Universitetet i Stavanger

Faculty of Science and Technology

MASTER'S THESIS

Study program/Specialization: Offshore Technologies/Asset Management	Spring semester, 2017 OPEN Open/Restricted Access
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Faculty supervisor: Reidar Brumer Bratvold External supervisor(s):	
Thesis title: Decision Analysis in Contract Type Selection for an Offshore Field Development	
Credits (ECTS): 30	
Keywords: Decision Analysis Contract Types Uncertainty Cost Estimation	Pages: Total: 96 Appendixes: 31 Stavanger, 15 June 2017 Date/year

Acknowledgments

“I dedicate this effort to God for his many blessings, to my beloved wife Carolina for her unconditional love, and my parents Francia and Erwin for their love, hard work and faith”

“I also want to say thanks to the University of Stavanger and my professors for gave me the opportunity to have a world class education and share their knowledge without hesitation”

Abstract

Different contract types means different incentives, burdens and relationships. The contract type responsibilities and price should be in accordance with the project needs and organization capacities, not knowing this could entail less project profitability and chances of success. It is necessary to understand the alternatives and how they behave, in order to develop the right strategies to avoid overruns and improve the project quality. The goal of this thesis is to develop a decision analysis model for contract type selection. This model will become a useful tool for contractor and client preferences in an easy and effective way.

In the literature, there are plenty of documents that describe the characteristics of the contract types but very few about how to select them. Decision analysis is a powerful tool that will help us to bring clarity of thought in this process; during this thesis it is described what is a project, its phases, activities and the components that comprise it, in the same way it is presented the contract management life cycle, where this thesis fits in and which type of contract types will be analyzed based on the FAR-16 (Federal Acquisition Regulation Part-16).

In the decision analysis sections, the methodology of the process will be shown and the decision model will be developed. This model attempts to link and assess the contract types alternatives differentiators and the client and contractor preferences in order to quantify the costs and benefits of each type, also which could be the best option. One priority of this thesis is to understand the synergetic relationship between contract type, contract management, project management and contract price, in order to take the best decision, increasing the probability to achieve a successful project execution.

As application example, a contract type selection for the EPCI (Engineering, Procurement, Construction & Installation) of a topside for a semisubmersible platform is presented. Here, we will measure and assess the characteristics of the contract types using the information contain in a topside cost estimation exercise. The @Risk software will be use to model the cost components and estimate the different prices for each contract type. Useful information to achieve a high-quality decision will be shown, and the reader may be the final decision maker about which contract type is the best one.

There has not been found specific information about this subject (decision analysis in contract type selection),the statements presented, evaluation criteria, and data contained are theoretical. Furthermore, all feedback will be welcome and helpful to improve and validate the model across the time.

Please send any comments to: felipe_medinasw@yahoo.com

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Glossary

Administrative burden	Costs imposed on businesses, when complying with information obligations arising from regulations to provide information and data [1].
Contract	An agreement between two or more parties –with the capacity to reach an understanding-, especially one that is written and enforceable by law (no immoral or criminal purposes or contrary to public policy). Only the terms expressed in the contract can be enforced; secret intentions are not recognized. [2]
Contract management	The process of managing, contracts, deliverables, deadlines, and contract terms and conditions while ensuring customer satisfaction. [2]
Contract type	Specific pricing arrangements or contracting methods used to structure the contract, that determine which cost and/or performance risks is allocated between the parties. [2]
Contract financing	A way to obtain the funds necessary for performing the contract, including payments methods, loan guarantees, advanced payments, progress payments, and contract funding. [2]
Decision	A conscious, irrevocable allocation of resources to achieve desired objectives. [3]
Good decision	An action we take that is logically consistent with our objectives and preferences, alternative perceived, and information available. [3]
Market research	Process used for collecting and analyzing information about the entire market available to satisfy the minimum agency needs to arrive at the most suitable approach to acquiring, distributing, and supporting supplies and services. [2]
Performance	The accomplishment of a given task measured against pre-set known standards like accuracy, completeness, cost, and others.
Probability	Tool we have, to describe how confident we are about events to occur or not. [3]
Project	An endeavor in which human material and financial resources are organized in a novel way, to undertake a unique scope of work of given specification, within constraints of cost and time, to achieve unitary, beneficial change, through the delivery of quantitative and qualitative objectives. [4]
Project management	The application of knowledge, skills, tools and techniques to project activities to meet the project requirements. [5]
Risk	Uncertainty about and severity of the consequences of an activity with respect to something that humans value. [6]
Uncertainty	Lack of perfect knowledge.

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1. Introduction

On any project, it is necessary to define what to do by ourselves and what to buy. The selection of the right contract type can minimize the probability of failure of a project, as well as the wrong one could lead to impose extra hurdles. The client and contractor parties need to be aware of the upside and downside of every contract type, analyze its components, and decide which one will bring more benefits to them.

The traditional contract type selection methodology, emphasizes on the different characteristics of the contracts in a binary way, using terms like low/high cost uncertainty, low/high engineering level of definition and others, as it is studied by Peeters [7]. This approach not only ignores the preferences of the decision maker, but also impede the possibility to asses in a wider and more precise way the cost and benefits of each contract type.

It is a common mistake to judge decisions by the outcome, having a bad result does not means to have done a bad choice, or vice versa, the decision should be based on the preferences, alternatives and information at the time of the decision. It is not optimum to frame our decisions under specific rules, without assessing and being conscious about all the impacts that every alternative carries. All the options have aspects that could be considered as positive or negative, and it is the decision maker responsibility to be fully aware of them and how important they are, in order to maximize the chances of getting what he wants.

The contract price should not be the sole decision criterion, there are many other factors that affect a successful project execution, specially the management responsibilities. The client and contractor relationship is determined by the type of contract chosen. During the development of this thesis we will establish the link between project management, contract types and decision analysis, and will establish a decision model, consistent with the FAR-16 [8] theory, that allows us to assess the different decision drivers from the client and the contractor point of view.

The structure of this thesis intends to expose the intimate relationship between the project activities, the contract type strategy, and how the decision analysis methodology can add value to the selection of the right contract type.

Chapter-2: Project management – how is the project lifecycle and how is the contract price established.
Chapter-3: Contract management – the different contract types that will be use as alternatives in the decision model and their characteristics.
Chapter-4: Decision analysis – how is a decision analysis model and how is the process to select the best choice
Chapter-5: Decision model for contract type selection – alternatives, decision criteria and measurement options to assess the cost and benefits of each contract type from the contractor and client point of view
Chapter-6: Application of decision model – understand the way how the model can be applied in order to achieve a high-quality decision.

2. Theory

2.1. Project Management

The project management life cycle -Figure *1*- could be defined as one of the main tools in contract management, given that provides to the client with a very thorough methodology able to address uncertainties related to the work to be achieve during the contract execution, especially the ones related to:

- Scope uncertainty (main delivery packages)
- Process to achieve scope (resources and sequence of activities)
- Cost associated to process execution
- Main sources of deviations (contingencies and escalation)

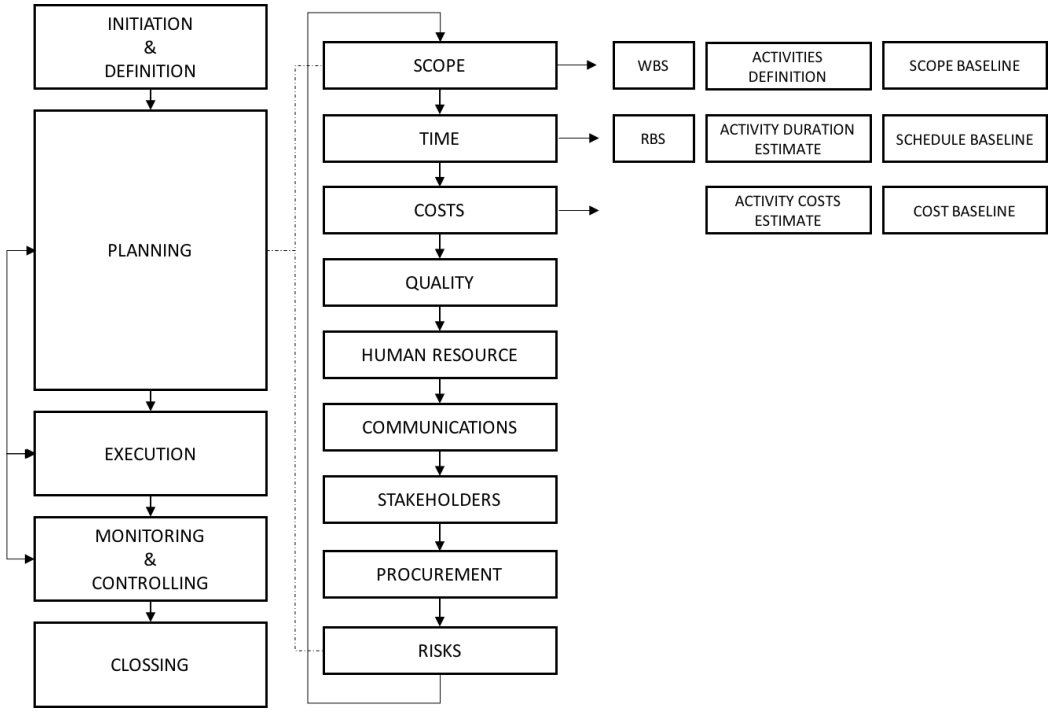


Figure 1- Project Management Life Cycle

The sensibility of our project to the 4 fields mentioned will drive in a major way our contract type selection process. In order to achieve and understand what constitutes fair risk sharing location and the associated contract price. The insight, knowledge and requirements level of definition of the work to execute (Statement of Work –SOW) is an iterative process aimed to reduce the uncertainties around the project and avoid cost-overruns. According to Zaheer & Fallows [9] one of the likely causes of cost over-runs is poor project definition at the sanction (AFE) stage, recommending to conduct a thorough Front End Planning (FEP) as this drives cost and schedule predictability. The ranges of cost estimate accuracy and engineering level of definition (costs classes) for engineering, procurement and construction used by the AACE [10] can be represented by the Figure *2*, as well as the behavior of the cost estimate according to the class [11] :

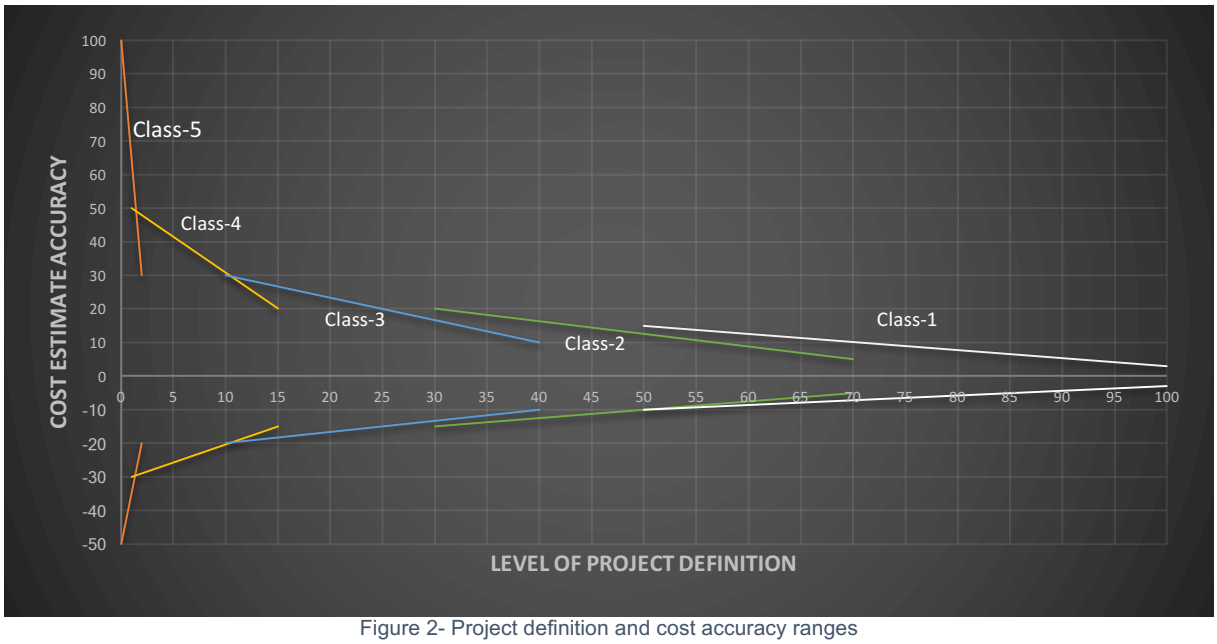


Figure 2- Project definition and cost accuracy ranges

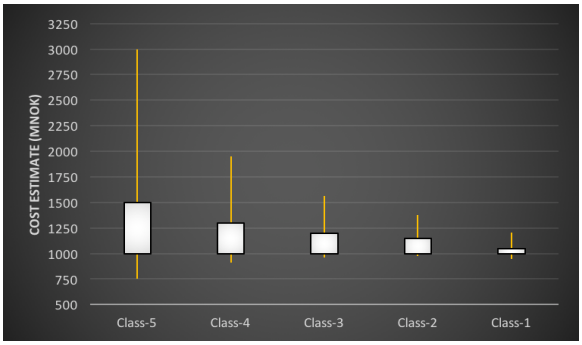
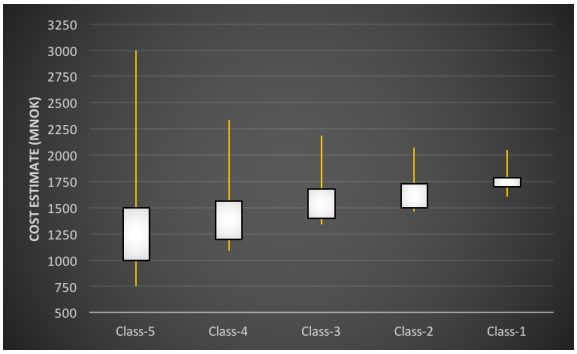
Perfect Cost Estimation	Successful Cost Estimation
	

Figure 3- Cost Estimation and Cost Classes

In the Table *1* we can see a map of the common basic deliverables and maturity of estimate deliverables against the estimate classification levels. The maturity level corresponds to the degree of completion of the deliverables (blank= not begun, s=started, p=preliminary, c=complete) [10]. Special attention has been placed to the Process Equipment List, given that is the main weight and cost estimation driver for an offshore facility.

	ESTIMATE CLASSIFICATION				
General Project Data:	**CLASS 5**	**CLASS 4**	**CLASS 3**	**CLASS 2**	**CLASS 1**
Project Scope Description	General	Preliminary	Defined	Defined	Defined
Plant Production/ Facility Capacity	Assumed	Preliminary	Defined	Defined	Defined
Plant Location	General	Approximate	Specific	Specific	Specific
Soils & Hydrology	None	Preliminary	Defined	Defined	Defined
Integrated Project Plan	None	Preliminary	Defined	Defined	Defined
Project Master Schedule	None	Preliminary	Defined	Defined	Defined
Escalation Strategy	None	Preliminary	Defined	Defined	Defined
Work Breakdown Structure	None	Preliminary	Defined	Defined	Defined
Project Code of Accounts	None	Preliminary	Defined	Defined	Defined
Contracting Strategy	Assumed	Assumed	Preliminary	Defined	Defined
Engineering Deliverables:					
Block Flow Diagrams	S/P	P/C	C	C	C
Plot Plans		S	P/C	C	C
Process Flows Diagrams (PFDs)		S/P	P/C	C	C
Utility Flow Diagrams (UFDs)		S/P	P/C	C	C
Piping & Instrumentation Diagrams (P&IDs)		S	P/C	C	C
Heat & Materials Balances		S	P/C	C	C

Process Equipment List		S/P	P/C	C	C
Utility Equipment List		S/P	P/C	C	C
Electrical On-line Drawings		S/P	P/C	C	C
Specifications & Datasheets		S	P/C	C	C
General Equipment Arrangements Drawings		S	P/C	C	C
Spare Parts Listing			S/P	P	C
Mechanical Discipline Drawings			S	P	P/C
Electrical Discipline Drawings			S	P	P/C
Instrument/Control System Discipline Drawings			S	P	P/C
Civil/Structural/Site Discipline Drawings			S	P	P/C

Table 1- Costs estimates classification & typical activities for the process industries

An offshore field development project is a big endeavour where the short-term (front-end) investments (wells, piping, production facilities, pipelines) become profitable through the long-term production of hydrocarbons. The decision to execute or not a field development project depends on a large series of stages and combination of uncertainties about the expected hydrocarbon production capacity of the field, the expected total cost of the development and the expected cost-benefit in relation with the policies of the company. These phases can be appreciated in the Figure *4*.

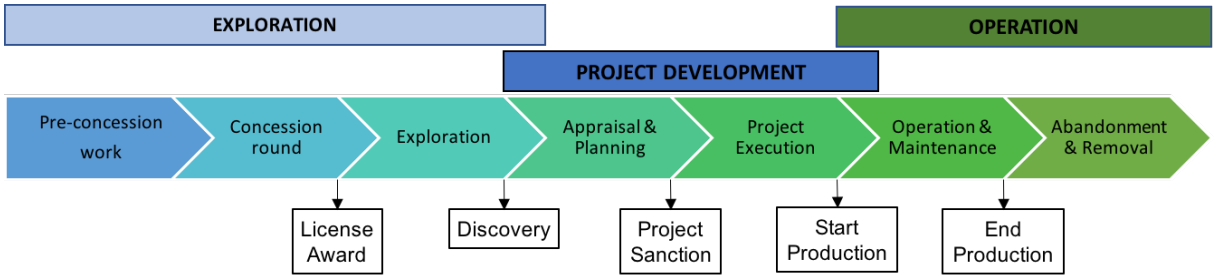


Figure 4- Offshore Field Development Phases *[12]*

From the moment that a hydrocarbon reservoir has been discovered to the project sanction (permission to execute project) and start of production there are many steps and decision gates that must to be achieved in order to maximize the likelihood of a successful project and a profitable hydrocarbon production. Figure *5*.

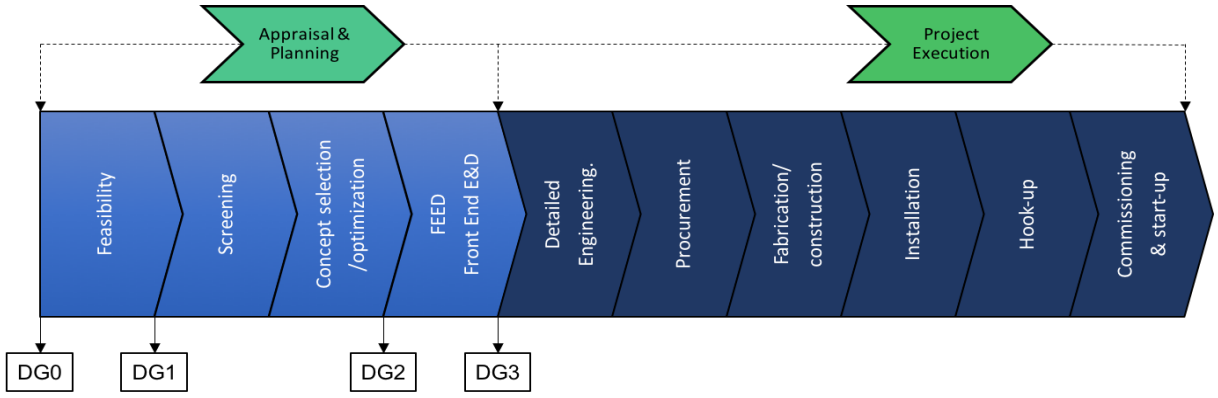


Figure 5- Planning and Execution Phases Steps *[12]*

During the appraisal & planning phase since a discovery is made until the final investment decision, the project will have to approve the following decision gates[1]:

- DG0- Feasibility phase: demonstrate the technical and commercial feasibility of the development.
- DG1- Screening phase: establish a short-list of promising field development concepts.
- DG2- Concept development and selection phase: the best cost-benefit concept development is chosen according to the predefined concept selection criteria.
- DG3- Definition phase (FEED phase): develop, optimize and describe the selected concept in more detail, preparing the plans for project execution and documents needed as basis for the final investment decision (project sanction). Two of the main documents for project sanction in Norway are the plan for development

[1] is a standardized control point where the projects phase is reviewed and/or audited and approved (or not) to continue with the next phase. The gates allow to verify if the project reaches the expected performance; the gate control allows the organization to validate whether the planning is good enough to face the next phase [11].

and operation of a petroleum deposit (PDO) and the plan for installation and operation of facilities for transport and utilisation of petroleum (PIO) [13].

The Figure *6* illustrate the concept of decision gates and project evolution.

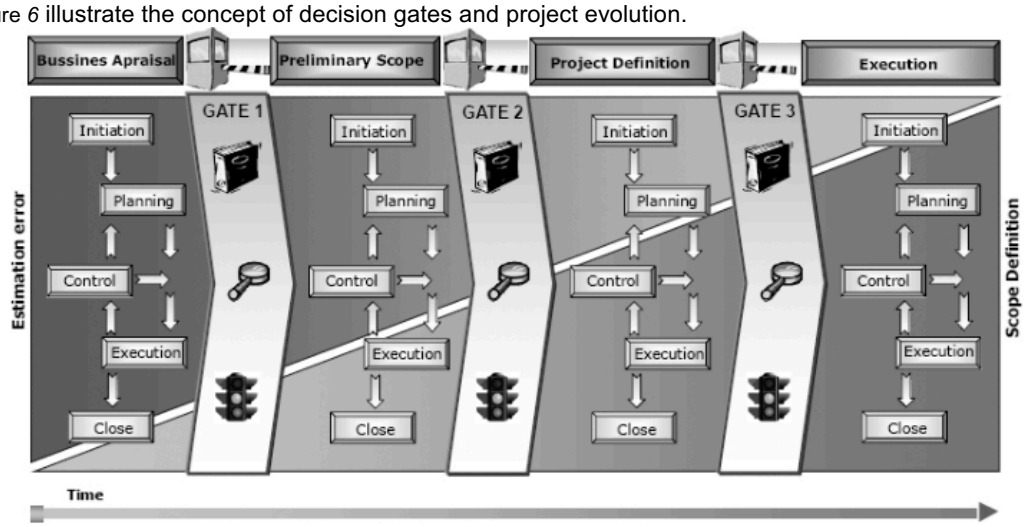


Figure 6- Decision gates and project evolution *[14]*

According to AACE [10], this process and the class estimates described before can be appreciated for the Norwegian case in the Figure *5*.

	AACE Classification Standard	AACE Engineering Definition Level	AACEI Suggested Contingency	Typical Purpose	Expected Cost Accuracy Range	Norwegian Project Management Association (NFP)	Major Oil Company (Confidential)
INCREASING PROJECT DEFINITION	Class 5	0% to 2%	50%	Concept Screening	L: -20% to -50% H: +30% to +100%	Concession Estimate	Class A Prospect Estimate
						Exploration Estimate	Class B Evaluation Estimate
						Feasibility Estimate	
	Class 4	1% to 15%	30%	Study or Feasibility	L: -15% to -30% H: +20% to +50%	Authorization Estimate	Class C Feasibility Estimate
							Class D Development Estimate
	Class 3	10% to 40%	20%	Budget authorization Or Control	L: -10% to -20% H: +10% to +30%	Master Control Estimate	Class E Preliminary Estimate
	Class 2	30% to 70%	15%	Control or Bid/Tender	L: -5% to -15% H: +5% to +20%	Current Control Estimate	Class F Master Control Estimate
	Class 1	50% to 100%	5%	Check Estimate or Bid/Tender	L: -3% to -10% H: +3% to +15%		Current Control Estimate

Figure 7- Cost estimates & contingencies classification

Finally and based on the PMBOK [5], we understand that the extent and number of uncertainties covered by the contractor during the project execution will be directly related to the contract price -*Figure 8* and *Figure 9*-

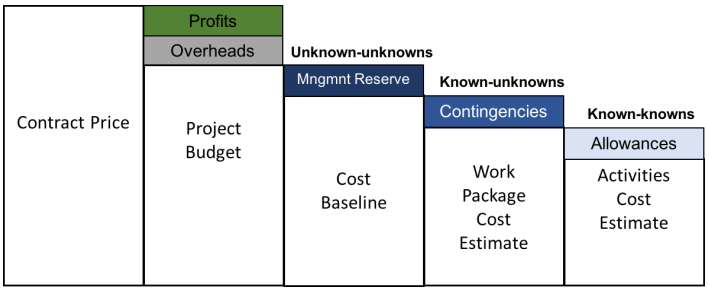


Figure 8- Contract price, full risk assumption by contractor

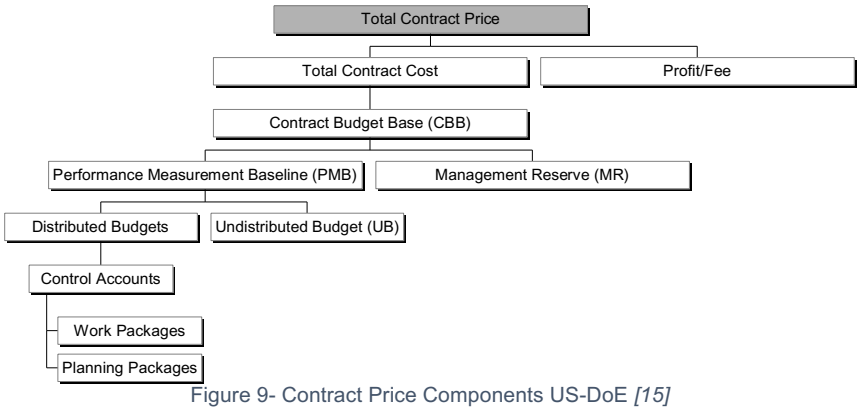


Figure 9- Contract Price Components US-DoE *[15]*

The final contract price will be established through the interaction between a risk-avoiding buyer tending to an optimistic cost estimation, and a risk-avoiding seller pushing for a pessimistic cost estimation that allows him to minimize the risk of agreeing to a price that may not cover its actual performance costs or allow a reasonable profit [16].

2.2. Contract Management

Contract management is the process of managing contracts, deliverables, deadlines, and contract terms and conditions while ensuring customer satisfaction [2]. This process has three major areas and some sub-components are showed in the Figure *10*, and can be defined as:

- Pre-award: areas that impact contract management during the entire contract management life cycle and influence decision making.
- Acquisition Planning & Strategy: all the activities and events required to prepare for, negotiate, and form a contract.
- Post-award: the processes that provide the oversight required to that both parties follow the contract requirements. The range and extent of the contract administration activities required will vary greatly, specially depending on the type of contract and complexity of the requirements.

Figure 10- Contract Management Phases CMBOK Based

During this thesis, we will focus on the contract type selection and processes that are related to it. Processes like contract interpretation & disputes, socioeconomic programs, laws & regulations, contract financing, source selection, and other criteria will not be explored, because although are important components that impact a successful contract, do not create differentiation between the contract types for the decision analysis process.

2.2.1. Contract Types

The classification and posterior description of the selected contract type for the decision analysis, will be based on the Federal Acquisition Regulation defined by the U.S Department of Defense [8], given the extent of information related to the contract type defined in it and it's widely use. The contract types define in [8] are -Figure *11*-:

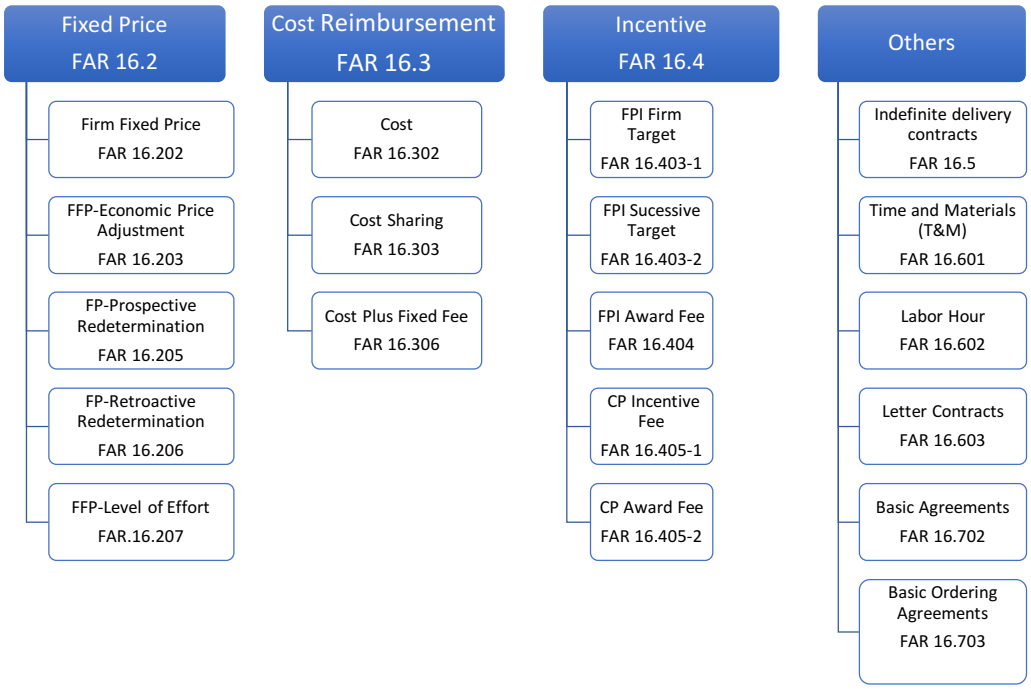


Figure 11- Contract Types and FAR References

Not all the contract types showed above will be used as alternatives for the decision model, a selection has been made according to:

- Amount of available literature and studies.
- Feasibility to incentivize the triple constraint (cost, time, quality).
- Feasibility to measure cost-benefit analysis between the different contract types.

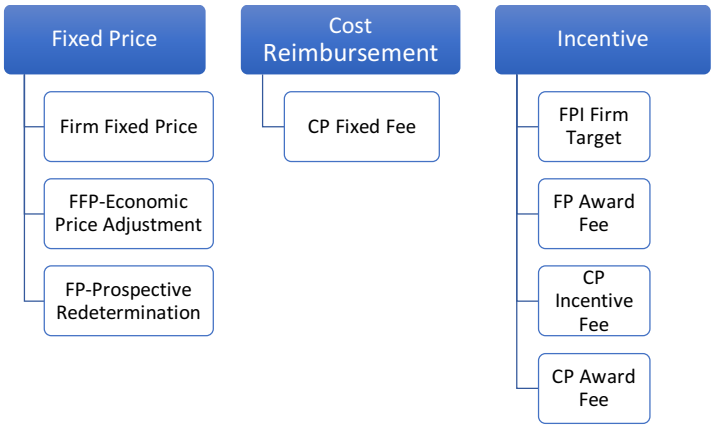


Figure 12- Contract Types Selected for Decision Analysis

It is important to state that it is considered by the author of this thesis that with these alternatives (contract types), it is created the widest range of characteristics and differentiation in the contract type selection process.

Fixed Price Contracts

Under a fixed-price contract, the contractor agrees to deliver the product or service required at a price not in excess of the agreed-to maximum. Fixed-price contracts should be used when the contract risk is relatively low, or defined within acceptable limits, and the contractor and the buyer can reasonably agree on a maximum price. [17]

2.2.1.1. Firm Fixed Price (FFP)

FAR-16.202 [18]

Firm-fixed-price contracts require a price that is not subject to any adjustment based on the contractor's actual cost to perform the contract. The level of risk assumed by the contractor is often reflected in the contract price. [2]

The typical application is well-defined programs with predictable cost and low implementations risks like commercial supplies and services, generally not appropriate for R&D. [17]

Usually this kind of contract shows the following characteristics:

Variable	Score	Risk	Measure	Score
Scope uncertainty	Low	Scope changes during contract execution and contract breach or renegotiation.	Requirements level of specifications	High
Process uncertainty	Low	Low and/or inadequate performance, schedule slippage.	Level of knowledge (know-how) and experience meeting requirements.	High
Cost uncertainty	Low	Contract price/costs estimation accuracy.	Assumptions, information and estimation methods about costs drivers in activities.	High
Market uncertainty	Low	Costs escalation.	Price/cost stability of main cost drivers during project execution	High
Administrative burden		Penalties or not effort recognition for not accomplishment with information obligations from regulations imposed by the client.	Procedures, activities and cost linked to information that businesses would not collect and provide in absence of legal obligation.	Low
Accounting system requirements		Not approval and payment of expenses.	Capacity of accounting system for price analysis, accountability, detailed specification and traceability of contract prices/costs.	Low
Contract flexibility		Scope Creep[2]	Capacity to introduce changes in the scope that don´t require different performance without affect contract price.	Low
Performance beyond requirements reward			Incentives payment to contractor for performance beyond requirements stated in the contract.	None
Costs & efficiency management			Contractor's profit sensitivity to costs and efficiency deviations (work package cost estimate). Full.	High
Risks management			Contractor's profit sensitivity to risks events occurrences (contingencies, management reserve) Full.	High

Table 2- FFP Characteristics & Risks

This contract type places the major monitoring and controlling responsibility on the contractor's side, the client basic responsibility is to accept or to reject the performance result delivered by the contractor.

The contractor vs client price assumption distribution could be represented like:

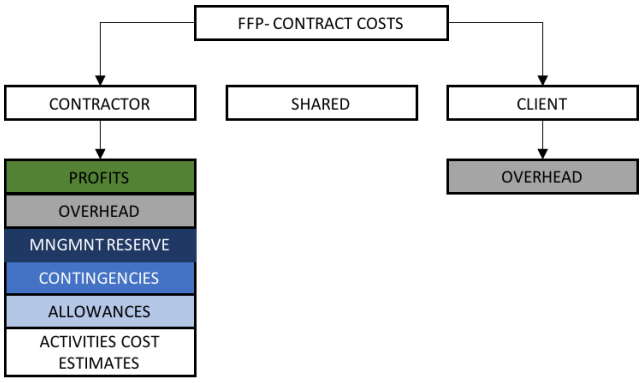


Figure 13- FFP Price components assumption

In a very overall way and according to the information showed above we could define the following equations:

[2] The uncontrolled expansion to product or scope project scope without adjustments to time, cost, and resources.

Client Pricing Formula	Contractor's Profits Formula	Elements
CP = FFP	cP = FFP – C	FFP = Firm Fixed Price at the contract C = Final costs of contract execution

Table 3- FFP overall price and profits equations

We can appreciate the behaviour of this formula in the next figure:

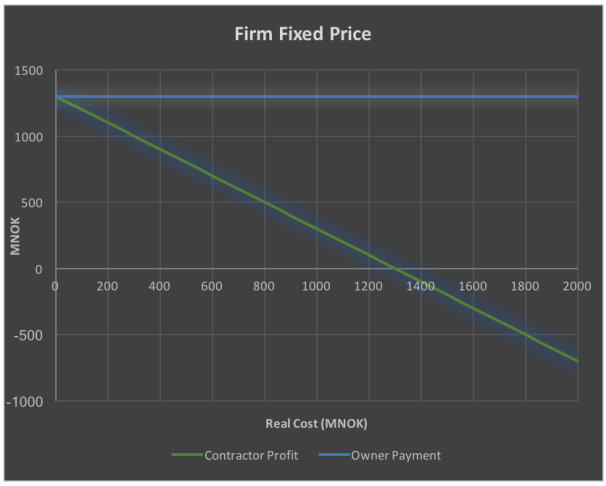


Figure 14- FFP Payment and Profit vs Cost

2.2.1.2. Firm Fixed Price Economic Price Adjustment (FFP-EPA)

FAR-16.203 [18]

FFP-EPA contracts require a price that could be subject to price adjustment based on occurrence of specified contingencies in the contract (significant fluctuations in labour, material costs or others).

This contract type is aimed to manage the contingencies occurrences during contract performance in unstable markets. The level of risk assumed by the contractor is minor than a FFP contract type and it should be reflected in the contract price.

The typical application is well defined programs with predictable effort but with uncertain stability of market and labour conditions like long-term contracts for commercial supplies and services during a period of high inflation. [17].

Usually this kind of contract shows the following characteristics:

Variable	Score	Risk	Measure	Score
Scope uncertainty	Low	Scope changes during contract execution and contract breach or renegotiation.	Requirements level of specifications	High
Process uncertainty	Low	Low and/or inadequate performance, schedule slippage.	Level of knowledge (know-how) and experience meeting requirements.	High
Cost uncertainty	Low	Contract price/costs estimation accuracy.	Assumptions, information and estimation methods about costs drivers in activities.	High
Market uncertainty	High	Costs escalation.	Price/cost stability of main cost drivers during project execution	Low
Administrative burden		Penalties or not effort recognition for not accomplishment with information obligations from regulations imposed by the client.	Procedures, activities and cost linked to information that businesses would not collect and provide in absence of legal obligation.	Low
Accounting system requirements		Not approval and payment of expenses.	Capacity of accounting system for price analysis, accountability, detailed specification and traceability of contract prices/costs.	Low
Contract flexibility		Scope Creep[2]	Capacity to introduce changes in the scope that don´t require different performance without affect contract price.	Low

Performance beyond requirements reward			Incentives payment to contractor for performance beyond requirements stated in the contract.	None
Costs & efficiency management			Contractor's profit sensitivity to costs and efficiency deviations (work package cost estimate). Full.	High
Risks management			Contractor's profit sensitivity to risks events occurrences (contingencies, management reserve) - Client.	Low

Table 4- FPEPA Characteristics & Risks

This contract type places the major monitoring and controlling responsibility on the contractor's side, the client basic responsibility is to accept or to reject the performance result delivered by the contractor and price adjustments for contingencies occurrence.

The contractor vs client price assumption distribution could be represented like:

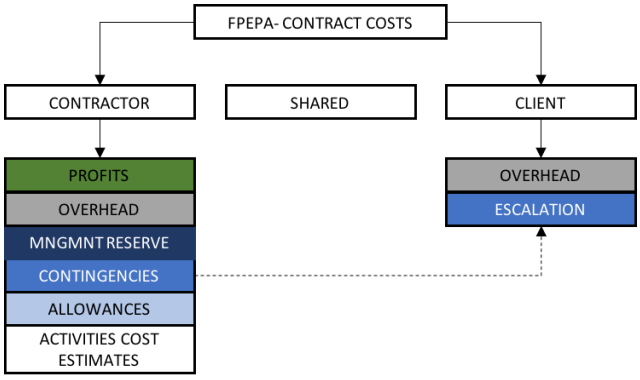


Figure 15- FFPEPA Price components assumption

In a very overall way and according to the information showed above we could define the following equations:

Client Pricing Formula	Contractor's Profits Formula	Elements
CP = FP(1+MbF)	cP = FP(1+MbF) – C	FP = Fixed Price at the contract MbF=Market behaviour factor C = Final costs of contract execution

Table 5- FFPEPA overall price and profits equations

We can appreciate the behaviour of this formula in the next figure:

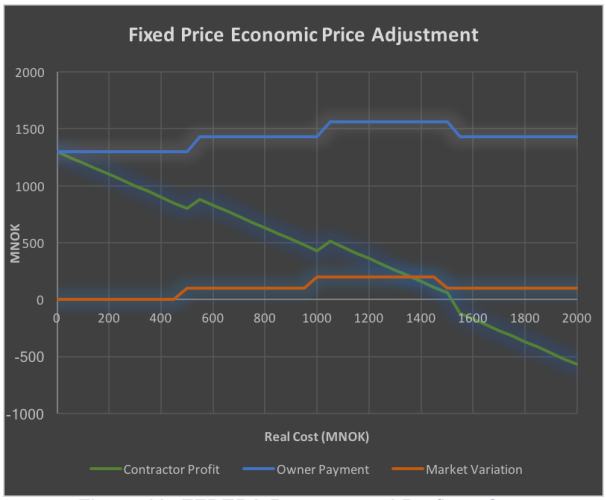


Figure 16- FFPEPA Payment and Profit vs Cost

2.2.1.3. Fixed Price with Prospective Redetermination (FPPR)

FAR-16.205 [18]

FPPR contracts combine a firm-fixed-price for an initial period of deliveries or performance and prospective redeterminations, at a stated time or times during performance, of the price for subsequent periods of performance. The initial period time should be the longest for which it is possible to negotiate a fair and reasonable FFP, each subsequent pricing period should be at least 12 months. The contract may provide for a ceiling price based on evaluation of the uncertainties involved in performance and their market conditions.

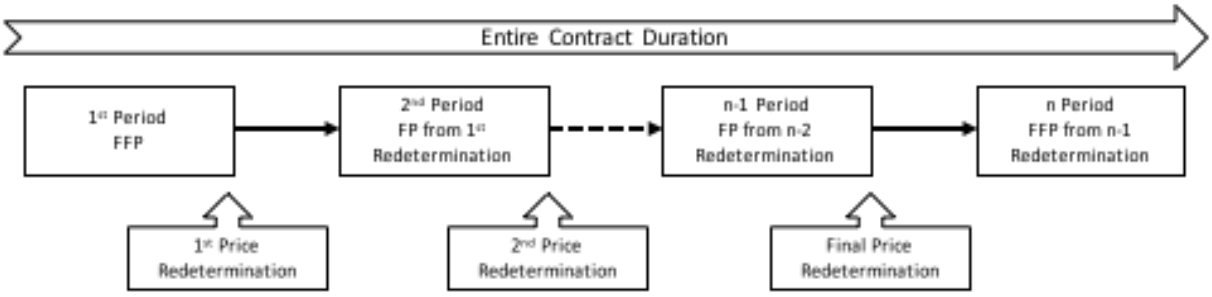


Figure 17- FPPR FP contracts and redeterminations

This contract type is aimed to acquire valuable information and reduce the uncertainties about specifications, cost and performance to be able to negotiate a future FFP, providing protection to client and contractor. The negotiation of re-determined prices applies to all cost factors including profit.

The typical application is long-term production of spare parts for a major system. [17]

Usually this kind of contract shows the following characteristics:

Variable	Score	Risk	Measure	Score
Scope uncertainty	Low	Scope changes during contract execution and contract breach or renegotiation.	Requirements level of specifications	High
Process uncertainty	High	Low and/or inadequate performance, schedule slippage.	Level of knowledge (know-how) and experience meeting requirements.	Low
Cost uncertainty	Medium	Contract price/costs estimation accuracy.	Assumptions, information and estimation methods about costs drivers in activities.	Medium
Market uncertainty	Medium	Costs escalation.	Price/cost stability of main cost drivers during project execution	Medium
Administrative burden		Penalties or not effort recognition for not accomplishment with information obligations from regulations imposed by the client.	Procedures, activities and cost linked to information that businesses would not collect and provide in absence of legal obligation. Objective KPI's.	Medium
Accounting system requirements		Not approval and payment of expenses.	Capacity of accounting system for price analysis, accountability, detailed specification and traceability of contract prices/costs.	Medium
Contract flexibility		Scope Creep[2]	Capacity to introduce changes in the scope that don´t require different performance without affect contract price.	Medium
Performance beyond requirements reward			Incentives payment to contractor for performance beyond requirements stated in the contract. Not related to any performance factor.	None
Costs & efficiency management			Contractor's profit sensitivity to costs and efficiency deviations (work package cost estimate). Full.	High
Risks management			Contractor's profit sensitivity to risks events occurrences (contingencies, management reserve). Full.	High

Table 6- FPPR Characteristics & Risks

The contractor vs client price assumption distribution could be represented like:

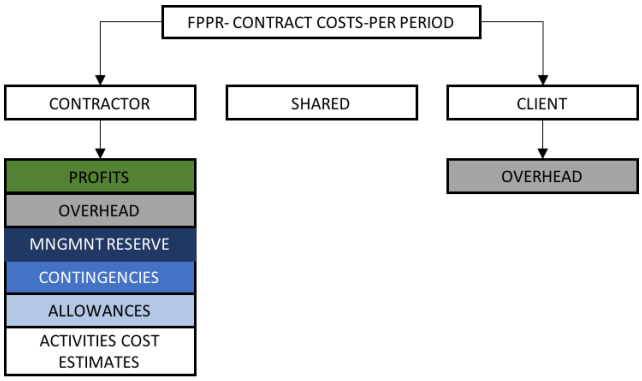


Figure 18- FPPR Price components assumption

In a very overall way and according to the information showed above we could define the following equations for a determined period:

Client Pricing Formula	Contractor's Profits Formula	Elements
CP=(FP*PeF)*(1+MbF)	cP=[(FP*PeF)*(1+MbF)]-C	FP = Fixed Price at the contract MbF=Market behaviour factor PeF=Performance evaluation factor C = Final costs of contract execution

Table 7- FPPR overall price and profits equations

We can appreciate the behaviour of this formula in the next figure:

Figure 19- FPPR Payment and Profit vs Cost
(same market adjustment, different performance +20% and -20%)

2.2.1.4. Fixed Price Incentive Firm Target (FPIF)

FAR-16.403-1 [18]

FPIF contracts the parties agree on possible range of cost of performance and negotiate initially: a reasonable target cost and target profit, a price ceiling, and positive, economic-incentive share formula for establishing final price in accord with relationship which final cost bears to target cost.

Applicable when nature of the supplies or services being acquired and other circumstances of the acquisition are such that the contractor's assumption of a degree of cost responsibility will provide a positive profit incentive for effective cost control and performance.

Typical application in situations where cost information or performance requirements are not sufficiently developed to permit negotiations –development program- of FFP like production of a major system based on a prototype [17].

Usually this kind of contract shows the following characteristics:

Variable	Score	Risk	Measure	Score
Scope uncertainty	High	Scope changes during contract execution and contract breach or renegotiation.	Requirements level of specifications	Low
Process uncertainty	Low	Low and/or inadequate performance, schedule slippage.	Level of knowledge (know-how) and experience meeting requirements.	High
Cost uncertainty	Medium	Contract price/costs estimation accuracy.	Assumptions, information and estimation methods about costs drivers in activities.	Medium
Market uncertainty	Medium	Costs escalation.	Price/cost stability of main cost drivers during project execution	Medium
Administrative burden		Penalties or not effort recognition for not accomplishment with information obligations from regulations imposed by the client.	Procedures, activities and cost linked to information that businesses would not collect and provide in absence of legal obligation. Objective KPI's.	Medium
Accounting system requirements		Not approval and payment of expenses.	Capacity of accounting system for price analysis, accountability, detailed specification and traceability of contract prices/costs.	Medium
Contract flexibility		Scope Creep[2]	Capacity to introduce changes in the scope that don´t require different performance without affect contract price.	Medium
Performance beyond requirements reward			Incentives payment to contractor for performance beyond requirements stated in the contract. Only cost related.	Medium
Costs & efficiency management			Contractor's profit sensitivity to costs and efficiency deviations (work package cost estimate). Shared.	Medium
Risks management			Contractor's profit sensitivity to risks events occurrences (contingencies, management reserve). Shared.	Medium

Table 8- FPPR Characteristics & Risks

The contractor vs client price assumption distribution could be represented like:

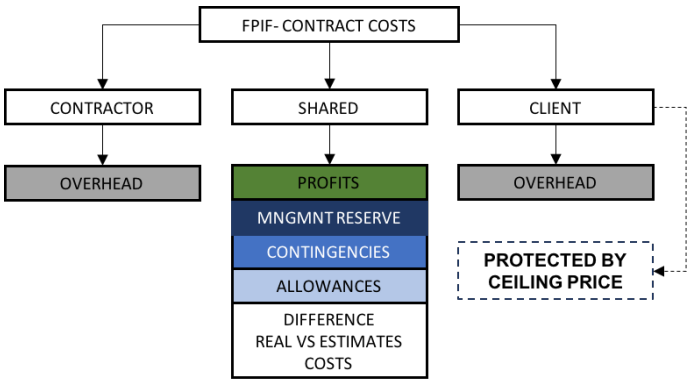


Figure 20- FPIF Price components assumption

In a very overall way and according to the information showed above we could define the following equations for a determined period:

Client Pricing Formula	Contractor's Profits Formula	Elements

If CP>=GMP Then
CP=GMP
If CP<GMP Then
CP=(C+TF)+(TC-C)sF
	If CP>=GMP Then
	cP=GMP-C
	If CP<GMP Then
	cP=TF+(TC-C)sF
		GMP=Guarantee Maximum Price
		C = Final costs of contract execution
		TC = Target Cost of Performance
		TF=Target Fee by contractor
		sF=Sharing percentage by customer

Table 9- FPPR overall price and profits equations

We can appreciate the behaviour of this formula in the next figure:

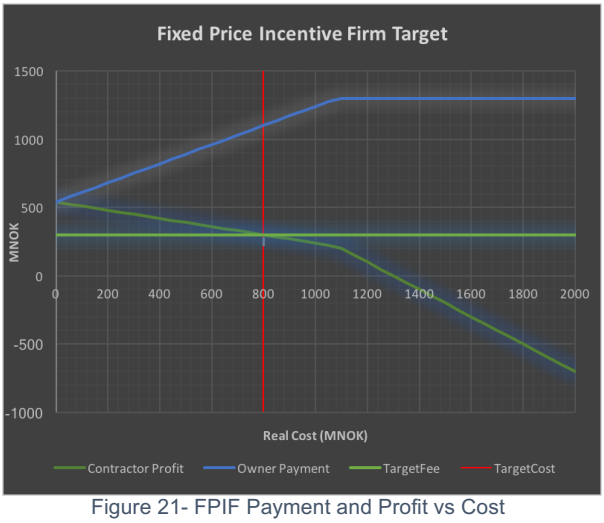


Figure 21- FPIF Payment and Profit vs Cost

2.2.1.5. Fixed Price Award Fee (FPAF)

FAR-16.404 [18]

FPAF contracts is used when it is difficult to include other incentives because seller performance cannot be measured objectively. A fixed-price award fee contract establishes a fixed price and includes profit (or base fee) paid for satisfactory contract performance. It also establishes an award fee that can be earned by the seller in addition to the fixed price based on the results of periodic evaluations of the seller's performance against an award fee plan.

Typical application in performance based contracts [17].

Usually this kind of contract shows the following characteristics:

Variable	Score	Risk	Measure	Score
Scope uncertainty	Low	Scope changes during contract execution and contract breach or renegotiation.	Requirements level of specifications	High
Process uncertainty	Low	Low and/or inadequate performance, schedule slippage.	Level of knowledge (know-how) and experience meeting requirements.	High
Cost uncertainty	Low	Contract price/costs estimation accuracy.	Assumptions, information and estimation methods about costs drivers in activities.	High
Market uncertainty	Low	Costs escalation.	Price/cost stability of main cost drivers during project execution	High
Administrative burden		Penalties or not effort recognition for not accomplishment with information obligations from regulations imposed by the client.	Procedures, activities and cost linked to information that businesses would not collect and provide in absence of legal obligation. Objective + subjective KPI's.	High
Accounting system requirements		Not approval and payment of expenses.	Capacity of accounting system for price analysis, accountability, detailed specification and traceability of contract prices/costs.	High
Contract flexibility		Scope Creep[2]	Capacity to introduce changes in the scope that don´t require different performance without affect contract price.	Low
Performance beyond requirements reward			Incentives payment to contractor for performance beyond requirements stated in the contract. More than cost related.	High
Costs & efficiency management			Contractor's profit sensitivity to costs and efficiency deviations (work package cost estimate). Full.	High
Risks management			Contractor's profit sensitivity to risks events occurrences (contingencies, management reserve). Full.	High

Table 10- FPAW Characteristics & Risks

The contractor vs client price assumption distribution could be represented like:

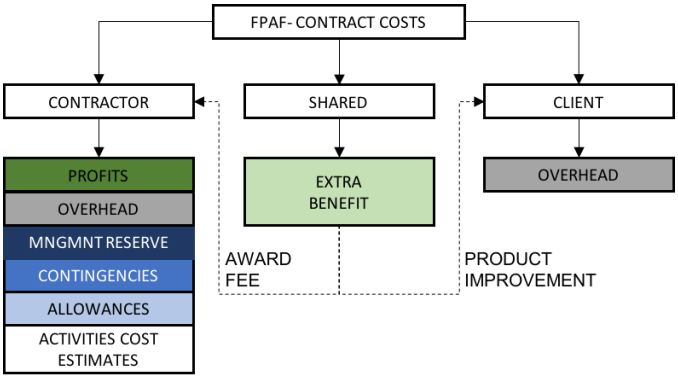


Figure 22- FPAF Price components assumption

In a very overall way and according to the information showed above we could define the following equations for a determined period:

Client Pricing Formula	Contractor's Profits Formula	Elements
CP=FP+AF*PeF	cP=FP-C+AF*PeF	FP="units fixed price" AF=Performance Award Fee PeF=Performance evaluation Factor

Table 11- FPAF overall price and profits equations

We can appreciate the behaviour of this formula in the next figure:

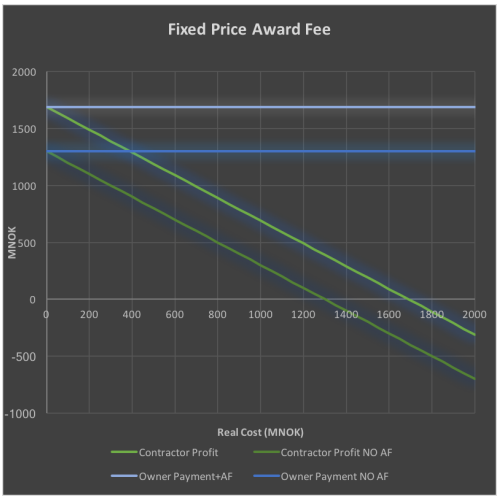


Figure 23- FPAF Payment and Profit vs Cost

Cost Reimbursement

Under all cost reimbursement contract, the contractor agrees to provide its best effort to complete the required contract. The buyer pays allowable[3], allocable[4], and reasonable[5] costs incurred during the performance of a contract to the extent that such costs are prescribed or permitted by the contract. These contracts establish an estimate of total cost to obligate funds and establish a ceiling that the contractor may not exceed (except at its own risk) without the buyer's approval. Use when any fixed price contract is inappropriate.

All the cost reimbursement contract must provide an accounting system capable of determine cost applicability to the contract [19]:

[3] A cost is allowable if are reasonable, allocable. And comply with the policies of the parties in the contract.
[4] A cost is allocable if it is incurred specifically for the contract, benefits both the contract and other work a can be distributed to them in reasonable proportion to the benefits received, or is necessary to the overall operation of the business, although a direct relationship to any particular cost objective cannot be shown.
[5] A cost is reasonable if, in its nature and amount, it does not exceed that which would be incurred by a prudent person in the conduct of competitive business.

- Allow segregation of direct costs from indirect costs
- Identification and accumulation of direct costs by contract
- Implement a logical and consistent method for the allocation of indirect cost to intermediate and final cost objectives
- Monitoring accumulation of costs under general ledger control
- Timekeeping system that identifies employees labour by intermediate or final cost objectives
- Labour distribution system that charges direct and indirect labour to the appropriate cost objectives
- Interim (at least monthly) determination of costs charged to a contract through routine posting of books of account.
- Earned Value Management monitoring and reporting.
- Allow audits to test whether invoiced costs are allowable.

Remember that the objective is not micromanage, the client set the expected results and then evaluates and rewards the contractor as appropriate for achieving the desired results. Communication with contractor personnel about performance should not lead to client direction of efforts in a manner that compromises the contractor's responsibility or ability to manage under the contract.

2.2.1.6. Cost Plus Fixed Fee (CPFF)

FAR-16.301 [18]

CPFF the buyer reimburses the seller for appropriate costs associated with contract performance and pays a fixed fee that is negotiated at the outset. The fixed fee doesn't vary with actual cost, but may be adjusted as a result of changes made in the work performed under the contract.

Typical application is in exploratory or developmental types of programs with uncertain level of effort and cost like in research studies [17], advanced developments, consulting or study programs.

Usually this kind of contract shows the following characteristics:

Variable	Score	Risk	Measure	Score
Scope uncertainty	High	Scope changes during contract execution and contract breach or renegotiation.	Requirements level of specifications	Low
Process uncertainty	High	Low and/or inadequate performance, schedule slippage.	Level of knowledge (know-how) and experience meeting requirements.	Low
Cost uncertainty	High	Contract price/costs estimation accuracy.	Assumptions, information and estimation methods about costs drivers in activities.	Low
Market uncertainty	High	Costs escalation.	Price/cost stability of main cost drivers during project execution	Low
Administrative burden		Penalties or not effort recognition for not accomplishment with information obligations from regulations imposed by the client.	Procedures, activities and cost linked to information that businesses would not collect and provide in absence of legal obligation.	High
Accounting system requirements		Not approval and payment of expenses.	Capacity of accounting system for cost analysis, accountability, detailed specification and traceability of contract prices/costs. (Allowable, allocable, reasonable).	High
Contract flexibility		Scope Creep[2]	Capacity to introduce changes in the scope that don´t require different performance without affect contract price.	High
Performance beyond requirements reward			Incentives payment to contractor for performance beyond requirements stated in the contract. Not related to any performance factor.	None
Costs & efficiency management			Contractor's profit sensitivity to costs and efficiency deviations (work package cost estimate).	None
Risks management			Contractor's profit sensitivity to risks events occurrences (contingencies, management reserve).	None

Table 12- FPAW Characteristics & Risks

The contractor vs client price assumption distribution could be represented like:

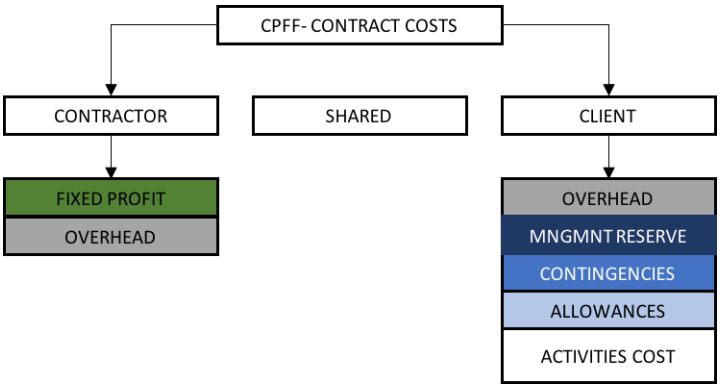


Figure 24- CPFF Price components assumption

In a very overall way and according to the information showed above we could define the following equations for a determined period:

Client Pricing Formula	Contractor's Profits Formula	Elements
CP=(C+FF)	cP=(C+FF)-C cP=FF	C = Final costs of contract execution FF=Performance Fixed Fee

Table 13- CPFF overall price and profits equations

We can appreciate the behaviour of this formula in the next figure:

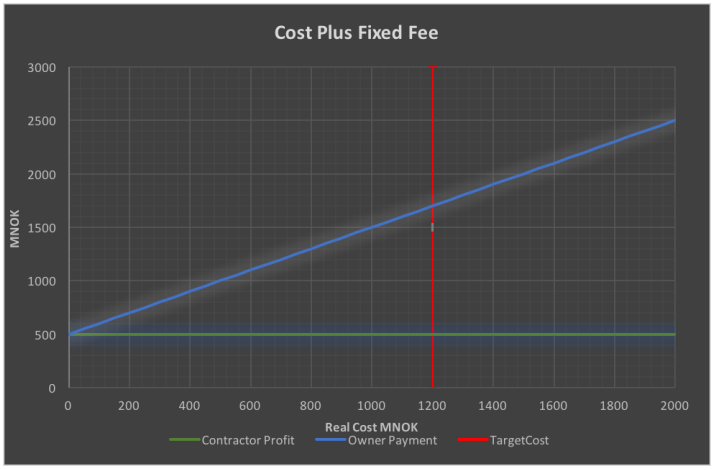


Figure 25- CPFF Payment and Profit vs Cost

2.2.1.1. Cost Plus Incentive Firm Target (CPIF)

FAR-16.405-1 [18]

CPIF contract that provides for an initially negotiated fee to be adjusted later by a formula based on the relationship of total allowable costs to total target costs. This contract type specifies a target cost, a target fee, minimum and maximum fees, and a fee adjustment formula. The cost range between the maximum and minimum earned fee is known as the range of incentive effectiveness.

Typical application is special development and test programs like research and development of the prototype for a major system [17].

Usually this kind of contract shows the following characteristics:

Variable	Score	Risk	Measure	Score
Scope uncertainty	High	Scope changes during contract execution and contract breach or renegotiation.	Requirements level of specifications	Low
Process uncertainty	Low	Low and/or inadequate performance, schedule slippage.	Level of knowledge (know-how) and experience meeting requirements.	High

Cost uncertainty	Medium	Contract price/costs estimation accuracy.	Assumptions, information and estimation methods about costs drivers in activities.	Medium
Market uncertainty	Medium	Costs escalation.	Price/cost stability of main cost drivers during project execution	Medium
Administrative burden		Penalties or not effort recognition for not accomplishment with information obligations from regulations imposed by the client.	Procedures, activities and cost linked to information that businesses would not collect and provide in absence of legal obligation. Objective KPI's.	High
Accounting system requirements		Not approval and payment of expenses.	Capacity of accounting system for cost analysis, accountability, detailed specification and traceability of contract prices/costs. (Allowable, allocable, reasonable).	High
Contract flexibility		Scope Creep[2]	Capacity to introduce changes in the scope that don´t require different performance without affect contract price.	High
Performance beyond requirements reward			Incentives payment to contractor for performance beyond requirements stated in the contract. Only cost related.	Medium
Costs & efficiency management			Contractor's profit sensitivity to costs and efficiency deviations (work package cost estimate). Shared.	Medium
Risks management			Contractor's profit sensitivity to risks events occurrences (contingencies, management reserve). Shared.	Medium

Table 14- FPAW Characteristics & Risks

The contractor vs client price assumption distribution could be represented like:

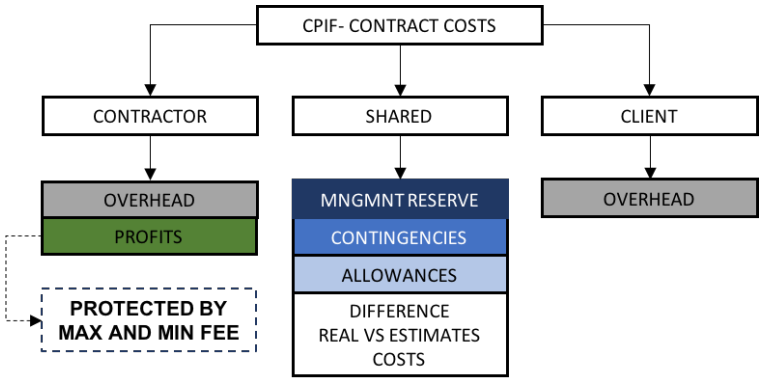


Figure 26- CPIF Price components assumption

In a very overall way and according to the information showed above we could define the following equations for a determined period:

Client Pricing Formula	Contractor's Profits Formula	Elements

For mF<=TF+(TC-C)sF<=MF then
CP=C+[TF+(TC-C)sF]
If TF+(TC-C)sF>MF then
CP=C+MF
If TF+(TC-C)sF<mF then
CP=C+mF
	For mF<=TF+(TC-C)sF<=MF then
	cP=C+[TF+(TC-C)sF]-C
	cP=TF+(TC-C)sF
	If TF+(TC-C)sF>MF then
	cP=C+MF-C
	cP=MF
	If TF+(TC-C)sF<mF then
	cP=C+mF-C
	cP=mF
		C = Final costs of contract execution
		TC = Target Cost of Performance
		TF=Target Fee by contractor
		sF=Sharing percentage by customer
		MF=Maximum Fee
		mF=minimum Fee

Table 15- CPIF overall price and profits equations

We can appreciate the behaviour of this formula in the next figure:

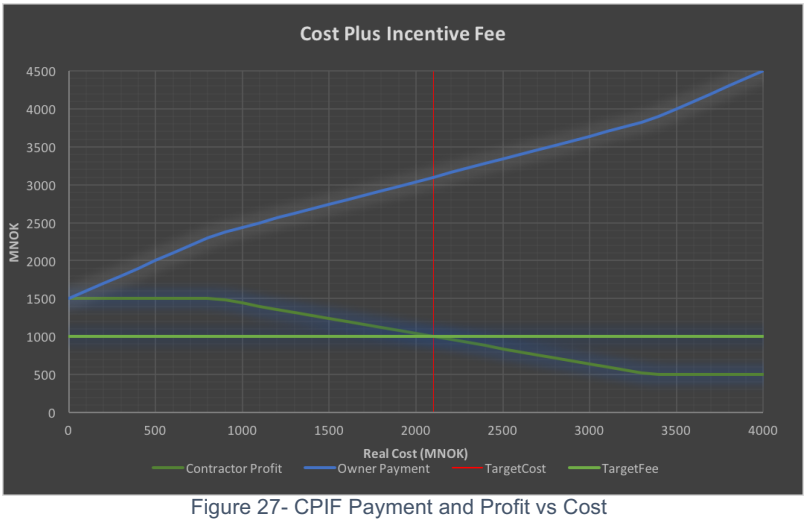


Figure 27- CPIF Payment and Profit vs Cost

2.2.1.1. Cost Plus Award Fee (CPAF)

FAR-16.405-2 [18]

CPAF contracts is used when it is difficult to include other incentives because seller performance cannot be measured objectively. A cost plus-award fee contract establishes a minimum fee and an award fee that can be earned by the seller in addition to the minimum fee based on the results of periodic evaluations of the seller's performance against an award fee plan.

Typical application is in complex programs with difficult to measure contract performance like large scale study research [17].

Usually this kind of contract shows the following characteristics:

Variable	Score	Risk	Measure	Score
Scope uncertainty	Low	Scope changes during contract execution and contract breach or renegotiation.	Requirements level of specifications	High
Process uncertainty	Low	Low and/or inadequate performance, schedule slippage.	Level of knowledge (know-how) and experience meeting requirements.	High
Cost uncertainty	High	Contract price/costs estimation accuracy.	Assumptions, information and estimation methods about costs drivers in activities.	Low
Market uncertainty	High	Costs escalation.	Price/cost stability of main cost drivers during project execution	Low
Administrative burden		Penalties or not effort recognition for not accomplishment with information obligations from regulations imposed by the client.	Procedures, activities and cost linked to information that businesses would not collect and provide in absence of legal obligation. Objective + subjective KPI's.	High
Accounting system requirements		Not approval and payment of expenses.	Capacity of accounting system for cost analysis, accountability, detailed specification and traceability of contract prices/costs. (Allowable, allocable, reasonable).	High
Contract flexibility		Scope Creep[2]	Capacity to introduce changes in the scope that don´t require different performance without affect contract price.	High
Performance beyond requirements reward			Incentives payment to contractor for performance beyond requirements stated in the contract. More than cost related.	High
Costs & efficiency management			Contractor's profit sensitivity to costs and efficiency deviations (work package cost estimate).	Low
Risks management			Contractor's profit sensitivity to risks events occurrences (contingencies, management reserve).	Low

Table 16- FPAW Characteristics & Risks

The contractor vs client price assumption distribution could be represented like:

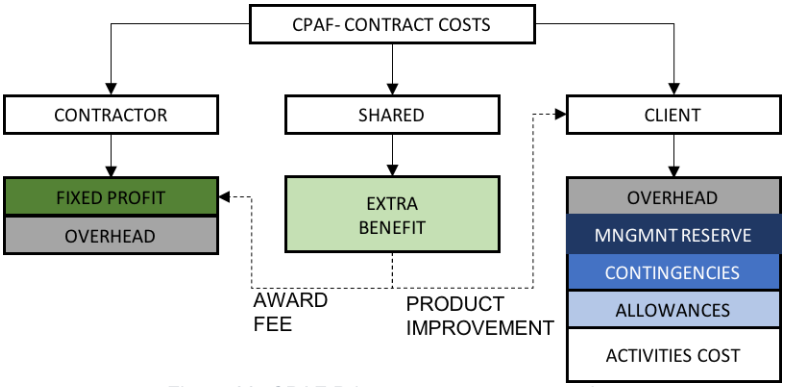


Figure 28- CPAF Price components assumption

In a very overall way and according to the information showed above we could define the following equations for a determined period:

Client Pricing Formula	Contractor's Profits Formula	Elements
CP=(C+FF)+AF*PeF	cP=(C+FF)+AF*PeF-C cP=FF+AF*PeF	C = Final costs of contract execution FF=Performance Fixed Fee AF=Performance Award Fee PeF=Performance evaluation Factor

Table 17- CPAF overall price and profits equations

We can appreciate the behaviour of this formula in the next figure:

Figure 29- CPAF Payment and Profit vs Cost

2.2.2. Traditional Contract Type Selection

In order to achieve a good decision respect to contract type selection, that will result in reasonable contractor risk with the greatest incentive for efficient and economical performance, it is necessary to fully understand the factors that affect contract performance and cost. It is impossible to make an unambiguous decision based upon one consideration only (cost). Moreover, when cost it is the result of many factors like -Figure *30*-:

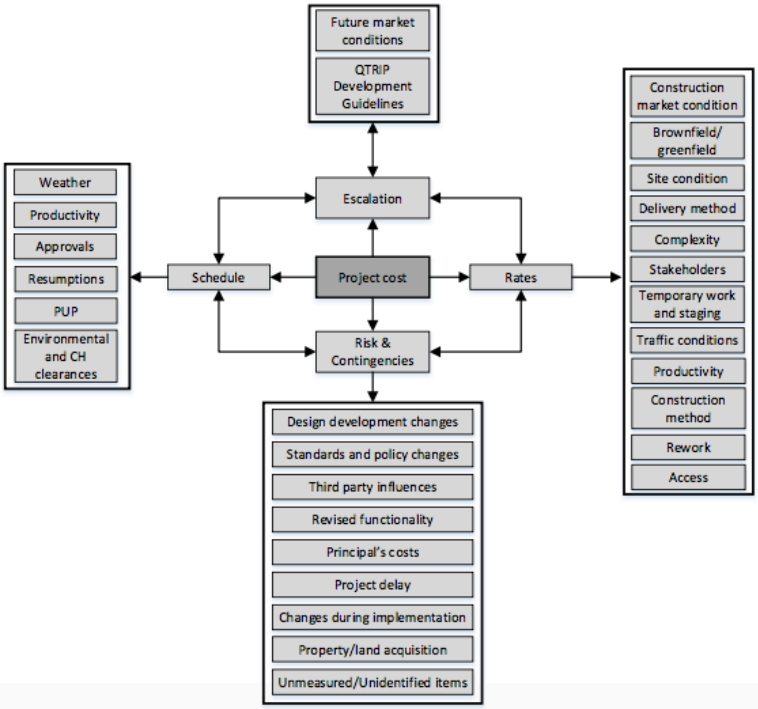


Figure 30- Project cost main influence factors

Given that contractors are profit oriented, the cost factor and related uncertainty will in general dominate the decision. We should not, however, neglect the technical uncertainty. Most contract cost risk is related to contract requirements and the uncertainty surrounding contract performance, if a contractor feels that the background needed falls outside his field of competence, his cost uncertainty will be influenced. Based on Turner & Cochrane [4], this technical uncertainty and contract types can be directly related as -*Figure 31*-:

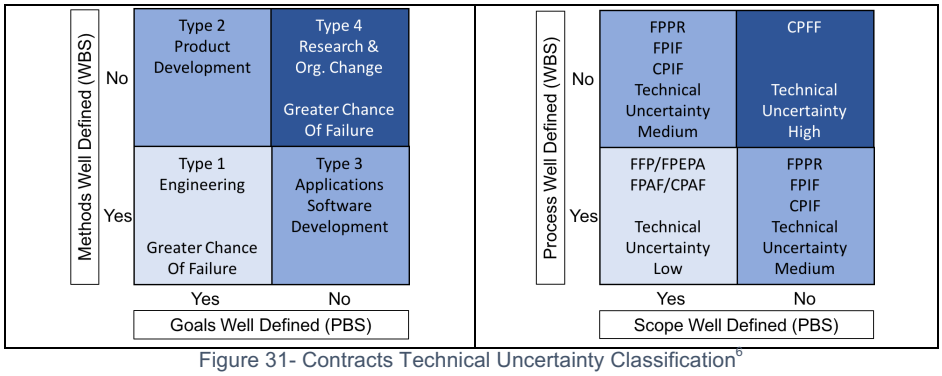


Figure 31- Contracts Technical Uncertainty Classification[6]

In a similar way, we may define the budget uncertainty considering two main differentiator factors -Figure *32*-:

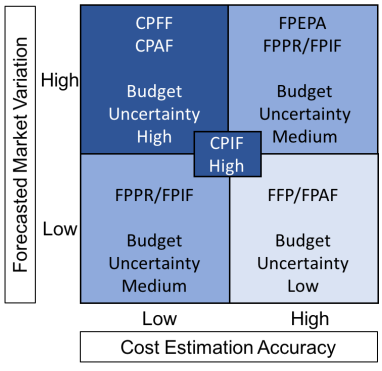


Figure 32- Contract types budget uncertainty

[6] This contract technical uncertainty classification is based on (Turner & Cochrane, 1993)

The above considerations lead us to a roughly classification of contract types like -Figure *33*-:

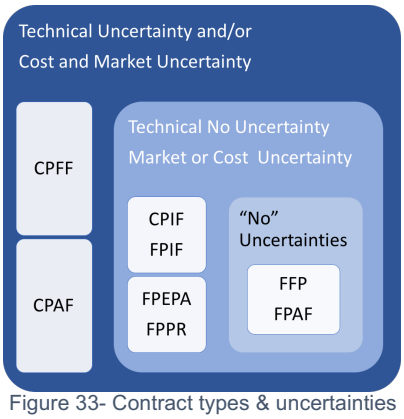


Figure 33- Contract types & uncertainties

Based on Peeters [7] we could propose the following systematic contract type selection logic from a not decision analysis method for contract type selection (0=no, 1=yes), taking into account the following considerations:

- Cost uncertainty = 0 if the cost estimated considered to be less accurate than 20% (accurate)
- Market uncertainty = 0 if are the cost driver elements of the contract behaviour during its execution expected to vary less than 20%
- Technical uncertainty = 0 if the technical elements in the requirements, with an important cost impact estimates expected to vary less than 20% (scope, performance, scheduling).

	Uncertainties			CONTRACT TYPES							
	Cost	Market	Technical	FFP	FPAF	FPEPA	FPPR	FPIF	CPIF	CPAF	CPFF
1	0	0	0	X	X						
2	0	0	1	X	X		X	X			
3	0	1	0			X	X	X	X	X	
4	0	1	1				X		X	X	X
5	1	0	0				X	X	X	X	X
6	1	0	1				X		X	X	X
7	1	1	0						X	X	X
8	1	1	1							X	X

Table 18- Systematic CT selection

The selection of the contract type looks very straightforward on the extreme sides. "No uncertainties" leading us to a FFP or FPAF and "all uncertainties" to CPFF or CPAF, the scenarios in between have in average 4 options, and the ones marked with the white X, could be considered off the applicable alternatives[7], but given the value of the limits and the binary discrimination used, these options could apply if they are close to the limits, and the risk is acceptable for us. In the same way, if we use 2 more differentiators we arrive to:

[7] Taking as example the combination 2, someone could consider a FFP inadequate to manage a technical uncertainty bigger than 20%, this is directly related with the risk attitude of the contract parties. Maybe a slightly bigger tolerance in risk assumption and use of a FFP could be more significant to the parties in exchange of less administrative burdens.

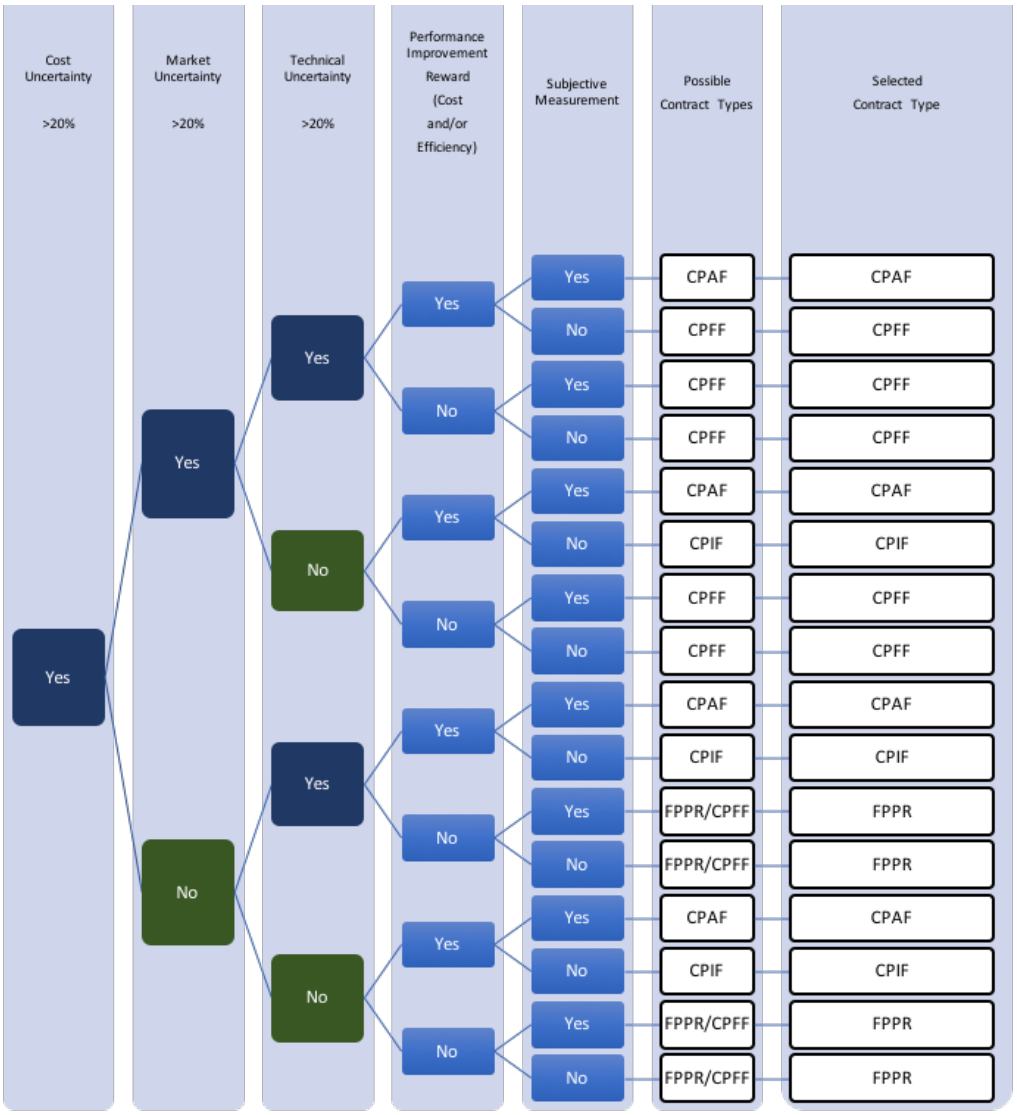


Figure 34- Systematic CT selection with cost uncertainty

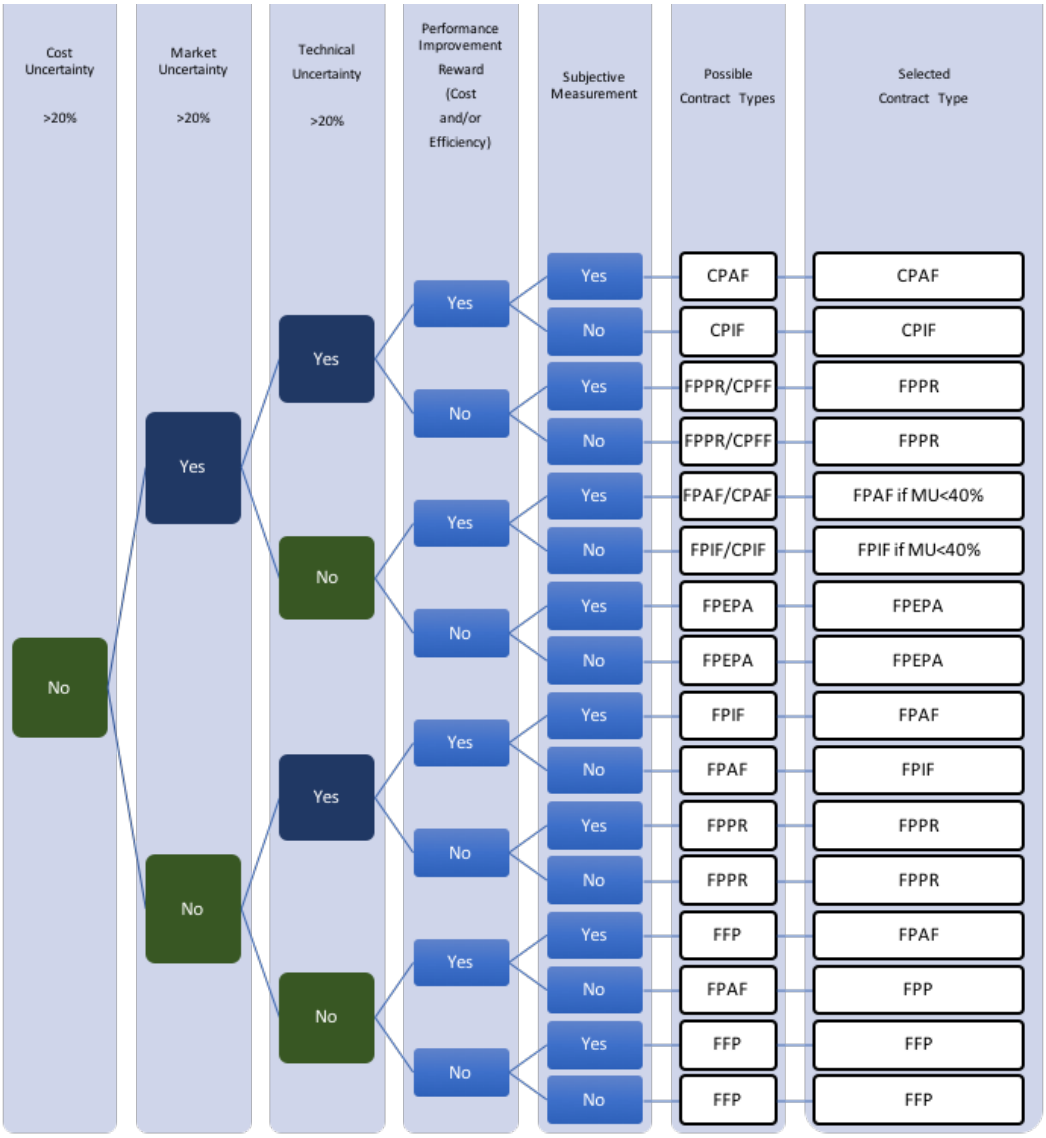
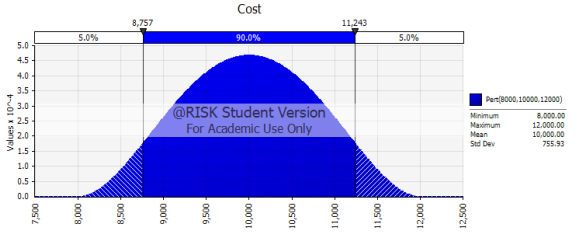
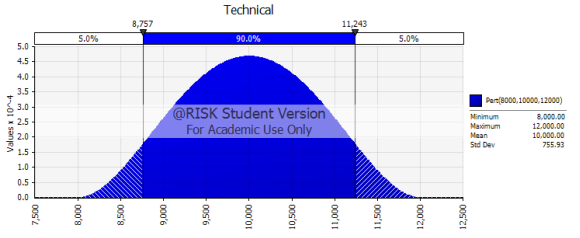


Figure 35- Systematic CT selection with NO cost uncertainty

According to the Figure *8* and to illustrate the exposed in the Table *18* related to the scenario 2, let's consider the following mental construction:

Uncertainty	Execution	Distribution	Min	Average	Max
Cost	Continuous	PERT	8.000	10.000	12.000
Technical	Continuous	PERT	8.000	10.000	12.000
Market	Event	PERT	3.600	4.000	4.400
Project Budget without risk components = Cost equipment + Technical execution of tasks					
Project Budget with 1 risk component = Work Package Cost Estimate + Market price variation (20% of WPCE)					
An extra consideration is that the market price variation only happens in 1 of 10 contracts. (Bernoulli binary distribution)					

Table 19- Price parameters example

Equipment Cost - Distribution	Technical execution of tasks - Distribution
	
Market variation	

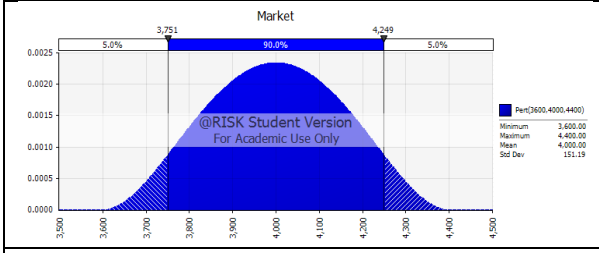
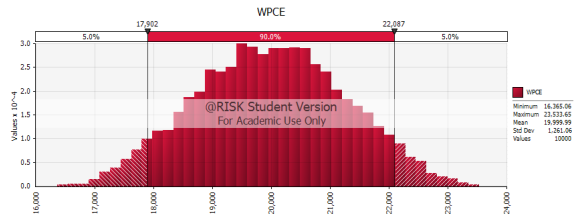
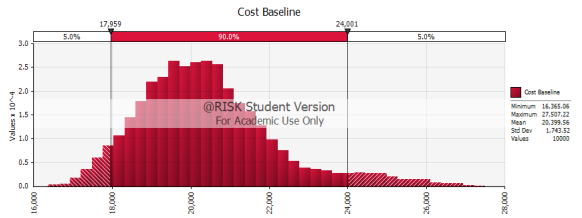
	
Project Budget Without Risk - Distribution	Project Budget With 1 Risk Component - Distribution
	
90% Confidence P0= 16.365 Mean = 19.999 P100=23.533	90% Confidence Min= 16.365 P0 = 20.400 P100=27.507

Table 20- Price initial-set distributions

Now let's consider a variation of ±10% extra in the technical uncertainty. We will get:

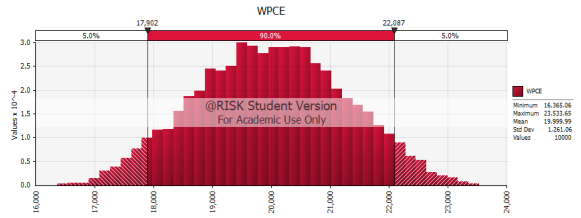
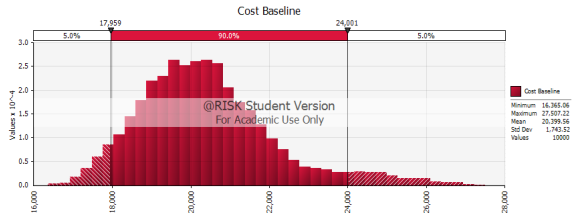
Project Budget Without Risk - Distribution	Project Budget With 1 Risk Component - Distribution
	
90% Confidence P0= 15.475 Mean = 20.000 P100=23.575	90% Confidence P0= 15.475 Mean = 20.399 P100=28.332

Table 21- Price second-set distributions

The difference of 10% between the first scenario and the second give us a difference less than 1.000, so based in this information we could say that the use of a FFP contract for the 2 case in the Table *18*. This can be easily validated with the following sensitivity cost baseline graphic:

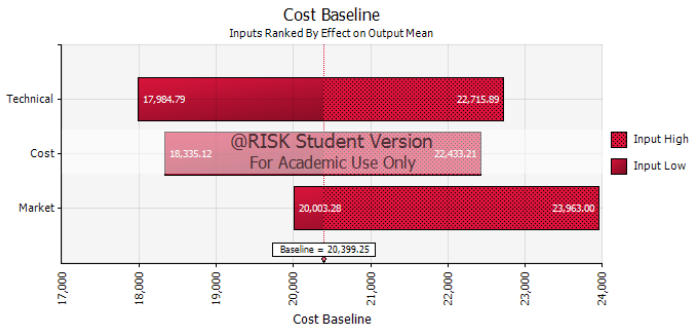


Table 22- Price sensitivity analysis

Based on this we can conclude that cost baseline main variation factor is our market uncertainty, and a small increment in the technical uncertainty (±10%) is no that significant. "The client should realize that some contract types need a considerable control effort; he will, therefore, sometimes prefer an easier type of contract, compared with his pure risk/uncertainty criterion" -*Figure 36*-:

Figure 36- Client Control Effort vs Risk *[20]*

2.2.1. Incentives

The relation between client-contractor could be understand through the principal-agent relationship[8] theory that has been widely studied by authors like Eisenhard [21], Casadesus [22] and many others. Here it is addressed the problem of moral hazard[9] and adverse selection as result of negotiations with asymmetric information (e.g. contractor knows better the work and deviations to perform and client knows better how much money is available); we need to understand that accordingly to the contract type (price arrangement) the incentives of the client and contractor will vary -Table *23*- and will influence the contract execution, specially the transaction costs due to changes and incentives to reduce costs [23]. "If both parties to the relationship are utility maximizers there is a good reason to believe the agent will not always act in the best interest of the principal. The principal can limit divergences from his interest by incurring monitoring costs" [24].

CONTRACTOR	Cost-Optimization	Technical Perf. Efficiency	Higher Quality	Comments
FFP	Built-In High Priority	Built-In High Priority	Not built-in No interest	All residual cost reductions (lower price supplies or higher performance) are incremental profits.
FPEPA	Built-In High Priority	Built-In High Priority	Not built-in No interest	All residual cost reductions (lower price supplies or higher performance) are incremental profits.
FPPR	Built-In Low Priority	Built-In Low Priority	Not built-in No interest	Cost savings and performance optimization adjust next period Fixed Price.
FPIF	Built-In Medium Priority	Built-In Medium Priority	Not built-in No interest	Every cost savings and performance optimization, is a shared dollar for contractor.
FPAF	Built-In Medium Priority	Built-In High Priority	Built-In High Priority	Main revenues stream form award fee
CPFF	Not built-in No interest	Not built-in No interest	Not built-in No interest	Cost and performance optimization do not represent extra money for contractor.
CPIF	Built-In High Priority	Built-In High Priority	Not built-in No interest	Every cost savings and performance optimization, is a shared dollar for contractor.
CPAF	Not built-in No interest	Built-In High Priority	Built-In High Priority	Main revenues stream form award fee

Table 23- Incentives and Contract types

In order to solve this agency problem[10] and reduce the risks, we may use some explicit incentives that are not implicitly embedded in the contract. Taking into account the following considerations:

- The resources and expected benefits of using implicit (contract type selection) or explicit incentives must outweigh the costs (administrative burden) of implementing the given benefit (quality, schedule, cost).
- No performance element should be incentivized more than once. If a separate cost incentive is used in a contract, then cost cannot also be incentivized [25].
- Contractors should not be rewarded for above-standard performance levels that are of no benefit to the client [25].
- Incentives shall not be added to contracts to reward contractors for agreed requirements achievement.
- The contractor will only exert effort or spend capital on cost-reducing innovations if it expects to at least earn its required cost of capital on the action (i.e. extra-expenditures and missed profits -overheads-) [26].

[8] Contract under which one or more persons (the principal(s)) engage another person (agent) to perform some service on their behalf which involves some decision-making authority to the agent [20].
[9] "Moral Hazard is created by a contract that cannot induce the contractor to put anything but the minimum effort towards delivering the desired contract outcome" [24].
[10] How to induce an "agent" to behave as if he were maximizing the "principal's" welfare.

- The client should state beyond any doubt the priorities and trade-offs between cost-time-quality. The contractor should not be rewarded for excelling in cost control to detriment of other important performance factors.

2.2.1.1. Cost Incentives

This incentive is based on "sharing", client and contractor share to a certain point in case of overruns or underruns. The effectiveness of this incentive relies on the proper selection of the "sharing-ratio", the contractor will only try to avoid overruns if he believes that it has negative effects on his overall profitability. A method for calculation of this incentive is proposed by Peeters in [7].

2.2.1.2. Delivery Incentives

The client should specify a table with the compensation scheme (early/late delivery vs reward/penalty scheme), as usually the contractor may have incurred in some extra-expenditure meeting some early delivery time this should be expressed in the compensation scheme Example for a FFP with external delivery incentive:

Delivery/Costs	-10 %	-5%	On budget	+5%	+10%
(-) 2 weeks	20% R	15% R	10% R	5% R	0
(-) 1 week	15% R	10% R	5% R	0	5% P
On Time	10% R	5% R	0	5% P	10% P
(+) 1 week	5% P	0	10% P	15% P	20% P
(+) 2 week	15% P	20% P	25% P	30% P	35% P

Table 24. Delivery Incentive Matrix

There is no contract type that implicitly address delivery incentives. This component will be an external component to any type of contract. This component will not be part of the decision analysis model.

2.2.1.3. Technical Performance Incentives

When a variety of specific characteristics contribute to the overall contract performance, you must balance the incentives so that no one of them is exaggerated to the detriment of overall contract performance. There are basically two types of performance incentives:

- Objective: quantitative measurement of performance (speed, mass, reliability, power, etc.)[11]
- Subjective: qualitative measurement of performance (appendix-A)

The objective incentives can be applied to any kind of contract and therefore will not be considered during the decision model, and the subjective incentives are addressed through Award Fee type contracts.

2.2.2. Contract Types Resume

Check appendix-B.

[11] A good example is the agreement between Atari and Steve Jobs (1975) for the improvement of the "Breakout" arcade game design. Atari offer Jobs a bonus of $100 for each TTL chip removed from the original design.

3. Decision Analysis

A good outcome is not necessarily indication that a good decision was made or vice versa. Decision making is a process that is constantly challenged by factors like:

- Different valuations about what is a good outcome. (What do we want?)
- The alternatives we have. (What can we do?)
- Knowledge uncertainty. (What do we know?)

Good decisions require more than accurate gut feelings or instincts, after all nobody can predicts the future and guarantee beyond any uncertainty degree the result of a decision made. We need to transform opaque decision problems into transparent decision problems, to achieve good decisions[12] that maximize our chances for good outcomes.

"Decision analysis is about how to achieve clarity of action in making decisions and, even more fundamentally, how to achieve clarity of thought."

Howard

In order to make high quality good decisions, the decision analysis discipline uses a systematic procedure with the following sequence of clearly defined steps --:

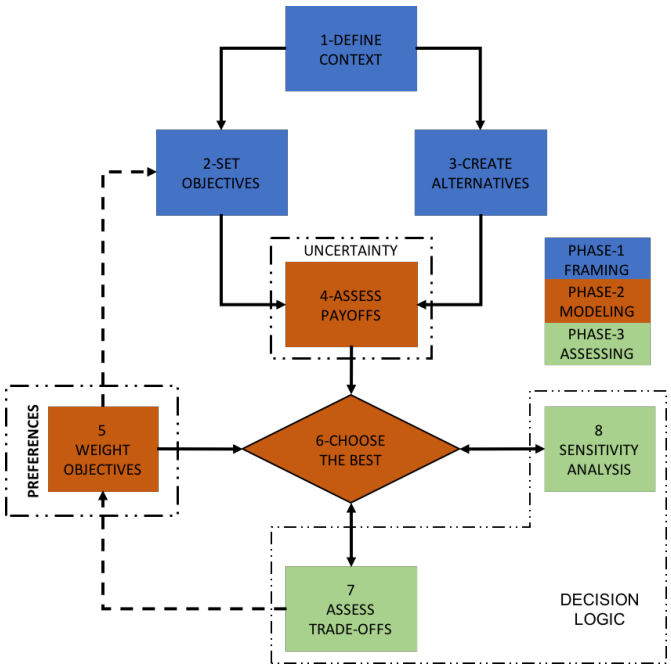


Figure 37- Decision Making - Methodology *[3]*

3.1. Framing

During this phase, the analysis team and decision maker will strive to identify and structure the relationship between the main elements of the decision problem (objectives, alternatives, information), the quality and effectiveness of the decision lies in this phase. It is the most important phase, it is the base of all the following efforts.

3.1.1. Defining the Decision Context

"There is nothing quite so useless, as doing with great efficiency, something that should not be done at all"
Peter Drucker

[12] A good decision is an action we take that is logically consistent with the alternatives we perceive, the information we have, and the preferences we have.

Define the real decision to be made and context where it will perform is not always an easy task, to achieve this, it is necessary to identify the real decision-maker[13], and the context where the decision will be executed with the constraints and assumptions related to the decision process. After all it is not the same to decide about buy or not to buy and electro domestic for Europe (220 VAC) or South America (110 VAC).

3.1.2. Objective Settings

"The ultimate goal of this step is to generate a set of appropriate objectives and their associated attribute scales with which to measure the value created by the different decision alternative" [3], by which the worth of each alternative will be judge. Value trees are often used to ease the clear identification of the final objectives, ensuring:

- Completeness: no significant issues are missing
- Operationality: objectives are clear enough to assess alternatives
- Independence: performance of an alternative on one objective is not related with more objectives.
- No redundancy: no objective is a rephrasing of another. Avoiding excess weighting.
- Minimum size: all the objectives are distinguishable between alternatives and are not more than necessary to achieve the decision (valuable).

3.1.3. Identifying Alternatives

"A decision can never be better than the best alternative identified"

Howard

Our goal in this step is to achieve sufficiently different value-maximizing alternatives, that can be assessed against the settled objectives. It is important to be cautious with the number of alternatives proposed, in order to keep the feasibility of the analysis.

3.2. Modelling and Evaluating

The goal of this phase is to reach a preliminary decision based on the alternatives identified, the objectives set, and the decision maker´s preferences for the relative importance of those objectives [3].

3.2.1. Assess Payoffs

In this section, we will create a payoff matrix that quantifies how well each alternative score on the objective attributes scales and to determine how much value is derived from them.

The payoffs are usually not known in advance (forecasted) and subject to uncertainty. During the execution of this step the goal of the objectives changes from helping to identify good alternatives to helping to choose between the alternatives; during the development of the payoff matrix we should consider:

- Any objective that does not create differentiation among the alternatives, no matter how important, should be removed from the list.
- Remove all alternatives that do not meet a "must have" criterion or constraint and the associated objective.
- Work across the rows of the payoff matrix rather than down its columns.
- If all the payoffs are numeric values, identify and eliminate any alternatives dominated[14] by others.

As example consider the following payoff matrix -Figure *38*-:

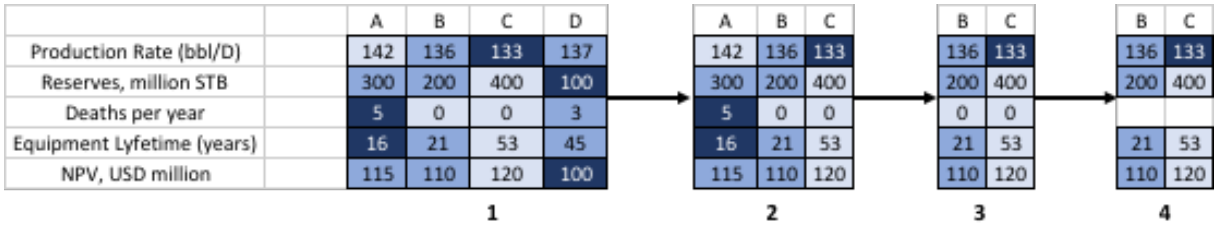


Figure 38- Payoff Matrix –Scores-

In this example, we can clearly appreciate the steps described above:

[13] The person/organization capable to assign the resources required to implement the decision.
[14] One alternative is said to dominate another if it has higher value on some objectives and is no worse on the remaining objectives.

- Step 1: Forecasted payoffs (numerical assessment of all the objectives vs alternatives)
- Step 2: Elimination of alternative D, given true-dominance by alternative C.
- Step 3: Elimination of alternative A, given practical-dominance[15] by alternative C.
- Step 4: Elimination of Safety objective, given the no further help to differentiation between B vs C.

3.2.2. Convert Scores to Values

The transformation from scores to values through value functions allows us the use of commons scales (natural or constructed) to assess the performance of an alternative on multiple objectives. The value functions can easily be defined using the range between the minimum and maximum scores for the various alternatives:

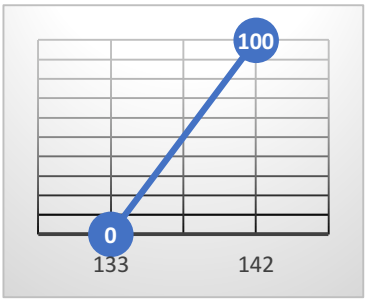
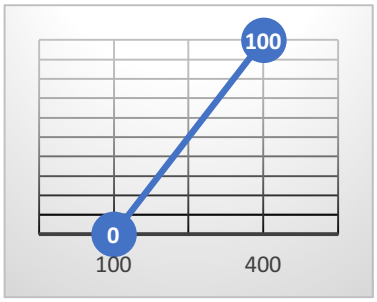
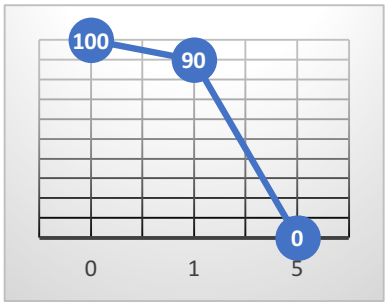
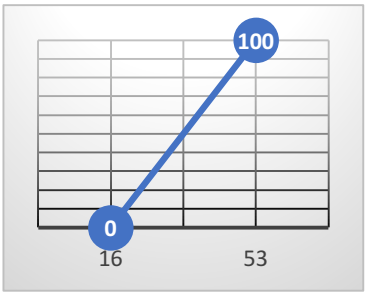
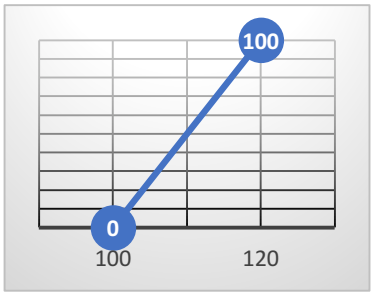
Production Rate	Reserves	Deaths per year
		
Equipment Lifetime	**NPV**	
		

Table 25. Scores to Values Transformation Graphics

3.2.3. Weight Objectives

Normally the weight assigned to each objective is used to describe the level of importance or preference by the decision maker, of the objective against the others (naive approach). Recall that the goal of the objectives in this phase is to help to create differentiation between the alternatives, thus the objectives should be ranking according to their capacity to fulfil this goal. “In the extreme, if the scores of all alternatives were the same, then the weight should be set to 0, which has the same effect as removing the alternative altogether”.

Objective	Rank	Weight	Normalized
Minimize Deaths per year	1	100	0,33
Maximize NPV	2	90	0,3
Maximize production rate	3	50	0,16
Maximize reserves	4	40	0,13
Maximize Equip. Lifetime	5	20	0,08
	Sum	**300**	**1**

Table 26. Objectives weighting “naive approach”

Attributes	A	B	C	D		Worst	Best		Swing Rank
Production Rate (bbl./D)	142	136	133	137		133	142		5
Reserves, million STB	300	200	400	100		100	400		1
Deaths per year	5	0	0	3		5	0		3

[15] The decision maker considers that in general an alternative A dominate other B, and the objectives where B perform better are no sufficiently enough to compensate major benefits of A.

Equipment Lifetime (years)	16	21	53	45		53	16		2
NPV, USD million	115	110	120	100		120	100		4

Table 27. Objectives weighting "swing weights"

After having determined the swing weights and apply the correspondent factors to scores, the payoff matrix can be inspected for practical dominance and objectives removal.

3.2.4. Choose the Best

In this step, we should to combine the scores on each objective to determine the overall value of each alternative and select the one with highest value. Obtaining a logically consistent maximizing value alternative, given:

- The alternatives defined
- Decision maker's objectives and weights
- Forecasted payoffs (according to the available information)
- Decision maker's preferences for payoffs

Attributes	S. Rank	Abs. W	Rel. W		A	B	C	D
Production Rate (bbl./D)	5	60	0,15		100	33	0	44
Reserves, million STB	1	100	0,25		66	33	100	0
Deaths per year	3	80	0,20		0	100	100	45
Equipment Lifetime (years)	2	90	0,22		0	14	100	78
NPV, USD million	4	75	0,19		75	50	100	0

Table 28. Payoff Matrix with Values

Attributes	S. Rank	Abs. W	Rel. W		A	B	C	D
Production Rate (bbl./D)	5	60	0,15		14,81	4,89	0,00	6,52
Reserves, million STB	1	100	0,25		16,30	8,15	24,69	0,00
Deaths per year	3	80	0,20		0,00	19,75	19,75	8,89
Equipment Lifetime (years)	2	90	0,22		0,00	3,11	22,22	17,33
NPV, USD million	4	75	0,19		13,89	9,26	18,52	0,00
Total Score		405	1		45,00	45,16	**85,19**	32,74

Table 29. Payoff Matrix weighted values and Best Choice

However, the highest ranked alternative may not be the preferred one if we consider that:

- We are not absolutely sure about the weights assigned.
- Some objectives may be conflicting.
- The alternatives could be slightly different in the overall scores, but they addressed significantly different objectives.

The stated above may be more easily understand using radar charts -Figure *39*-:

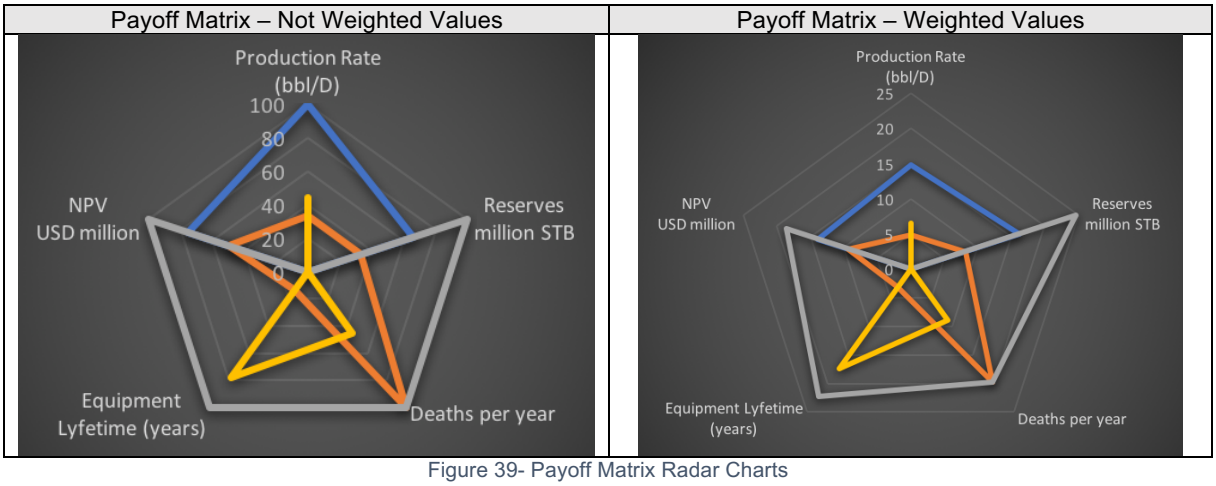


Figure 39- Payoff Matrix Radar Charts

The weights assigned, depend on the alternatives, objectives and useful information available during the decision process. Any change in these variables may affect our preferences (weights). In the further development of this thesis, these values will be assigned according to our beliefs (no survey data will be supply).

3.3. Assessing and Deciding

In order to achieve a good decision, it is necessary to measure the results obtained in the previous phase, it is necessary to perform what we could call a cost-benefit analysis. This is important specially for the nature of some competing objectives and the likely similar final overall scores between the different alternatives available. To achieve this, we will consider the impacts of any competing objectives and the convenience of making trade-offs between them, and conduct a sensitivity analysis of the decision to some input variables and parameters.

3.3.1. Trade-offs

"To get profit without risk, experience without danger, and reward without work, is as impossible as it is to live without being born"

A.P. Gouthey

During this step, we will categorize of the objectives between two classes cost (undesirable, normally the ones that we want to minimize) and benefits (desirable, normally the ones that we want to maximize), execute and plot the overall sum of these subsets for all the alternatives. Let's consider he hypothetical matrix and C-B plot:

Attributes	Type	Desire	A	B	C	D
Production Rate (bbl./D)	Benefit	Maximize	X	X	X	X
Reserves, million STB	Benefit	Maximize	X	X	X	X
NPV, USD million	Benefit	Maximize	X	X	X	X
Overall Benefit Score			**6**	**12**	**10**	**8**
Deaths per year	Cost	Minimize	X	X	X	X
Equipment Training	Cost	Minimize	X	X	X	X
Overall Cost Score			**5**	**10**	**15**	**20**
Total Overall Score			**11**	**22**	**25**	**28**
Total Overall Ranking			**4**	**3**	**2**	**1**

Table 30. Payoff Matrix Cost vs Benefit

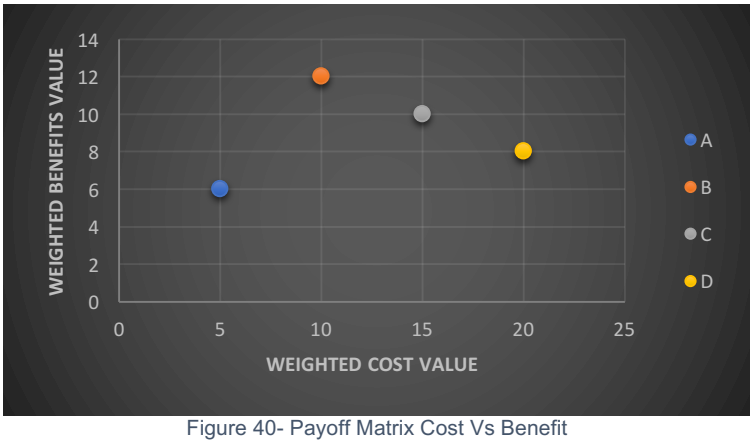


Figure 40- Payoff Matrix Cost Vs Benefit

If we consider the *Figure 40* we could reach a different choice that the one used from the *Table 30*. In this figure, the alternative D and C cost-benefit relation is clearly dominated by the option B, except the option A. If we eliminate those options we need to decide between the option A and B, that from a risk neutral point of view are equal.

3.3.2. Sensitivity Analysis

As final step in our endeavour to achieve high quality decisions it is necessary to understand the many sources of change that impact our decision and how sensitive we are (payoffs variation) to it, achieving a good decision will be the consequence of understanding the behaviour of our model related to uncertainty drivers and value levers.

There are mainly 3 types of quantitative inputs to our model:

- Value Type: subjective assignments (weights, value functions).
- Informational Type: uncertainty level about the forecasted payoffs.
- Choice Type: parameters whose value we choose (e.g. #wells in a field development, facilities capacity)

Two procedures excel for the purpose to understand our decision sensitivity:

- Tornado charts (MISO[16]): analyse the behaviour of a single output (e.g. overall weighted value) against the variation of multiple input uncertainties (e.g. single payoff of objectives). This is especially useful to notice which input (objective) has the bigger impact over the decision and maybe we should assess more thoroughly.

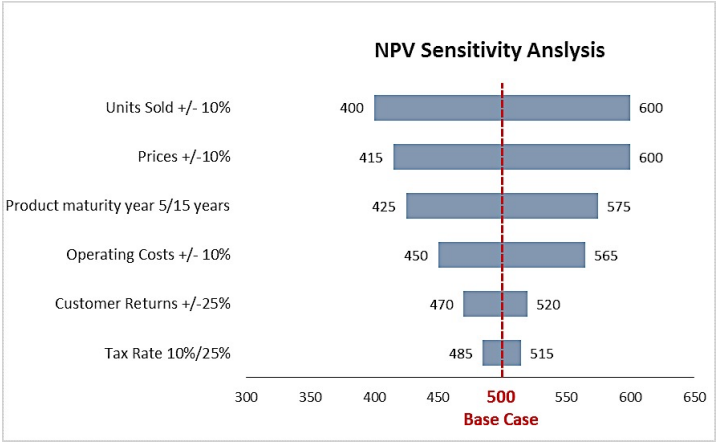


Figure 41- NPV Tornado Chart Example

- Spider charts (SIMO[17]): analyse the behaviour of multiple outputs (e.g. objective payoff among alternatives) against the variation of a single input uncertainty (e.g. weight factor). This is especially helpful to investigate the sensitivity of the decision to the weights of the objectives.

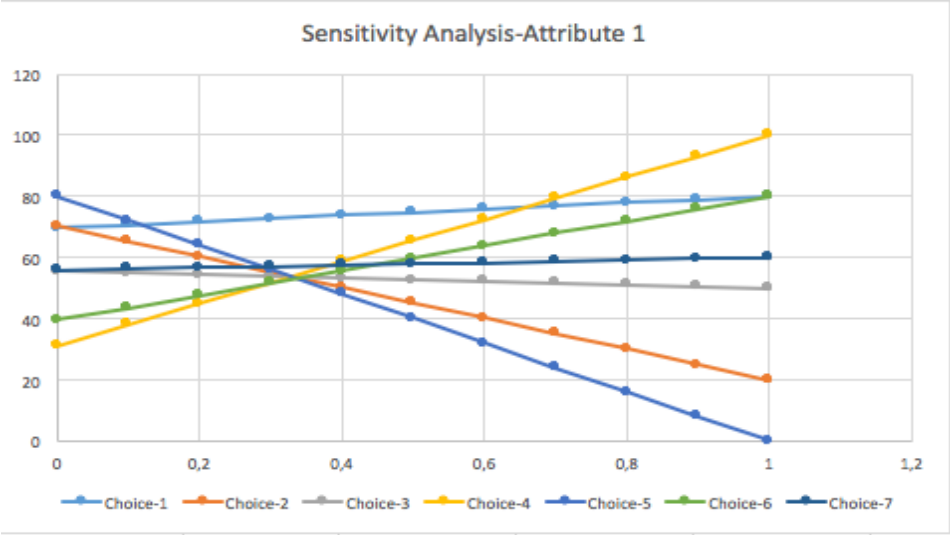


Figure 42- NPV Spider Chart Example

It is very important to recall that any decision is not stronger than its weakest link. If any step of the decision process is executed with low quality, the decision made will be low quality. No matter how good the other steps are.

[16] MISO: Multiple Input Single Output
[17] SIMO: Single Input Multiple Output

4. Contract Type Selection Decision Model

It is very unlikely that a project fits perfectly with the characteristics of a specific contract type, and there is not a right one for every contracting situation. The selection must be made on a case-by-case basis considering the values of the contractor and client and how effectively the available alternatives fulfil them.

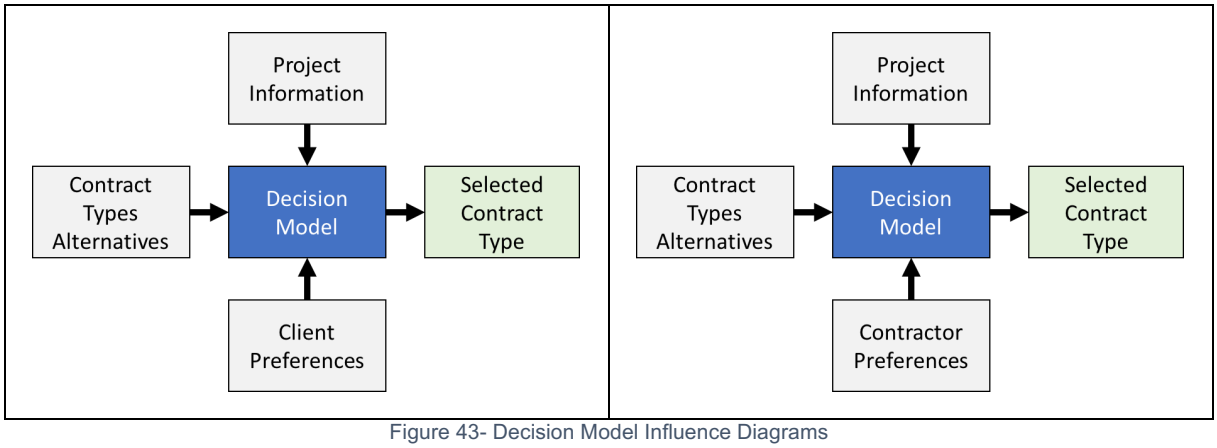


Figure 43- Decision Model Influence Diagrams

As common advice in the literature the contract type that places the most responsibility on the contractor to successfully perform should be selected, commensurate with the other benefits and burdens[18]. It is very likely that for the same situation the contractor and client decides for different contract types (i.e. different values, weights assignment and trade-offs), underpinning the need to understand the counterpart decision values as key success factor during the contract negotiation, reason why it will be implemented two decision models considering the interests of the client and contractor by separate, with the same alternatives and project information, basing the respective decisions on values, preferences and performance of the alternatives. The assessment of the performance and evaluation criteria will be based on the characteristics exposed in the Appendix-B, Table 70.

4.1. Objective & Context

Considering that the contractor profits comes from a successful strive of the project execution aimed to deliver an agreed product according to the client's requirements, and that the client main profits stream comes from the endeavor operation of the delivered product, it is possible to define the following contract type selection objectives:

- Contractor: To select the contract type with the highest probability of profits and lowest effort.
- Client: To select the contract type with the highest performance delivery and lowest cost.

The decision model context will be framed wherever two or more contract types -Figure *12*- can be applied, the incentives will be only inherent to the contract type -Table *23*-, and contracts are selected from a TCE perspective. The final contract type and price will be established through the interaction between a risk-avoiding buyer tending to an optimistic cost estimation (minimizing the risk of agreeing to a price with excessive profit payment), and a risk-avoiding seller pushing for a pessimistic cost estimation that allows him to minimize the risk of agreeing to a price that may not cover its actual performance costs or allow a reasonable profit [16]. "An effective payment scheme may considerably reduce the need for information-systems approaches to contractor control. The nature and size of contract payments is the primary means of motivating the contractor" [27].

This thesis will present the decision models for the client and contractor, and will evaluate these models respect a specific application. However, in case that the resultant contract type of the client and contractor do not match, the negotiation process aimed to select the final agreement will not be studied.

4.2. Value Trees

To achieve the main objective of the client and contractor it is necessary to breakdown these high-level desires into measurable criteria. In the Figure *44* it is shown the difference between the value trees of the client and contractor and in the APPENDIX-C it is available the attributes and scales to assess the alternatives.

[18] To compensate for the lack of trust between the parties, elaborated surveillance and control systems are implemented, layers of managerial hierarchy, specialized staff and specific surveillance and control systems are implemented generating different transaction costs arrangements according to the contract type. A key concern for the client is how best to select and motivate a contractor to perform as the client would prefer, taking into account the difficulties in monitoring the contractor's activities. [26]

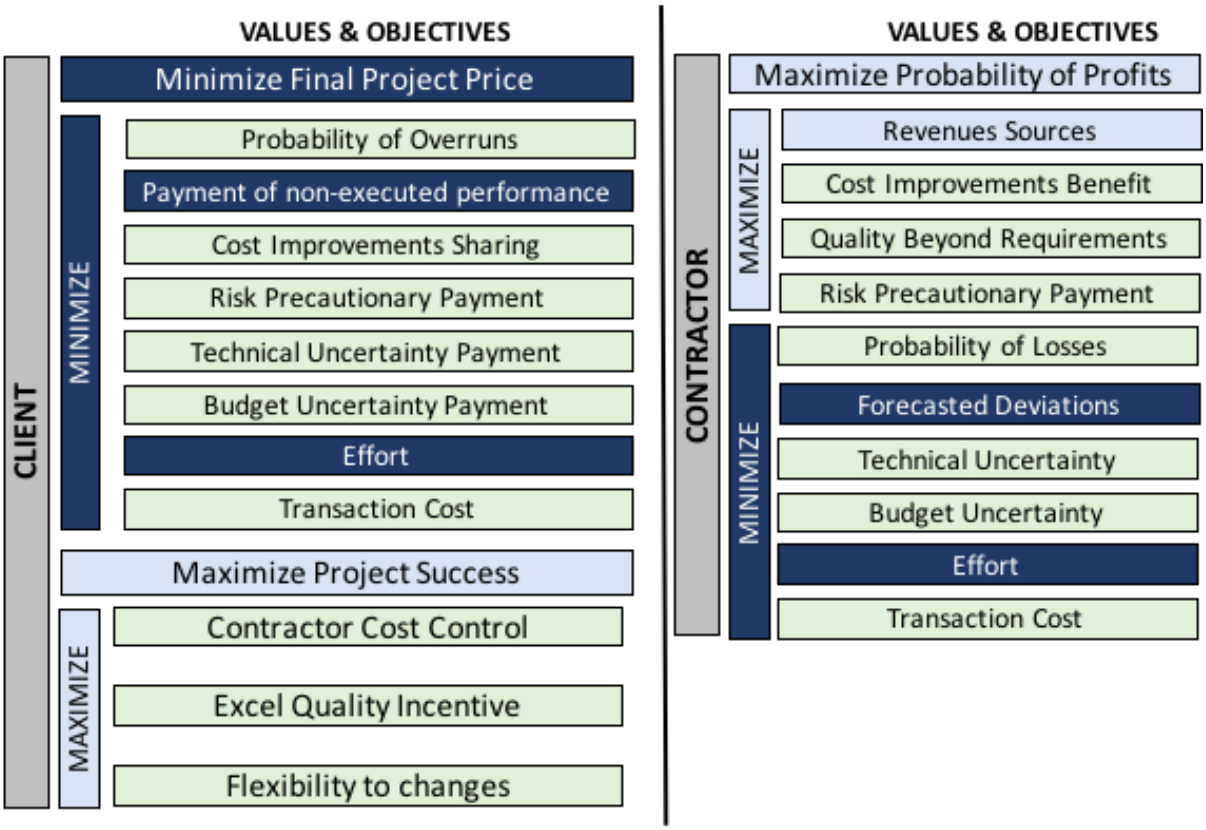


Figure 44- Client vs Contractor Values & Objectives

4.3. Payoffs – Values to Scores

Given that the alternatives have already been chosen, we will proceed to assess the payoff matrixes corresponding to the client and contractor using the information available in the APPENDIX-B. During this assessment, we will use the following colors convention:

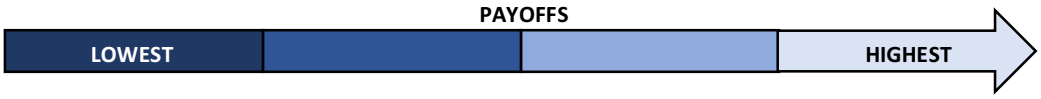


Figure 45- Payoffs color convention

4.3.1. Client

For a detailed description of the factors influencing the scores, refer to APPENDIX-D.

4.3.1.1. Overruns Probability

This evaluation attribute does not consider the effect of change over the contract price.

Contract Type	Grade	Score	Ranking
FFP	None	100	1
FPEPA	Low	70	2
FPAF	None	100	1
FPPR	None	100	1
FPIF	Low	80	3
CPIF	High	0	4
CPAF	High	0	4
CPFF	High	0	4

Table 31. Price Overruns Uncertainty Payoffs

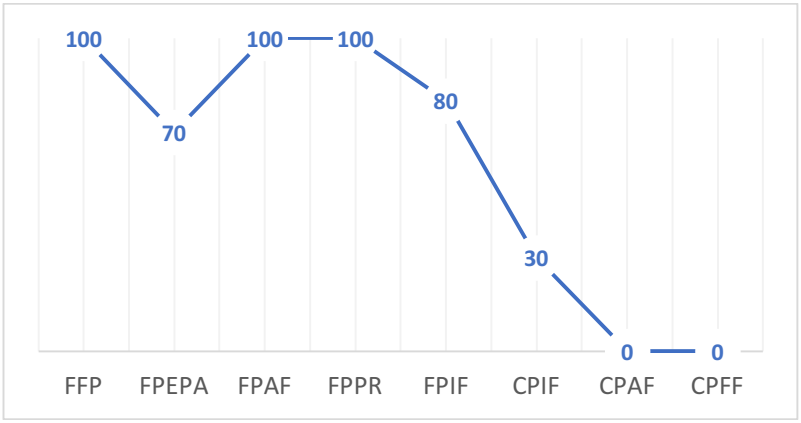


Figure 46- Overruns Probability Payoffs Graphic

4.3.1.2. Cost Improvements-Sharing

Contract Type	Grade	Score	Ranking
FFP	None	0	4
FPEPA	Low	20	3
FPAF	None	0	4
FPPR	None	0	4
FPIF	Medium	50	2
CPIF	Medium	50	2
CPAF	High	100	1
CPFF	High	100	1

Table 32. Cost Improvement Sharing Payoffs

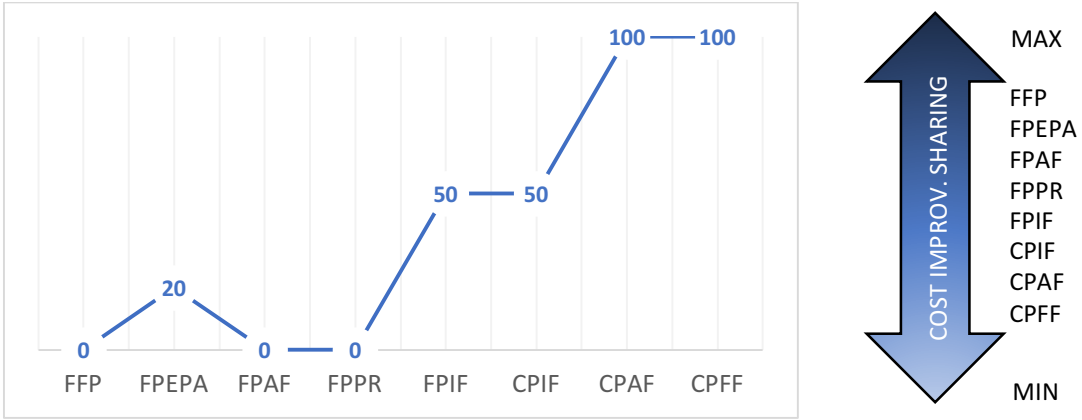


Figure 47- Cost Improvement Sharing Graphic

4.3.1.3. Risk Precautionary Payment

We do not consider the consequence on the contract price if a risk occurs just the precautionary measures appliance or not by the client.

Contract Type	Grade	Score	Ranking
FFP	High	0	6
FPEPA	Medium	20	5
FPAF	High	0	6
FPPR	Medium	30	4
FPIF	Low	50	2
CPIF	Low	70	3
CPAF	None	100	1
CPFF	None	100	1

Table 33. Risk Precautionary Payment Payoffs

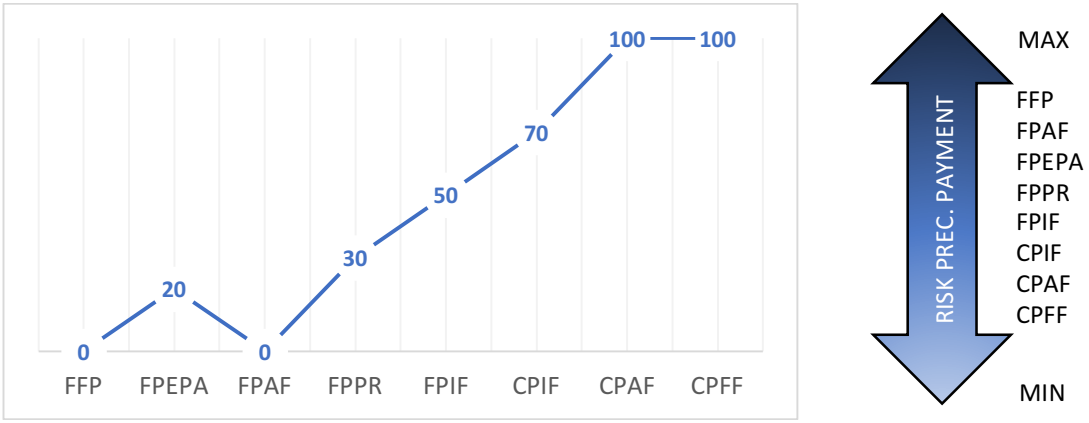


Figure 48- Risk Precautionary Payment Payoffs Graphic

4.3.1.4. Technical Uncertainty Payment

The uncertainty about the forecasted time, procedures and resources needed to accomplish specific activities and objectives of the contract will be a base element of the contract price, and will be assumed by the contractor or the client according to the contract type.

Contract Type	Grade	Score	Ranking
FFP	High	0	4
FPEPA	High	0	4
FPAF	High	0	4
FPPR	High	0	4
FPIF	Medium	50	3
CPIF	Medium	70	2
CPAF	None	100	1
CPFF	None	100	1

Table 34. Technical Uncertainty Payment Payoffs

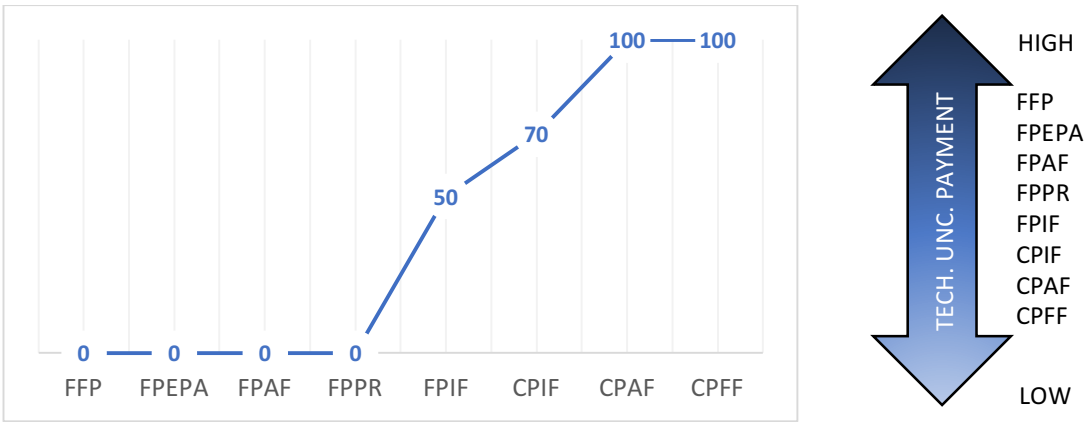


Figure 49- Technical Uncertainty Payment Payoffs Graphic

4.3.1.5. Budget Uncertainty Payment

The uncertainty about the forecasted budget to acquire the resources needed to accomplish the specific activities and objectives of the contract are the main contract price components, and will be assumed by the contractor or the client according to the contract type.

Contract Type	Grade	Score	Ranking
FFP	High	0	6
FPEPA	Medium	20	5
FPAF	High	0	6
FPPR	Medium	30	4
FPIF	Low	50	3
CPIF	Low	70	2
CPAF	None	100	1
CPFF	None	100	1

Table 35. Budget Uncertainty Payment Payoffs

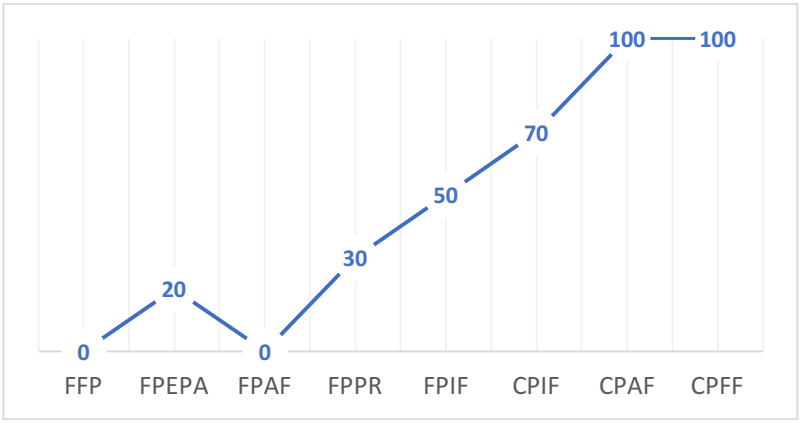


Figure 50- Budget Uncertainty Payment Payoffs Graphic

4.3.1.6. Managerial Effort

Contract Type	Grade	Score	Ranking
FFP	Low	100	1
FPEPA	Low	90	2
FPAF	High	30	4
FPPR	Medium	60	3
FPIF	Medium	60	3
CPIF	High	20	5
CPAF	High	0	6
CPFF	High	30	4

Table 36. CAS Managerial Effort Payoffs

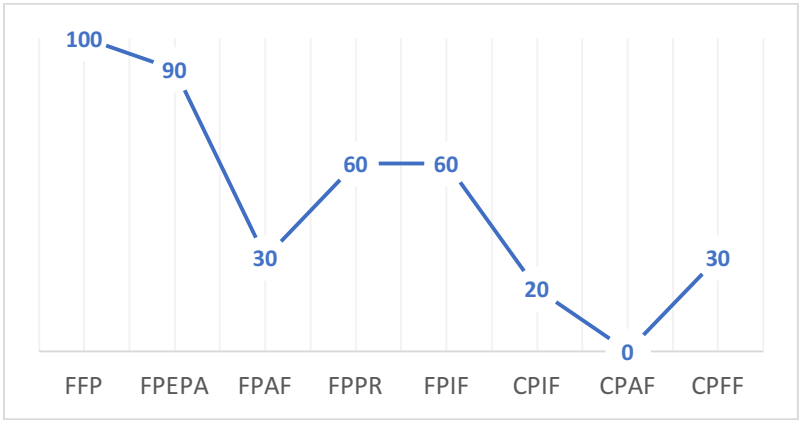


Figure 51- CAS Managerial Effort Payoffs Graphic

4.3.1.7. Contractor Cost Control

Contract Type	Grade	Score	Ranking
FFP	High	100	1
FPEPA	High	90	2
FPAF	High	80	3
FPPR	Medium	40	6
FPIF	Medium	70	4
CPIF	Medium	50	5
CPAF	Low	20	7
CPFF	Low	0	8

Table 37. Contractor Cost Control Payoffs

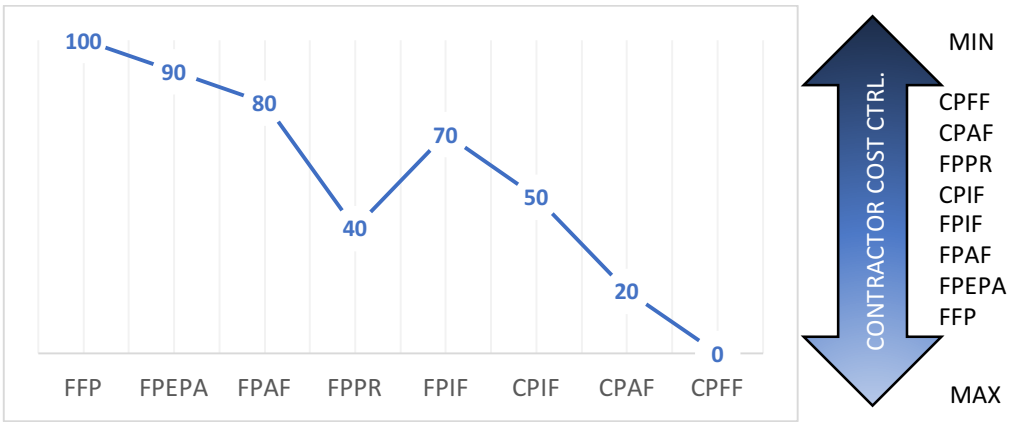


Figure 52- Contractor Cost Control Graphic

4.3.1.8. Excel Quality Incentive

Contract Type	Grade	Score	Ranking
FFP	None	0	3
FPEPA	None	0	3
FPAF	High	100	1
FPPR	Low	30	2
FPIF	None	0	3
CPIF	None	0	3
CPAF	High	100	1
CPFF	None	0	3

Table 38. Excel Quality Incentive Payoffs

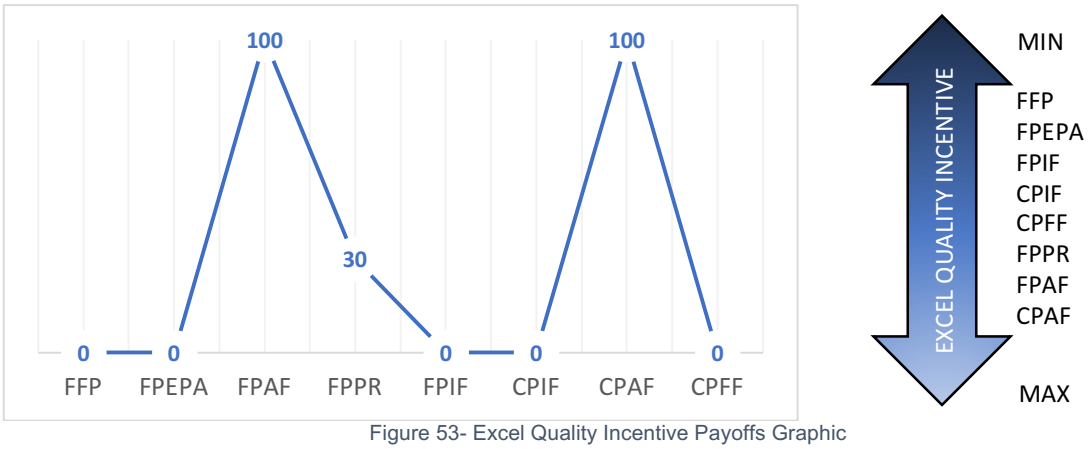


Figure 53- Excel Quality Incentive Payoffs Graphic

4.3.1.9. Change flexibility

Contract Type	Grade	Score	Ranking
FFP	None	0	4
FPEPA	None	0	4
FPAF	None	0	4
FPPR	Low	30	3
FPIF	None	0	4
CPIF	High	80	2
CPAF	High	100	1
CPFF	High	100	1

Table 39. Change flexibility Payoffs

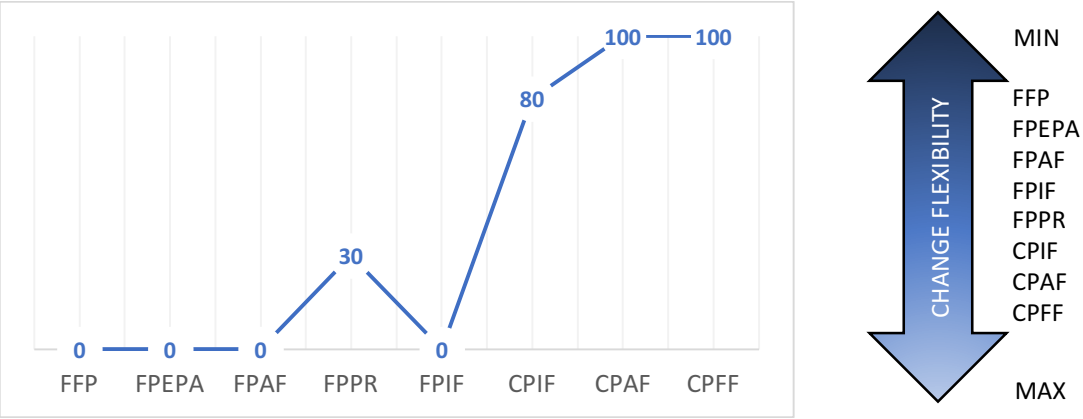


Figure 54- Change Flexibility Payoffs Graphic

4.3.2. Contractor

For a detailed description of the factors influencing the scores, refer to **Error! Reference source not found.**.

4.3.2.1. Cost Improvements-Benefits

Contract Type	Grade	Score	Ranking
FFP	High	100	1
FPEPA	High	90	2
FPAF	High	100	1
FPPR	High	80	3
FPIF	Medium	70	4
CPIF	Medium	50	5
CPAF	None	0	6
CPFF	None	0	6

Table 40. Cost Improvements Payoffs

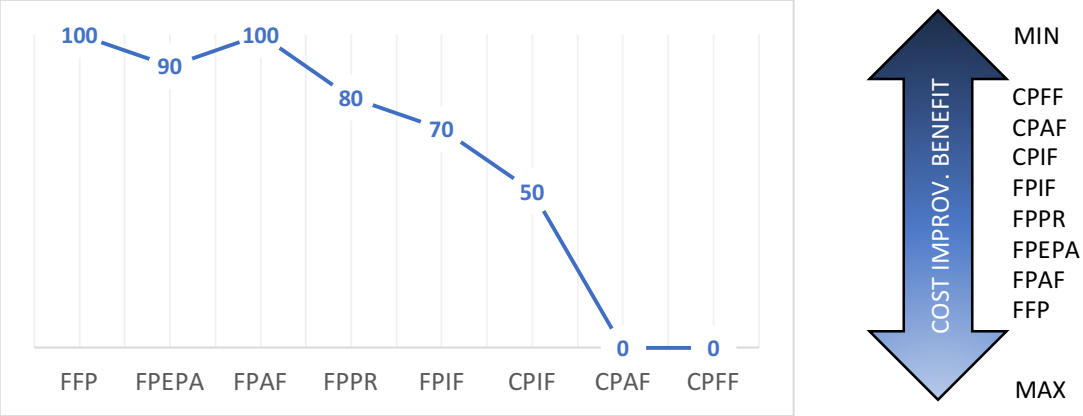


Figure 55- Cost Improvements Payoffs Graphic

4.3.2.2. Quality Beyond Requirements

Contract Type	Grade	Score	Ranking
FFP	None	0	3
FPEPA	None	0	3
FPAF	High	100	1
FPPR	Low	30	2
FPIF	None	0	3
CPIF	None	0	3
CPAF	High	100	1
CPFF	None	0	3

Table 41. Quality Beyond Requirements Payoffs

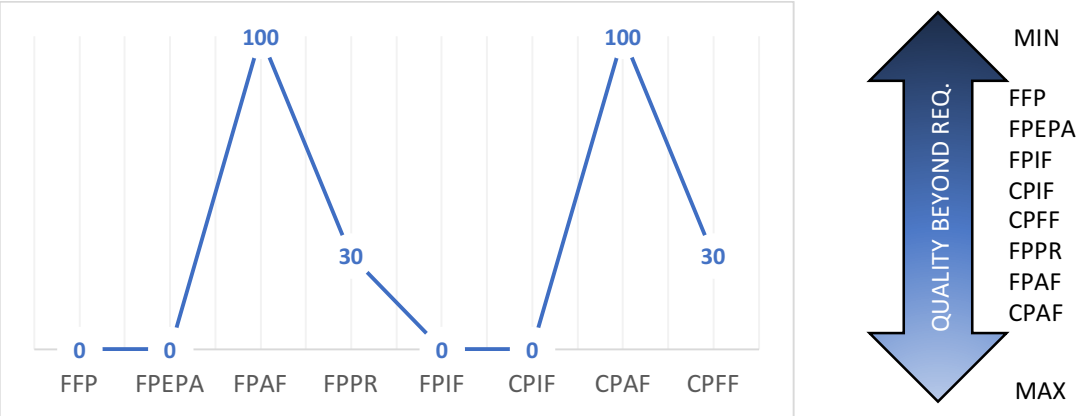


Figure 56- Quality Beyond Requirements Payoffs Graphic

4.3.2.3. Risk Precautionary Payment

Contract Type	Grade	Score	Ranking
FFP	High	100	1
FPEPA	High	80	2
FPAF	High	100	1
FPPR	High	70	3
FPIF	Medium	50	4
CPIF	Low	30	5
CPAF	None	0	6
CPFF	None	0	6

Table 42. Risk Precautionary Payment Payoffs

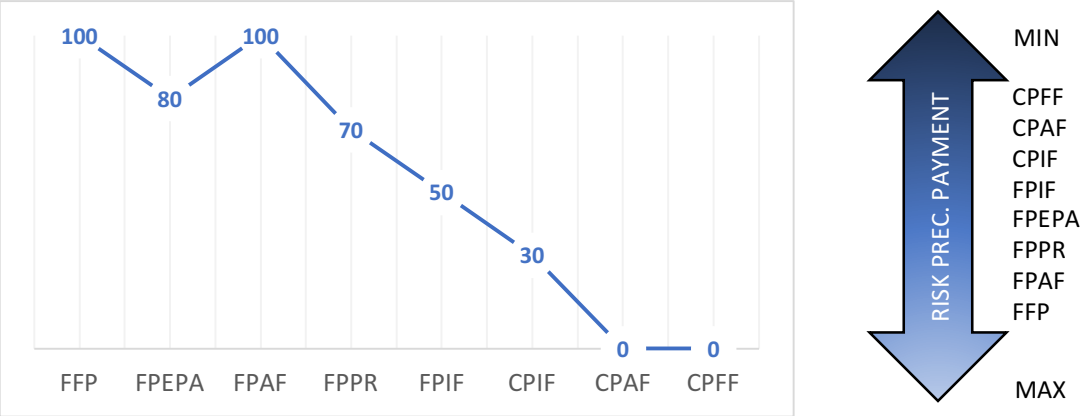


Figure 57- Risk Precautionary Payment Payoffs Graphic

4.3.2.4. Probability of Losses

Contract Type	Grade	Score	Ranking
FFP	High	0	7
FPEPA	High	20	6
FPAF	High	0	7
FPPR	High	30	5
FPIF	Medium	50	4
CPIF	Low	80	3
CPAF	Low	90	2
CPFF	None	100	1

Table 43. Probability of Losses Payoffs

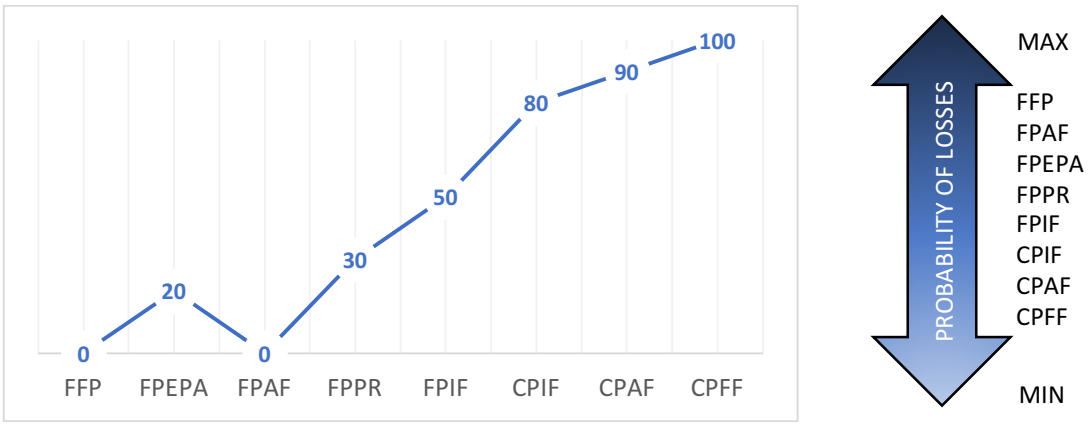


Figure 58- Probability of Losses Payoffs Graphic

4.3.2.5. Technical Deviations Consequences

Contract Type	Grade	Score	Ranking
FFP	High	0	4
FPEPA	High	0	4
FPAF	High	0	4
FPPR	High	10	3
FPIF	Medium	50	4
CPIF	Medium	60	2
CPAF	None	80	1
CPFF	None	100	1

Table 44. Technical Deviations Consequence Payoffs

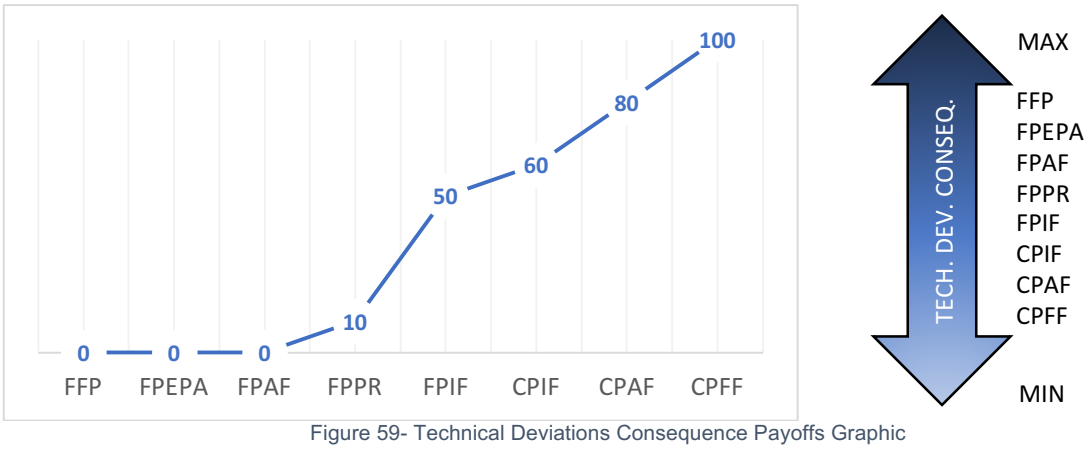


Figure 59- Technical Deviations Consequence Payoffs Graphic

4.3.2.6. Budget Deviations Consequences

Contract Type	Grade	Score	Ranking
FFP	High	0	6
FPEPA	High	30	4
FPAF	High	0	6
FPPR	High	20	5
FPIF	Medium	50	3
CPIF	Medium	70	2
CPAF	None	100	1
CPFF	None	100	1

Table 45. Budget Deviations Consequence Payoffs

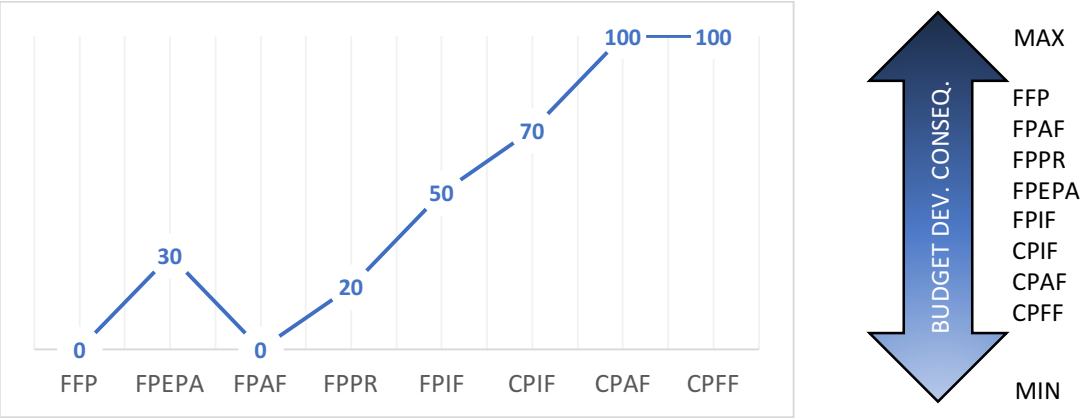


Figure 60- Budget Deviations Consequence Payoffs Graphic

4.3.2.7. Managerial Effort

Contract Type	Grade	Score	Ranking
FFP	Low	100	1
FPEPA	Low	90	2
FPAF	High	30	4
FPPR	Medium	60	3
FPIF	Medium	60	3
CPIF	High	20	5
CPAF	High	0	6
CPFF	High	30	4

Table 46. Managerial Effort Payoffs

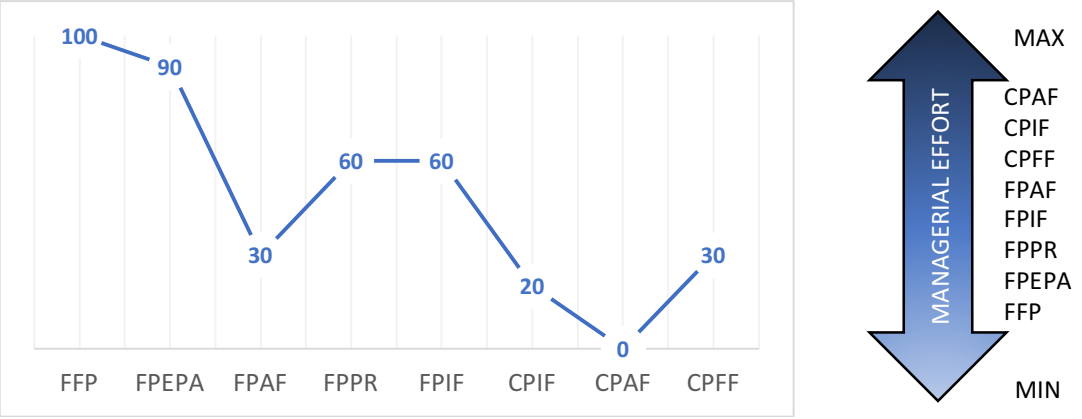


Figure 61- Managerial Effort Payoffs Graphic

4.4. Payoffs – Matrix

4.4.1. Client

The following tables are the compilation of the information showed in the previous section -4.3.1-.

Type	FFP	FFP-EPA	FPAF	FPPR	FPIF	CPIF	CPAF	CPFF
Probability of Overruns	None	Low	None	None	Low	High	High	High
Cost Improvements Sharing	None	Low	None	None	Medium	Medium	High	High
Risk Precautionary Payment	High	Medium	High	Medium	Low	Low	None	None
Technical Uncertainty Payment	High	High	High	High	Medium	Medium	None	None
Budget Uncertainty Payment	High	Medium	High	Medium	Low	Low	None	None
Managerial Effort	Low	Low	High	Medium	Medium	High	High	High
Contractor Cost Control	High	High	High	Medium	Medium	Medium	Low	Low
Excel Quality Incentive	None	None	High	Low	None	None	High	None
Change Flexibility	None	None	None	Low	None	High	High	High

Table 47. Client Payoffs Matrix - Values

Type	FFP	FFP-EPA	FPAF	FPPR	FPIF	CPIF	CPAF	CPFF
Probability of Overruns	100	70	100	100	80	30	0	0
Cost Improvements Sharing	0	20	0	0	50	50	100	100
Risk Precautionary Payment	0	20	0	30	50	70	100	100
Technical Uncertainty Payment	0	0	0	0	50	70	100	100
Budget Uncertainty Payment	0	20	0	30	50	70	100	100
Managerial Effort	100	90	30	60	60	20	0	30
Contractor Cost Control	100	90	80	40	70	50	20	0
Excel Quality Incentive	0	0	100	30	0	0	100	0
Change Flexibility	0	0	0	30	0	80	100	100
Total Scores	300	310	310	320	410	440	620	530

Table 48. Client Payoffs Matrix - Scores

The performance of the different contract types according to the evaluation factors obtained from the value tree expressed in the Table *48* can be appreciated in the following radar diagram:

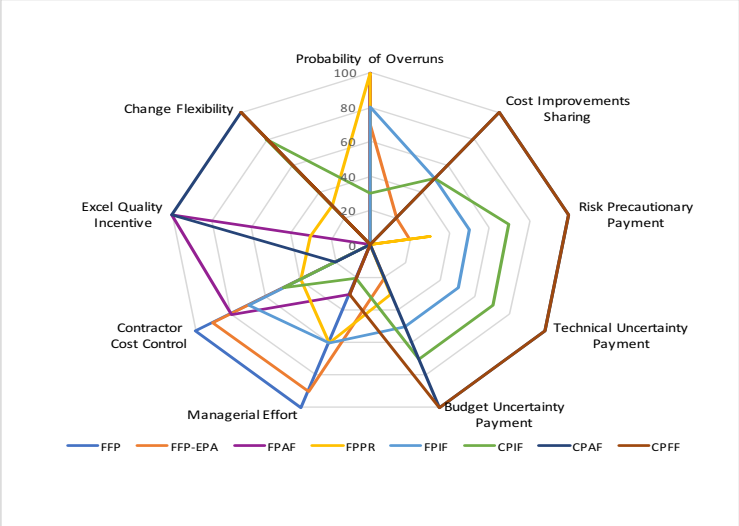


Figure 62- Client Radar Diagram Payoffs – Without Weights

The scores showed above do not express or have into account the preferences of the client respect which attributes are going to be prioritized, thus the decision cannot be made yet. The weight assignation is a subjective process that will be unique to every company, and the resultant "best choice"[19] will vary according to it.

Type	Weight	Pond. W	FFP	FFP-EPA	FPAF	FPPR	FPIF	CPIF	CPAF	CPFF
Probability of Overruns	100	0,22	21,7	15,2	21,7	21,7	17,4	6,5	0,0	0,0
Cost Improvements Sharing	30	0,07	0,0	1,3	0,0	0,0	3,3	3,3	6,5	6,5
Risk Precautionary Payment	20	0,04	0,0	0,9	0,0	1,3	2,2	3,0	4,3	4,3
Technical Uncertainty Payment	20	0,04	0,0	0,0	0,0	0,0	2,2	3,0	4,3	4,3
Budget Uncertainty Payment	40	0,09	0,0	1,7	0,0	2,6	4,3	6,1	8,7	8,7
Managerial Effort	100	0,22	21,7	19,6	6,5	13,0	13,0	4,3	0,0	6,5
Contractor Cost Control	100	0,22	21,7	19,6	17,4	8,7	15,2	10,9	4,3	0,0
Excel Quality Incentive	50	0,11	0,0	0,0	10,9	3,3	0,0	0,0	10,9	0,0
Change Flexibility	0	0,00	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Total Scores	460	1	65,2	58,3	56,5	50,7	57,6	37,2	39,1	30,4
Final Ranking			1	2	4	5	3	7	6	8

Table 49. Client Payoffs Matrix with weights

[19] In this step, the "best choice" is selected on the highest scores. Trade-offs and sensitivity analysis have not been performed yet.

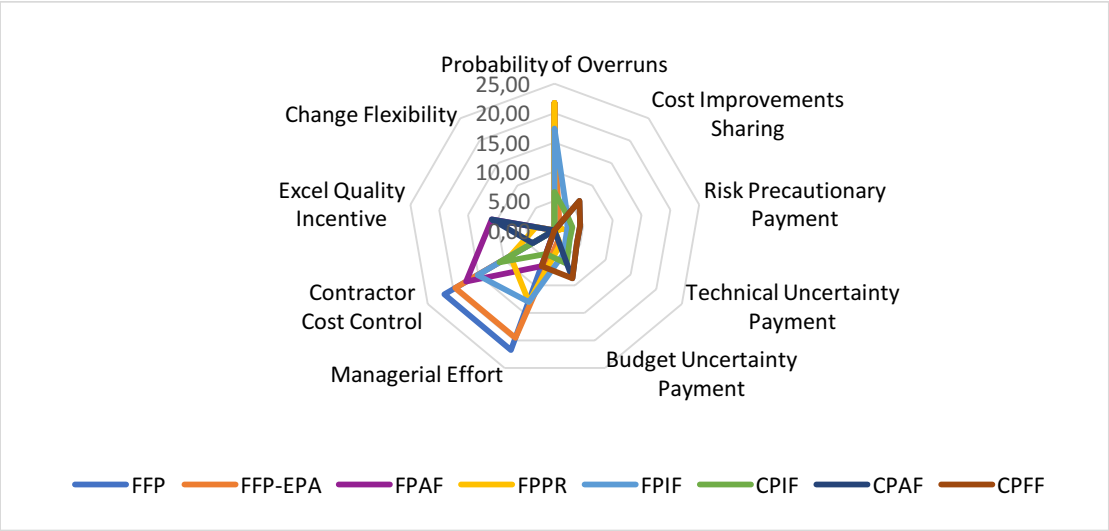


Figure 63- Client Radar Diagram Payoffs – With Weights

4.4.2. Contractor

The following tables are the compilation of the information showed in the section -4.3.2-.

Type	FFP	FFP-EPA	FPAF	FPPR	FPIF	CPIF	CPAF	CPFF
Cost Improvements Benefit	High	High	High	High	Medium	Medium	None	None
Quality Beyond Requirements	None	None	High	Low	None	None	High	None
Risk Precautionary Payment	High	High	High	High	Medium	Low	None	None
Probability of Losses	High	High	High	High	Medium	Low	Low	None
Technical Deviations Consequences	High	High	High	High	Medium	Medium	None	None
Budget Deviations Consequences	High	High	High	High	Medium	Medium	None	None
Managerial Effort	Low	Low	High	Medium	Medium	High	High	High

Table 50. Contractor Payoffs Matrix - Values

Type	FFP	FFP-EPA	FPAF	FPPR	FPIF	CPIF	CPAF	CPFF
Cost Improvements Benefit	100	90	100	80	70	50	0	0
Quality Beyond Requirements	0	0	100	30	0	0	100	30
Risk Precautionary Payment	100	80	100	70	50	30	0	0
Probability of Losses	0	20	0	30	50	80	90	100
Technical Deviations Consequences	0	0	0	10	50	60	80	100
Budget Deviations Consequences	0	30	0	20	50	70	100	100
Managerial Effort	100	90	30	60	60	20	0	30
Total Scores	300	310	330	300	330	310	370	360

Table 51. Contractor Payoffs Matrix – Scores

The performance of the different contract types according to the evaluation factors obtained from the value tree expressed in the Table *51* can be appreciated in the following radar diagram:

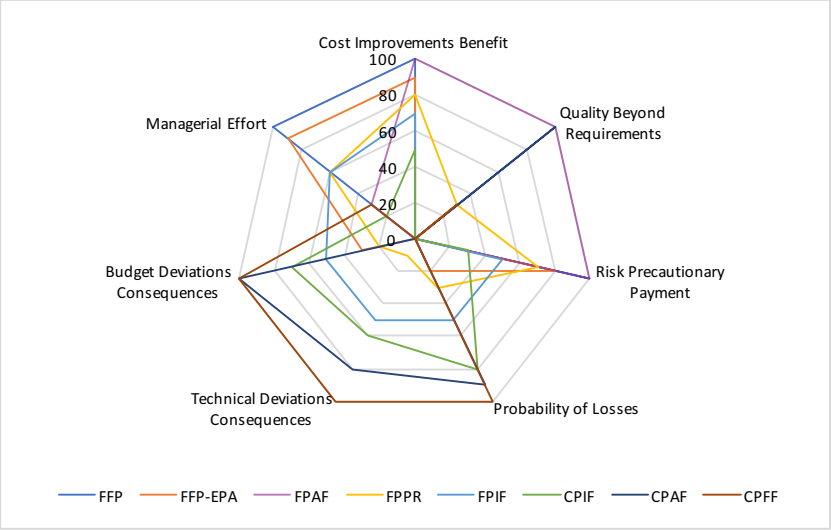


Figure 64- Contractor Radar Diagram Payoffs – Without Weights

The scores showed above do not express or have into account the preferences of the contractor respect which attributes are going to be prioritized, thus the decision cannot be made yet. The weight assignation is a subjective process that will be unique to every company, and the resultant "best choice"[19] will vary according to it.

Type	Weight	Pond. W	FFP	FFP-EPA	FPAF	FPPR	FPIF	CPIF	CPAF	CPFF
Cost Improvements Benefit	100	0,24	23,8	21,4	23,8	19,0	16,7	11,9	0,0	0,0
Quality Beyond Requirements	0	0,00	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Risk Precautionary Payment	100	0,24	23,8	19,0	23,8	16,7	11,9	7,1	0,0	0,0
Probability of Losses	100	0,24	0,0	4,8	0,0	7,1	11,9	19,0	21,4	23,8
Technical Deviations Consequences	40	0,10	0,0	0,0	0,0	1,0	4,8	5,7	7,6	9,5
Budget Deviations Consequences	30	0,07	0,0	2,1	0,0	1,4	3,6	5,0	7,1	7,1
Managerial Effort	50	0,12	11,9	10,7	3,6	7,1	7,1	2,4	0,0	3,6
Total Scores	420	1	59,5	58,1	51,2	52,4	56,0	51,2	36,2	44,0
Final Ranking			1	2	5	4	3	5	8	7

Table 52. Contractor Payoffs Matrix with weights

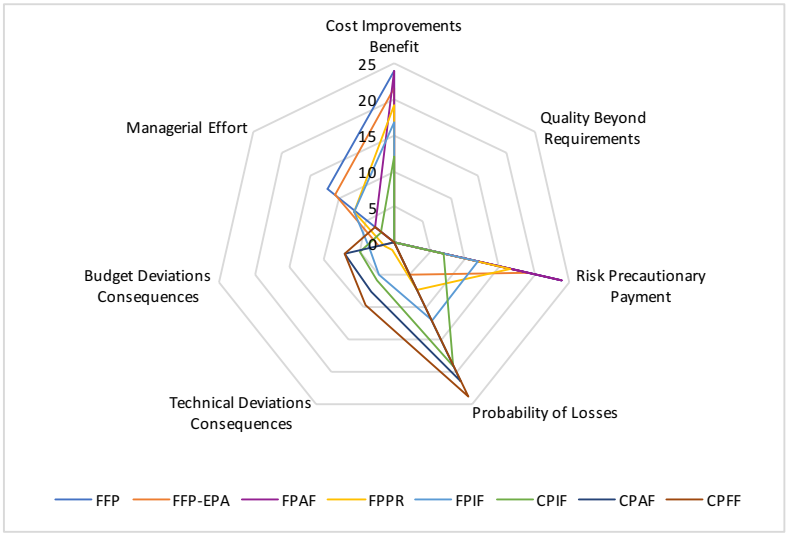


Figure 65- Contractor Radar Diagram Payoffs – With Weights

4.5. Sensitivity and Trade-offs

After having pre-chosen the "best alternative" either the client and contractor should execute a sensitivity analysis to know which are the attributes that have the greatest influence on the decision given their weight variation.

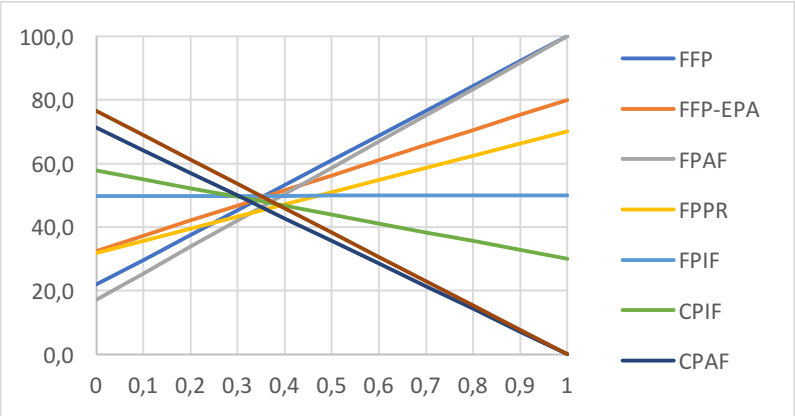


Figure 66- Contractor Risk Precautionary Payment – Sensitivity Analysis

Once the decision maker has assessed the sensitivity of the attributes over the result, it is necessary to compare the different cost-benefits of the best contract types to achieve a high-quality decision. This is done through the application of the last step in the decision analysis methodology using the cost-benefit graphic and deciding if the cost-benefit relationship is the most suitable according to the decision maker preferences:

Contractor	
Cost Improvements Benefit	Benefits
Quality Beyond Requirements	
Risk Precautionary Payment	
Probability of Losses Avoidance	
Technical Deviations Consequences	Costs
Budget Deviations Consequences	
Managerial Effort	

Client	
Cost Improvements Sharing	Costs
Risk Precautionary Payment	
Technical Uncertainty Payment	
Budget Uncertainty Payment	
Managerial Effort	
Probability of Overruns	Benefits
Contractor Cost Control	
Excel Quality Incentive	
Change Flexibility	

Table 53. Trade-off graphic Axes Parameters

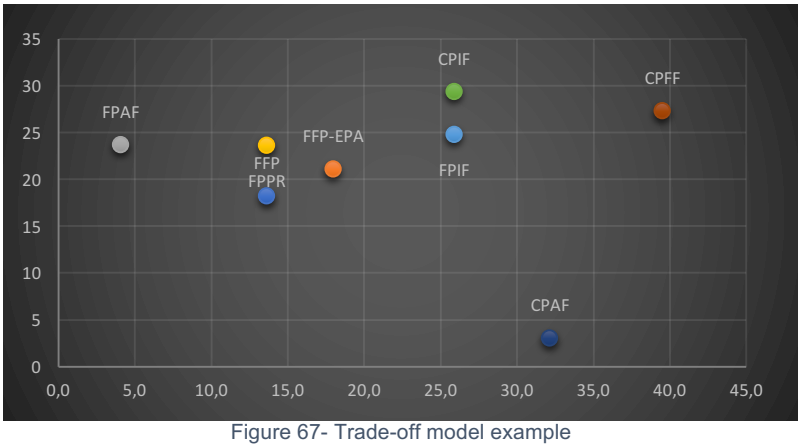


Figure 67- Trade-off model example

5. Decision Model Application

The following case is a theoretical example based on an exercise developed in the OFF-515 course -module 19- [12] at the UiS. We need to estimate the project execution cost -Figure 5- for a semisubmersible platform with the following estimated equipment weight parameters:

Equipment	Tonnes
Living quarters	23
Power generation area	574
Water injection area	387
Utilities area	790
Well/riser area	65
Separation area	309
Gas treatment area	113
Gas compression area	334
Other equipment (cranes, life boats....)	513

Table 54- Equipment list summary

Figure 68- Petrobras P55 Processing Platform in Roncador Field

Using the Bulk factors method for weight estimation, we obtain:

ITEM	Equipment	Electrical	Instrument	Piping	Safety	HVAC	Surface Protection	Architectural	Bulk	Structural steel	Weight by Area
Living quarters	23	69	12	16	19	107	10	573	805	997	1825
Utilities area	790	255	120	305	87	146	24	205	1142	2328	4260
Water injection area	387	41	15	161	11	22	7	34	290	668	1346
Power generation area	574	177	9	42	17	25	7	84	360	698	1632
Well/riser area	65	23	31	395	31	0	15	5	499	1465	2029
Drilling Module	0	0	0	0	0	0	0	0	0	0	0
Separation area	309	31	43	240	16	23	7	28	388	658	1356
Gas treatment area	113	21	8	88	9	9	4	16	154	386	653
Gas compression area	334	27	23	166	21	15	0	33	285	542	1161
Other equipment (cranes, life boats....)	513										513
Weight by Discipline	3108	643	261	1413	211	347	73	978	3925	7743	14776

Table 55- Platform Weight Estimation Breakdown

The estimated costs parameters for this development are:

Discipline vs Costs	Engineering		Procurement	Fabrication/Installation		Marine Operations	Hook-up & Commisioning	
	MHR/Tonne	USD/MHR	USD/Tonne	MHR/Tonne	USD/MHR	USD/Tonne	MHR/Tonne	USD/MHR
Equipment	90	175	88.000,00	20	170	5000	20	245
Electrical	90	175	41.000,00	450	170	5000	20	245
Instrument	90	175	90.000,00	400	170	5000	20	245
Piping	90	175	50.000,00	350	170	5000	20	245
Safety	90	175	25.000,00	300	170	5000	20	245
HVAC	90	175	32.000,00	300	170	5000	20	245
Surface Protection	90	175	25.000,00	1600	170	5000	20	245
Architectural	90	175	25.000,00	150	170	5000	20	245
Structural Steel	90	175	4.000,00	100	170	5000	20	245
				Atshore			Offshore	

Table 56- Cost Parameters Estimate Values

We will assume the following overhead values according to the different of contracts:

FFP	FPEPA	FPAF	FPPR	FPIF	CPIF	CPAF	CPFF
15%	20%	25%	20%	20%	25%	30%	25%

Table 57- Management Tariffs

Calculating the total cost of the project without any uncertainty, - estimated costs are true values- we will have:

Discipline	**Weight Tonnes**	Eng. (MUSD)	Proc. (MUSD)	F&I (MUSD)	Marine Ops (MUSD)	HU&C (MUSD)	Total Costs (MUSD)
Equipment	3108	48,95	273,50	10,57	15,54	15,23	
Electrical	643	10,13	26,36	49,19	3,22	3,15	
Instrument	261	4,11	23,49	17,75	1,31	1,28	
Piping	1413	22,25	70,65	84,07	7,07	6,92	
Safety	212	3,32	5,28	10,76	1,06	1,03	
HVAC	347	5,47	11,10	17,70	1,74	1,70	
Surface Protec.	78	1,15	1,83	19,86	0,37	0,36	
Architectural	978	15,40	24,45	24,94	4,89	4,79	
Structural Steel	7743	121,95	30,97	131,63	38,72	37,94	
Overall	14783	**232,74**	**467,63**	**366,46**	**73,89**	**72,41**	**1.213,13**

Table 58- Project Cost Baseline without Distributions consideration

To calculate the cost of the contracts respect the data above, we will do the following statements:

- The cost values showed above are true values (perfect estimation[20]).
- The exchange rate USD to NOK is 1 to 8,5.
- The final contract price will be agreed in NOK.
- The sharing factor between client-contractor is 70/30.
- The profit will be 10% of the project budget (FFP-FPEPA).
- The maximum award fee will be 5% of the project budget (50% increment on profit-AF).
- The guaranteed maximum price will be 20% of management reserve plus overhead cost (FPIF).
- The maximum and minimum fee will be 30% the target fee (CPIF).
- The fixed fee in the cost-plus contract types will be equal to the profit in the fixed-price contract types (the work to perform has change, just the contract type)

C-Type	Project Budget		Overhead		Max. Profit		Max. Contract Price (MUSD)	Max. Contract Price (MNOK)
	MUSD	MNOK	MUSD	%	MUSD	%		
FFP	1.213,13	10.311,6	181,97	15	121,13	10	1.516,23	12.887,95
FPEPA	1.213,13	10.311,6	242,62	20	121,13	10	1.576,88	13.403,48
FPAF	1.213,13	10.311,6	303,28	25	181,97	10+5	1.698.38	14.436,23
FPPR	1.213,13	10.311,6	242,62	20	121,13	10	1.576,88	13.403,48
FPIF	1.213,13	10.311,6	242,62	20	157,71	-	1.698,38	14.436,23
CPIF	1.213,13	10.311,6	303,28	25	157,71	10+3	1.638,38	13.926,23
CPAF	1.213,13	10.311,6	363,94	30	181,97	10+5	1.759,04	14.951,84
CPFF	1.213,13	10.311,6	303,28	25	121,97	10	1.638,38	13.926,23

Table 59- Contract Prices if perfect estimation occurs

Based on Hollman [28], we will consider that the estimated values showed above are not true values. These cost components will have the following characteristics -APPENDIX-E:

- Class estimation type: 3
- Estimator: Mean or Median (P50)
- Contingency: 20%
- Confidence level: 80%
- Project budget will be set at a P90 confidence

Important: it is considered that the client is interested only in accomplishment of the requirements expressed on the contract, none improvements will carry on extra profits to the contractor and it will be agreed without reassessment periods; the exogenous risks besides market behavior had not been considered. Therefore, the contract types FPPR-FPAF-CPAF will not be part of the decision alternatives, and the risk precautionary payment will and quality beyond requirements will not be decision attributes.

Using the simulation data using @Risk regards the behavior of the different contract types from the Table *95* till Table *98*, it is possible to set the following contract parameters:

[20] The estimated cost and the final real cost are equal.

Contract Type	Expect/Real Cost MNOK-P90	Expect/Real Overhead MNOK-P90	Expect/Real Profits MNOK-P90	Expect/Real C. Price MNOK-P90	S. Ratio Client-Contract	Target Price /Cost	Min Fee	Target Profit /Fee	Max Fee
FFP	12.852	1.927,80	1.285,20	16.064,98	0/100	-	-	-	-
FPEPA	11.971,09	2.394,22	1.197,11	15.562,42	0/100	-	-	-	-
FPIF	12.852	2.763,48	1.381,74	16.997 Expected 17.962,64 GMP	70/30	14.079 Mean	-	1.083 Mean	-
CPIF	12.852	3.213	1,083 Mean	17.148	70/30	10.830 Bud. Mean	877 -19%	1.083 Mean	1.382 +28%
CPFF	12.852	3.213	1,083 Mean	17.148	100/0	-	1,083 Mean	-	1.083 Mean

Table 60- Contract Types Parameters

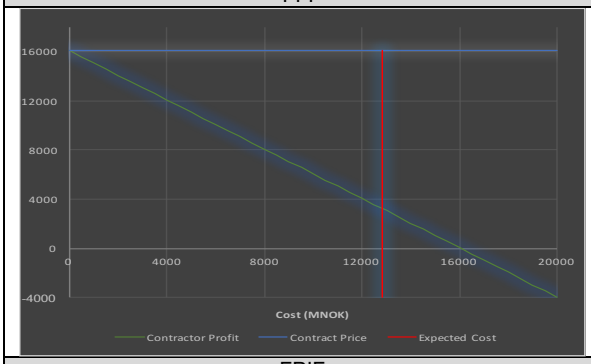
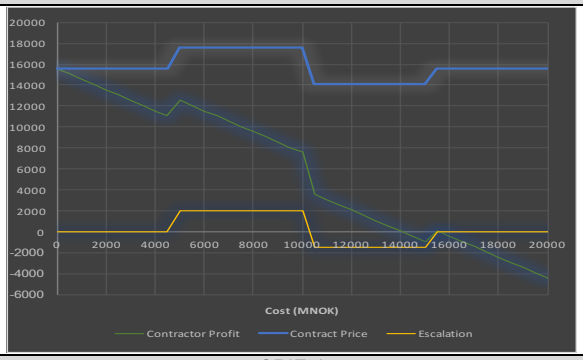
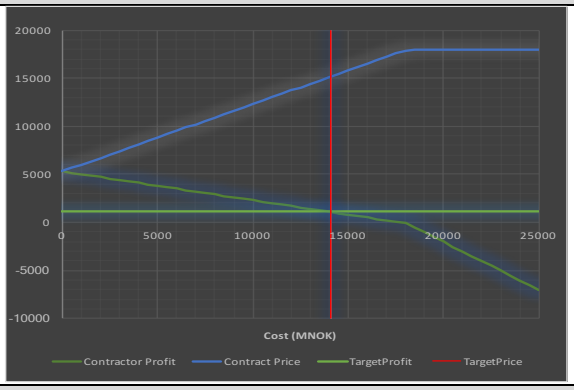
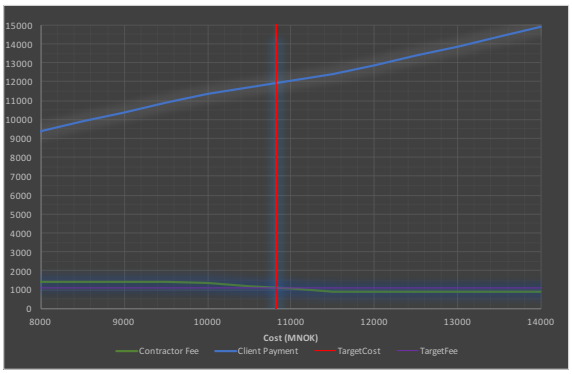
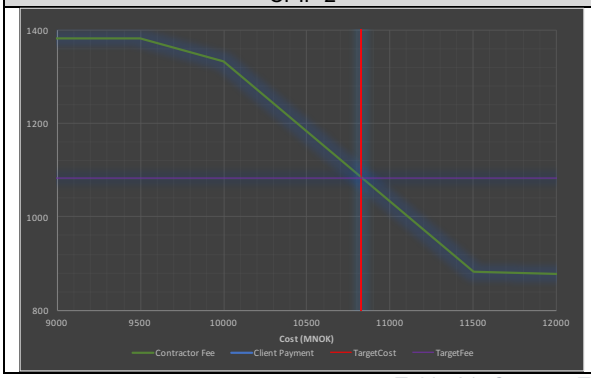
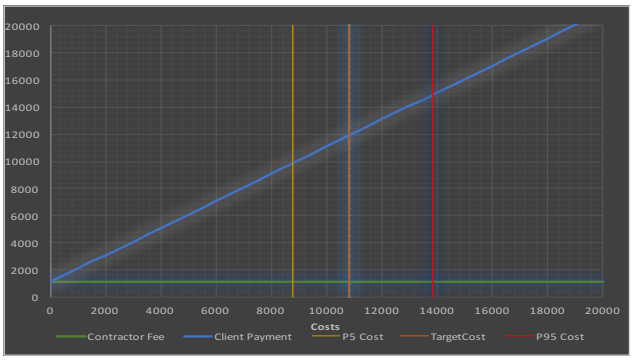
FFP	FPEPA
	
FPIF	**CPIF-1**
	
CPIF-2	**CPFF**
	

Table 61- Contract Types Graphics from Table 60

5.1. Contractor

According to the statements in the page 50 for the contractor we will have the following decision criteria:

- Cost Improvements Benefits: What happen if some main cost contributors behave in an optimistic way (probable values fall into the P0 to P5 zone)
- Probability of Losses Avoidance: What happen if some main profits contributors behave in a pessimistic way (probable values fall into the P90 to P95 zone)
- Technical Deviations Consequences: What happen with the contractor's profits when technical deviations occur (scope change, low performance).
- Budget Deviations Consequences: What happen with the contractor's profits when budget deviations occur (higher costs, market variations of currency exchange).
- Managerial Effort: How much does it cost (expected value).

Using the data in the APPENDIX-E, Table *60- Contract Types Parameters* and the formulas in the 2.2.1 section we obtain the following payoffs:

Contractor Payoff Matrix	Units	FFP	FPEPA	FPIF	CPIF	CPFF
Cost Improvements Benefits	MNOK	7.334,9[21]	5.818,13[21]	2.495,31[21]	1.382	1.082,98
Probability of Losses Avoidance	MNOK	-979,39[22]	-328,36	-30	877	1.082,98
Technical Deviations Consequences	MNOK	-436,56[23]	-105,48	-20	877	1.082,98
Budget Deviations Consequences	MNOK	-1536,68[24]	1302,28	506	877	1.082,98
Managerial Effort	MNOK	1.927,80	2.394,22	2.763,48	3.455,99	3.455,99

Table 62- Contractor Payoffs Matrix

Given that all the components in the matrix above use the same units, it is not necessary to convert these values to scores. As next step, we will evaluate the matrix applying the weights according to contractor's preferences.

Type	Weight	Pond. W	FFP	FFP-EPA	FPIF	CPIF	CPFF
Cost Improvements Benefits	20	0,07	489,0	387,9	166,4	92,1	72,2
Probability of Losses Avoidance	100	0,33	-326,5	-109,5	-10,0	292,3	361,0
Technical Deviations Consequences	60	0,20	-87,3	-21,1	-4,0	175,4	216,6
Budget Deviations Consequences	70	0,23	-358,6	303,9	118,1	204,6	252,7
Managerial Effort	50	0,17	321,3	399,0	460,6	576,0	576,0
Total Scores	300	1,00	38,0	960,2	731,0	1340,5	1478,5
			5	3	4	2	1

Table 63- Contractor Payoffs Matrix with Weights and Ranking

Given the highest payoff values, the best option given the preferences of the contractor is the CPFF contract type. This partial decision is driven by the high weights related to the attributes that assurance of profits (2,3,4). To take a high-quality decision, it is necessary to evaluate all the information available including the trade-offs[25] between the different alternatives and the sensitivity of our decision to the weights values -Table 100-.

5.2. Client

According to the statements in the page 50 for the contractor we will have the following decision criteria:

- Probability of Overruns: Client happen whit the client payment amount, if Top-3 main cost contributors behave in a pessimistic way (probable values fall into the P90 to P95 zone)
- Cost Improvements Sharing: Difference between expected contract price and final contract price, if Top-3 main cost contributors behave in an optimistic way (probable values fall into the P0 to P5 zone)
- Technical Uncertainty Payment: How much more the client pays over the expected budget to cover technical deviations (scope change and performance components are set to expected value).
- Budget Uncertainty Payment: How much more the client pays over the expected budget to cover budget deviations (costs and market variation components are set to expected value).

[21] @Risk stress analysis on cost with the Top-3 main variation contributors over contract price from the tornado chart settled from P0 to P5, and the effect over contractor's profits.
[22] @Risk stress analysis on cost with the Top-3 main variation contributors over contract price from the tornado chart settled from P90 to P95, and the effect over contractor's profits.
[23] @Risk stress analysis on cost with the Top-3 main variation contributors over the quantity of man-hours from the tornado chart settled from P90 to P95, and the effect over contractor's profits. Table 99
[24] @Risk stress analysis on the profit with the Top-3 main budget variation contributors settled from P90 to P95, and the effect over contractor's profits.
[25] Cost Improvements Benefit and Probability of Losses Avoidance are considered as benefits, the other attributes are considered costs.

- Managerial Effort: How much does it cost (expected value).
- Contractor Cost Control: Rewards to the contractor if the control over the main cost contributors is executed in an effective way (probable values fall into the P0 to P5 zone).
- Change Flexibility: how easy is to use introduce changes to the scope

Using the data in the APPENDIX-E, Table *60- Contract Types Parameters* and the formulas in the 2.2.1 section we obtain the following payoffs:

Client Payoff Matrix	Units	FFP	FPEPA	FPIF	CPIF	CPFF
Probability of Overruns	MNOK	16.064,98	17.030,42[26]	17.962,64 GMP	21.073,25	21.279,23
Cost Improvements Sharing	MNOK	0	536[27]	923	2.480,25	2.985,7
Technical Uncertainty Payment	MNOK	680	680	280	225	0[28]
Budget Uncertainty Payment[29]	Score	0	20	50	70	100
Managerial Effort	MNOK	1.927,80	2.394,22	2.763,48	3.455,99	3.455,99
Contractor Cost Control	MNOK	7334,9	5818,1321	2495,3121	1382	1082,98
Change Flexibility	Score	0	0	0	80	100

Table 64- Client Payoffs Matrix Values

Given that not all the components in the matrix above use the same units, it is necessary to convert these values to scores -Table 101-, obtaining the following table:

Client Payoff Matrix	Units	FFP	FPEPA	FPIF	CPIF	CPFF
Probability of Overruns	Score	100	81	64	4	0
Cost Improvements Sharing	Score	0	18	31	83	100
Technical Uncertainty Payment	Score	0	0	59	67	100
Budget Uncertainty Payment	Score	0	20	50	70	100
Managerial Effort	Score	100	69	45	0	0
Contractor Cost Control	Score	100	76	23	5	0
Change Flexibility	Score	0	0	0	80	100

Table 65- Client Payoffs Matrix Scores

As next step, we will evaluate the matrix applying the weights according to contractor's preferences:

Client Payoff Matrix	Weight	Pond. W	FFP	FFP-EPA	FPIF	CPIF	CPFF
Probability of Overruns	100	0,24	24,4	19,9	15,5	1,0	0,0
Cost Improvements Sharing	30	0,07	0,0	1,3	2,3	6,1	7,3
Technical Uncertainty Payment	20	0,05	0,0	0,0	2,9	3,3	4,9
Budget Uncertainty Payment	40	0,10	0,0	2,0	4,9	6,8	9,8
Managerial Effort	100	0,24	24,4	16,9	11,1	0,0	0,0
Contractor Cost Control	100	0,24	24,4	18,5	5,5	1,2	0,0
Change Flexibility	20	0,05	0,0	0,0	0,0	3,9	4,9
Total Scores	300,00	1,00	73,2	58,6	42,1	22,2	26,8
			1	2	3	5	4

Table 66- Client Payoffs Matrix with Weights and Ranking

Given the highest payoff values, the best option given the preferences of the client is the FFP contract type. This partial decision is driven by the high weights related to the attributes that avoid overruns and maximize the cost control (1,6). To take a high-quality decision, it is necessary to evaluate all the information available including the trade-offs[30] between the different alternatives and the sensitivity of our decision to the weights values -Table 102 -.

[26] Fixed Price plus the effect of variations (P90 to P95) on currency exchange rate, inshore labour cost and atshore labour cost.
[27] Fixed Price minus the effect of variations (P0 to P5) on currency exchange rate, inshore labour cost and atshore labour cost.
[28] The client will pay for actual performance not for expected.
[29] Values from APPENDIX-E
[30] Cost Control and Change Flexibility are considered as benefits, the other attributes are considered costs.

6. Conclusions

A decision analysis methodology has been proposed as a new approach for contract type selection. The results obtained are consistent with the FAR-16 theory given the alternatives behavior for the client and contractor, the Table 100 and Table 102 shows the matching of the model with the widely described and accepted risk exposure relationship with the contract type in the Figure 72.

The model represents and allows to measure in a simple way, the interests of both the client and the contractor when choosing a type of contract. Moreover, the difference in prices between the types of contract and its link with the different responsibilities and risks of the parties is clear and quantifiable. This will help the decision maker to think about the capacity and interests of the organization before pre-selecting a type as good or bad.

Terms such as high / low scope / technical uncertainty have been broken down and measured through specific indicators in project management theory, this helps to clearly understand why some specific kind of contracts are suggested for some specific type of projects. This assessment also gives the possibility to measure each field in a more precise way extending the range of possible performance values.

This tool could improve negotiation practices, raising the awareness about the real cost-benefits of each contract type, assessing and valuing the impacts over the client and contractor organizations. It is important to remind that the successful application of decision analysis is based on the ability to obtain quality information about the industry in which the type of contract and the interests of the parties will be selected. Furthermore, the access and consolidation of wide database about work performance, cost variation, cost of equipments, … will help us to define more accurate estimations and develop better management strategies.

One of the consistent main components affecting cost estimates of a project budget, is the currency exchange. This factor will impact heavily on the price and risk exposure of the client and contractor, it is necessary to assess how the escalation risks will be generally value in the industry where the contract type selection model will apply, in order to improve the estimates of the tenders.

Some further work that could improve effectively this thesis are:

- Validate from a wide survey between experienced managers (no matter the industry sector) the decision criteria for the contractor and the client
- Study and establish the common typical overhead percentages, management structures and earn value measurement procedures according to each contract type, specially in the cost reimbursement type.

Remember that:

> “Essentially, all the models are wrong but some are useful”
>
> George Edward Pelham Box

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APPENDIX

1. APPENDIX-A

The following information is based on the NASA document Award Fee Contracting Guide [25].

Subjective measured contracts are special case contracts (FPAF-CPAF), where key elements (requirements, standards) cannot provide for an accurate and fair measure of the contractor's performance. Most elements of performance can only be evaluated using subjective criteria and assessment of achieved performance and tantamount award fee using judgement.

Award fee contracts are the least preferred -*Figure 69*-. Recall that any contract plus contract should be selected if there is a fixed price contract that can fulfil the contract requirements, and objectively measured contracts are preferred over subjectively measured ones.

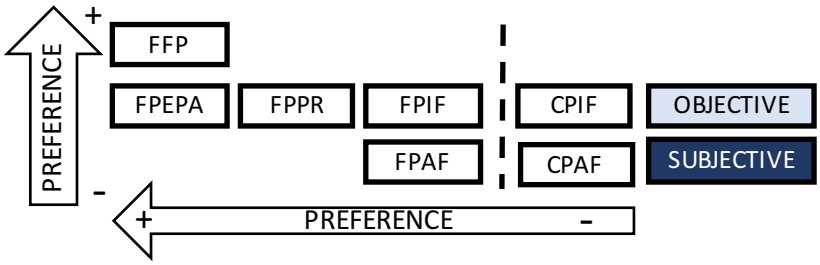


Figure 69- Performance Based Contracts Preference

Since award fee contracts require additional administrative effort, they should only be used when the contract values, performance period, and expected results warrant that additional management effort. Careful tailoring of the contract should prevent a situation in which the award fee administrative burden is out of proportion to the improvements expected in the quality of the contractor's performance and in overall project management. A cost-benefit analysis (administrative cost vs expected benefits) must be executed prior contract award to guarantee that the value added to the program by using an award fee type contract is greater than the costs to administer it.

The administrative cost is calculated using the grade levels and hours required to monitor, evaluate, brief and implement the award fee process. A general award fee structure is showed in Figure *70* and the fee awarding process is showed in Figure *71*.

Fee Determination Offical	•Establish the PEB •Approbe the award fee evaluation plan and changes •Evaluate award fee with PEB •Decide final awarde fee amount
Performance Evaluation Board	•Evaluate contractor performance and reccomend a for approval award fee amount based on performance monitors reports •Develop the performance evaluation plan (PEP) •Reccomend changes to PEP in order to reflect program evolution
Functional Monitors (Optional)	•Performance Evaluation Coordinators •Used when a large number of performance monitors are involved •Responsible by functional areas to coordinate monitors and execute Functional Monitor Report (FMR) for the PEB.
Performance Monitors	•Provide the Performance Monitor Report (PMR) to the PEB •Are specialists intimately familiar with the evaluated areas •Reccomend changes in performance evaluation plan

Figure 70- Award Fee Organizational Levels

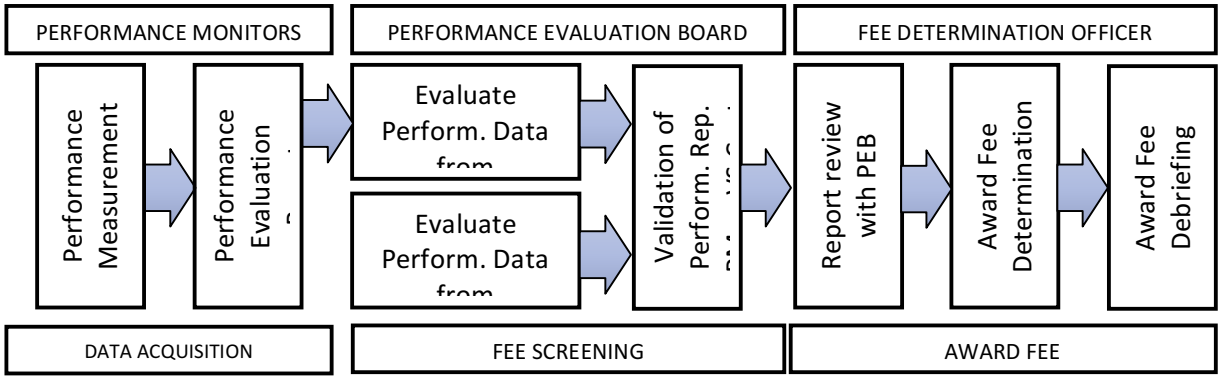


Figure 71- Award Fee Process

Performance monitoring and assessment skills for subjectively measured and evaluated contract types are higher that objectively ones. Training of all personnel involved in the award fee process is essential for successful monitoring and evaluation of contractor performance and should cover things like the award fee plan, roles and responsibilities, documentation requirements, and evaluation techniques. It is important to understand:

- Award fee plan phases and important parameters
- What is being evaluated? (e.g., factors and sub factors)
- Data collection processes; what techniques will be used?
- Data sampling (e.g., daily, weekly or monthly)
- Evaluation scoring processes

The factors and sub factors to be used must be carefully structured in order to avoid increased costs for little or no improvement in performance, or cost savings with a corresponding loss in performance. An example of this could be:

- Technical Performance
  - Design: Approach in design concepts, analysis, execution and low cost design and manufacturing.
  - Development: Conception/execution of manufacturing processes, test plans and techniques.
  - Quality: Quality assurance
  - Technical: weight control, maintainability, reliability, design reviews, test procedures.
  - Processing Documentation: Timely and efficient preparation, implementation and closeout.
  - Schedule: Meeting milestones and contractual delivery dates, reaction time and response to changes.
  - Safety: Providing a safe work environment, inspections, safety training for all personnel.
  - Information Management: Ability to provide adequate, timely and cost effective support.
  - Material Management: Efficient and effective processing of requisitions.
- Project Management
  - Program Planning/Organization/Management
  - Compliance with contract provisions: Effectiveness of property and material control, Equal Employment Opportunity Program, Minority Business Enterprise Program, system and occupational safety and security.
  - Timely and accurate financial management reporting.
- Cost Control
  - Control of indirect and overtime costs.
  - Control of direct labour costs.
  - Economies in use of personnel, energy, materials, computer resources, facilities, etc.
  - Reduced purchasing costs through increased use of competition, material inspection, etc.

An example of the subjective scoring is -Table 67-:

Adjectival Rating	Points	Description
Excellent	100-91	Exceptional Performance beyond requirements in key parameters Positive time and budget delivery/underruns deviations Very minor (if any) quality deviations No negative effect on overall performance
Very Good	90-81	Very effective

		Requirements accomplishment No time and budget delays/overruns deviations Minor quality deviations No negative effect on overall performance
Good	80	Effective performance Requirements accomplishment Small time and budget delays/overruns deviations Reportable quality deviations Minor negative effect on overall performance.
Satisfactory	70-61	Standard performance Acceptable requirements accomplishment Reportable time and budget delays/overruns deviations Reportable quality deviations Single area negative effect on overall performance.
Poor/ Unsatisfactory	Less than 61	Not acceptable requirements accomplishment Remedial actions required Multiple areas negative effect on overall performance

Table 67. Subjective Scoring Table

It is important to highlight that the contractor will earn a base fee (fixed amount part of the award fee scheme) for satisfactory contract performance and for poor/unsatisfactory performance could earn no fee.

If you want a more detailed description and example of the process described above please refer to the NASA document Award Fee Contracting Guide [25].

2. APPENDIX-B

The literature related to contract types is very consistent on the risk exposure classification of the contract types but ambiguous defining and quantifying the risk levels, mainly because risk assessment is an exercise merely subjective and related to size, nature and knowledge of the company that executes or for who the work is been done. It is common to find terms like low, lower, high, higher, and moderate, but it is very consistent with the risk exposure showed in the Figure *72*:

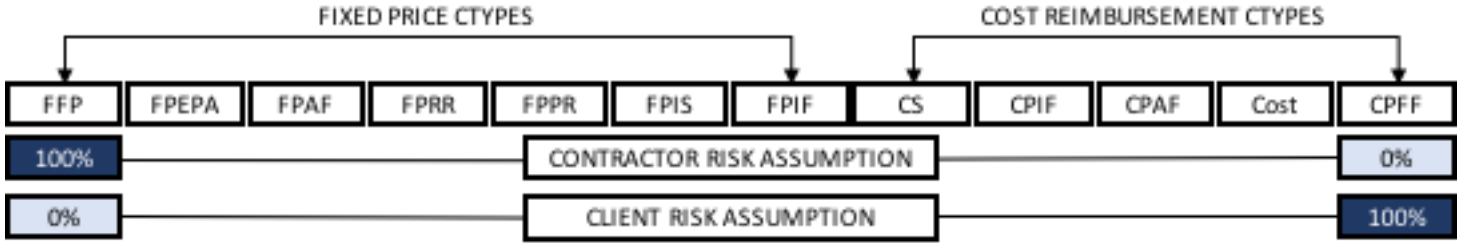


Figure 72- Risk Exposure and Contract Types

For the decision model, will use the following contract types -Figure *73*-:

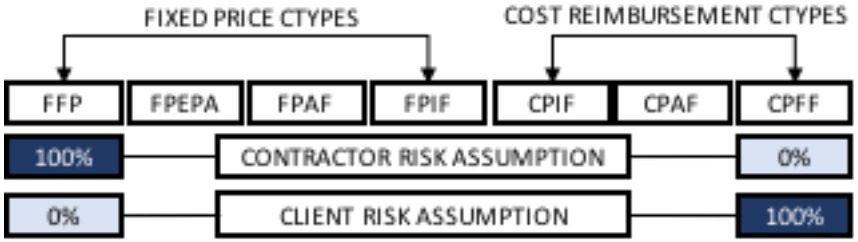


Figure 73- Risk Exposure and Contract Types for Decision Model

According to the expose among the section 2.2.1 of this thesis we can build the *Table 68. Contract Types Summary*:

TECHNICAL UNCERTAINTY	**Scope Specification Level**											
	Attribute	**FFP**	**FFP-EPA**	**FPAF**	**FPPR**		**FPIF**		**CPIF**		**CPAF**	**CPFF**
	Work to Perform	Detailed	Detailed	Detailed	Detailed		Detailed		Detailed		Detailed	Detailed
	Product to Deliver	Detailed	Detailed	Detailed	Detailed	General	Detailed	General	Detailed	General	Detailed	General
	Grade	High	High	High	High	Low	High	Low	High	Low	High	Low
	Process Execution Level of Knowledge											
	Attribute	**FFP**	**FFP-EPA**	**FPAF**	**FPPR**		**FPIF**		**CPIF**		**CPAF**	**CPFF**
	Activities, Resources and Sequences	Proficient or Expert	Proficient or Expert	Proficient or Expert	Advanced Beginner or Competent	Proficient or Expert	Advanced Beginner or Competent	Proficient or Expert	Advanced Beginner or Competent	Proficient or Expert	Proficient or Expert	Advanced Beginner or Competent
	Risks and Contingencies	Proficient or Expert	Proficient or Expert	Proficient or Expert	Advanced Beginner or Competent	Proficient or Expert	Advanced Beginner or Competent	Proficient or Expert	Advanced Beginner or Competent	Proficient or Expert	Proficient or Expert	Advanced Beginner or Competent
	Grade	High	High	High	Low	High	Low	High	Low	High	High	Low
	Technical Uncertainty-Score	Low	Low	Low	Medium		Medium		Medium		Low	High

BUDGET UNCERTAINTY	**Cost Uncertainty**							
	Attribute	**FFP**	**FFP-EPA**	**FPAF**	**FPPR**	**FPIF**	**CPIF**	**CPAF**	**CPFF**
	Estimated Cost	Based on updated, historic and pertinent information. High accuracy	Based on updated, historic and pertinent information. High accuracy	Based on updated, historic and pertinent information. High accuracy	Based on updated, historic and pertinent information. High accuracy	Based on updated, historic and pertinent information. High accuracy	Based on updated, historic and pertinent information. High accuracy	Based on updated, historic and pertinent information. High accuracy	Based on updated, historic and pertinent information. High accuracy
	Variance	Low	Low	Low	Medium	Medium	Medium	High	High
	Grade	Low	Low	Low	Medium	Medium	Medium	High	High
	Forecasted Market Behaviour								
	Attribute	**FFP**	**FFP-EPA**	**FPAF**	**FPPR**	**FPIF**	**CPIF**	**CPAF**	**CPFF**
	Information Quality	Based on updated, historic and pertinent information. High quality	Based on updated, historic and pertinent information. High quality	Based on updated, historic and pertinent information. High quality	Based on updated, historic and pertinent information. High quality	Based on updated, historic and pertinent information. High quality	Based on updated, historic and pertinent information. High quality	Based on updated, historic and pertinent information. High quality	Based on updated, historic and pertinent information. High quality
	Variance	Low	High	Low	Low	Low	Medium	High	High

	Grade	Low	High	Low	Low	Low	Medium	High	High
	Budget Uncertainty-Score	Low	Low	Low	Medium	Medium	High	High	High
MANAGERIAL EFFORT	**Administrative Burden**								
	Attribute	**FFP**	**FFP-EPA**	**FPAF**	**FPPR**	**FPIF**	**CPIF**	**CPAF**	**CPFF**
	KPIs	Objective	Objective	Subjective	Objective	Objective	Objective	Subjective	Objective
	Payment Procedures	Fixed Invariable price Based on accomplishment of requirements	Fixed Price vary under specific conditions Based on accomplishment of requirements	Formula Based Price vary under specific conditions Based on periodic custom & specialized performance evaluations	Fixed Invariable price Based on accomplishment of requirements	Formula Based Price Analysis for payment determination	Formula Based Cost Analysis for fee determination Justification of allowability, reasonability and allocability of costs.	Formula Based Cost Analysis for fee determination Justification of allowability, reasonability and allocability of costs. Based on periodic custom & specialized performance evaluations	Fixed Cost Analysis for fee determination Justification of allowability, reasonability and allocability of costs.
	Grade	Low	Low	High	Low	Medium	High	High	High
	Monitoring & Control Effort								
	Attribute	**FFP**	**FFP-EPA**	**FPAF**	**FPPR**	**FPIF**	**CPIF**	**CPAF**	**CPFF**
	Performance Monitoring	Objective	Objective	Subjective	Objective	Objective	Objective	Subjective	Objective
	Project Control	Contractor is responsible for project execution and delivery of agreed product Forecasted vs Actual performance based	Contractor is responsible for project execution and delivery of agreed product Forecasted vs Actual performance based Monitoring of market conditions trigger for EPA	Contractor is responsible for project execution and delivery of agreed product Custom & Specialized assessment techniques for fee determination. Expert personnel on final delivered performance areas.	Contractor is responsible for project execution and delivery of agreed product Price analysis and performance monitoring for renegotiation of next period contract price.	Contractor is responsible for project execution and delivery of agreed product Forecasted vs Actual performance based Price analysis for fee determination	Client is responsible for project delivery of final product Contractor is responsible for execution of an agreed performance	Client is responsible for project delivery of final product Contractor is responsible for execution of an agreed performance	Client is responsible for project delivery of final product Contractor is responsible for execution of an agreed performance
	Grade	Low	Low	High	Medium	Low	High	High	High
	Managerial Effort-Score	Low	Low	High	Medium	Medium	High	High	High

Change Flexibility								
Attribute	**FFP**	**FFP-EPA**	**FPAF**	**FPPR**	**FPIF**	**CPIF**	**CPAF**	**CPFF**
Scope change consequences	Any change on the scope is susceptible to renegotiation of price process.	Any change on the scope is susceptible to renegotiation of price process.	Any change on the scope is susceptible to renegotiation of price process. Renegotiation of award fee scheme according to new conditions.	Scope adjustments require renegotiation of next period contract price	Any change on the scope is susceptible to renegotiation of price process. Renegotiation of formula parameters according to new conditions.	Easy to adjust the scope or make variations without significant problems Cost baseline changes will require renegotiation of formula parameters	Easy to adjust without significant problems Cost baseline changes does not require renegotiation Scope changes may require renegotiation of award fee schemes.	Easy to adjust the scope or make variations without significant problems Cost baseline changes does not require renegotiation of formula parameters.
Grade	Low	Low	Low	Medium	Low	High	High	High
Contractor Cost Control Incentive								
Attribute	**FFP**	**FFP-EPA**	**FPAF**	**FPPR**	**FPIF**	**CPIF**	**CPAF**	**CPFF**
Owner of improvements by cost reduction or higher efficiency	All savings belongs to contractor.	Savings belongs to contractor. It doesn't include market uncertainty	All savings belongs to contractor. Cost improvement may be linked to award fee scheme, but is not the main one.	Savings during contract period belongs to contractor. Next period contract price will be reduced according to savings of former period.	Savings are shared according to a formula between client-contractors Contractor has no guaranteed profits Price ceiling for client	Savings are shared according to a formula between client-contractors Contractor has guaranteed minimum and maximum fee No price ceiling for client	Cost improvement may be linked to award fee scheme, but is not the main one. Fixable cost aligned principal-agent relationship	Cost improvements are not linked to contractor's profits. Contractor has guaranteed profits. Strong competitive principal-agent relationship
Grade	High	High	High	Low	Medium	Medium	Low	None
Excel Quality Incentive								
Attribute	**FFP**	**FFP-EPA**	**FPAF**	**FPPR**	**FPIF**	**CPIF**	**CPAF**	**CPFF**
Recognition of quality beyond requirements	Quality improvements are not linked to any extra profit Strong competitive Principal-Agent relationship	Quality improvements are not linked to any extra profit Strong competitive Principal-Agent relationship	Quality improvement represent the main profits components in award fee scheme Aligned principal-agent relationship	Quality improvement may signify an extra profit, not the main one. Fixable aligned principal-agent relationship	Quality improvements are not linked to any extra profit Strong competitive Principal-Agent relationship	Quality improvements are not linked to any extra profit Strong competitive Principal-Agent relationship	Quality improvement are the main profits components in award fee. Aligned principal-agent relationship	Quality improvement are not linked to any extra profit Strong competitive Principal-Agent relationship
Grade	None	None	High	Low	None	None	High	None
Contractor Risk Level								

Attribute	FFP	FFP-EPA	FPAF	FPPR	FPIF	CPIF	CPAF	CPFF
Profits	Not Guaranteed Fixed Price	Not Guaranteed Fixed Price	Not Guaranteed Fixed Price	Not Guaranteed Fixed Price	Not Guaranteed Price Ceiling	Guaranteed Maximum and Minimum Fee	Guaranteed Minimum + Award Fee	Guaranteed Minimum Fee
Forecast Period	Entire Contract	Entire Contract	Entire Contract	Next contract period	Entire Contract	Entire Contract	Entire Contract	Entire Contract
Risk Assumption	All risks occurrence All performance deviations	All risks occurrence besides escalation All performance deviations	All risks occurrence besides escalation All performance deviations	All risks occurrence besides escalation All performance deviations	Shared risks occurrence Shared performance deviations	Shared risks occurrence besides escalation Shared performance deviations	None	None
Grade	High	High	High	Medium	Medium	Low	Low	Low
Client Risk Level								
Attribute	**FFP**	**FFP-EPA**	**FPAF**	**FPPR**	**FPIF**	**CPIF**	**CPAF**	**CPFF**
Contract Price Overrun	None Fixed Price	Low Fixed Price+ Escalation	None Fixed Price+ Award Fee	None Fixed Price	None Maximum Price	Probable No Price Limit Maximum and Minimum Fee	Probable No Price Limit	Probable No Price Limit
Forecast Period	Entire Contract	Entire Contract	Entire Contract	Next contract period	Entire Contract	Entire Contract	Entire Contract	Entire Contract
Risk Assumption	None	Escalation	None	None	Shared risks occurrence Shared performance deviations	Shared risks occurrence Shared performance deviations	All risks occurrence All performance deviations	All risks occurrence All performance deviations
Grade	None	Low	Low	None	Medium	High	High	High

Table 68. Contract Types Summary

	FFP	FFP-EPA	FPAF	FPPR		FPIF		CPIF		CPAF	CPFF
Scope Specification Level	High	High	High	High	Low	High	Low	High	Low	High	Low
Process Execution Level of Knowledge	High	High	High	Low	High	Low	High	Low	High	High	Low
Technical Uncertainty	Low	Low	Low	Medium		Medium		Medium		Low	High
Cost Uncertainty	Low	Low	Low	Medium		Medium		Medium		High	High
Market Uncertainty	Low	High	Low	Low		Low		Medium		High	High
Budget Uncertainty	Low	Low	Low	Medium		Medium		High		High	High
Administrative Burden	Low	Low	High	Low		Medium		High		High	High
Monitoring & Control Effort	Low	Low	High	Medium		Low		High		High	High
Managerial Effort	Low	Low	High	Medium		Medium		High		High	High

Change Flexibility	Low	Low	Low	Medium	Low	High	High	High
Contractor Cost Control Incentive	High	High	High	Low	Medium	Medium	Low	None
Excel Quality Incentive- Grade	None	None	High	Low	None	None	High	None
Contractor Risk Level- Grade	High	High	High	Medium	Medium	Low	Low	Low
Client Risk Level- Grade	None	Low	Low	None	Medium	High	High	High

Table 69. Contract Types Grades-A

	FFP	**FFP-EPA**	**FPAF**	**FPPR**	**FPIF**	**CPIF**	**CPAF**	**CPFF**
Technical Uncertainty	Low	Low	Low	Medium	Medium	Medium	Low	High
Budget Uncertainty	Low	Low	Low	Medium	Medium	High	High	High
Managerial Effort	Low	Low	High	Medium	Medium	High	High	High
Change Flexibility	Low	Low	Low	Medium	Low	High	High	High
Contractor Cost Control Incentive	High	High	High	Low	Medium	Medium	Low	None
Excel Quality Incentive	None	None	High	Low	None	None	High	None
Contractor Risk Level	High	High	High	Medium	Medium	Low	Low	Low
Client Risk Level	None	Low	Low	None	Medium	High	High	High

Table 70. Contract Types Grades-B

3. APPENDIX-C

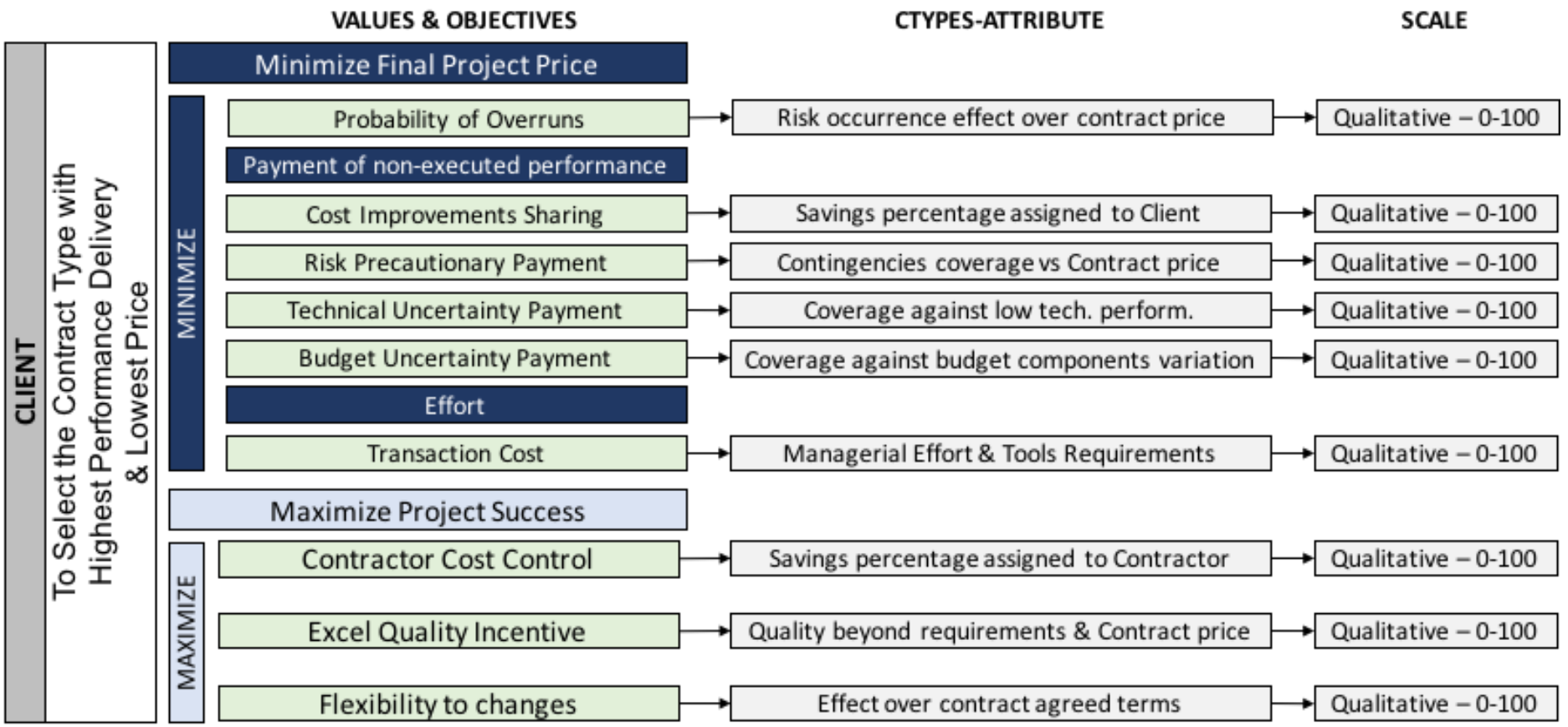


Figure 74- Client Value Tree

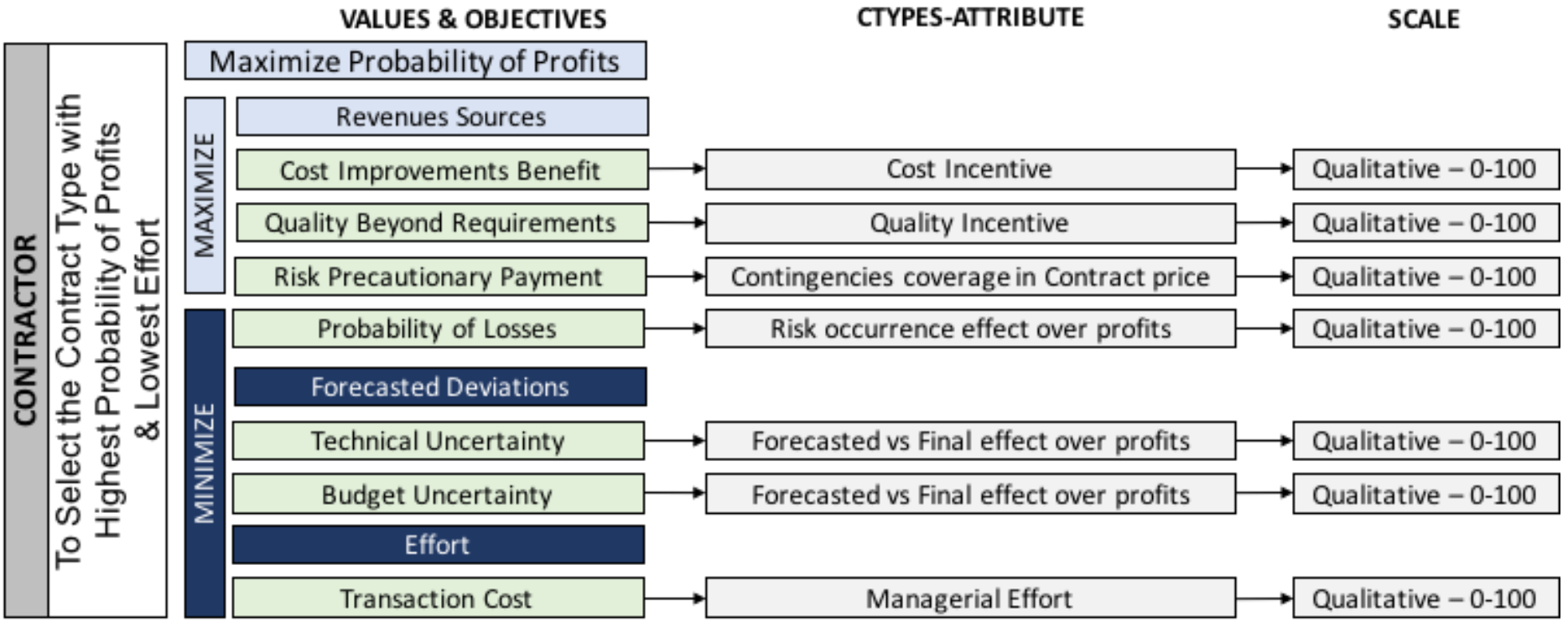


Figure 75- Contractor Value Tree

4. APPENDIX-D

Value: Minimize Client's Final Project Price							
Objective: Minimize Client's probability of Overruns							
Measurement: Risks and deviations consequences over contract price							
Contract Type	Risk Effect	Tech. Deviations	Cost Deviations	Renegotiation	Price Ceiling	Grade	Score
FFP	None	None	None	No	Yes	None	100
FPEPA	Escalation	None	None	No	Yes	Low	70
FPAF	None	None	None	No	Yes	None	100
FPPR	Next Period Contract Price	Next Period Contract Price	Next Period Contract Price	Yes	Yes	None	100
FPIF	Shared Sharing Formula	Shared Sharing Formula	Shared Sharing Formula	No	Yes	None	80
CPIF	Shared Sharing Formula	Shared Sharing Formula	Shared Sharing Formula	No	None	High	30
CPAF	Full Assumption	Full Assumption	Full Assumption	N/A	None	High	0
CPFF	Full Assumption	Full Assumption	Full Assumption	N/A	None	High	0

Table 71- Client's Decision Model-Evaluation Factor-1

Value: Minimize Client's Payment of not executed performance to contractor						
Objective: Minimize Client's Cost Improvements Sharing						
Measurement: Savings percentage assigned to Client if savings exist.						
Contract Type	Higher Efficiency	Lower Final Costs	Risk Management	Grade	Score	
FFP	0	0	0	None	0	
FPEPA	0	0	Escalation	Low	20	
FPAF	0	0	0	None	0	
FPPR	0	0	0	None	0	
FPIF	Sharing Formula	Sharing Formula	Sharing Formula	Medium	50	
CPIF	Sharing Formula	Sharing Formula	Sharing Formula	Medium	50	
CPAF	100	100	100	High	100	
CPFF	100	100	100	High	100	

Table 72- Client's Decision Model-Evaluation Factor-2

Value: Minimize Client's Payment of not executed performance to contractor
Objective: Minimize Client's Risk Precautionary Payment
Measurement: Amount of money included in the contract price for exogenous risk coverage

Contract Type	Contingencies (%)	Escalation (%)	Forecast Range	Price Ceiling	Renegotiation	Grade	Score
FFP	100	100	Full Contract	Yes	No	High	0
FPEPA	100	0	Full Contract	Yes	No	Medium	20
FPAF	100	100	Full Contract	Yes	No	High	0
FPPR	100	100	Next Period	Yes	Yes	Medium	30
FPIF	Sharing Formula	Sharing Formula	Full Contract	Yes	No	Low	50
CPIF	Sharing Formula	Sharing Formula	Full Contract	None	No	Low	70
CPAF	0	0	Full Contract	None	No	None	100
CPFF	0	0	Full Contract	None	No	None	100

Table 73- Client's Decision Model-Evaluation Factor-3

Value: Minimize Client's Payment of not executed performance to contractor						
Objective: Minimize Client's Technical Uncertainty Payment						
Measurement: Amount of resources paid for performance (Activities, time, labor, materials)						
Contract Type	Performance	Deviations	Forecast Range	Renegotiation	Grade	Score
FFP	Estimated	Estimated	Full Contract	No	High	0
FPEPA	Estimated	Estimated	Full Contract	No	High	0
FPAF	Estimated	Estimated	Full Contract	No	High	0
FPPR	Estimated	Estimated	Next Period	Yes	High	0
FPIF	Estimated Sharing Formula	Estimated Sharing Formula	Full Contract	No	Medium	50
CPIF	Actual Sharing Formula	Actual Sharing Formula	Full Contract	No	Medium	70
CPAF	Actual	None	N/A	N/A	None	100
CPFF	Actual	None	N/A	N/A	None	100

Table 74- Client's Decision Model-Evaluation Factor-4

Value: Minimize Client's Payment of not executed performance to contractor						
Objective: Minimize Client's Budget Uncertainty Payment						
Measurement: Cost of resources paid for performance during contract execution						
Contract Type	Cost	Market Behavior	Forecast Range	Renegotiation	Grade	Score
FFP	Estimated	Estimated	Full Contract	No	High	0
FPEPA	Estimated	Actual	Full Contract	No	Medium	20
FPAF	Estimated	Estimated	Full Contract	No	High	0
FPPR	Estimated	Estimated	Next Period	Yes	Medium	30
FPIF	Estimated Sharing Formula	Estimated Sharing Formula	Full Contract	No	Low	50

CPIF	Actual Sharing Formula	Actual Sharing Formula	Full Contract	No		Low	70
CPAF	Actual	Actual	N/A	N/A		None	100
CPFF	Actual	Actual	N/A	N/A		None	100

Table 75- Client's Decision Model-Evaluation Factor-5

Value: Minimize Client's Effort							
Objective: Minimize Client's Transaction Costs							
Measurement: Managerial Effort							
Contract Type	Admin. Burden	Monitoring	Project Ctrl	Custom Training	Price Structure	Grade	Score
FFP	Requirements	Objective	Contractor	No	Fixed	Low	100
FPEPA	Escalation	Objective	Contractor	No	Simple	Low	90
FPAF	Special KPI's	Subjective	Contractor	Yes	Custom	High	30
FPPR	Price KPI's	Objective	Contractor	No	Fixed	Medium	60
FPIF	Price analysis	Objective	Contractor	No	Formula	Medium	60
CPIF	Cost Analysis	Objective	Client	No	Formula	High	20
CPAF	Cost Analysis	Subjective	Client	Yes	Custom	High	0
CPFF	Cost Analysis	Objective	Client	No	Simple	High	30

Table 76- Client's Decision Model-Evaluation Factor-6

Value: Maximize Project Success							
Objective: Maximize Contractor's Cost Control							
Measurement: Savings percentage assigned to Contractor if savings exist.							
Contract Type	Higher Efficiency	Lower Final Costs	Risk Management	Fee Driver	Price Ceiling	Grade	Score
FFP	100	100	100	Cost	Yes	High	100
FPEPA	100	100	Escalation	Cost	Yes	High	90
FPAF	100	100	100	Quality	Yes	High	80
FPPR	100	100	100	Cost	Yes	Medium	40
FPIF	Sharing Formula	Sharing Formula	Sharing Formula	Cost	Yes	Medium	70
CPIF	Sharing Formula	Sharing Formula	Sharing Formula	Cost	None	Medium	50
CPAF	0	0	0	Quality	None	Low	20
CPFF	0	0	0	None	None	Low	0

Table 77- Client's Decision Model-Evaluation Factor-7

Value: Maximize Project Success					
Objective: Maximize Final Product Quality					
Measurement: Contractor's extra profits for quality beyond requirements					
Contract Type	Effect on Price	Fee Driver		Grade	Score
FFP	None	Cost		None	0
FPEPA	None	Cost		None	0
FPAF	Award Fee	Quality		High	100
FPPR	Next Period Contract Price Adjustment	Cost		Low	30
FPIF	None	Cost		None	0
CPIF	None	Cost		None	0
CPAF	Award Fee	Quality		High	100
CPFF	None	None		None	0

Table 78- Client's Decision Model-Evaluation Factor-8

Value: Maximize Project Success						
Objective: Maximize Flexibility to Changes						
Measurement: Effects on contract caused by changes						
Contract Type	Work to Perform	Scope	Project Ctrl		Grade	Score
FFP	Contract Renegotiation	Contract Renegotiation	Contractor		None	0
FPEPA	Contract Renegotiation	Contract Renegotiation	Contractor		None	0
FPAF	Contract Renegotiation	Contract Renegotiation	Contractor		None	0
FPPR	Contract Renegotiation	Next Period Contract Price Adjustment	Contractor		Low	30
FPIF	Contract Renegotiation	Contract Renegotiation	Contractor		None	0
CPIF	Contract Renegotiation	Fee Components Renegotiation	Client		High	80
CPAF	Contract Renegotiation	Additional Fee	Client		High	100
CPFF	Contract Renegotiation	Additional Fee	Client		High	100

Table 79- Client's Decision Model-Evaluation Factor-9

Value: Maximize Probability of Profits									
Objective: Minimize Probability of Losses									
Measurement: Risks and deviations consequences over contract price									
Contract Type	Risks Assumption	Tech. Deviations Assumption	Budget Dev. Assumption	Assumption Ceiling	Guaranteed Profit	Forecast Range	Renegotiation		Grade	Score
FFP	Contractor	Contractor	Contractor	No	No	Full Contract	No		High	100

FPEPA	Contractor	Contractor	Contractor Except Escalation	No	No	Full Contract	No	High	80
FPAF	Contractor	Contractor	Contractor	No	No	Full Contract	No	High	100
FPPR	Contractor	Contractor	Contractor	No	No	Next Period	Yes	Medium	70
FPIF	Shared Sharing Formula	Shared Sharing Formula	Shared Sharing Formula	No	No	Full Contract	No	Medium	50
CPIF	Shared Sharing Formula	Shared Sharing Formula	Shared Sharing Formula	Yes	Minimum Fee May be <=0	Full Contract	No	Low	20
CPAF	Client	Contractor AF	Client	None	Minimum Fee	N/A	N/A	Low	10
CPFF	Client	Client	Client	None	Fixed Fee	N/A	N/A	None	0

Table 80- Contractor's Decision Model-Evaluation Factor-1

Value: Maximize Revenues Sources						
Objective: Cost Improvements Benefits						
Measurement: Savings percentage assigned to Contractor if savings exist.						
Contract Type	Higher Efficiency	Lower Final Costs	Risk Management	Limited Max. Profits	Grade	Score
FFP	100	100	100	No	High	100
FPEPA	100	100	Escalation	No	High	90
FPAF	100	100	100	No	High	100
FPPR	100	100	100	No	High	80
FPIF	Sharing Formula	Sharing Formula	Sharing Formula	No	Medium	70
CPIF	Sharing Formula	Sharing Formula	Sharing Formula	Yes	Medium	50
CPAF	0	0	0	Yes	None	0
CPFF	0	0	0	Yes	None	0

Table 81- Contractor's Decision Model-Evaluation Factor-2

Value: Maximize Revenues Sources					
Objective: Quality Beyond Requirements					
Measurement: Contractor's extra profits for quality beyond requirements					
Contract Type	Effect on Price	Fee Driver		Grade	Score
FFP	None	Cost		None	0
FPEPA	None	Cost		None	0
FPAF	Award Fee	Quality		High	100

FPPR	Next Period Contract Price Adjustment	Cost		Low	30
FPIF	None	Cost		None	0
CPIF	None	Cost		None	0
CPAF	Award Fee	Quality		High	100
CPFF	None	None		None	0

Table 82- Contractor's Decision Model-Evaluation Factor-3

Value: Maximize Revenues Sources							
Objective: Risk Precautionary Payment							
Measurement: Amount of money included in the contract price for exogenous risk coverage							
Contract Type	Contingencies (%)	Escalation (%)	Forecast Range	Limited Max. Profits	Renegotiation	Grade	Score
FFP	100	100	Full Contract	No	No	High	100
FPEPA	100	0	Full Contract	No	No	High	80
FPAF	100	100	Full Contract	No	No	High	100
FPPR	100	100	Next Period	No	Yes	High	70
FPIF	Sharing Formula	Sharing Formula	Full Contract	No	No	Medium	50
CPIF	Sharing Formula	Sharing Formula	Full Contract	Yes	No	Low	30
CPAF	0	0	Full Contract	Yes	No	None	0
CPFF	0	0	Full Contract	Yes	No	None	0

Table 83- Contractor's Decision Model-Evaluation Factor-4

Value: Minimize Forecasted Deviations						
Objective: Technical Uncertainty						
Measurement: Effect of negative technical deviations on contractor's profits						
Contract Type	Deviations Assumption	Assumption Ceiling	Forecast Range	Renegotiation	Grade	Score
FFP	Contractor	No	Full Contract	No	High	0
FPEPA	Contractor	No	Full Contract	No	High	0
FPAF	Contractor	No	Full Contract	No	High	0
FPPR	Contractor	No	Next Period	Yes	High	10
FPIF	Shared Sharing Formula	No	Full Contract	No	Medium	50
CPIF	Shared Sharing Formula	Yes	Full Contract	No	Medium	60

CPAF	Client	Yes	N/A	N/A		None	80
CPFF	Client	Yes	N/A	N/A		None	100

Table 84- Contractor's Decision Model-Evaluation Factor-5

Value: Minimize Forecasted Deviations								
Objective: Budget Uncertainty								
Measurement: Effect of negative budget deviations on contractor's profits								
Contract Type	Cost + Risks Deviations	Escalation Deviations	Assumption Ceiling	Forecast Range	Renegotiation		Grade	Score
FFP	Contractor	Contractor	No	Full Contract	No		High	0
FPEPA	Contractor	Client	No	Full Contract	No		High	30
FPAF	Contractor	Contractor	No	Full Contract	No		High	0
FPPR	Contractor	Contractor	No	Next Period	Yes		High	20
FPIF	Shared Sharing Formula	Shared Sharing Formula	No	Full Contract	No		Medium	50
CPIF	Shared Sharing Formula	Shared Sharing Formula	Yes	Full Contract	No		Medium	70
CPAF	Client	Client	Yes	N/A	N/A		None	100
CPFF	Client	Client	Yes	N/A	N/A		None	100

Table 85- Contractor's Decision Model-Evaluation Factor-6

Value: Minimize Effort								
Objective: Minimize Transaction Costs								
Measurement: Managerial Effort								
Contract Type	Admin. Burden	Monitoring	Project Ctrl	Custom Training	Price Structure		Grade	Score
FFP	Requirements	Objective	Contractor	No	Fixed		Low	100
FPEPA	Escalation	Objective	Contractor	No	Simple		Low	90
FPAF	Special KPI's	Subjective	Contractor	Yes	Custom		High	30
FPPR	Price KPI's	Objective	Contractor	No	Fixed		Medium	60
FPIF	Price analysis	Objective	Contractor	No	Formula		Medium	60
CPIF	Cost Analysis	Objective	Client	No	Formula		High	20
CPAF	Cost Analysis	Subjective	Client	Yes	Custom		High	0
CPFF	Cost Analysis	Objective	Client	No	Simple		High	30

Table 86- Contractor's Decision Model-Evaluation Factor-7

5. APPENDIX-E

The following simulated distributions and data has been obtained using @Risk at 50.000 iterations

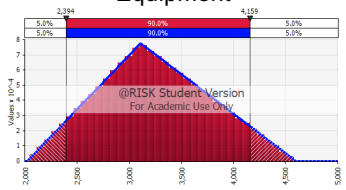
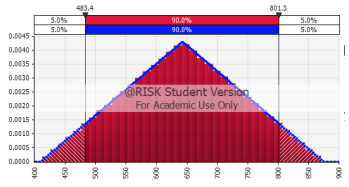
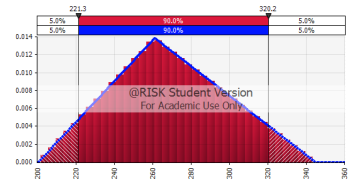
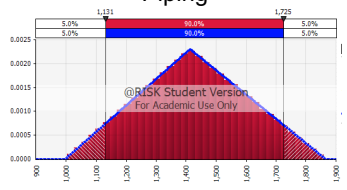
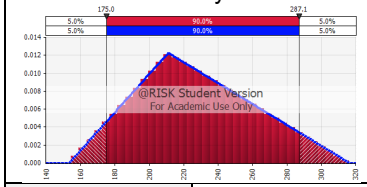
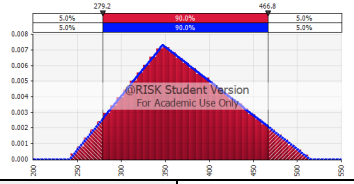
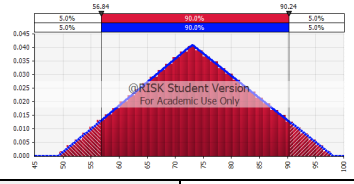
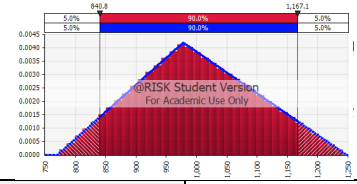
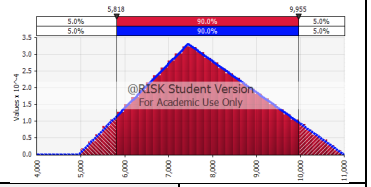
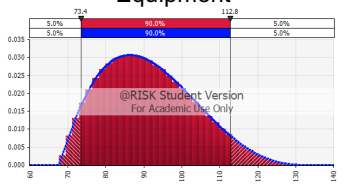
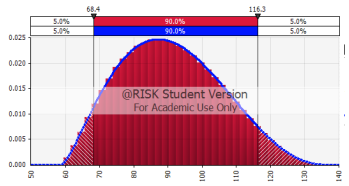
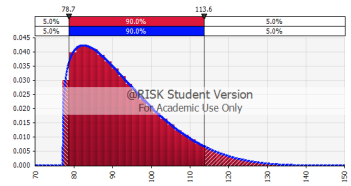
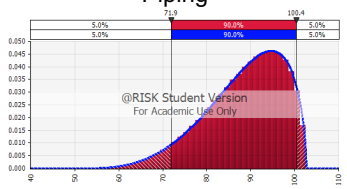
Component	Weight	Equipment		Electrical		Instrument		Piping	
Units	Tonnes								
Distribution	Triangular								
Estimator	Mean								
Contingency	20%								
Notes: Technical Uncertainty-Scope									
Mean	Mode	**3242**	3212	**643**	644	**269**	261	**1425**	1411
P10	P90	2549	3978	514	771	230	310	1187	1667
Acc. (-)	Acc. (+)	-21%	19%	-20%	17%	-14%	13%	-17%	15%
Safety		HVAC		Surface Protection		Architectural		Structural Steel	
									
227	212	**368**	347	**74**	78	**999**	978	**7837**	7738
184	275	295	447	60	87	870	1134	6178	9527
-19%	17%	-20%	18%	-19%	15%	-13%	12%	-21%	18%

Table 87- Weight estimation components and distributions

Component	Engineering	Equipment		Electrical		Instrument		Piping	
Units	MHR/Tonne								
Distribution	PERT								
Estimator	Median								
Contingency	20%								
Notes: Technical Uncertainty- Process level of knowledge									
Median(P50)	Mode	**90**	87	**90**	87	**90**	82	**90**	95
P10	P90	76	108	72	111	80	108	76	99
Acc. (-)	Acc. (+)	-16%	17%	-20%	19%	-11%	17%	-16%	9%
Safety		HVAC		Surface Protection		Architectural		Structural Steel	

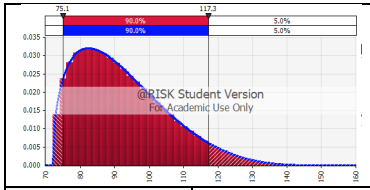
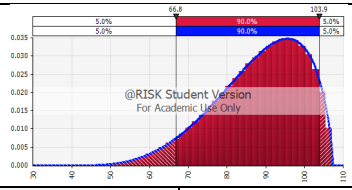
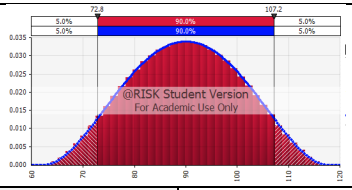
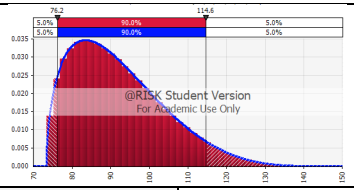
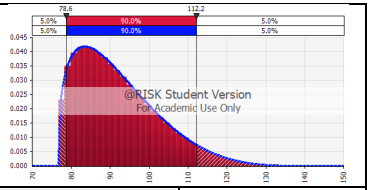
									
90	83	**90**	95	**90**	90	**90**	83	**90**	83
77	111	72	102	76	104	78	109	80	107
-14%	19%	-20%	12%	-16%	13%	-13%	17%	-11%	16%

Table 88- Engineering MHR estimation components and distributions

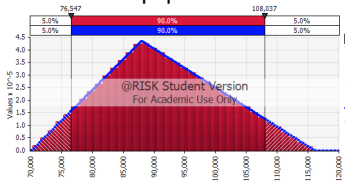
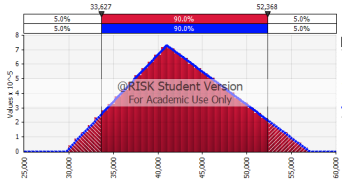
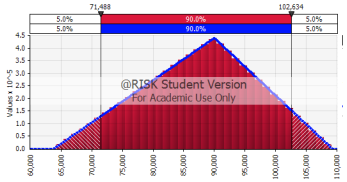
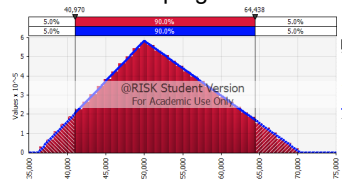
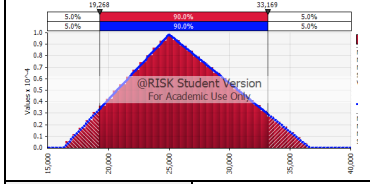
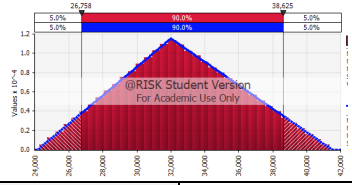
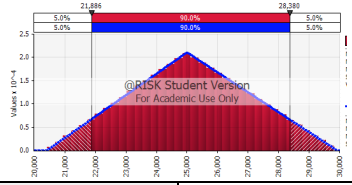
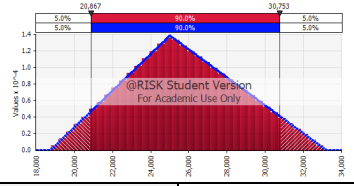
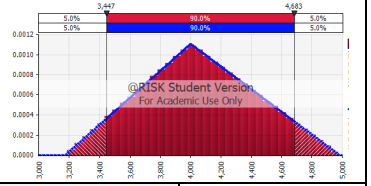
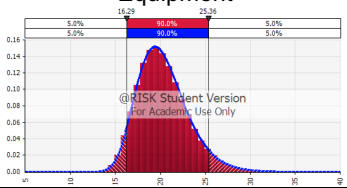
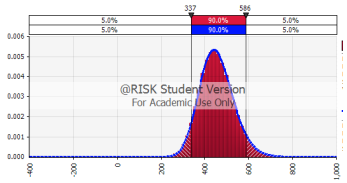
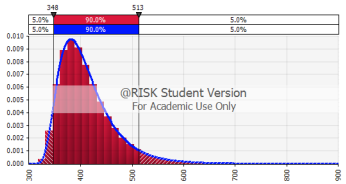
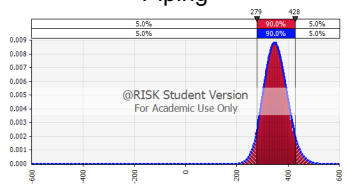
Component	Procurement	Equipment		Electrical		Instrument		Piping	
Units	USD/Tonne								
Distribution	Triangular								
Estimator	Mean								
Contingency	20%								
Notes: Budget Uncertainty-Cost									
Mean	Mode	**91407**	88144	**42586**	41027	**87680**	89965	**52149**	49985
P10	P90	79200	104720	35260	50430	74700	99899	43000	62.000
Acc. (-)	Acc. (+)	-13%	13%	-17%	16%	-15%	12%	-18%	16%
Safety		HVAC		Surface Protection		Architectural		Structural Steel	
									
25967	24963	**32550**	32422	**25107**	25009	**25644**	25014	**4052**	3998
20500	31750	27840	37440	22500	27750	21750	29750	3560	4560
-21%	18%	-14%	13%	-10%	10%	-15%	14%	-12%	11%

Table 89- Procurement cost estimation components and distributions

Component	Fabric-Install	Equipment	Electrical	Instrument	Piping
Units	MHR/Tonne				
Distribution	Lognormal				
Estimator	Median				
Contingency	20%				
Notes: Technical Uncertainty-					

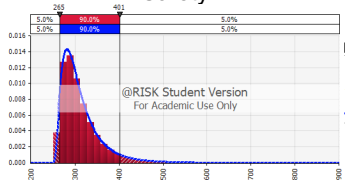
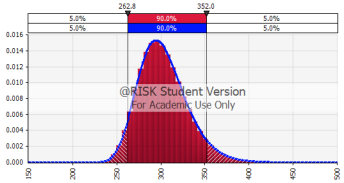
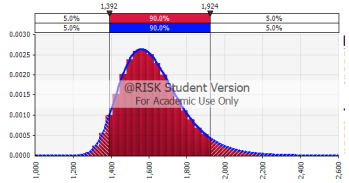
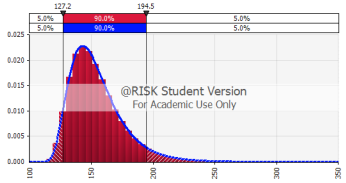
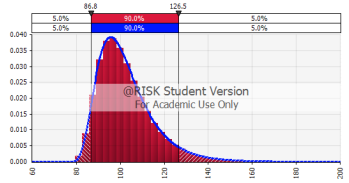
Process level of knowledge									
Median(P50)	Mode	**20**	19	**450**	443	**400**	382	**350**	347
P10	P90	17	24	360	554	356	480	294	410
Acc. (-)	Acc. (+)	-15%	17%	-20%	19%	-11%	17%	-16%	15%
Safety		HVAC		Surface Protection		Architectural		Structural Steel	
									
300	282	**300**	296	**1600**	1552	**150**	143	**100**	96
270	369	270	339	1430	1840	131	182	89	119
-10%	19%	-10%	12%	-11%	13%	-13%	18%	-11%	16%

Table 90- Fabrication and Installation MHR estimation components and distribution

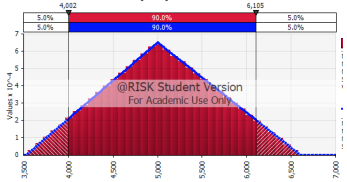
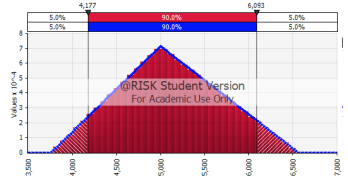
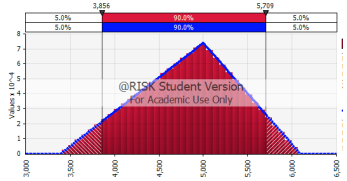
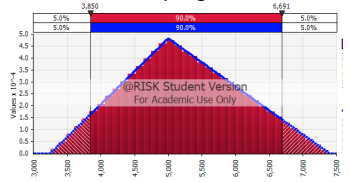
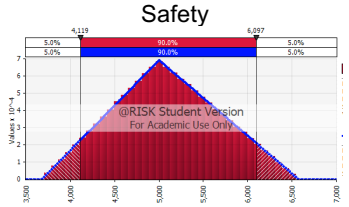
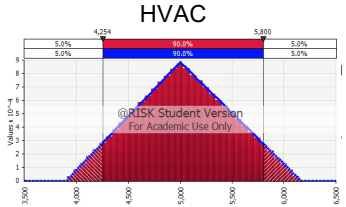
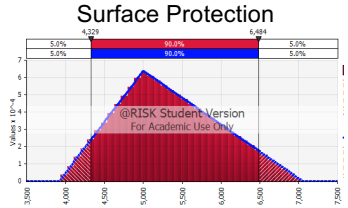
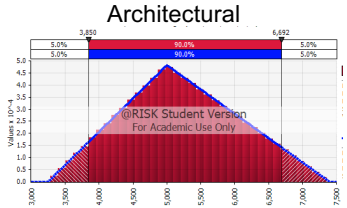
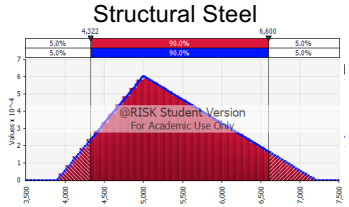
Component	Marine Ops	Equipment		Electrical		Instrument		Piping	
Units	USD/Tonne								
Distribution	Triangular								
Estimator	Mean								
Contingency	20%								
Notes: Budget Uncertainty-Cost									
Mean	Mode	**5043**	5009	**5107**	5004	**4828**	4999	**5215**	5006
P10	P90	4200	5900	4350	5900	4050	5550	4100	6400
Acc. (-)	Acc. (+)	-17%	15%	-15%	13%	-16%	13%	-21%	19%
Safety		HVAC		Surface Protection		Architectural		Structural Steel	
									
5086	4999	**5021**	4999	**5323**	4999	**5215**	5006	**5363**	5002
4300	5900	4400	5650	4500	6250	4100	6400	4500	6350
-15%	14%	-12%	11%	-15%	15%	-21%	19%	-16%	15%

Table 91- Marine operations cost components and distributions

Component	HU&C	Equipment		Electrical		Instrument		Piping	
Units	MHR/Tonne								
Distribution	PERT								
Estimator	Median								
Contingency	20%								
Notes: Technical Uncertainty- Process level of knowledge									
Median(P50)	Mode	**20**	18	**20**	19	**20**	18	**20**	21
P10	P90	17	25	16	25	18	24	17	22
Acc. (-)	Acc. (+)	-15%	20%	-20%	20%	-10%	17%	-15%	9%
Safety		HVAC		Surface Protection		Architectural		Structural Steel	
20	19	**20**	21	**20**	20	**20**	19	**20**	18
16	25	16	23	17	23	17	24	18	24
-20%	20%	-20%	13%	-15%	13%	-15%	17%	-10%	17%

Table 92- HU&C MHR estimation components and distributions

Component	Labor	At shore		Inshore		Offshore			
Units	USD/MHR								
Distribution	Normal								
Estimator	Mean								
Contingency									
Notes: Budget Uncertainty-Cost									
Mean	Mode	**175**	174	**170**	170	**245**	244		
P10	P90	157	193	161	179	184	306		
Acc. (-)	Acc. (+)	-10%	9%	-5%	5%	-25%	20%		

Table 93- Labor cost estimation components and distributions

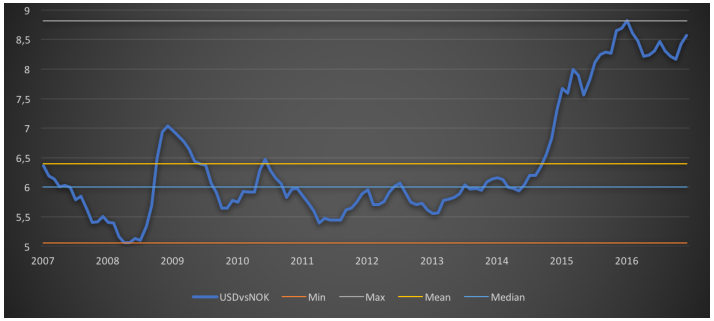
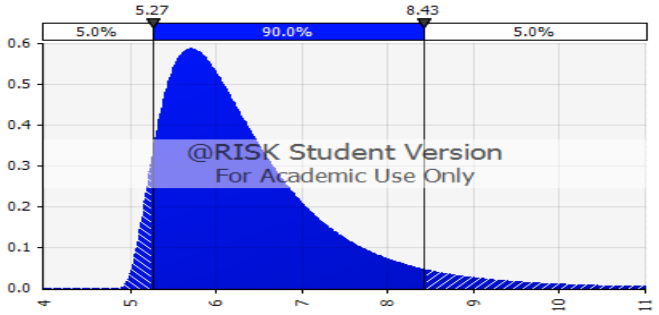
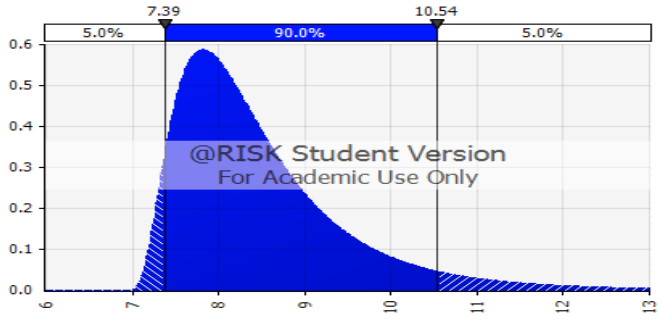
Currency Exchange USD-NOK: Budget Uncertainty-Market	Estimated Distribution	Distribution Parameters	
		Distribution	Lognormal
		Estimator	Mean
		Mean	**6,3945**
		Mode	5,7086
		Median	6,1228
		μ	1,6169
		σ	1,0784
		Shift	4,7776
		Samples	120
		Tool	@Risk
		Note: Past Behavior	
The currency exchange past behavior has been estimated from historic data available on internet [29], taking the monthly average from Jan-2007 till Dec-2016. The estimated future behavior has been calculated using the distribution (behavior) and varying the mean to the currency exchange value of the date 5-June-2017, from the same website.		Distribution	Lognormal
		Estimator	Mean
		Mean	**8,5069**
		Mode	7,8210
		Median	8,2352
		μ	1,6169
		σ	1,0784
		Shift	6,89
		Samples	N/A
		Tool	@Risk
		Note: Estimated Future Behavior	

Table 94- Currency exchange behavior estimation

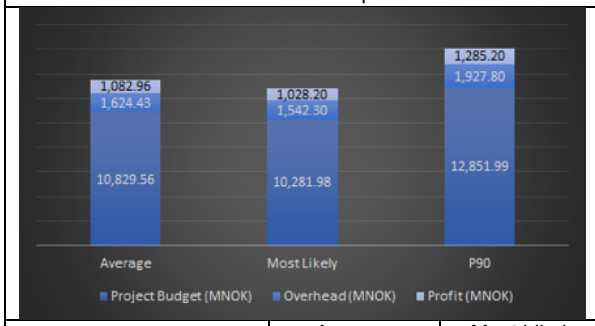
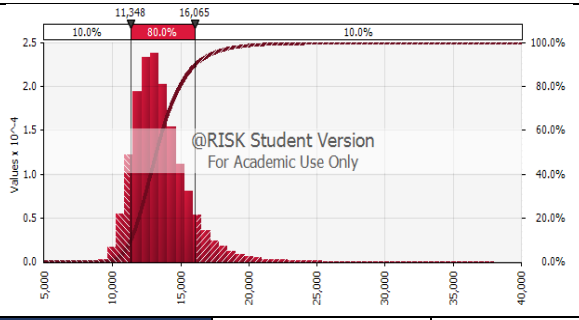
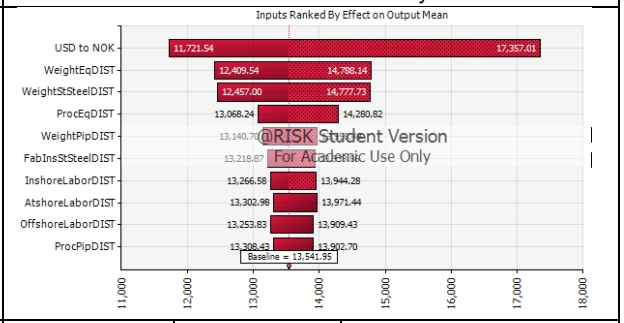
Firm Fixed Price - FFP								
Contract Price Components			Contract Price Distribution			Contract Price Sensitivity		
								
	Average	Most Likely	P90	Contingency	M. Reserve	Accuracy (-)	Accuracy (+)	Comments
P-Budget -MNOK	10.829,56	10.281,98	12.851,99	547,66	2.022,34	-16%	19%	Confidence Level 80%
Overhead (15%) -MNOK	1.624,43	1.542,30	1.927,80	82,15	303,35	-16%	19%	
Profit (10%) –MNOK	1.082,96	1.028,20	1.285,20	54,77	202,23	-16%	19%	
Contract Price –MNOK	13.536,95	12.852,48	16.064,98	684,58	2.527,93	-16%	19%	

Table 95- FFP Total contract price components estimation

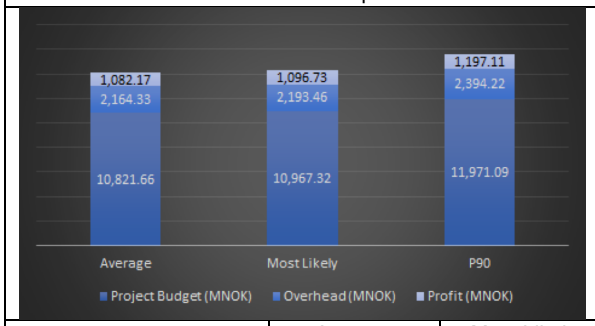
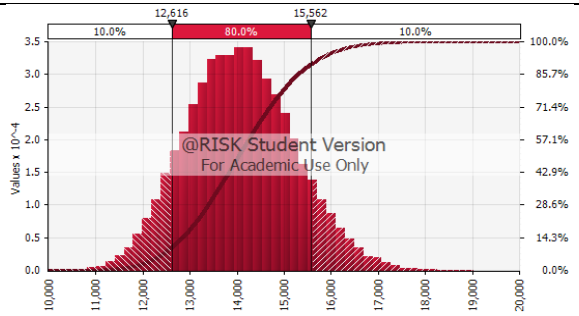
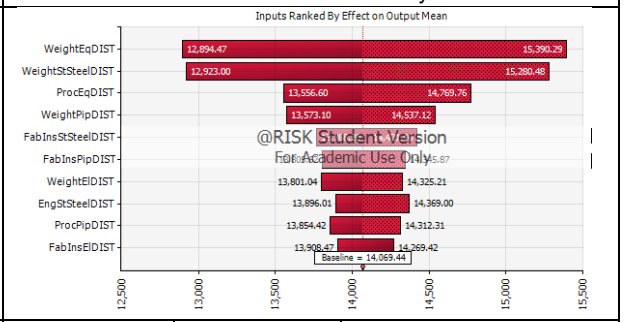
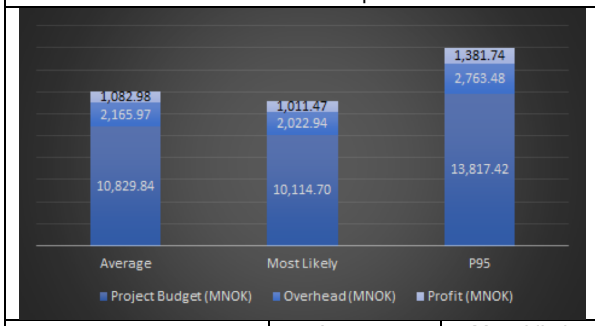
Fixed Price Economic Price Adjustment - FPEPA								
Contract Price Components			Contract Price Distribution			Contract Price Sensitivity		
								
	Average	Most Likely	P90	Contingency	M. Reserve	Accuracy (-)	Accuracy (+)	Comments
P-Budget -MNOK	10.820,86	10.967,32	11.971,09	146,47	1.150,23	-10%	11%	Confidence Level 80%
Overhead (20%) -MNOK	2.164,17	2.193,46	2.394,22	29,29	230,05	-10%	11%	
Profit (10%) –MNOK	1.082,09	1.096,73	1.197,11	14,65	115,02	-10%	11%	
Contract Price –MNOK	14.067,12	14.257,52	15.562,42	190,41	1.495,30	-10%	11%	

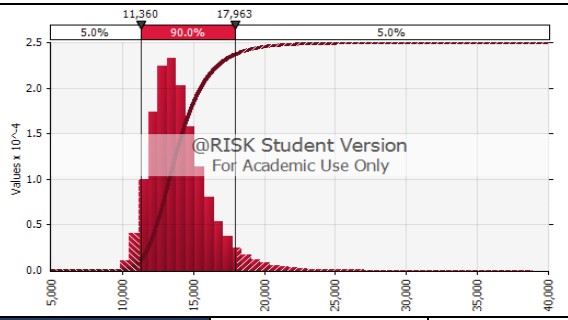
Table 96- FPEPA Total contract price components estimation

Fixed Price Incentive Fee (Firm Target) - FPIF

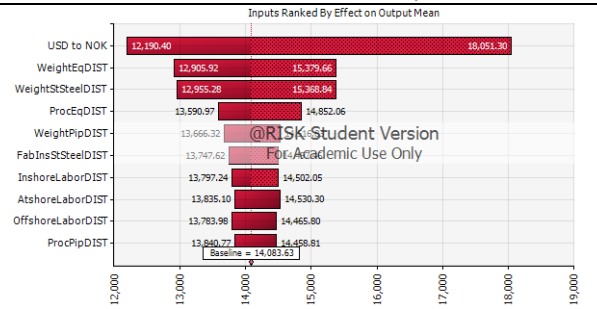
Contract Price Components



Contract Price Distribution



Contract Price Sensitivity

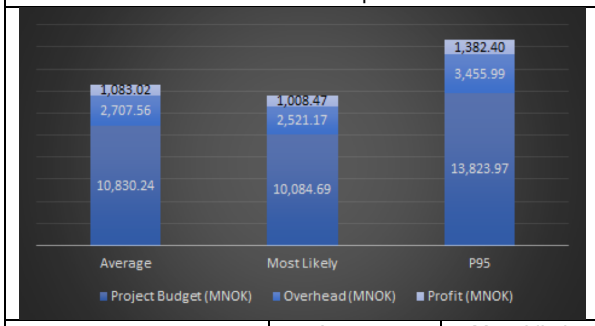


	Average	Most Likely	P95	Contingency	M. Reserve	Accuracy (-)	Accuracy (+)	Comments
P-Budget -MNOK	10,829.84	10,114.70	13,817.42	714,94	2987,77	-14%	28%	Confidence Level 90% The profits showed are not the total profits assigned to the contractor. Sharing factor.
Overhead (20%) -MNOK	2,165.97	2,022.94	2,763.48	142,99	597,55	-14%	28%	
Profit (10%) –MNOK	1,082.98	1,011.47	1,381.74	71,49	298,78	-14%	28%	
Contract Price –MNOK	14,078.80	13,149.11	17,962.64	929,42	3884,11	-14%	28%	

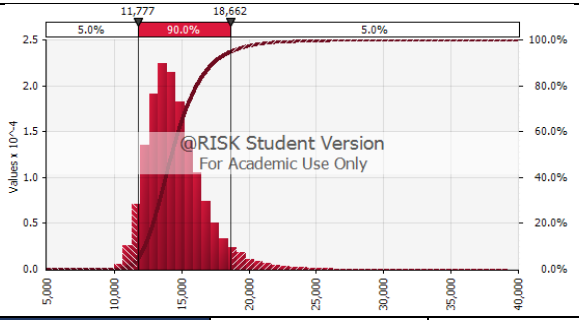
Table 97- FPIF Total contract price components estimation

Cost Plus Incentive Fee – CPIF & Cost Plus Fixed Fee - CPFF

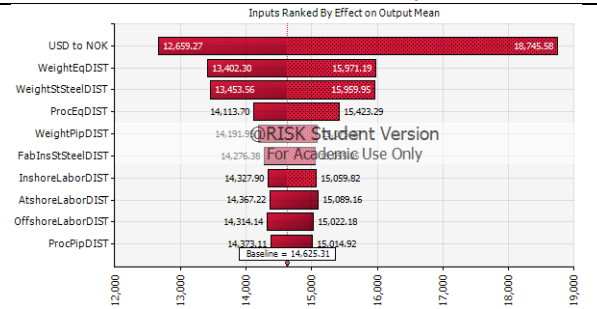
Contract Price Components



Contract Price Distribution



Contract Price Sensitivity



	Average	Most Likely	P95	Contingency	M. Reserve	Accuracy (-)	Accuracy (+)	Comments
P-Budget -MNOK	10,830.24	10,084.69	13,823.97	744,95	4042,35	-19%	28%	Confidence Level 90% The use of P95 estimates are for project approval and performance metrics.
Overhead (20%) -MNOK	2,707.56	2,521.17	3,455.99	186,24	299,43	-19%	28%	
Profit (10%) –MNOK	1,083.02	1,008.47	1,382.40	74,50	748,58	-19%	28%	
Contract Price –MNOK	14,620.82	13,614.33	18,662.36	1005,68	2994,33	-19%	28%	

Table 98- CPIF & CPFF Total contract price components estimation

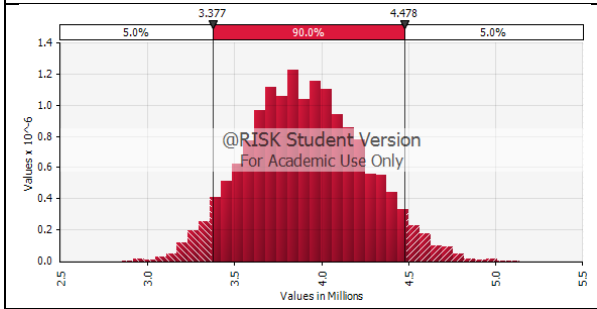
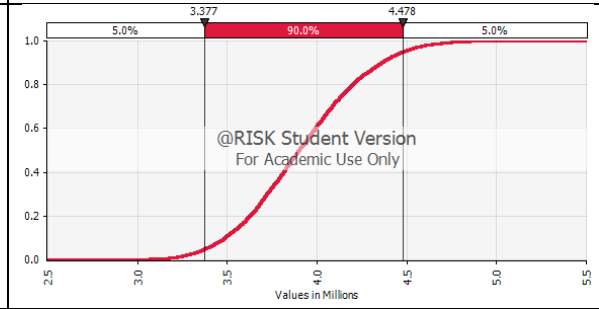
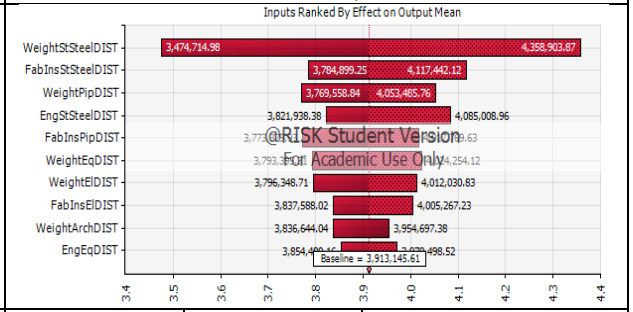
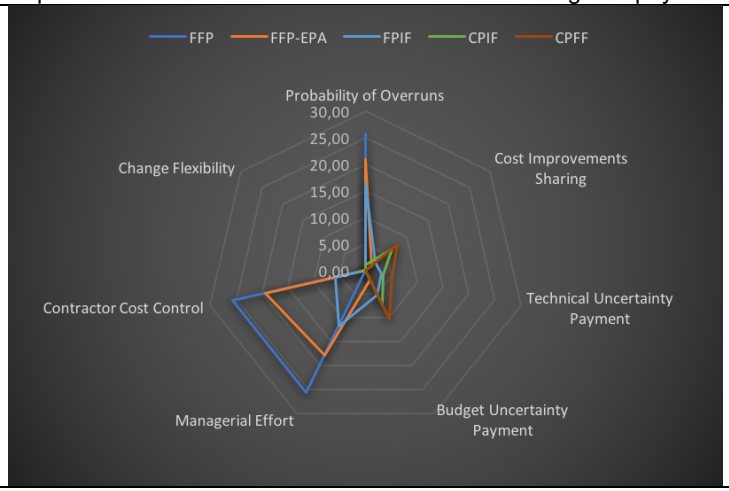
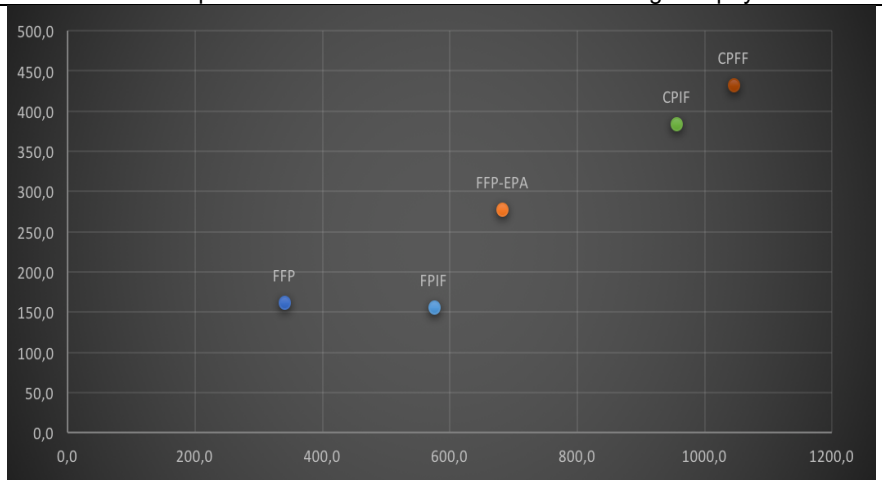
Total Project MHR								
Distribution			S-Curve			Sensitivity		
								
	Average	Most Likely	P95	Contingency	M. Reserve	Accuracy (-)	Accuracy (+)	Comments
Total MHR	3.913.146	3.827.477	4.478.167	85669	565021	-11%	14%	Confidence Level 90%

Table 99- Technical Deviation MHR

Spider Chart – Contractor Decision Alternatives weighted payoffs	Tradeoffs plot – Contractor Decision Alternatives weighted payoffs
	
Cost Improvement Benefits-Sensitivity Diagram	Probability of Losses Avoidance-Sensitivity Diagram

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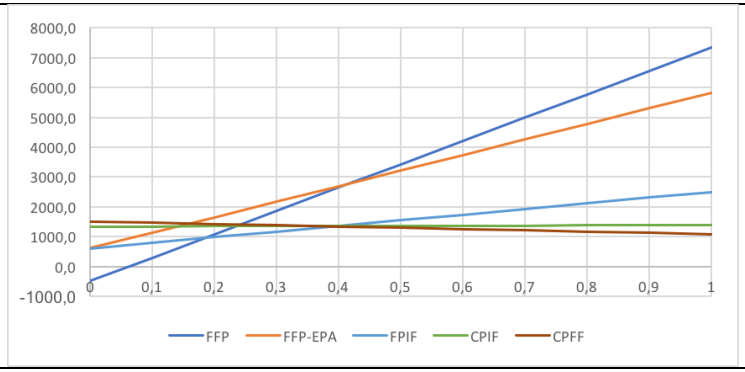
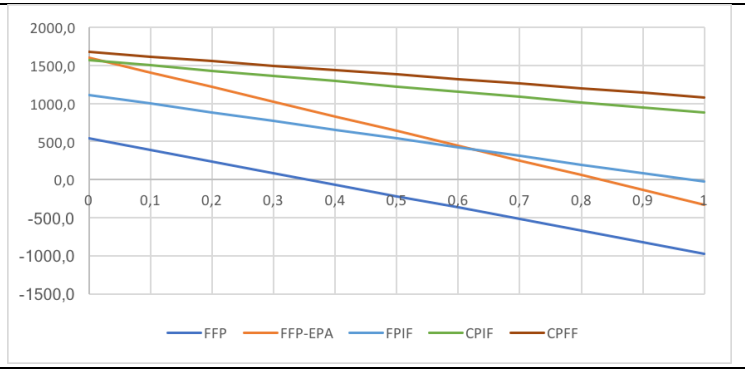
<tr><td> 
</td><td> 
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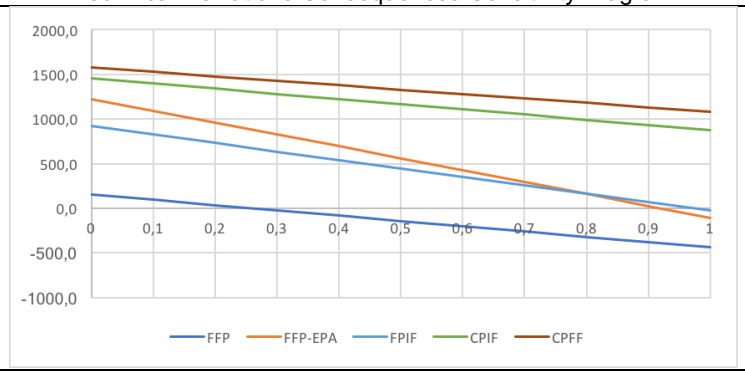
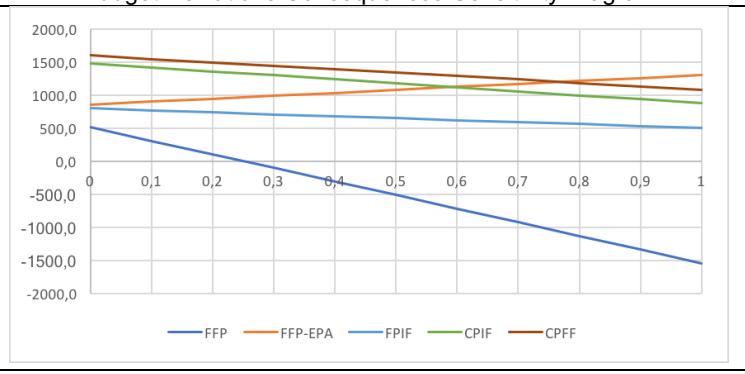
<tr><td>Technical Deviations Consequences-Sensitivity Diagram</td><td>Budget Deviations Consequences-Sensitivity Diagram</td></tr>
<tr><td> 
</td><td> 
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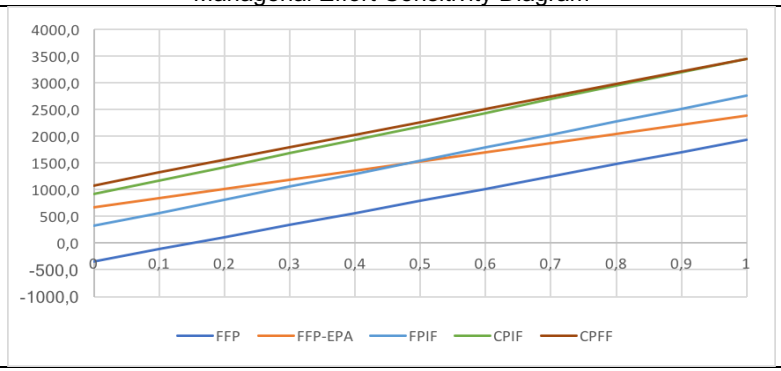
<tr><td>Managerial Effort-Sensitivity Diagram</td><td></td></tr>
<tr><td> 
</td><td>The selection of the “best” contract type for the contractor is not an objective of this thesis, because the “best” contract type is a personal choice of the decision maker. Instead it is presented useful information given the data to help the decision maker to achieve a high-quality decision.</td></tr>
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Table 100- Contractor Performance and Sensitivity Diagrams

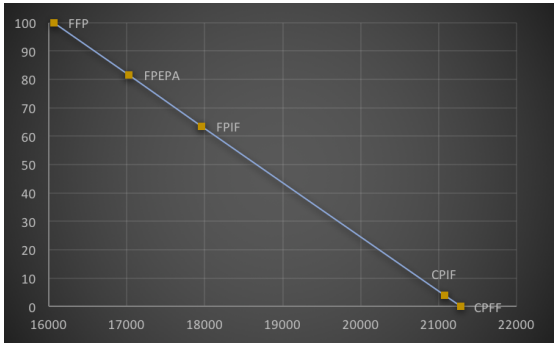
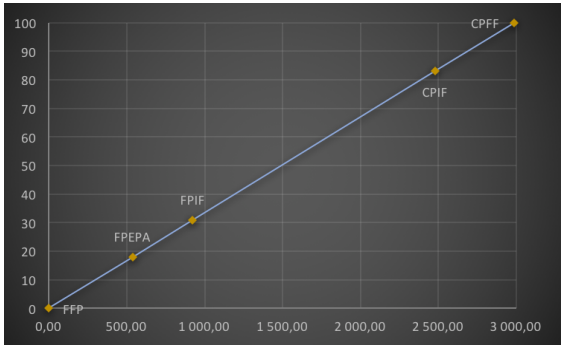
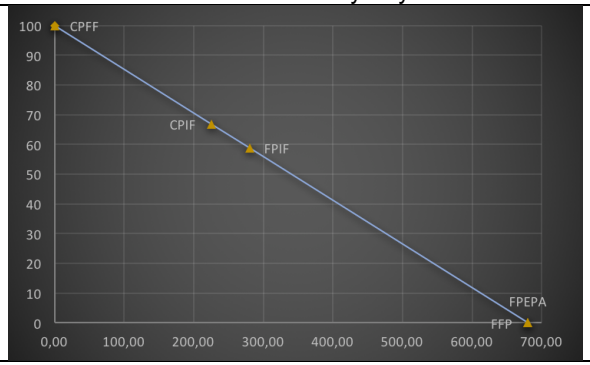
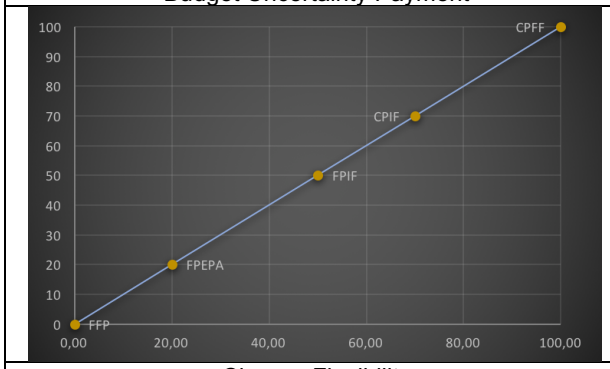
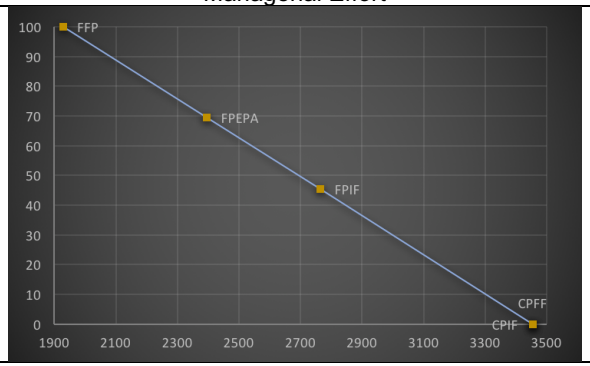
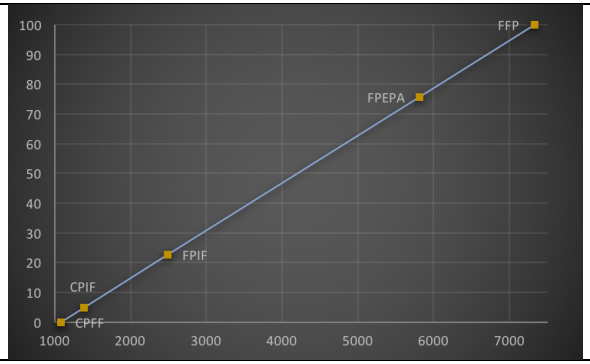
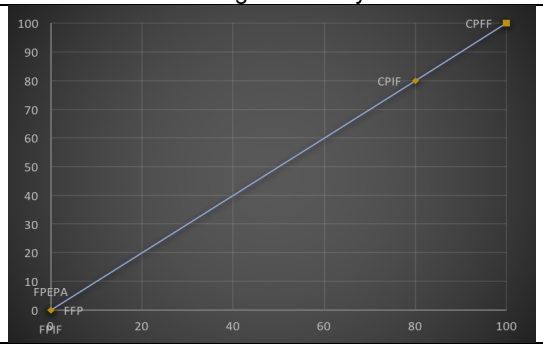
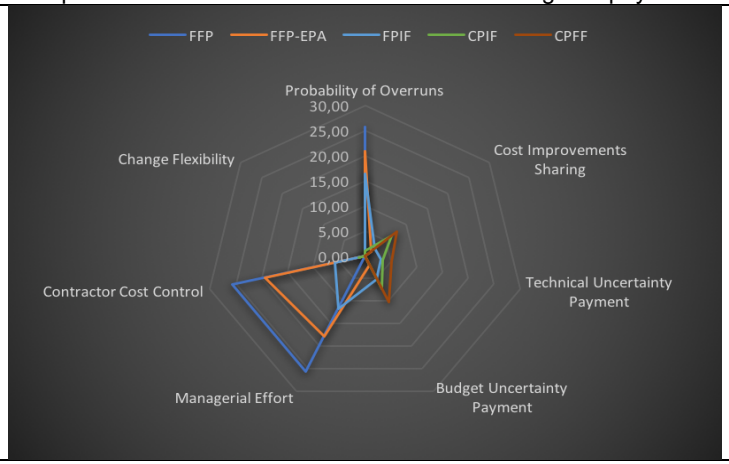
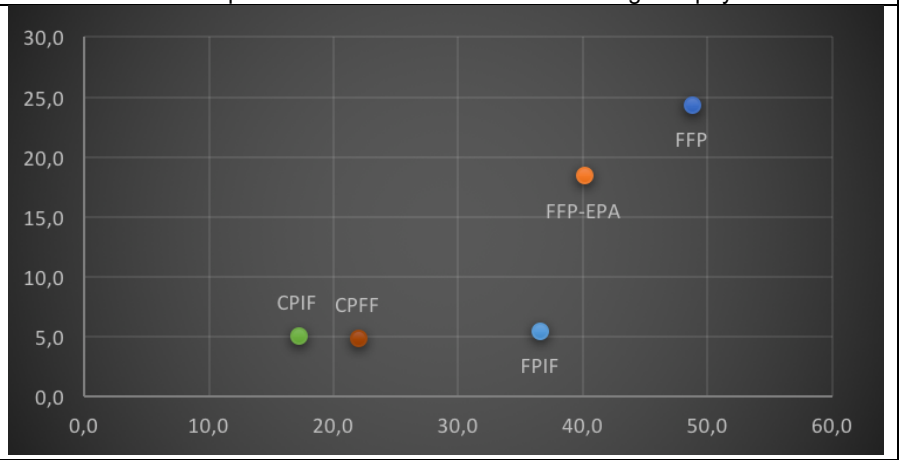
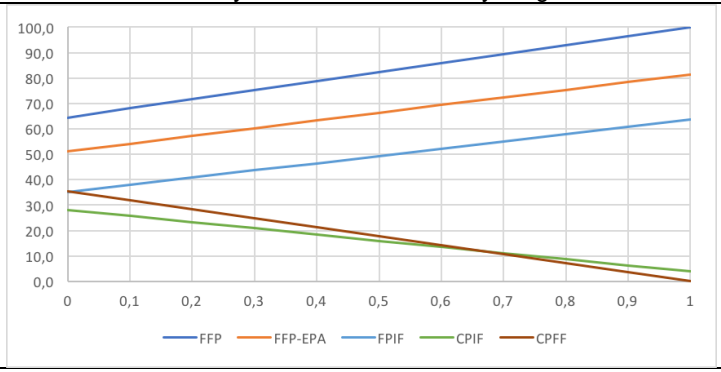
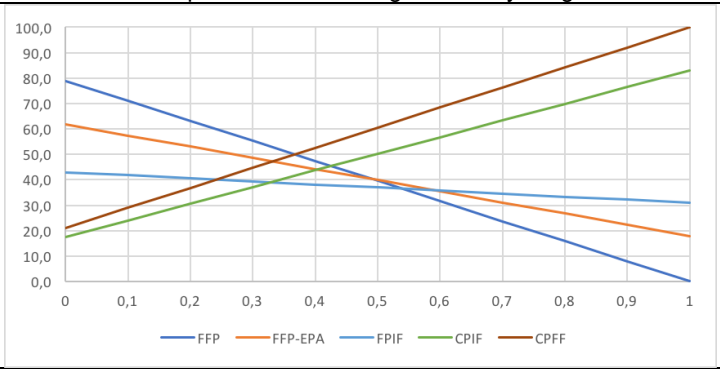
Probability of Overruns	Cost Improvements Sharing	Technical Uncertainty Payment
		
Budget Uncertainty Payment	**Managerial Effort**	**Contractor Cost Control**
		
Change Flexibility		
		

Table 101- Client Values to Scores

Spider Chart – Client Decision Alternatives weighted payoffs	Tradeoffs plot – Client Decision Alternatives weighted payoffs
	
Probability of Overruns-Sensitivity Diagram	Cost Improvements Sharing-Sensitivity Diagram
	
Technical Uncertainty Payment-Sensitivity Diagram	Budget Uncertainty Payment-Sensitivity Diagram

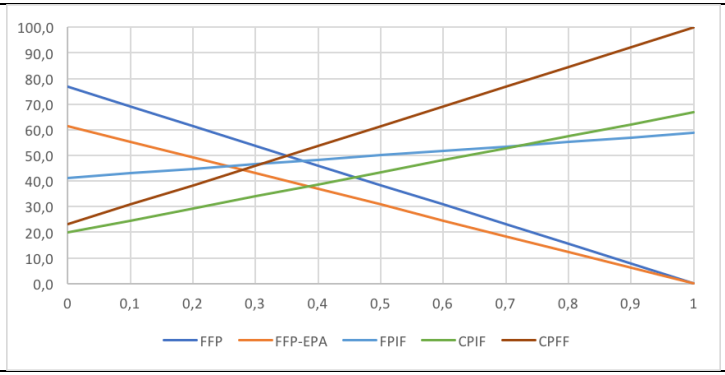
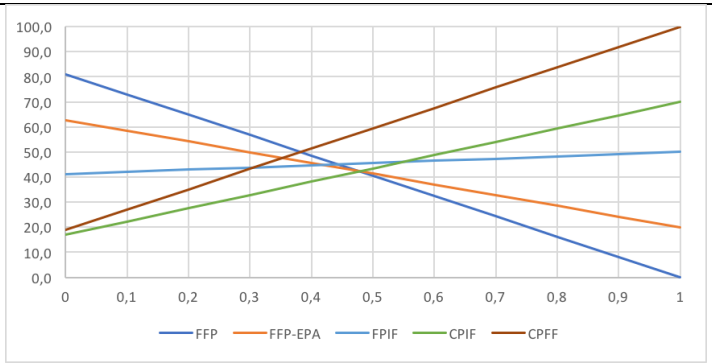
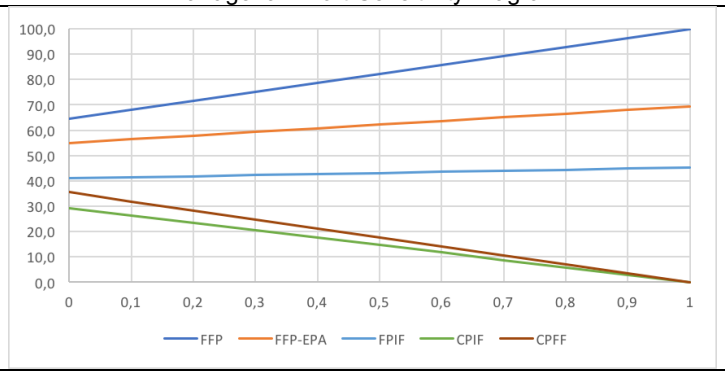
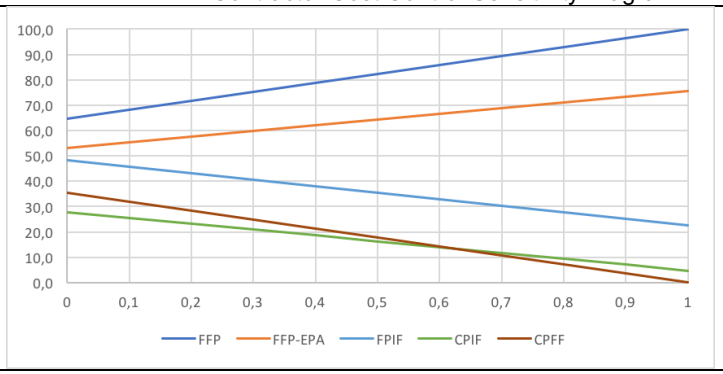
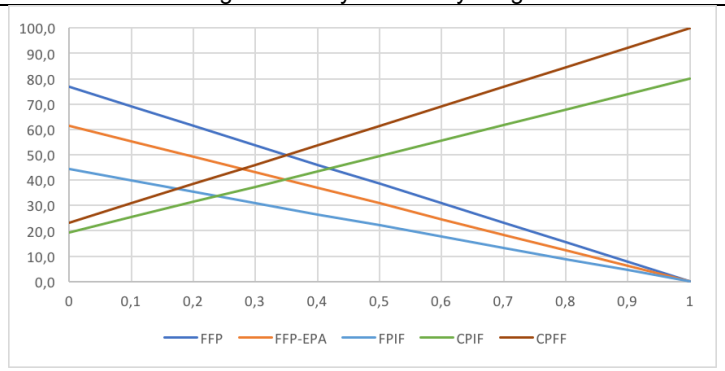
<table>
<tr><td> 
</td><td> 
</td></tr>
<tr><td>Managerial Effort-Sensitivity Diagram</td><td>Contractor Cost Control-Sensitivity Diagram</td></tr>
<tr><td> 
</td><td> 
</td></tr>
<tr><td>Change Flexibility-Sensitivity Diagram</td><td></td></tr>
<tr><td> 
</td><td>The selection of the “best” contract type for the client is not an objective of this thesis, because the “best” contract type is a personal choice of the decision maker. Instead it is presented useful information given the data to help the decision maker to achieve a high-quality decision.</td></tr>
</table>

Table 102- Client Performance and Sensitivity Diagrams