assessing a risk quantitatively should take an advantage of all available resources whether it is historical data from past projects to expert opinions.

Projects set their risk contingency reserves according to value of risks that they have decided to include in calculations. All case project relied on their simulation model in their decision making. According to interviews case projects set the level of contingency as 50^{th} to 60^{th} percentile of simulated risk distribution. One case project stated that their risk distribution is beta distributed, two other projects are implied to use normal distribution in their calculations.

5.2. Pay-off method application to risk contingency reserve

Setting appropriate risk contingency reserve in a managerial decision made by alliance. Finding tools to help decision makers is however important to ensure that decisions made are correct to steer alliance towards its goals and creating maximum value for project owner. The most accurate tools however require expensive licensing and expertise in use.

To be able to apply proposed model as intended, the numbers used in actual risk contingency reserve calculations must be used. For some case projects they are found in risk register as their own category and for some they must be determined manually from available data. Research question 2 of this thesis requires us to find conclusions about which risks should be considered in risk reserve calculations. The clear definitions are that risk must be alliances responsibility (C-type risk), risk must be relevant when risk contingency reserve is decided and priced into target cost and risk realizing must have quantifiable value. To achieve this, case projects have been prioritizing cost variable of risk. This may lead to neglect of other impacts of risks because time is limited in design phase of projects.

All case projects rely on Monte Carlo -simulation model to guide the decision on risk contingency reserve. Case projects are however large-scale alliances that can afford the cost of such systems. Applying Pay-off method risk contingency reserve calculation aims to simplify the process by creating a fuzzy risk distribution from total values of risks considered in contingency reserve calculation. This means including all possible risk scenarios in distribution along with most likely one. To compare model based on pay-off method, results are compared to normally distributed Monte Carlo simulation model and Beta-distributed Monte Carlo simulation model. Each simulation has 10 000 runs to ensure reliability of results. The 60th percentile of simulation results are the value used as calculated risk reserve that will be compared to POSROV of Pay-off method.

Table 9 presents the results of Case project one for each three methods used. Case one has more opportunities in its risk register when compared to other case projects. This creates an interesting situation where the distance from minimum to most likely value is almost as large as distance from maximum value to most likely value.

Table 9: Case 1 comparison of methods

Method	Minimum	Maximum	Average	Median	Calculated Risk reserve
Normal distributed MC	-13,329M€	41,967M€	12,613M€	12,598M€	14,368M€
Beta distributed MC	0,583M€	22,772M€	10,903M€	10,894M€	11,680M€
Pay-Off Method	-30,549M€	57,371M€	11,934M€	8,979M€	13,497M€

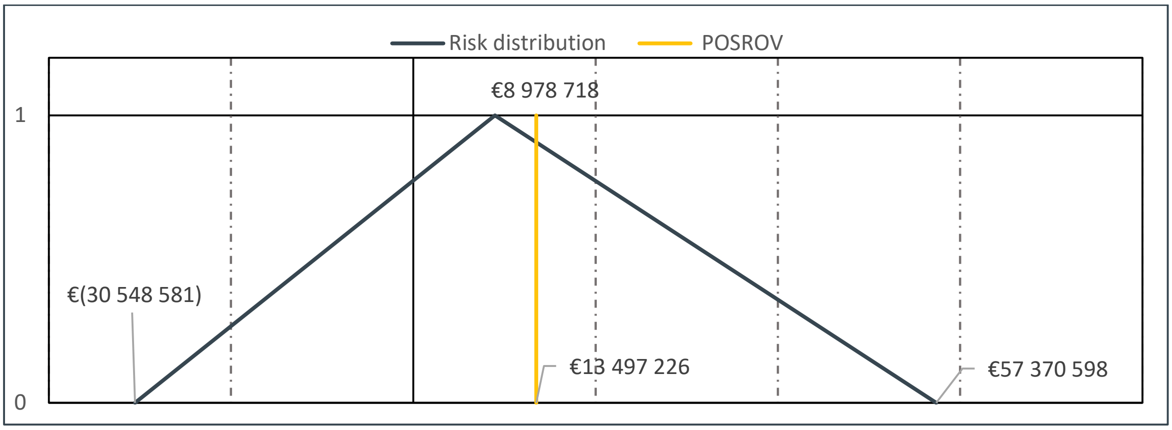

Figure 9: Risk distribution and POSROV of Case 1

Case 1 (Table 9) shows that even if the range of values from simulation is different from the possibilistic range used in pay-off method, all three methods arrive at similar values for middle values and calculated risk reserve value. As expected, beta distributed model's range of values stay closer to middle value. Normal distributed MC method gives the largest risk reserve value of three methods. When comparing to actual risk reserve of 11M€, one can see that normally distributed simulation and Pay-off method results get bit higher than projects risk reserve. However, Case 1 the largest difference between minimum and maximum scenarios of all three projects and larger difference is expected.

Table 10: Case 2 comparison of methods

Method	Minimum	Maximum	Average	Median	Calculated Risk reserve
Normal distributed MC	0,819M€	17,452M€	9,389M€	9,374M€	9,995M€
Beta distributed MC	4,687M€	11,603M€	7,821M€	7,794M€	8,044M€
Pay-Off Method	-5,335M€	25,796M€	8,947M€	6,379M€	7,847M€

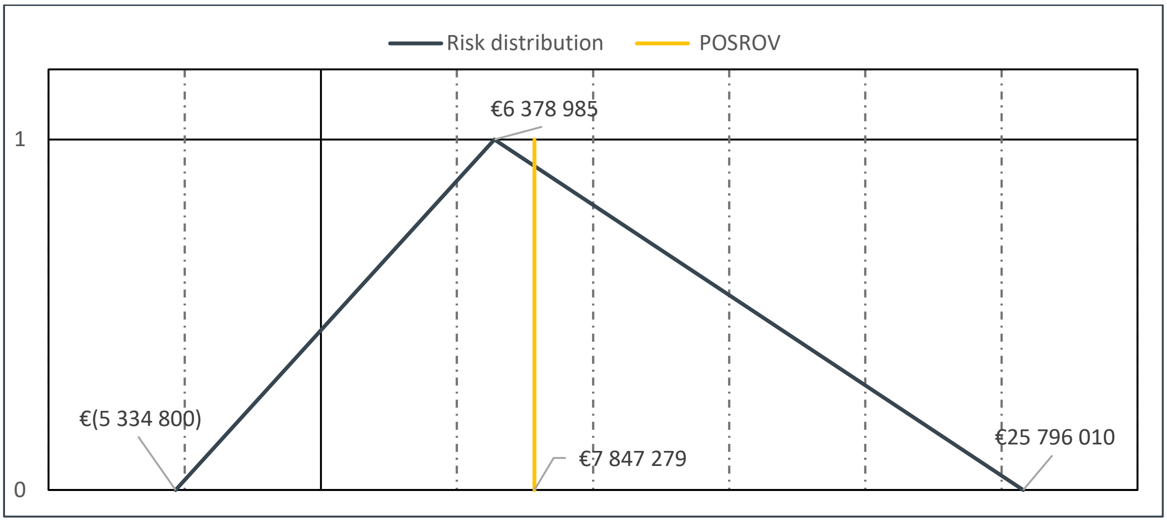

Figure 10: Risk distribution and POSROV of Case 2

Risk distribution of Case 2 (Table 10) is more conventional than in Case 1. There are less opportunities in risk register, which shifts the distribution to the right towards the maximum. Same kind of behavior can be seen from the numbers between methods. POSROV is like simulated 60th percentiles. As in Case 1, Normal distributed MC -method gives the largest risk reserve value, but contrary to other two cases Pay-off method gives slightly lower result than beta-distributed MC. Beta-distributed simulation and Pay-off method compare well to case project's actual risk reserve value of 7,7M€.

Table 11: Case 3 comparison of methods

Method	Minimum	Maximum	Average	Median	Calculated Risk reserve
Normal distributed MC	1,479M€	8,021M€	4,867M€	4,872M€	5,087M€
Beta distributed MC	3,059M€	5,378M€	3,992M€	3,980M€	4,056M€
Pay-Off Method	-0,030M€	11,372M€	5,122M€	4,025M€	4,573M€

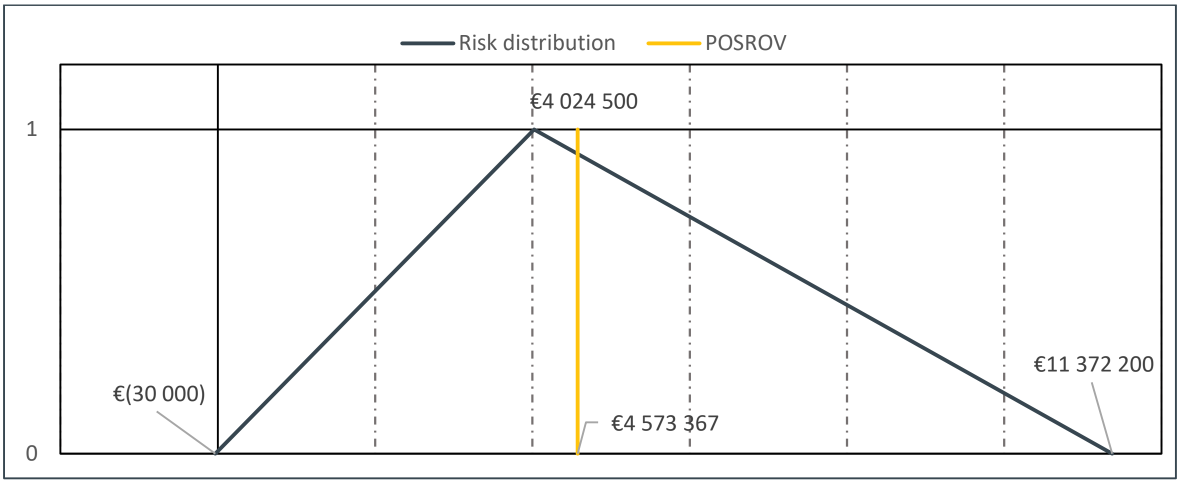

Figure 11: Risk Distribution and POSROV of Case 3

Results for Case 3 (Table 11) follow same pattern as other cases. Risk reserve values for each method are similar with the normally distributed Monte Carlo method giving the largest risk reserve value as result. Pay-off method places risk reserve value between the other methods used. Comparing results to actual risk reserve (Table 8), one can see that results from Pay-off method are comparable to actual risk reserve of the case project.

Results from three cases indicate that using Pay-off method to calculate risk reserve it is possible to arrive to equivalent results as using Monte Carlo simulation methods. In two out of three cases POSROV of Pay-off method is between the 60th percentiles of simulation methods. It also shows that no changes to how risks valuations are documented in risk register are necessary to use Pay-off method in risk contingency reserve calculations. When compared to actual risk reserves (Table 8), one can see that results from pay-off method are still valid and can be used as a basis for decision making.

Results show that case projects are similar in their risk management. This can be expected since each project is a tram infrastructure project. The risk management practices in each case aim to create a clear picture of threats and opportunities regarding project from project management to construction. Risks are categorized to support project management and includes geographical, technical, time-based and impact-based categories.

6. Conclusions

In scope of risk management, setting risk contingency reserve is the final decision on how the project can tolerate risk. In cooperative and integrating implementation models, risk reserve is an important part of the target cost of the project. However, if project does not have simulation software available, setting of risk contingency reserve usually ends up being decision not based on existing information. In this thesis, Pay-off method is applied as a solution in the middle of this spectrum between pure managerial decision and complicated simulation model.

Categorizing risks is a decision for project managers to make. Successful system for risk categorization can consider project managers needs for reporting, monitoring and budgeting. This includes information about time, place, nature and severity of impact and responsibility of risk. Research question 1 was "How to categorize risks in project alliancing??" Question is approached from literature and interviews. Finding a unilateral solution to this question would require further research in wider industry scope. What is clear though, is that standardizing practices are needed to further develop the lean culture in construction industry. Standard solution should consider multiple dimensions of project. One of the main topics for development in this area is creating phases inside implementation phase of the project to better manage risks. For example, when building is 50% ready, how much of the total risk considering the construction can be considered closed by either individual risks realizing or risks being impossible to realize since work related to risk is done. Challenge is to create a template for risk categorization that can consider the necessary elements in most collaborative construction projects.

The second research question was "What risks should be identified and valuated in risk reserve calculation process?" As in research question 1, interviews and literature were used to discover answers. From results it can be concluded that risk contingency reserve should include the risks that have low impact but high probability. The risks that cannot be managed with active measures or risks whose measures are too expensive to effectively manage. These risks should be valued at level that allows for analysis of total risk level in project and calculation of risk contingency reserve. Minimum, most likely and maximum impact levels are preferable for any project. One must consider the capability of project and the value that risk management gives to project. The best option for each project is dependent on size of the project, risk group and time available to analyze risks. The exact value of risk is hard to predict. Therefore, cost uncertainty and risk management must be documented to create data to steer next projects to better decision making.

To create an alternative solution to simulating uncertainty in risk contingency reserve calculation, Pay-off method was chosen as an alternative method. To facilitate this, research question 3 was formulated as: "How the pay-off method performs in relation to project alliance risk reserve calculation methods?" To get answers, Pay-off method was compared two different simulation models in three different cases. In each case, Pay-off method is consistent with compared methods in calculation of risk contingency reserve. The value for risk reserve when Pay-off method is used is between the values calculated from normally distributed and beta distributed values. Normally distributed value is the largest one in two of the three cases presented. Values from Pay-off method compare well with actual risk reserves that projects had decided on. In this thesis the fully possibilistic variant by Stoklasa et al. (2021) was used and possibilistic real option value (POSROV) was used as the value for risk contingency reserve. There is a scope for different methods for calculating middle value for the possibilistic risk distribution and that topic would deserve its own research. For example, using possibilistic mean as the value for risk reserve.

Main findings of this thesis are that the method for calculating risk reserve and considering uncertainty in the estimates is not the most important aspect of risk reserve calculation. Number of methods are suitable, and they have their own strengths. For any method to give reliable results, the entire process from identifying the risk to their final value estimates and choosing whether they are included in risk reserve or managed in other ways must be in order. Especially the analysis of probability and impact of the risks is important to determine the actions needed to manage the risks in question are important. Equally important is to decide who owns the risk. Only alliance's risks can be included in alliance's risk reserve.

The advantages of using Pay-off method compared to simulation are its speed of computation, it is easily understandable, and results are easy to present visually. Also, the fact no need for any additional software other than Microsoft Excel or Google Sheets is needed, speaks for using Pay-off method. Finding the right risk contingency reserve for a project is a process that requires dealing with considerable amounts of uncertainty and usually relies on expert opinion. Assuming that value of the risk is distributed in certain way is a big assumption especially when considering that values are expert estimates. Results show that difference between chosen distributions can be significant in Monte Carlo simulations. Being able to choose not to assume beta or normal distribution for the risk is a degree of freedom in the process that using pay-off method can provide. Possibilistic setting of fuzzy pay-off method is designed to tackle these issues of subjectivity.

Categorizing and valuing risks are important parts of monitoring risks through all phases of alliance. Finding owners, place, time, nature of impact or any other attribute of risk creates clearer picture of individual risk. When risks are analyzed as a group, more insight can be found, and risky parts of project can be identified or verified and actions to manage risk can planned. Importance of documenting information in a structured manner in risk register will be even more important in the future when status monitoring and status dashboards become more common tool in risk and project management. Together with other information management practices constriction industry can deliver more value through increased productivity in future projects. (KPMG, 2021)

Main contribution of this thesis is showing that using Fuzzy pay-off method to calculate alliance's risk contingency reserve is an option that provides similar results to actual risk reserves that were used in case projects. Being able to use actual data that is not available publicly from three different albeit similar projects is contributing to advances in finding use cases for Fuzzy pay-off method. Fuzzy pay-off method being a good option risk contingency calculation, the next step is applying Fuzzy pay-off method in this context to projects varying in size and type of construction. The scope for further research in topics of the thesis is wide. In area of risk management finding solutions to standardize processes and risk registers would be important topic. Secondly studying workable solutions to dealing with unknown unknowns of the project is an important topic.

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