Contracting Economics
of
Large Engineering and Construction Projects

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Summary

Contracting Economics of Large Engineering and Construction Projects

Large Engineering and Construction Projects (LECPs) form an important area of economic activity, covering a range of different artefacts. These projects have in common that they are massive undertakings, spanning long time periods and they involve large capital investments. Uncertainty and risk are the ruling paradigms. In the oil, gas and petrochemical industry, Engineering Contractors (ECs) play a key role in the development and implementation of the LECPs for processing facilities. The contract between owner and EC formalises their relationship, specifying the obligations and liabilities of the parties as well as the allocation of risk. The *contracting process* (covering the entire project life-cycle) comprises an important governance mechanism on LECPs. An experience-based theoretical framework of contracting for LECPs is developed by analysing and modelling contracting strategies and tactics (e.g. contract types) and validation through normalised data.

Traditionally the selection of an EC for an LECP in the oil, gas and petrochemical industry is largely done through a (closed) competitive bidding process on the basis of a single Lump Sum/Fixed Price (LSFP) contract for Engineering, Procurement and Construction (EPC). The LSFP/EPC bid prices are composed of a (stochastic) cost estimate of the work, multiplied by a certain mark-up. When establishing this mark-up, bidders have to optimise potential profits and the probability of winning the bidding event. Existing bidding models (which require many open bidding events) cannot be used on LECPs. An alternative model for bid optimisation, using an 'applied approach', is presented. A quantitative analysis of data from a case study owner organisation shows that in a competitive market (that existed in the industry in the 1980s and 1990s), the owner's contract cost for implementing LECPs was in the case of a single bidder some 14% and 22% higher than in the case of two and three bidders respectively. The model provides a practical proposition to study competitive bidding for LECPs without the large number of published bid prices required by existing models.

The traditional strategies to contract out the development and implementation of LECPs are based on a highly competitive market. They are not longer effective, in the current 'sellers market', to mitigate the economic inefficiencies associated with the oligopolistic market where a limited number of ECs, sheltered by significant entry barriers, have the potential for economic profits for a prolonged period of time. Alternative contracting strategies recognise that the *coordination* role of ECs in the development and implementation of LECPs is crucial to the successful execution of these projects. Rather than the procurement of a product (i.e. the processing facility) under a LSFP/EPC contract, the owner engages the EC for Engineering, Procurement and Construction management (EPCm) services. Under a Cost Plus Percentage Fee (CPPF) or Cost Plus Incentive Fee (CPIF) remuneration structure, the owner reimburses the EC for all costs associated with the project (i.e. materials and equipment as well as construction cost). To align owner and EC interests and to induce the latter to act as the owner's agent rather than its adversary, CPIF contracts contain a performance related fee structure. The CPIF (and CPPF) contract shields the EC from the conditions that prevail at the contracting and procurement market at the time during project implementation when purchase orders and construction contracts have to be placed. On risky LECPs, with large amounts of capital and ECs that are generally not well placed to bear the consequences of the associated risks, CPIF contracts provide an economically efficient alternative to the traditional (single) LSFP/EPC approach. This

is particularly relevant in a sellers' market where the price premium under a single LSFP/EPC approach are substantially higher than in a buyers' market.

Effective cooperation requires reciprocal interdependencies between the contract parties. Lack of reciprocity results in relational risk; i.e the risk of opportunistic behaviour of the EC. This is particularly relevant for CPIF/EPCm contracts where the owner relies on the EC acting for and on its behalf. The most effective governance mechanisms to reduce the room for and intent towards opportunistic behaviour are performance monitoring (rather than contract terms), building trust and creating a reciprocal dependency between owner and EC during the contracting process.

The time value of money plays a central role in the economic evaluation of LECPs, but is often underexposed in the analysis of contract cost performance. For LECPs in the oil, gas and petrochemical industry, Earned Value (EV) provides a good description of the actual cash flow requirements and projects typically follow the same generic EV curve. There is an established practice of advance payments on LSFP contracts, following a generic schedule. The cost (on the basis of a Net Present Value calculation) of advance payments under LSFP contract vis-à-vis the payments under a CPF contract amount to some 6% of the Total Installed Cost.

An empirical analysis of project performance under CPIF, LSFP and CPPF contracts has been conducted, using a database of 32 projects of the case study owner organisation. The analysis indicates that the stochastic cost estimates underlying the database display objectivity and precision. The relative owner contract cost under LSFP and CPPF contracts was some 8% and 16% higher, respectively, than under CPIF contracts (taking into account the differences in expenditure phasing). This suggests that the incentive arrangements have been effective with respect to *cost level* performance. LSFP contracts deliver the best *cost predictability*. The LSFP contracts also provide the best relative schedule performance for project implementation if the time required for tendering is excluded. Taking the latter into account, CPIF contracts provide the best schedule performance. Projects with a CPPF contract display the worst cost performance and the worst schedule performance. An analysis of CPIF contracts indicates that the effectiveness of incentive constructs can be improved by limiting the number of performance criteria. A stochastic simulation model indicates that in many cases the initial target cost is set too low and that fee limitations are in many cases unduly restrictive.

Contract theory, particularly the economics of information, indicates how alternative contracting strategies on LECPs can be used to overcome economic inefficiencies. To enable practitioners to use theoretical contracting (economics) concepts, these need to be translated into practical experience-based models. Theorists need to have access to data for empirical research, to expand and validate existing models and develop new ones. Closer cooperation between theorists and practitioners will enable both to play their part in addressing the challenges and opportunities associated with LECPs in the future.

In the future, contracting will be a core competency of any successful owner organisation involved in the development and implementation of LECPs. Owners with the required in-house project management and contracting competencies and the ability and willingness to accept financial risks, will be able to realise LECPs faster and at lower capital cost than companies that do not possess these attributes. Furthermore, an inability to deploy a range of different contracting strategies and tactics will result in viable projects not being implemented.

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Samenvatting

Economie van contracten voor grote technische ontwerp- en constructieprojecten

Grote technische ontwerp - en constructie projecten (*Large Engineering and Construction Project*s, LECP's) vormen een belangrijke economische activiteit in de vorm van zeer uiteenlopende 'kunstwerken'. Deze projecten onderscheiden zich doordat het enorme werken zijn die zich uitstrekken over lange periodes waarbij grote geldbedragen gemoeid zijn. Onzekerheid en risico zijn prominent aanwezig. In de olie-, gas- en petrochemische industrie spelen ingenieursbureaus (*Engineering Contractors,* EC's) een belangrijke rol in de ontwikkeling en uitvoering van LECP's voor procesinstallaties. De overeenkomst tussen de opdrachtgever en de EC is de formele neerslag van hun relatie, waarin de verplichtingen en rechten van de partijen zijn neergelegd en ook het risico wordt verdeeld. Het *contractproces* (dat de gehele levenscyclus van het project omvat) is een belangrijk middel voor sturing van LECP's. Een theoretisch raamwerk voor contracten voor LECP's, gebaseerd op praktijkervaring, is ontwikkeld door middel van het analyseren en modelleren van contractstrategieën en tactieken (zoals verschillende soorten contracten) gevalideerd door middel van genormaliseerde data.

Vanouds vindt de selectie van een EC voor een LECP, in de olie-, gas- en petrochemische industrie, voornamelijk plaats via een (besloten) biedingproces gebaseerd op een *Single Lump Sum/Fixed Price* contract (*Vaste Prijs,* LSFP) voor *Engineering, Procurement en Construction* (Ontwerp, Inkoop en Constructie, EPC). De LSFP/EPC biedingprijzen zijn gebaseerd op een (stochastische) kostenraming van het werk, die wordt vermenigvuldigd met een zekere marge. Bij het vaststellen van deze marge moeten de bieders hun potentiële winst en de waarschijnlijkheid dat het contract aan hen gegund wordt optimaliseren. De bestaande biedingmodellen (waarvoor vele open biedingen nodig zijn) kunnen niet worden gebruikt voor LECP's. Er wordt een alternatief model voor de biedingoptimalisatie voorgesteld waarbij een 'toegepaste benadering' wordt gebruikt. Een kwantitatieve analyse van de data van een opdrachtgever geeft aan dat in een markt met veel concurrentie (zoals gedurende de jaren tachtig en negentig van de vorige eeuw), de relatieve contract kosten voor de opdrachtgever voor implementatie van LECP's bij één enkele bieder ongeveer 14% hoger was dan met twee bieders en ongeveer 22% hoger dan met drie bieders. Het model biedt een praktische methode voor het analyseren van biedingsprocessen voor LECP's zonder de vele biedinggegevens die nodig zijn bij bestaaande modellen.

De gebruikelijke strategieën voor het uitbesteden van de ontwikkeling en implementatie van LECP's zijn gebaseerd op een sterk concurrerende markt. Ze voldoen niet in de huidige markt met relatief weinig competitie. Met deze strategieën wordt namelijk geen matigend effect gecreëerd ten aanzien van de economische inefficiënties in een oligopolide markt die een beperkt aantal EC's, beschermt door aanzienlijke toetredingbeperkingen, in staat stelt om een economische winst te maken gedurende een lange periode. In alternatieve contractstrategieën wordt erkend dat de *coördinerende* rol van de EC in de ontwikkeling en implementatie van de LECP's cruciaal is voor de succesvolle uitvoering van deze projecten. Het is niet zozeer de inkoop van een *product* (m.a.w. de procesinstallatie) onder een LSFP/EPC contract, maar eerder de aankoop van *diensten* op het gebied van ontwerp, inkoop en constructie management (*Engineering, Procurement and Construction management* EPCm) waarvoor de opdrachtgever de EC nodig heeft. In een Kosten-Plus-Percentage-Vergoeding (*Cost Plus Percentage Fee,* CPPF) of Kosten-Plus-Bonus-Vergoeding (*Cost Plus Incentive Fee*, CPIF) contract vergoedt de opdrachtgever aan de EC alle kosten die samenhangen met het project (zoals materialen en apparatuur, evenals de constructiekosten). Om de belangen van de opdrachtgever en EC op één lijn te brengen en de laatste te stimuleren om op te treden als een agent van de opdrachtgever in plaats van als zijn tegenstrever, bevatten CPIF contracten een prestatie gerelateerde bonusstructuur. Met het CPIF (en CPPF) contract wordt de EC beschermd tegen fluctuaties in de prijzen van materialen, apparatuur en constructiewerk, gedurende de implementatie van het project als de aankooporders en constructiecontracten moeten worden gegund. Bij grote, risicovolle LECPs, waarmee grote sommen geld gemoeid zijn en de EC in het algemeen niet in staat is om de financiële gevolgen van de inherente risico's te dragen, vormen CFIF-contracten een alternatief dat vanuit een economisch standpunt interessanter is dan een (vaste prijs) LSFP benadering. Dit is vooral van belang in een markt met weinig concurrentie, wanneer de 'prijs premie' voor een (enkelvoudige) LSFP/EPC benadering substantieel hoger is dan in een markt met veel concurrentie.

Effectieve samenwerking betekent dat de contractpartijen wederzijds van elkaar afhankelijk zijn. De afwezigheid van reciprociteit creëert een relationeel risico: m.a.w. het risico van opportunistisch gedrag van de EC. Dit is vooral van belang bij de CPIF/EPCm contracten waarbij de opdrachtgever afhankelijk is van de EC die voor en namens hem optreedt. Het meest effectieve sturingsmechanisme om de ruimte en intentie voor opportunistisch gedrag te beperken is het controleren van de prestaties (meer dan de contractvoorwaarden) en het werken aan het vertrouwen en de reciprociteit tussen de opdrachtgever en de EC gedurende het contractproces.

De tijdwaarde van geld speelt een centrale rol in de economische evaluatie van de LECP's, maar blijft vaak onderbelicht in de analyse van de contractkosten. Voor LECP's in de olie-, gas- en petrochemische industrie geeft de Verdiende Waarde (*Earned Value*, EV) een goede beschrijving van de feitelijk vereiste cash flow en projecten kenmerken zich doordat zij dezelfde generieke EV-curve volgen. Het is gebruikelijk in de praktijk om onder LSFP contracten voorschotten te betalen op basis van een generiek schema. De kosten van de voorschotten (op basis van de Netto Contante Waarde, *Net Present Value Calculation*), onder een LSFP contract ten opzichte van de betalingen onder een CPF contract lopen op tot ongeveer 6% van de totale project kosten.

Er wordt een empirische analyse gemaakt van de projectresultaten onder CPIF, LSFP en CPPF contracten, waarbij gebruik is gemaakt van een database met 32 projecten van een opdrachtgever. Op grond van de analyse kan worden gesteld dat de stochastische kostenschattingen, die ten grondslag liggen aan de database, objectief en nauwkeurig zijn. De relatieve kosten voor de opdrachtgever onder LSFP en CPPF contracten waren ongeveer, respectievelijk, 8% en 16% hoger dan onder CPIF contracten (waarbij is gecorrigeerd voor de verschillen in cash flow). Dit suggereert dat de prestatiegerelateerde vergoedingsstructuur effectief is geweest met betrekking tot het *kostenniveau*. Bij LSFP contracten scoort de *voorspelbaarheid* van de kosten het beste. Deze laatst genoemde contractvorm geeft de beste relatieve resultaten ten aanzien van de tijdsduur van project implementatie, als de periode van biedingproces buiten beschouwing wordt gelaten. Als dit laatste element wel wordt meegenomen, geeft een CPIF contract de beste resultaten. CPPF contracten geven de slechtste resultaten met betrekking tot de kosten en het presteren volgens de tijdsplanning. Een analyse van CPIF contracten geeft aan dat de prestatiegerelateerde bonusstructuur kan worden verbeterd door het aantal prestatiecriteria te verminderen. Een stochastisch simulatiemodel geeft aan dat in veel gevallen de initiële richtprijs te laag wordt gezet en dat een limitering van de bonus onnodige beperkingen oplegt.

In de contracttheorie, vooral de informatie economie, wordt aangegeven hoe alternatieve contractstrategieën bij LECP's kunnen worden benut om economische inefficiënties tegen te gaan. Om de praktijk behulpzaam te zijn bij het gebruik van theoretische contract(-economische) concepten dienen deze te worden vertaald in praktische, op ervaring gebaseerde modellen. De wetenschap dient toegang te hebben tot data voor de uitvoering van empirisch onderzoek om bestaande modellen uit te breiden, te valideren en nieuwe modellen te ontwikkelen. Betere samenwerking tussen wetenschappers en praktijkmensen betekent dat beiden hun eigen rol in de uitdagingen en mogelijkheden met betrekking tot LECP's beter kunnen vervullen.

In de toekomst zal contacteren een kerncompetentie van opdrachtgevers zijn voor de succesvolle ontwikkeling en implementatie van LECP's. Opdrachtgevers met de vereiste interne competenties met betrekking tot project management en contracteren en het vermogen en de bereidheid om financiële risico's te aanvaarden, zullen in staat zijn om LECP's sneller en tegen lagere kosten te realiseren dan opdrachtgevers die deze vaardigheden ontberen. Bovendien zal het gebrek aan deze vaardigheden leiden tot het niet uitvoeren van economisch aantrekkelijke projecten.

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Contents

1

Introduction

1.1 Large engineering and construction projects

Large Engineering and Construction Projects (LECPs) form an important area of economic activity, covering a large range of artefacts such as tunnels, bridges, dams and processing facilities. Whereas the artefacts may be different, all these LECPs have in common that they are massive undertakings with a big impact on their environment. They span long time periods, involve large capital investments and *"require competence to cope with risks and turbulence, and they become manageable through the design of strategic systems, the infusion of governability, the transformation of institutions, the design of financial arrangements, and the building of owner-contractor relationships"* (Miller and Lessard, 2000). The research described in this thesis considers the latter and more particularly the process of contracting for engineering, procurement and construction (management), formalising the relationship between owner and main contractor. The context is the oil, gas and petrochemical industry and the LECPs pertain to processing facilities with a capital cost in excess of Euro 200 million. Many of the considerations, however, are equally relevant for other businesses.

1.2 Contracting in the oil, gas and petrochemical industry

Affordable, clean and reliable energy is essential for sustainable development; i.e. meeting the needs of the present without compromising the ability of future generations to meet their own needs. Fossil fuels currently supply around 85% of the world's primary energy needs with oil and natural gas accounting for some 60% (EIA, 2005). It is expected that after 2025, renewable sources of energy will start to make a significant contribution as their costs continue to decrease while prices for oil and gas increase. Until the middle of the century, however, alternatives in sufficient amounts and at a marketable price will not be available. During this period fossil fuels will continue to be the dominant sources of energy and LECPs for new processing facilities will continue to be an important feature of the (capital intensive) oil, gas and petrochemical industry.

International Engineering Contractors (ECs) have become an indispensable part of the development and implementation of LECPs. In most owner organisations, engineering and project management capabilities are only present in the form of a relatively small, core organisation nowadays. During the 1980's and 1990's, owners contracted out the implementation of LECPs to a large extent on the basis of (competitively tendered) single Lump Lum / Fixed Price (LSFP) contracts for Engineering, Procurement and Construction (EPC). Through these contracts they were able to transfer the project implementation risk at a relatively small premium to ECs in a business environment that displayed the characteristics of a 'buyer's market'. This situation has taken a dramatic turn during the last 5 – 10 years. The procurement market for materials and equipment has become constrained, skilled construction labour is scarce and there is a shortage of experienced EC personnel. The 'risk premium' associated with LSFP/EPC contracts has increased to such a level that many projects are not longer viable. Increasingly, owners as well as ECs are looking at for Cost Plus Fee (CPF) type contracts for Engineering, Procurement and Construction management (EPCm) services whereby the owner takes the risk for (bulk) materials, equipment and construction. With these contracts, the EC acts as an agent 'for-and-on-behalf-of' the owner and many have a Cost Plus Incentive Fee (CPIF) remuneration structure to induce the EC to perform the EPCm services in a manner that serves the interests of the owner (as well as its own).

A typical project organisation, illustrating the key role of the EC, is shown in Figure 1.1. Generally, some 20% of the project implementation cost pertains directly to EC involvement; 40% is procured from suppliers of materials and equipment and another 40% from construction contractors (Berends and Dhillon, 2004)[1].

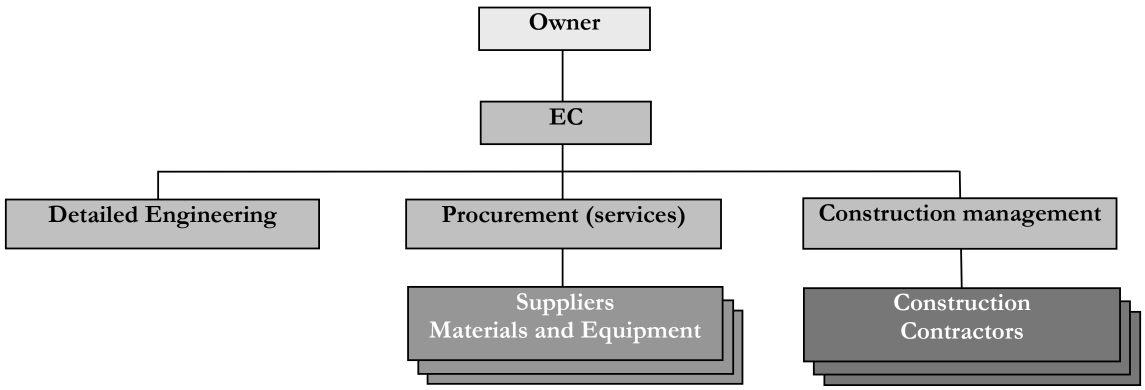

Figure 1.1
Typical project organisation and work breakdown structure on LECPs

1.3 Research objectives and scope

Over the last decades, a vast amount of economics literature on contracts was developed, dominated by the principal-agent model and (Nash equilibrium) utility theory; e.g. (Laffont and Martimort, 2002) and (Bolton and Dewatripont, 2005). The essential paradigm in the principal-agent model is that principal and agent both pursue their self-interest and that they are asymmetrically informed. In some relationships there is an inherent alignment between the interests of the service provider (i.e. the agent) and the party buying the service (i.e. the principal). In most business transactions, however, this is not the case and monetary incentives are required to create (in an economic sense) efficient[2] coordination between the contract parties.

Despite the great advances in the economics of contracts, the practical application of theoretical analyses to the development and implementation of projects has remained limited due to restrictive theoretical assumptions and the difficulty to obtain high quality, normalised data. Project managers and contracting practitioners on the other hand are steeped in experience and consider themselves primarily as 'builders'. In many cases they have an intrinsic aversion against theoretical constructs, unless they are factual and directly applicable in practice. The considerable project management literature (e.g. PMI, 2000) is largely focussed on control processes and procedures. Whilst these are essential tools for the successful execution of projects, they do not provide practitioners with a theoretical framework for the contracting process. Such a framework is particularly important for LECPs which, due to their size, complexity and duration, are governed by specific dynamics.

The objective of the research described in this thesis then, is *the development of an experience-based theoretical framework of contracting for LECPs by analysing and modelling contracting strategies and tactics (e.g. contract types) and validation through normalised data*.

The research has the hallmarks of a project in the sense that it requires the organisation of (human) resources in a novel way, to undertake a unique scope of work, within constraints of time (and cost) to achieve beneficial change (Turner, 1993). It aims to build a bridge between contract theorists and industry practitioners. The main perspective is that of the owner organisation, although many considerations are equally relevant for the EC.

1.4 Research methodology

Because LECPs are unique endeavours, the study of contracting on LECPs is generally difficult. The development of theoretical models is also hampered by the fact that data is usually inaccessible to academics for empirical research, because it is considered confidential by owners.

The framework developed in this thesis is based on an 'applied approach', with an emphasis on the practical application of the theoretical models. This also involves a learning process as initial model outputs are scrutinised and results that do not correspond with intuitive understanding, lead to model changes and/or a new understanding and updating intuition (Chapman, Ward and Bennell, 2000). A number of different, complementary research methodologies are used: analysis of empirical data, case study research and a survey supplemented by focused interviews. In doing so, the 'what', 'how' and 'why' of the various concepts are addressed (Yin, 2003).

For the validation of the theoretical models, a dataset from a *case study owner organisation* (Royal Dutch Shell) is used. The comprehensive, high quality, stable dataset avoids the limitations of comparing cross-company data that lack a common basis. Obviously, one should be careful in generalising data from one company, as the results could be idiosyncratic. This risk is mitigated by comparing the findings, where possible, with those from related studies from the literature.

1.5 Thesis outline

Chapter 2 describes the development and implementation of LECPs and the organisational arrangements between the main stakeholders. The contracting market structure in the oil, gas and petrochemical industry is analysed particularly with respect to the (contractual) relationship between owner and EC. The theoretical basis of the main types of contract pricing is presented. Traditional and alternative contracting strategies and tactics are discussed together with an application of (economic) contract theory based on the principal-agent model.

In ***Chapter 3*** a conceptual model is developed for (traditional) closed, competitive bidding on the basis of a single LSFP/EPC contract. Existing bidding models are largely based on the one described by Friedman in his seminal paper of 1956. These existing models require many bidding events and routinely published bid data; conditions which are not fulfilled for LECPs. The alternative bid optimisation model presented here does not rely on these prerequisites. It provides for a practical application by knowledgeable owners that execute LECPs on a regular basis. The model is applied to a dataset of the case study owner organisation.

Effective cooperation of owner and EC requires reciprocal dependencies between contract parties. In ***Chapter 4*** three case study projects (with a similar scope of work) are analysed using independent benchmarking data and direct participant observations. One project was executed on the basis of a LSFP/EPC type contract. On the other two a CPIF/EPCm type contract was used. The cost and schedule performance of the three case study projects is discussed together with the relation between contract type and contracting market conditions prevailing at the time of execution.

Lack of reciprocity between owner and EC results in relational risk; i.e. the risk of opportunistic behaviour. This is particular relevant for CPIF/EPCm contracts. In ***Chapter 5*** the factors that create relational risk under these contracts and possible mitigating actions are investigated. Particular attention is paid to trust attributes. A conceptual model and research hypotheses are developed, based on decision (behavioural economics) and transaction cost theory. These are empirically tested through a survey and multivariate statistical analysis, supplemented by focused interviews. The population consists of the case study owner organisation and all major ECs.

The time value of money is an underexposed aspect of projects with a long implementation schedule such as LECPs and needs to be considered when comparing project cost performance under different types of contract. In ***Chapter 6*** the earned value concept is used to investigate the differences in expenditure phasing under LSFP/EPC and CPF/EPCm contracts. Parameterised S-curves are developed on the basis of an empirical analysis of data from the case study owner. The findings are validated through a comparison with the results from similar studies in the literature.

In ***Chapter 7*** the results of a comparative analysis of cost and schedule performance (level/duration and predictability) on LSFP/EPC and CPIF/EPCm contracts are presented (taking into account the results of chapter 6). The effectiveness of multidimensional incentive constructs under CPIF/EPCm contracts (described in chapters 4 and 5) is investigated through stochastic simulation. Specific attention is given to setting the target cost, which forms a crucial performance criterion. The incentive fee levels on CPIF/EPCm contracts are discussed in conjunction with the profit levels under LSFP/EPC contracts (described in chapter 3).

Each of the chapters 2-7 contains a summary, introduction and conclusions pertaining to the chapter specific subject matter. ***Chapter 8*** outlines the main conclusions of the preceding chapters as well as an outlook on capital contracting.

Notes

1 Whilst these percentage are typical for LECPs in the oil, gas and petrochemical industry, differences exist between projects.

2 The outcome *x* of a certain event is efficient if it is feasible and there is no other feasible outcome *y* that gives all parties at least as much utility (value) as outcome *x* while giving at least one party strictly more utility than *x* (Campbell, 1995).

1.6 References

Berends T.C., Dhillon J.S., 2004. *An analysis of contract cost phasing on engineering and construction projects*, The Engineering Economist, 49(4), pp 327-337.

Bolton P., Dewatripont M, 2005. *Contract theory*, Massachusetts Institute of Technology (MIT) Press, USA.

Campbell D.E., 1995. *Incentives – Motivation and the economics of information*, Cambridge University Press, UK, p1, p27.

Chapman C.B., Ward S.C., Bennell J.A., *Incorporating uncertainty in competitive bidding,* International Journal of Project Management 18 (2000) 337-347

Energy Information Administration (EIA), *International Energy Outlook 2005*.

Friedman L., *A competitive bidding strategy,* Operations Research, 4 (1) 1956; 104-112

Laffont J-J, Martimort D., 2002. *The theory of incentives, The principal-agent model*, Princeton University Press, USA.

Miller R., Lessard D.R., 2000. *The strategic management of large engineering projects*, p16, Massachusetts Institute of technology, Cambridge, USA.

PMI, Project Management Institute, 2000. *A guide to the Project Management Body of Knowledge (PMBOK ©)*, Newtown Square, PA, USA.

Turner J.R., 1999. *The handbook of project based management – Improving the processes for achieving strategic objectives*, McGraw-Hill Book Company, Maidenhead, England, Second Edition, p3.

Yin R.K., 2003. *Case study research – Design and methods*, Sage Publications Inc., Thousand Oaks, California, USA, p1-18.

2

Contracting and market conditions

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The amount of global oil and gas processing capacity required to meet demand during the next 20 years is more than twice the amount realised during the last decades. ECs play a key role in the development and implementation of LECPs for these facilities. In this chapter the characteristics of LECPs are examined together with demand & supply of the contracting market and the strategies traditionally adopted by owners to contract out the development and implementation of these projects to ECs. These traditional strategies are generally based on a highly competitive market and they are not longer effective, in the current 'sellers' market', to mitigate the oligopolistic economic inefficiencies. A limited number of ECs sheltered by significant entry barriers have the potential for economic profits for a prolonged period of time. Contract theory, particularly the economics of information on LECPs, indicates how alternative contracting strategies can be used to overcome economic inefficiencies. These alternative strategies require increased owner involvement and their effectiveness is contingent upon owner competency and ECs acting as the owner's agent rather than its adversary. This will require an organisational and behavioural change process for both owners and ECs.

2.1 Introduction

During the next 20 years, the global marketed energy consumption is projected to grow by some 40%; i.e. approximately the same annual percentage increase as the last 20 years (EIA, 2005). In *absolute terms*, this means that the processing capacity that has to be realised during the next 20 years is more than twice the amount realised during the last decades. Already, owners in the oil and gas industry are facing an overheated contracting market for engineering and construction projects. This situation is expected to continue for a considerable number of years, which will significantly affect the way projects for new processing facilities are developed and implemented.

In this chapter the characteristics of the (technical) development and implementation of LECPs are discussed. A demand and supply analysis is presented, describing the workings and constraints of the contracting market for LECPs. Prevailing contracting strategies are considered and how insights from contract theory and the economics of information can be used to establish optimum contracting strategies and tactics under different market conditions.

2.2 Project characteristics

2.2.1 The project life-cycle

The project management of LECPs centres around the project life-cycle: the staged process of creating the facility. The project life-cycle can be broken down in various ways (e.g. Ward and Chapman, 1995). For the purpose of the analyses in this thesis a breakdown in two phases is sufficient:

(a) Development;

(b) Implementation.

Development[1] is in many ways the most critical part of the project life-cycle, when the geographical location and main functionality parameters of the new facility are defined in essence. Here, functionality is defined as: the facility's capacity to create value through the conversion of feedstock into products, during its lifetime, in specified quantities and to a specified quality. Main considerations with respect to choosing the location are feedstock access and consumer proximity. The functionality and other project dimensions (capital cost, schedule and organisation) are developed in progressively more detail in a number of sequential stages. At the end of each stage, an evaluation is made whether or not to proceed, to avoid development cost being spent on projects that are not viable. The implementation (detailed engineering and construction) phase follows a positive Final Investment Decision (FID), taken at the end of development. Another distinct reference point in the project life-cycle (at the end of implementation) is the start-up of the facility when the responsibility is transferred from the project organisation to the operations management organisation.

LECPs for new processing facilities in the oil and gas industry are technically complex, involving the integration of many different technical disciplines on the basis of a large codified body of knowledge. The technical complexity is perhaps best illustrated by the high level of technical availability[2], typically over 95%, during the lifetime of the facility (typically 20-25 years). This places high demands on the quality of the technical development and implementation process to achieve the required functionality. The risks on LECPs are high because:

(a) The large investment yields no revenue until after implementation and delays in project completion will generally have a major impact on the profitability of the project;

(b) The facility is indivisible with limited possibilities to reduce exposure through breaking up the scope of work;

(c) Transferring the facility to another location is generally not feasible with limited options for redeployment of equipment; and

(d) Development and Implementation times are long, typically 2-3 years and 3-5 years respectively.

Risk management is therefore an integral part of project management during both project development and implementation (Chapman, 1997). Indeed, the main reason for staged development is to enable effective management of the inherent uncertainty. The cost of development tends to be 1-3% of the total installed cost of the facility. Because projects are unique endeavours, these development costs and the associated valuable (owner) resources are largely sunk if the project is not implemented. Once a positive investment decision has been taken, major commitments have to be made early during project implementation (Berends and Dhillon, 2004).

2.2.2 Institutional arrangements

The development and implementation of LECPs constitutes a change process, bringing together a large number of institutions or stakeholders involved in creating the facility[3]:

(a) The owner of the facility (and its shareholders), lenders, export credit agencies, insurers, etc.;

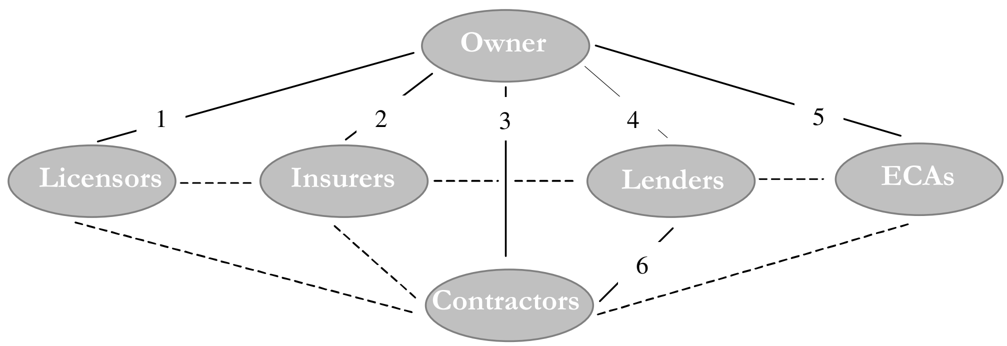
(b) Contractors (licensors, engineering contractors, construction contractors, suppliers of equipment and materials, etc.);

(c) Authorities (governmental as well as local), local communities, non governmental organisations, etc..

For the successful realisation of LECPs, a systemic organisational framework for institutional cooperation is critical (rather than traditional project control procedures). All projects inherently require the ability to adapt to changes and uncertainty in the business environment during development and implementation (Olsson, 2006). But this flexibility is particularly important for LECPs, due to the long project life-cycle.

It is appropriate to consider the role of the lenders because, in the case of project financing, they will exert significant influence on the contracting strategy and tactics. Using 'project financing' to obtain the capital required for an LECP provides a number of advantages for the owner. It will involve only a limited amount of (shareholder) equity, it enables risk transfer to lenders and it protects corporate shareholder organisations through the non-recourse (or limited recourse) nature of the loan agreement. Project financing also has a number of drawbacks however. Notably, the transaction costs are high and the arrangement restricts the owner's project management flexibility (Esty, 2004). To safeguard the collateral associated with the loan agreement, the latter will generally include rights for the lenders with respect to the way the project is executed, including the main agreements. See also Figure 2.1. This collateral relates to the tangible project assets as well as the agreements and other (intangible) assets related to the project's value generating capacity. The owner has an obligation to keep the lenders informed regarding the status of the project during implementation. Furthermore, lenders may insist on so-called 'direct agreements' with the main contractors, enabling the lenders to take over and complete the project if the owner defaults on its obligations under the loan agreement (Scriven, Pritchard and Delon, 1999a).

Financing for projects in parts of the world with a (perceived) political risk will often require the involvement of an Export Credit Agency (ECA). These provide guarantees of loans, subject to goods and services being purchased from the country concerned, thus creating restrictions for contractors. ECAs are becoming increasingly flexible in their offerings and are lately also considered as a complementary source of capital (Newendorp, 2005).



——	Contracts
-----	Influence

1: License agreement
2: Construction all-risk insurance (CAR)
3: Engineering, procurement and construction (EPC) contracts
4: Loan agreement
5: Export credit agency guarantee
6: Direct agreement

Figure 2.1
Typical stakeholders agreements map

2.3 Demand and supply analysis

2.3.1 Demand for oil refining and gas processing facilities

As indicated in paragraph 2.1, fossil fuels will be the dominant source of energy during the next decades. Oil will continue to play an important part as the primary energy source for transportation, with refineries being mostly located close to the end users. Since 1980, global consumption of refinery products has grown by some 28% from 60.7 to 77.5 million barrels of crude per day (MMbc/d); see Table 1. Whilst in this period total global refinery capacity has grown by a mere 4%, significant regional changes have taken place. Consumption in North America has increased whereas refinery capacity has decreased, resulting in the region currently being a net importer of refined products. The recent calls (in the aftermath of Hurricane Katrina) to expand the refinery capacity in the United States illustrate the sensitivity in this area. In Western Europe, the overcapacity that existed in 1980 has disappeared due to a relatively small decrease in consumption coupled with a strong decrease in capacity (particularly during the early 1980s). In Eastern Europe, consumption is less than half of what it was in 1980 and (mainly old) refinery capacity is still being taken out. In the Asia Pacific region, capacity has increased strongly, but the current regional capacity is insufficient because consumption has increased with 124% since 1980.

Table 2.1
Global Refinery Capacity and Consumption [MMbc/d]
Calculated from: (OPEC, 2005).

	Capacity				Consumption			
	1980		2005		1980		2005	
North America	20.6	25%	19.1	22%	18.8	31%	22.4	29%
Latin America	8.7	11%	8.1	9%	4.3	7%	6.7	9%
Western Europe	21.1	26%	15.5	18%	15.1	25%	14.7	19%
Eastern Europe	13.5	16%	9.8	11%	10.1	17%	4.8	6%
Africa	2.2	3%	3.3	4%	1.0	2%	2.2	3%
Middle East	3.9	5%	6.7	8%	1.6	3%	4.8	6%
Asia Pacific	12.4	15%	22.8	27%	9.7	16%	22.1	29%
Total	82.3		85.5		60.7		77.5	

Since 1980, capital investment projects in Western Europe have predominantly been related to facilities for conversion and treating (rather than distillation capacity), driven by: (i) environmental considerations; and (ii) deteriorating crude oil quality (Oil & Gas Journal, 1980-2005). These forces will continue to drive demand for upgrading projects in the rest of the world as well during the next decades. Refinery capacity in North America is expected to grow to overcome the current sensitivity to any disturbances in regional capacity and to meet additional consumption. In the Asia Pacific region, high levels of economic growth and demographic factors (the region accounts for the largest population growth in the world) will continue to drive demand for additional refinery capacity. Globally, the Energy Information Administration (EIA) projects an annual growth of 1.9% during the next 20 years (EIA, 2005). Based on the current global capacity, this additional annual capacity amounts to four new refineries like the one of Royal Dutch/Shell in Pernis, The Netherlands.

The global natural gas consumption is projected to grow by some 60% during the next 20 years, making it a fast growing primary energy source. Half of this increase pertains to electric power generation, replacing oil- and coal-fired plants that are more carbon intensive than natural gas. The other half relates to residential, commercial and transport uses. Liquefied Natural Gas (LNG) will become increasingly important. During the last decade, LECPs for new gas processing facilities have grown in size due to technological improvements. The increased economies of scale have resulted in a fall in specific capital cost of processing facilities (Cogan, 2005). Many natural gas resources are located either a long distance from end users or they lack a pipeline infrastructure. These factors coupled with a sharp drop in LNG carrier prices during the last decade makes LNG increasingly competitive vis-à-vis supply via pipeline (Robertson, 2005). In the period 1990-2000, LNG production capacity increased yearly by an average of 5 million tonnes per year (MMtpy) and during 2000-2005 by 8 MMtpy. For the next decades, this is expected to increase to 20 MMtpy additional capacity per year; see Figure 2.2. Obviously, the demand for re-gasification terminals (close to end users) will increase accordingly.

Recently, 'Gas-To-Liquids' (GTL) technology has attracted significant attention as an alternative way to commercialise natural gas resources. This will further increase the demand for oil and gas processing facilities.

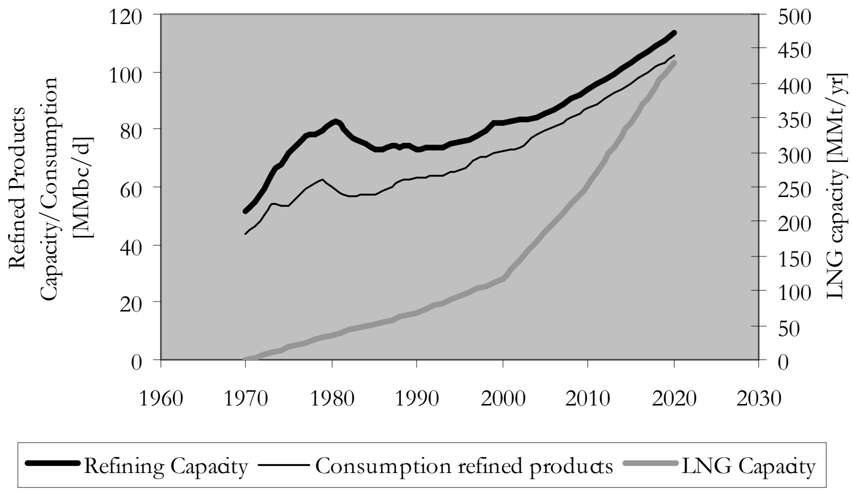


Figure 2.2.
Historical/Projected Global Refinery Capacity [MMbc/d] and LNG Production Capacity [Mmt/yr]

Note: LNG capacity is in many cases 'sold' through long-term sales agreements prior to completion. Consequently, the demand and supply curves for LNG are almost the same.

Calculated from: (Cook, 2005a), (Cook, 2005b), (EIA, 2005), (Hydrocarbon Processing, 2000-2005), (Oil & Gas Journal, 1980-2005), (Oil & Gas Journal, 2003), (OPEC, 2005), (Robertson, 2005), (Wood Mackenzie, 2006).

2.3.2 Supply of engineering, procurement and construction services

In the 1960s and early 1970s, the oil industry was dominated by a limited number of International Oil Companies (IOCs). In the middle of the 1970s, they lost most of their power in the (upstream part of) business to National Oil Companies (NOCs) of the exporting countries through new production agreements and expropriation of assets (Yergin, 1991). Up to that time the IOCs executed most of the EPCm activities on projects themselves. Small and medium size projects were executed by local organisations and LECPs by central engineering and project organisations. The actual construction work was contracted out to (local) construction companies or labour was engaged on a 'direct hire' basis.

During the 1970s, these EPCm capabilities, once considered to be the exclusive domain of the IOCs, started to shift to ECs. Initially, their involvement was limited to occasional drafting services for detailed engineering. During the 1980s however the profits of the oil companies plummeted, leading to a focus on cost reduction and core competencies[3]. This included contracting out all detailed engineering work to ECs. Over time the ECs expanded their services to procurement and eventually companies emerged capable of tackling all EPCm activities (Van Rooij and Homburg, 2002). Nowadays, EPCm activities on LECPs (and smaller projects) are carried out in virtually all cases by ECs and they have become increasingly involved in project development as well (Smith, Dunn, Yarossi and Merrow, 1993), (BRT, 1997). Construction work on LECPs is frequently executed by international construction companies, which integrate several technical disciplines and are specialised in the construction of complex process facilities. This includes companies, specialised in the design and construction of certain facilities, such as marine works and storage tanks. Many ECs also are licensors for certain process technologies. In order to share the risks, a number of ECs usually work together on the implementation of

LECPs in the form of a joint venture. This may be a separate legal entity (usually in the form of a limited liability company) or an unincorporated structure with a contractual arrangement between the participants (Sriven, Pritchard and Delon., 1999b).

Despite becoming increasingly involved in project development and implementation, the reduced investments in oil and gas processing facilities in the 1980s created a crisis for the ECs resulting in redundancies and large-scale consolidations. Furthermore, during the last decade, the profitability of the ECs has been poor and they have found it difficult to attract young technical talent. In the last 15 years, more than 75 ECs were acquired, merged, or went out of business (Stell, 2003). Medium size companies have largely disappeared and less than 20 large international ECs with the capability to (jointly) execute LECPs have remained. The capacity of these remaining ECs is geared to the demand levels that existed during the last decades and not to the substantially higher levels that will be required during the next decades. Many ECs have opened offices in countries like India and/or have entered into agreements with local engineering contractors to reduce cost. These 'new engineering centres' will provide additional resources. It is questionable however whether these can be integrated fast enough into the existing EC organisational structures to meet the increased demand levels whilst sustaining the required quality. Due to the technical complexity referred to earlier, knowledge of the large, industry specific, codified body of knowledge is required to work in the industry. The management of multiple operating centres will be a key factor with respect to organisational effectiveness (Dudley, 2005).

2.3.3 Structure of the contracting market

The number and size of buyers and sellers is an important characteristic of market structure. Refining facilities are in many cases located close to the end users and are owned by a large number of different NOCs and IOCs. Natural gas liquefaction plants on the other hand are located close to the gas resources, with owners consisting of NOCs as well as joint ventures of NOCs and IOCs. Hence, the number of owners is large and their financial strength is substantial. The number of ECs capable of taking on LECPs on the other hand is quite small (as outlined in section 2.3.2) as is their market capitalisation. In a number of emerging economies (e.g. China) national engineering contractors execute most of the LECPs, although their resources are increasingly stretched as well. The fact that ECs mostly operate on LECPs in the form of joint ventures further reduces the number of bidders in a competitive tendering situation. As will be discussed below, this has a significant impact on the strategic and tactical contracting options available to owners.

Service differentiation is another market characteristic. Some ECs have particular strengths in engineering, some in procurement and others in construction management, though all essentially carry out the same EPCm activities. On oil refining (and petrochemical) projects, service differentiation predominantly relates to process technology (e.g. an EC acting as licensor) and associated project specific experience, resulting in higher efficiency of certain ECs. Differences in cost level between EC's are relatively small.

The dissemination of cost and quality information in the contracting market is generally good. As indicated in paragraph 1.2, only 20% of the project implementation cost pertains directly to EC involvement (i.e. the EPCm activities); 40% is procured from suppliers of materials and equipment and another 40% from construction contractors. The cost information associated with materials, equipment and construction can be obtained by all ECs. Cost information on EPCm services is exchanged through EC joint ventures and (indirectly) through the costing of the industry's large transient workforce. The corollary of this is that (in economic terms) the amount of available cost information is relatively large and the information cost is low. Information regarding the quality of the product/service offering pertains to the project dimensions schedule and functionality. With respect to schedule information, the start up date of an LECP is generally the subject of press announcements and consequently schedule delays attract not only the attention of the institutions involved but also from a wider audience. Information regarding the functionality (e.g. the technical availability of the facility) is generally less widely available. Also, any problems in this respect can be attributable to a wide range of causes and are therefore not considered to be a reliable measure of the quality of EC service provision.

Entry barriers for new (EC) entrants effectively exist due to owners displaying risk adverse behaviour. The risky nature of LECPs (as described in paragraph 2.1) has resulted in a tendency of owners to select only known, established ECs. This is particularly relevant for gas processing, a relatively new business compared to oil refining with new facilities costing several billion dollars.

Oligopoly effects result from the market characteristics outlined above. The differences in cost level between ECs is relatively small and dissemination of *cost information* is good. This does not hold true for *price information*. Contracts for implementation of LECPs for new oil and gas processing facilities are typically awarded through a closed (sealed) bidding process or through negotiation with one EC. In both cases bid price information is not made public. The price and output decisions of ECs are driven by strategic considerations; i.e. the decisions of an individual EC are, in part, based on the anticipated response from competitors. Classic economic oligopoly models are those by Cournot published in 1838 and Bertrand published in 1883, based on firms competing through choosing quantity and price of output respectively (Jehle and Reny, 2001). These have subsequently been developed through game theory, based on the concept of a non-cooperative equilibrium by Nash published in 1951 (Gibbons, 1992). Despite great theoretical advances during the last decades, modeling the current contracting market remains difficult due to the dynamics associated with the shift in demand and complex constraints. The latter pertains to (resource) input and financial (liabilities) constraints for individual firms as well as the number of firms being fixed in the 'short term'.

2.4 Contracting strategies and tactics

2.4.1 Generic strategy options

As indicated in section 2.3.2, owners largely contract out the technical development and implementation of LECPs to ECs. In essence, the different contracting strategies commonly used in the oil and gas industry, for the realisation of processing facilities, can be described by three generic models, which are schematically depicted in Figure 2.3.

In strategy (a), which is the approach used by most owners during the last decades, a development EC is selected after competitive tendering. The main deliverable of the development contract is a basic engineering package suitable for competitive tendering of the implementation work. The EC for implementation is selected after competitive tendering between a number of ECs. Strategy (b) comprises a 'design competition', also colloquially known as 'dual FEED'. Two ECs are selected after competitive tendering to (separately) develop a basic design on the understanding that one of them will be awarded the implementation contract. At the end of development, a (relatively short) tendering process between the two development ECs takes place. In strategy (c), a contract for development is awarded to an EC which subsequently also is awarded a contract for implementation following a (short) re-negotiation process at the end of development. If the owner and development contractor cannot reach agreement, the owner can put up the work for competitive tendering; i.e. switching to strategy (a). Strategy (c) means that effectively at the start of the development phase, an EC is selected for the entire project life cycle.

Schedule is in many cases an important consideration in selecting the optimum contracting strategy for a project. In strategy (c) a single EC is selected for development as well as implementation and the owner will therefore seek to agree the implementation contract as far as possible before committing itself to the development contract. Consequently, in most cases the initial tendering process under strategy (c) will take longer than under strategies (a) and (b). Under strategy (b), the owner is faced with the task of managing two development processes in parallel. This requires additional resources of and extensive coordination by the owner to ensure that (i) two comparable designs are obtained to facilitate an equitable bid evaluation; and (ii) intellectual property of one development EC is not transferred to the other. In practice this will generally result in the development schedule being longer than under strategies (a) and (c). Tendering and/or (re)negotiation for the implementation contract under strategy (b) and (c) can take place during (the last part of) development resulting in a shorter time period than when tendering under strategy (a). Also, the time and cost associated with mobilisation and familiarisation of a 'new' EC (i.e. an EC other than the development EC) can potentially be saved under strategies (b) and (c) resulting in many cases in a shorter implementation schedule than under strategy (a).

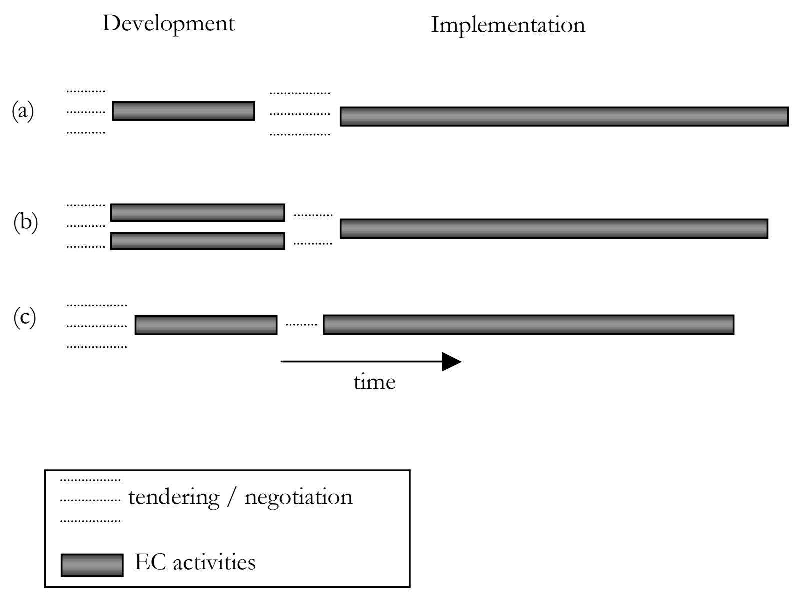


Figure 2.3
Contracting Strategies

Competitive tendering is a principle means for owners to obtain information on the optimum price in a contracting market. Under strategies (a) and (b) the entire project work scope is contracted out as one package in one tendering event. Under strategy (c), the development contract and the subsequent contract for EPCm services is tendered as one event (including some single source negotiation at the end of development). The 80% of project cost associated with materials, equipment and construction contracts is competitively tendered at the appropriate time during detailed design and engineering.

The transaction cost under strategy (b) is higher than under strategy (a) and (c), due to the additional cost associated with duplication of development work. In strategy (c) the owner and the EC have to negotiate a contract for implementation at some time during development. In the absence of tendered price information, the owner must rely on its in-house cost-estimating competency (supported by independent benchmarking as the case may be) in these negotiations. Another disadvantage is the lack of (price moderating) competitive market forces, although this may be overcome through certain types of contract pricing (see also section 2.4.2). On the other hand, in a 'buyers market' the development EC will have invested valuable resources in development, which could have been allocated more profitably to implementation contracts. Hence strategy (c) creates a mutual dependency between owner and EC at the end of development, providing an incentive for cooperation (Berends, 2005).

Information symmetry amongst all bidders is a basic condition for the tendering process to be efficient. Under strategy (a), this condition is fulfilled if the development EC does not take part in the tendering process for the implementation contract. The EC's involvement in implementation is much bigger than its involvement in development however; winning the implementation contract is by far the bigger prize. Therefore ECs may not be interested to tender for development work if this precludes them from taking part in the tendering process for implementation. On the other hand, if the development EC does participate in the tendering for the implementation contract, symmetry of ex ante information does not exist. Indeed, the development EC will in most cases also be better informed than the owner. The problem of bidders not being equally informed is reflected in the fact that under strategy (a) owners are finding it difficult to solicit interest and to obtain tenders for project implementation, if (i) it is known that the development EC is participating in the tendering process; and/or (ii) in the case of the expansion of an existing facility, the EC involved in the earlier project is participating. In a 'buyers' market', where there is strong incentive for ECs to tender for scarce opportunities, this may not be a problem for owners. But in a 'sellers' market' like the one currently prevailing in the oil and gas industry, owners find it difficult to solicit interest from ECs to compete with the incumbent EC. Under strategy (b), a 'level tendering field' for the implementation contract exists for the two development ECs.

Quality considerations are often mentioned as one of the reasons to select strategy (c) because it facilitates the retention of the implicit knowledge obtained during development (i.e. the tacit knowledge of the people involved) through continuity of key EC staff. The same applies for strategy (b) whereas under strategy (a) the continuity advantages do not exist in the event of the development contractor not being successful in winning the implementation contract.

2.4.2 Types of contract pricing

A large variety of contract pricing mechanisms is used in the oil, gas and petrochemical industry. Most of these can be described through the following model:

$$\Pi = \Pi_t + \alpha\,(C_t - C) \qquad (2.1)$$

$$C_c = C + \Pi \qquad (2.2)$$

where:
- Π actual EC profit
- Π_t target profit
- α EC sharing rate cost related profit; $0 \leq \alpha \leq 1$
- C_t target cost
- C actual cost (including EPCm service cost)
- C_c owner contract cost

The cost parameters above exclude owner's cost. The parameter C (and consequently Π and C_c) are stochastic by nature. The sharing rate α determines the type of the contract.

Under a Lump Sum / Fixed Price (LSFP) contract, the EC is paid a specified contract C_c sum for executing the work scope. The satisfactory completion of the project remains the obligation of the EC, regardless of the difficulties and troubles that may be experienced in the course of executing the work. If the actual project cost C exceed the contract sum C_c (i.e. Π becomes negative in equation (2.2)), the EC has to absorb the loss, try to renegotiate the contract or claim additional money through the contract provisions regarding a change in the work. During the last decades, owners have contracted out the implementation of LECPs to ECs mostly on the basis of LSFP contracts, with the scope of work comprising the entire project. In these cases the contract sum includes the risk premium that the owner has to pay for the EC carrying the project cost risk. Under an LSFP contract the sharing rate $\alpha = 1$, which gives:

$$\Pi = \Pi_t + C_t - C \qquad (2.3)$$

$$C_c = \Pi_t + C_t \qquad (2.4)$$

The sum $\Pi_t + C_t$ comprises the bid price; the owner will generally not obtain (reliable) information regarding the constituent parts nor on the ex post actual project cost C and the ex post actual EC profit Π. A knowledgeable owner will however be able to form its own ex ante opinion on the expected actual cost C vis-à-vis the bid price and from that, the expected EC profit subject to the variability in market conditions being limited. In a volatile market, owners will generally have difficulty in obtaining accurate, up-to-date actual data because (i) the number of projects going on at a particular time is generally limited (even for large owner organisations); and (ii) the owners' insight in actual cost is very limited under a LSFP contract. On LECPs many owners have traditionally used LSFP for project implementation under strategy options (a) and (b).

Under a Cost Plus Fixed Fee (CPFF) contract the owner reimburses the EC for all costs associated with the project work scope. The owner carries the cost risk for executing the work and the contract cost C_c remains uncertain until completion. Project development work is in many cases contracted out on the basis of a CPFF contract. With a CPFF contract, the EC profit Π does not vary with the actual cost C of executing the work. Hence, there is a certain incentive for the EC to execute the work in as diligent a way as possible. Expeditious handling of construction for example will minimise time and free resources for other contracts, subject to the available business opportunities. Under a CPFF contract the sharing rate $\alpha = 0$, which gives:

$$\Pi = \Pi_t \qquad (2.5)$$

$$C_c = C + \Pi_t \qquad (2.6)$$

The bidding process is based on hourly rates for EPCm services and on the target profit Π_t. In principle, there will be no ex post asymmetry of information between the owner and the EC, subject to the owner having the competency to analyse and interpret the available information.

A Cost Plus Incentive Fee (CPIF) contract is similar to a CPFF contract with the exception that if $C < C_t$ then $0 < \alpha < 1$ and if $C > C_t$ then $\alpha = 0$. Hence the actual EC profit Π is not fixed but equal to the target profit Π_t and a share of the 'underrun' if the actual cost are lower than the target cost. Under a CPIF contract the minimum profit Π_t is generally 'guaranteed' although there are also arrangements whereby the entire profit Π is subject to performance criteria other than cost; e.g. schedule, safety, quality, etc. (Berends, 2005). The subject of multidimensional incentive contracting is discussed in detail in chapters 4 and 7. Under a CPIF contract the owner essentially carries the project cost risk and there is cost performance incentive for the EC if $C < C_t$. This is reflected in the profit levels, which under a CPIF contract are significantly lower than under a LSFP contract. Also, under a CPIF contract the cost related profit element $\alpha (C_t - C)$ is usually capped. Generally, CPIF contracts are used for project implementation work under strategy (c) although competitive tendering on the basis of a CPIF contract is also possible. Tendering/negotiation for EPCm services is based on hourly rates, the target profit Π_t, the target cost C_t, the sharing rate α and the cap on the cost related profit.

Under a Cost Plus Percentage Fee (CPPF) contract the fee is a percentage of the EPCm cost. The EPCm services (cost) are a function of the overall project work (actual cost). This means in terms of equation (2.1) that the sharing rate α can be negative (unlike a CPIF contract). A disadvantage of this contract type is that there is an incentive for the EC to increase the overall amount of work (i.e. cost) as this will increase its profit.

Cost Plus Fee (CPF) contracts such as CPPF, CPIF and CPPF require more ex ante knowledge and effort than LSFP type contracts with respect to contract design. The owner organisation needs to have the capability to assess the actual cost and for CPIF contracts, the owner also needs to design an effective incentive arrangement, including the negotiation of a target cost. The contract between the owner and the EC relates to the effective delivery of EPCm services, rather than an obligation to deliver the facility in accordance with the agreed contract sum, time schedule and functionality.

Many different forms of contract exist in the form of variations to the three generic types discussed above [5].

Stochastic modelling of the expected actual cost C offers owners and ECs a quantitative tool for analysing/evaluating the bidding parameters in equations (2.1) and (2.2); a range of powerful and user-friendly software packages are commercially available to model and analyse uncertainty and variability. The project cost can be represented by a probability density function with a spread that depends on the level of scope definition, the geographical location and the contracting and procurement market. Based on knowledge of (i) demand and supply; (ii) the effect of competition; and (iii) opportunistic behaviour due to bounded rationality, the profit levels under different forms of contract can be estimated. Examples of such analyses are presented in chapters 3 and 7.

2.4.3 The economics of contracts

Contract theory describes a contract as "an agreement under which two parties make reciprocal commitments in terms of their behaviour – a bilateral cooperation arrangement" (Brousseau and Glachant, 2002). In economic terms, such a contract consists of two essential elements: (i) information transmission; and (ii) incentives. Both elements go hand-in-hand. On contracts for LECPs, neither the owner nor the EC can play its part effectively unless they exchange information about their role and responsibilities. Through incentives the owner can induce the agent to (i) disclose the relevant information; and (ii) perform the work in a manner that is compatible with the principal's interests. But owner and EC have conflicting interests. The owner strives to maximise the value generated by the investment; i.e. the present value of its expected future net cash flows during the lifetime of the facility (20-25 years). This means in most cases [6] realising the required functionality at the lowest capital cost. The EC aims to maximise its return from executing the work; i.e. the creation of the facility (3-5 years). In case of an LSFP/EPC contract, this means obtaining the contract at the highest possible price, taking into account any competitive pressures that may exist (see also chapter 3). Furthermore, an essential reason to engage an EC is that the latter has certain competencies which the owner does not possess. This leads to situations where the EC has information about the execution of the work which the owner does not have. This contractual combination of conflicting objectives and asymmetric information between the parties forms the basis of the 'principal-agent' model which forms a big part of (managerial) economics today. The principal (i.e. the owner) is the party that proposes the contract and the agent (i.e. the EC) is the party that has to accept or reject the contract. Most theoretical models include the restrictive assumption that the contract is not subject to negotiation (although in reality this is usually the case).

In the principal-agent model, two basic cases are distinguished:

(a) Adverse selection; and

(b) Moral hazard;

The terms 'adverse selection' and 'moral hazard' stem from the insurance business. Adverse selection is sometimes also referred to as 'hidden information' or 'hidden characteristic'. An adverse selection problem occurs when the agent has ex ante information that the principal does not have or the principal cannot assess the characteristics (in economics also referred as 'type') of the agent ex ante. This affects the selection of the agent as well as the design of the contractual arrangement. Closely linked to this case is 'signalling'; i.e. the agent sending a signal after the principal has issued the contract but prior to entering into the contract (Macho-Stadler, 2001). An example of this is the attitude of the agent(s) with respect to the type of pricing and associated terms and conditions of contract issued by the principal. Moral hazard is sometimes also referred to as 'hidden action'. A moral hazard problem occurs when the agent has ex post information, which the principal does not have and which influences the way the agent executes the work to be performed under the contractual arrangement. Closely linked to moral hazard is the issue of 'non-verifiability', which occurs when the principal and the agent share ex post the same information but no third party (e.g. a court of law) can observe this information. This relates to a fundamental characteristic of any contract: it exists at law and the rights of the contract parties can be enforced. Indeed, whilst contracts define the scope of work and the responsibilities of the parties involved, above all they define the consequences of non-performance and the associated liabilities. An important consideration in this respect is that a satisfactory execution of the contract is generally in the interest of both principal and agent because of substantial enforcement costs. Furthermore, the principal (i.e. the owner) finds itself ex post in a 'hostage situation' as sales agreements for the facility's products will in many cases have been concluded prior to project completion. These 'consequential damages' are generally not recoverable under the contract with the EC. In view of the good dissemination of information in the contracting market (see section 2.3.3), the agent (i.e. the EC) has a long-term interest in maintaining a good reputation. On the other hand, the agent may also take advantage of a good reputation (see chapter 5).

Development work of LECPs is generally contracted out on the basis of a CPF contract with knowledgeable owners having information on the prevailing hourly rates. At the time of first EC engagement, the owner is generally better informed about the project than the EC (owners generally carry out the first stages of development in-house). Because only established ECs are invited to tender for development work, hidden characteristic problems are limited. The moral hazard problem, on the other hand, is significant. As we have mentioned above, LECPs are technically complex, and many owners do not have the in-house competency to assess the effort of the development EC. This is aggravated by the fact that on many LECPs the owner consists of a Joint Venture (JV) of an NOC and an IOC. The JV owner organisation will in many cases not be fully established yet at the time of development which hinders the effective collaboration between the JV partners. In these circumstances contract theory indicates that it is in the principal's interest to propose a variable remuneration scheme that is a function of the basic design quality (Keser and Willinger, 2002). A knowledgeable owner may be able to assess the basic design quality at the end of development. Furthermore, most implementation contracts include an obligation of the implementation contractor to 'verify' the basic design in a specified period of time. After this period, the implementation contractor accepts responsibility for the basic design (with the possible exception of so-called 'rely-upon-items'). Deficiencies in the technical development work will come to light during this verification or, ultimately, during commissioning, start-up and the initial phases of operation. The cost of rectification grow progressively over time, and it is therefore in the owner's interest to identify deficiencies as early as possible.

Implementation work under contracting strategy (a), with the development EC not participating, can be tendered with all bidders equally (imperfectly) informed. What remains in this situation is a moral hazard problem with the owner having to design a remuneration scheme that is a function of the quality of EPC work. On an LSFP contract this can be achieved through certain performance guarantees and on a CPF contract through an arrangement whereby the fee is subject to service performance. If the development EC participates in the tendering for the implementation contract, the bidders are not equally informed, as described above. There is also an incentive for the development EC to withhold information during development and to use this when tendering for the implementation contract. Thus the moral hazard problem during project development results in an adverse selection problem for project implementation. In these circumstances, contract theory indicates that the principal needs to provide an incentive to the development EC to disclose the hidden information. In practice it is extremely difficult and costly to design an effective mechanism to achieve this. Therefore most owners restrict themselves to mitigation actions such as detailed specification of basic design requirements

(Turner and Muller, 2004) and (partly) compensating other ECs to participate in the bidding process for the implementation contract.

Implementation work under contracting strategy (b) is tendered with both ECs being equally informed, subject to (i) both development ECs having similar capabilities; (ii) both development ECs having access to the same information; and (iii) no collusion taking place. Whilst the latter is always an essential requirement for efficient bidding, it is particularly relevant for a restricted process like contracting strategy (b). Indeed, strategy (b) could be regarded as a variation of strategy (a) with the additional cost of the 'Dual FEED' being the cost of mitigating the asymmetry of information amongst bidders and the adverse selection problem described above. The only remaining adverse selection problem under strategy (b) pertains to one or both development ECs withholding information with a view to use this to claim a change in the work during implementation. This type of ex post renegotiation is closely linked to the issue of bargaining power. Generally, the owner has most power ex ante, whereas the EC has the upper hand ex post; e.g. due to the owner having secured supply contracts for products of the facility already. Mitigation measures adopted by knowledgeable owners include a detailed specification of the facility's functional requirements and performance guarantees.

Implementation work under contracting strategy (c) is awarded through a renegotiation with the development EC, involving an adverse selection problem. To mitigate these problems and to capture the potential benefits outlined in section 2.4.1, strategy (c) is often used in combination with a CPFF contract or a CPIF contract for implementation. In this approach, colloquially called 'open book', the owner has access to all the information generated during implementation, unlike an LSFP contract where the cost information is not revealed to the owner. Sub-contracts for materials, equipment and construction work are awarded after competitive tendering on a LSFP basis, by the owner or 'for-and-on-behalf-of' the owner by the EC. It is closely linked to cooperative forms of contracting which are aimed at aligning owner and EC objectives. If this alignment is indeed achieved and there is no conflict of interest between owner and EC, the moral hazard problem during development does not occur and the adverse selection problem for implementation becomes irrelevant. These forms of contracting require more extensive owner involvement and places greater demands on owner project management and contracting competencies than strategies (a) and (b).

2.5 Conclusions

The additional oil and gas processing capacity required during the next 20 years to meet demand is more than twice the new capacity realised during the last decades. In parallel, the oil and gas industry is facing a surge in upstream activity driven by high crude oil prices. Consequently, LECPs will be an important area of economic activity during the next decades. Owners have come to rely heavily on ECs for the development and implementation of these projects.

Contracts are inherently incomplete due to the complexity and long lifecycle of LECPs, which means that in many cases the ex ante conditions change during execution of the work. Traditional contracting strategies are based on early EC involvement on the basis of a CPF contract followed by competitive tendering (with participation of the development EC) on the basis of an LSFP contract, transferring the cost risk of project implementation to ECs. Only a small number of ECs is capable of executing LECPs and their capacity in terms of (specialised) human resources is limited. Furthermore, their market capitalisation is relatively small compared to the financial risks associated with LECPs. Consequently their capacity to take on financial liabilities is limited. The traditional contracting strategies lead to economic inefficiencies due to:

(a) Cost risks being carried by a party not being in the best position to bear the consequences in case a risk materialises;

(b) Information asymmetry during the project lifecycle between EC and owner (development: moral hazard; implementation: adverse selection problem).

In the past, owners were able to mitigate these inefficiencies through strong competition between ECs. But in the current 'sellers' market', the oligopolistic characteristics of the contracting market are more pronounced than the 'buyers' market', which existed until recently.

As discussed in section 2.3.2, ECs have a human resource geared up for the (relatively low) demand levels of the last decades and they have found it difficult to attract young technical talent resulting in a demographic problem in the current 'boom' times. The large codified body of knowledge that exists for the design engineering and construction of LECPs restricts rapid expansion of resources. The limited capacity of ECs to accept financial liabilities further constrains growth. Owners and ECs increasingly acknowledge (Lavelle, 2006) that alternative contracting strategies are required.

Contract theory indicates that disclosure mechanisms need to be incorporated in the contracting process to limit the ability of the 'informed' party (i.e. the EC) to take advantage of the 'under-informed' (i.e. the owner). A strategy based on 'Dual FEED' overcomes the problem of information asymmetry between bidders but does not address the cost risk allocation problem. Cooperative forms of contracting do address the latter as well and also provide an opportunity to remove the current entry barriers in the contracting market. They involve little EC risk and consequently do not require a JV of ECs (other than for resource reasons). It should be recognised however that the use of 'new ECs' will also introduce an adverse selection problem in contracting for project development. Cooperative forms of contracting (and to a lesser extent Dual FEED) require more extensive owner involvement (again) in the project management and contracting process. Their effectiveness is contingent upon owner (and EC) organisations where contracting for LECPs is a core competency. This will involve an organisational and behavioural change process. Owner organisations will need to acquire an in-depth understanding of the business drivers and cost structure of ECs as well as the contracting and procurement market for materials, equipment and construction work. The ECs have to act truly as the owner's agent and not as its adversary to achieve a (long term) stable business environment. The role of lenders will become increasingly important to provide the capital required in the next decades and they have to be appraised of the advantages and disadvantages of these alternative forms of contracting. The problems of optimising agent selection and (performance) incentives have received considerable attention in the economics literature during the last thirty years. The application of contract theory to practical situations (such as contracting for LECPs), will benefit from closer collaboration between economic theorists and professionals and scholars in other disciplines.

Notes

1 Development is sometimes also referred to as basic engineering or 'Front End Development' (FED) and the last stage of FED is also referred to as 'Front End Engineering Development' (FEED).

2 Technical availability is defined as actual production divided by theoretically possible production, in a certain period, adjusted for loss of production which is not attributable to technical reasons.

3 The research in this thesis focuses on the process of creating the facility. Therefore feedstock suppliers, (product) customers and the associated agreements (e.g. Supply Purchase Agreements) are only considered where they have a direct impact on the contractual arrangements during the project life-cycle.

4 Core competencies are the sum of knowledge, experience, capabilities and the attitude of people that has become an inherent part of an organisation (Boekhof, 1997).

5 A variation to an LSFP contract is a so-called *Fixed Price Incentive (FPI)* contract, characterised by a cost sharing arrangement with $0 < \alpha < 1$. If $C < C_t$ the actual EC profit Π will be higher than the target profit Π_t. If $C > C_t$ the actual profit will be lower than the target profit, thus providing a cost performance incentive for the EC. The total contract C_c is usually subject to a maximum. This 'price cap' C_{cmax} limits the owner's cost risk. If C <

C_{cmax} owner and EC effectively share the project cost risk. If C > C_{cmax} the EC assumes total responsibility for the cost of executing the work.

6 The Total Cost of Ownership (TCO) concept incorporates the total cost during the life of the facility and provides a better measure than capital cost only. On LECPs the capital cost is however still the dominant selection criterion as the TCO is more difficult to establish objectively.

2.6 References

Berends T.C., 2005. *Cooperative contracting on major engineering and construction projects*, The Engineering Economist, 51(1), pp 35-51.

Boekhof T., 1997. *Managen van kennis, ('Managing knowledge')*, p40, Kluwer bedrijfsinformatie, Deventer, The Netherlands.

Brousseau E., Glachant J-M., 2002. *The economics of contracts and the renewal of economics*, in *The economics of contracts, Theories and applications*, Brousseau E., Glachant J-M., p3, Cambridge University Press, Cambridge, United Kingdom.

BRT, 1997. *The business stake in effective project systems*, The Business Round Table, Construction cost effectiveness task force.

Chapman C., Ward S., 1997. *Project risk management – Processes, techniques and insights*, pp9-12, John Wiley & Sons, Chichester, England.

Cogan J.P., July-September 2005. *Contracting practices evolve for new global LNG trade*, Oil & gas Journal, LNG Observer, p14.

Cook L., 2005a. *The role of LNG in a global gas market*, Oil & Money Conference, London, 21st September 2005.

Cook L., 2005b. Forging strong links – Enabling the global expansion of natural gas, Society of Petroleum Engineers (SPE), Technical Conference, Dallas, 10th October 2005.

Dudley, B., 11 October 2005. *Can the E&C industry meet the growing demands?*, Keynote address 8th Annual Rice Global E&C Forum.

Energy Information Administration (EIA), *International Energy Outlook 2005*.

Esty B.C., 2004. *Modern project finance – A casebook*, pp3-7, pp133-150, (John Wiley & Sons, Inc.), Harvard Business School Publishing, Boston, MA, USA.

Gibbons R., 1992. *Game theory for applied economists*, pp 8-22, Princeton University Press.

Hydrocarbon Processing Industry, *Construction Boxscore*, February and October issues, 2000-2005.

Jehle G.A., Reny, P.J., 2001. *Advanced microeconomic theory*, International edition, Second edition, pp 161-164, Addison Wesley, Boston, USA.

Keser C., Willinger M., 2002. *Experiments on moral hazard and incentives: reciprocity and surplus-sharing*, in: Brousseau, E., Glachant, J.M. (editors), *The economics of contracts, Theories and applications*, p293, Cambridge University Press, Cambridge, UK.

Lavell M., *Boom times for megaprojects*, U.S.News & World Report, 24 September 2006.

Macho-Stadler I, Perez-Castrillo J.D., 2001. *An introduction to the economics of information - Incentives and contracts*, pp9-14, Oxford University Press, New York, USA, Second edition.

Newendorp T., Clark W., October-December 2005. *LNG project financing faces changes in 21st century*, LNG Observer, Oil & gas Journal, pp 4-11.

Oil & Gas Journal, *World Wide Construction*, October issues, 1980 – 2005.

Oil & Gas Journal, November 2003. *2003 LNG World Trade and Technology*.

Olsson N.O.E., 2006. *Management of flexibility in projects*, International Journal of Project Management, 24, pp 66-74.

Organisation of Petroleum Exporting Countries (OPEC), *Statistical Bulletin 2005*.

Robertson, S., July-September 2005. *Wave of new plants, terminals, tankers will drive $67-billion market by 2009*, LNG Observer, Oil & Gas Journal, pp 10-13.

Rooij van A., Homburg E., 2002. *Building the plant – A history of engineering contracting in the Netherlands*, p16, Walburg Pers, Zutphen, The Netherlands.

Scriven J., Pritchard N., Delon J., 1999a. *A contractual guide to major construction projects*, pp 229-230, Sweet & Maxwell Ltd., London.

Scriven J., Pritchard N., Delon J., 1999b. *A contractual guide to major construction projects*, pp 16-19, Sweet & Maxwell Ltd., London.

Smith I., Dunn, J., Yarossi M.E., Merrow E., 1993. *The changing role of design contractors: Their effective use in project definition*, p1, Independent Project Analysis Inc., Chelford, UK.

Stell J., 24 November 2003. *E&C contractors face tight margins, more risk*, Oil & Gas Journal, pp20-21.

Turner J.R., Muller R., 2004. *Communication and co-operation on projects between the project owner as principal and the project manager as agent*, European Management Journal, 22 (3), pp 327-336.

`Ward S.C., Chapman C.B., 1995. *Risk-management perspective on the project life-cycle*, International Journal of Project Management, 13(3), pp145-149.

Wood Mackenzie, 2006. *Global LNG Online*, www.woodmacresearch.com, accessed 17 February, 2006.

Yergin D., 1991. *The Prize – The epic quest for oil, money and power*, pp 781-783, Simon & Schuster Ltd., London, UK.

3

Competitive lump sum bidding

The selection of an EC for an LECP is largely done through a (closed) competitive bidding process on the basis of a single LSFP contract for EPC. These LSFP/EPC bid prices are composed of a (stochastic) cost estimate of the work, multiplied by a certain mark-up. When establishing this mark-up, bidders have to optimise potential profits with the probability of winning the bidding event. In this chapter the effects of competition and risk on bid pricing are investigated. Existing bidding models (which require many open bidding events) cannot be used on LECPs. An alternative model, using an 'applied approach', is presented and used to perform a quantitative analysis of data from the case study owner. The model provides a practical proposition to study competitive bidding without extensive information requirements of existing models. The results provide a quantitative insight into traditional competitive single LSFP/EPC bidding for the implementation of LECPs.

3.1 Introduction

As discussed in chapter 2, during the last decades the selection of an EC for LECPs has to a large extent been done through a competitive bidding process on the basis of a (single) LSFP/EPC contract (i.e. generic strategy option (a) in section 2.4.1). For ECs this form of contracting constitutes a big gamble as they have to establish a bid price when the project only exists in the form of a basic design and technical, commercial and organisational risks can only be assessed in outline. These LSFP/EPC bid prices are composed of a (stochastic) *cost estimate* of the work, multiplied by a certain *mark-up*. When establishing this mark-up, bidders have to optimise the (potential) profits and the probability of winning the bidding event.

This balancing act in the case of competitive bidding for work on the basis of single LSFP/EPC contracts has received considerable attention in the literature as for instance illustrated by the bibliographies published by Stark (1971) and Stark, Rothkopf (1979). Many of the published theories are based on Friedman's model described in his classical paper of 1956. A frequently cited criticism of these theoretical models is that their practical application is limited due to restrictive model assumptions, not reflecting real situations, and excessive information requirements (Ward, Chapman and Klein, 1991). In the case of competitive bidding for LECPs, a problematic issue is that in most models the probability of winning a bidding event, is established through a statistical analysis of (historical) bidding behaviour of competitors (Gates, 1967), (Gates, 1971), (Carr, 1977), (King and Mercer, 1985), (King and Mercer, 1991), (Holt, Olomolaiye and Harris, 1995), (Clough, Sears and Sears, 1995), (Drew, Kitmore and Lo, 2001), (Williams, 2003). This requires many bidding events and routinely published bid prices; i.e. a bidding processes in 'open' form where all bids are opened and read publicly. On LECPs in the oil, gas and petrochemical industry the number of bidding events is inherently limited and nearly always a process in 'closed' form is used; i.e. one where bid prices are not published. Furthermore, bidders consist in many cases of EC consortia and the composition of these consortia differs per bidding event. The above makes it impossible to establish the 'typical bidding behaviour' of a specific competitor nor is it possible to compile a profile of an 'average competitor'. Consequently the classical model of Friedman cannot be used.

In this chapter the 'traditional' way of contracting out the implementation of LECPs is examined; i.e. a closed competitive bidding process on the basis of a single LSFP/EPC contract. EC bidding behaviour is theorised and an alternative bidding model is developed, based on an 'applied approach' (Chapman, Ward and Bennell, 2000). The model is used to conduct a quantitative analysis of a case study. The difference between cost and (bid) price is discussed together with actual bid data. The case study owner organisation has been using a structured business process of project development and bidding for several decades which was used on all bids in the dataset. The normalised calibration parameters for the case study model are derived from this high quality dataset.

3.2 Conceptual model

3.2.1 Bidding behaviour

ECs for LECPs are usually selected through a process of (pre-)qualification, bidding, negotiation and award at the end of project development. The purpose of the (pre-)qualification is to ensure that only ECs with the required capabilities participate in the bidding process.

In the Invitation To Bid (ITB) the owner specifies the scope of work and the format of the bids. This may include a requirement to submit bids in three parts: (i) a 'technical' proposal; (ii) an 'unpriced' commercial proposal; and (iii) a 'priced' commercial proposal. In the technical proposal bidders specify how the work will be executed. In the unpriced commercial proposal bidders indicate deviations to the terms and conditions of contract, proposed by the owner as part of the ITB. The priced commercial proposal contains the lump sum price for executing the work as well as a pricing mechanism for any changes in the work that may occur during execution. The bid submission in three parts facilitates a bid evaluation in two phases; first the technical and unpriced commercial proposals and subsequently the priced commercial proposals. During the first phase, the bids are 'equalised' as far as possible, including negotiation on the terms and conditions of contract and pricing of differences in the submitted bids if appropriate. This process enables the owner to evaluate the priced commercial proposal without being biased by the evaluation results of the technical and unpriced commercial proposals. Several authors have suggested a bidding approach for single EPC/LSFP contracts taking into account multi-criteria (e.g. (Holt, Olomolaiye and Harris, 1995), (Cagno, Caron and Perego, 2001), (Seydel and Olson, 2001)). In the oil, gas and petrochemical industry however, lowest bid price is still the most important selection criterion in competitive bidding.

<u>Lemma 1:</u> Contractor selection is based on lowest bid price only.

As discussed in section 2.3.3, the number of international ECs participating in bidding events is small and the differences in cost level between these ECs are relatively small. Furthermore these small differences pertain only to the 20% of the total EPC cost that is directly related to the EC's own activities; i.e. detailed design engineering, procurement and construction management. The other 80% is contracted out by the EC and pertains to the procurement of materials and equipment and to (sub)contracts for construction work. All bidders operate in the same (global) procurement and construction contracting market. Although some differences will exist with respect to procurement efficiency, these will have only a relatively small effect on the overall cost estimate.

<u>Lemma 2:</u> In an efficient market, the cost estimates underlying competitive bids will have a distribution which is determined by the stochastic cost estimate of the work.

As indicated in paragraph 3.1, LSFP/EPC bid *prices* are composed of a (stochastic) *cost estimate* of the work, multiplied by a certain mark-up. From this observation and Lemma 1 follows that if there were no mark-ups, the cumulative cost probability function would describe the bid distribution.

<u>Corollary 1:</u> In a bidding situation with low cost mark-ups, the cumulative stochastic cost estimate provides a good approximation of bid prices distribution.

The mark-up which bidders apply to the cost estimate to determine the bid price, depends on a number of factors governing the bidding behaviour:

(a) Competition level;

(b) Workload;

(c) Ability to take on (financial) liabilities; and

(d) Strategic considerations.

Owner organisations (and lenders) typically display risk adverse behaviour. This risk adverse behaviour is not only caused by the large amounts of capital at stake but also by obligations with respect to supply agreements for products which generally are concluded well before start-up of the facility. The LSFP/EPC contract does not shield the owner from these 'consequential damages' and therefore owners have a natural tendency to only engage ECs with a proven track record. The bidding behaviour of ECs in the resulting oligopolistic contracting market (see also section 2.3.3) is strongly influenced by the (anticipated) behaviour of competitors. This does not mean excess profit levels are guaranteed. Indeed, competition has been vigorous during the last decades resulting in several take-overs, mergers and a reduction in the number of international ECs.

As described in section 2.2.1, LECPs are developed in a number of sequential stages and at the end of each stage the owner takes a decision whether or not to proceed, ultimately resulting in a final investment decision based on expected project value (which takes into account capital cost). These value considerations may also be strategic; i.e. a modest project value may be acceptable if it is expected to yield additional value on future projects. For an EC the value of a project lies in the profit and the turnover it yields. ECs may opt to secure work through low bid prices if there is a shortage of work, not recovering all (fixed) overheads they would otherwise allocate to a project. If an EC has sufficient work, it may still decide to bid for work provided the price is sufficient to cover the cost of attracting additional (temporary) resources plus a premium. Hence, the workload of the bidders and the (international) EPC contracting market at the time of bidding will have a large impact on the bid prices owners can expect to receive.

Through the LSFP/EPC contract, the EC acts as a 'quasi-insurer' for the owner regarding the cost of building the project, with the associated risk premium being included in the bid price (Ward, Chapman and Curtis, 1991). In most cases only a joint venture of ECs is capable of taking on the large financial risks associated with the execution of an LECP on the basis of a single LSFP/EPC contract. The joint venture may take different forms, but in all cases the owner (and any lenders) wish to ensure that the consortium is able to honour its obligations under the contract, e.g. through 'joint and several liability' undertakings and/or parent company guarantees of the participants (Scriven, Pritchard and Delmon, 1999). With respect to the project dimensions functionality and time, contracts typically contain provisions in the form of 'Liquidated Damages' (LDs). These constitute an ex ante compensation for the owner for any shortfall in plant performance or delay in completing the project and LDs also act as a limitation of the EC's liability in these areas. In order to price the risk, ECs have to assess the level of contractual liabilities and probability of occurrence.

Strategic considerations will also play a role in the mark-up ECs apply when establishing bid prices. For instance, ECs may decide to moderate their bid prices in order to obtain access to new markets and/or customers or to develop new capabilities (e.g. linked to new process technologies).

3.2.2 The probability of winning

Bid pricing is an optimisation game. Bidding high vis-à-vis the stochastic cost estimate of the work, increases the prospective profit in case of a successful bid but decreases the probability of winning the bidding event. Bidding low, decreases the prospective profit in case of a successful bid but increases the probability of winning. The optimum bid price takes both aspects into account. This is done through the concept of expected (relative) profit which can be expressed in general terms as:

$$\pi(b) = (b - c) * P(b) \tag{3.1}$$

where:

	$\pi(b)$	expected relative profit; $\pi = \Pi / E$
	b	relative bid price; $b = B/E$
	c	relative cost of performing the work; $c = C/E$
	B	bid price
	$P(b)$	probability of winning with a relative bid price b
	E	owner's cost estimate of the work

Notation: $P(b)_n$: probability of winning with a relative bid price b and n bidders.

As mentioned before, ECs' bid prices are composed of a cost estimate of the work multiplied by a certain mark-up and the intrinsic cost of executing LECPs is essentially the same to all ECs. The mark-up applied by ECs is inversely related to the level of competition. At (relatively) high levels of competition, some contractors will face a shortage of work and the applied mark-up in the *winning bid price* is reduced to a minimum level where it yields little or no value to the (winning) contractor. The LSFP/EPC contracting market for LECPs has oligopolistic characteristics and the dissemination of information is generally good. Hence ECs will be aware of the state of the market, the level of competition and the need to bid low to secure work in a buyers' market. From Corollary 1 follows that at high levels of competition (and low cost mark-ups), a *'credible stochastic cost estimate'*, i.e. one displaying objectivity and precision) provides a good approximation of bid prices distribution. From Corollary 1 and Lemma 2 follows:

Corollary 2: A credible inverse cumulative cost probability function describes the probability of winning as a function of bid price in a stable contracting/procurement market with high levels of competition.

Projects executed on the basis of a CPF/EPCm approach will provide owners with detailed information of the underlying cost. With a single LSFP/EPC contract they will generally not obtain this information. Owners that execute projects regularly, using different contracting strategies and different types of contract pricing will be able to obtain sufficient (quality) information to establish credible stochastic cost estimates. A pre-requisite for this is that the contracting /procurement market is stable; i.e. historical data can be used to model the future.

In paragraph 7.2.2 an analysis is presented of relative owner contract cost on 32 projects. The results indicate that the stochastic cost estimates of the case study owner organisation are *credible* and can be represented accurately by a *Normal*(μ,σ) distribution (where μ and σ are the mean and standard deviation respectively). Figure 3.1 shows the inverse cumulative cost probability function resulting from the analysis.

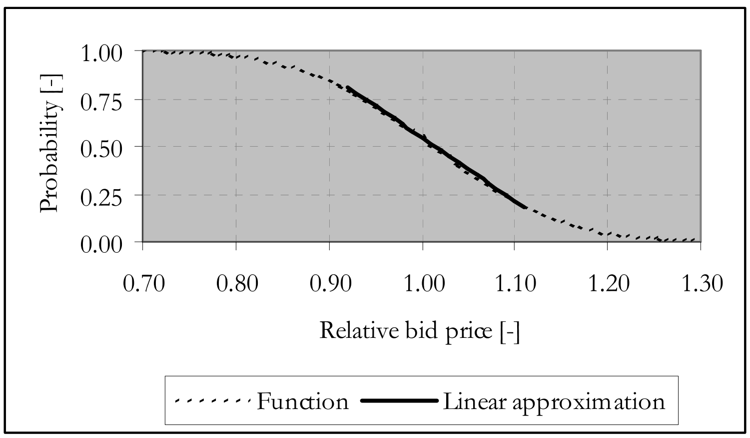


Figure 3.1
Inverse cumulative cost probability function with linear approximation

Preparing a LSFP/EPC bid for LECPs involves considerable effort and money and ECs will generally not submit a bid unless there is a reasonable probability of winning. At the same time, achieving a very high probability of winning will be sub-optimal in terms of expected profit and/or the probability of loss (i.e. $c > b$). Therefore, actual bid prices will generally be such that 20% < $P(b)_n < 80\%$. A linear approximation of $P(b)$ in this range is given by:

$$P(b) = A - Bb \qquad (3.2)$$

where A and B are constant.

The parameter B in equation (3.2) is determined by the shape of the stochastic cost estimate of the work (see also Figure 3.1). The parameter A describes the mark-up applied by ECs to establish the bid price. Owners can determine the factors A and B as a function of the number of bidders by monitoring the results of bidding events.

Substitution of equation (3.2) in (3.1) gives a concave quadratic approximation of the expected (relative) profit function:

$$\pi(b) = -Bb^2 + (A + Bc)b - Ac \qquad (3.3)$$

Profit maximisation under risk neutral behaviour occurs when: $d\pi/db = 0$ which gives:

$$b = ½\,(A/B + c) \qquad (3.4)$$

3.3 Basis for empirical analysis

3.3.1 Dataset dimensions

The dataset comprises bid prices submitted for LECPs in Asia Pacific, the Middle East, Africa and Europe of the case study owner organisation. The projects in the dataset cover a period of 15 years and the owner organisation used the same codified business process for project development and competitive bidding on all projects in the dataset. The projects had a similar level of scope definition at the time of bidding (i.e. the end of project development) and the bids in the dataset were based on comparable terms and conditions of contract. These are important pre-requisites to analyse bid data of different projects because the level of scope definition determines the contingency included in the stochastic cost estimate of a bidder. The contractual terms and conditions define the liabilities (e.g. LDs) bidders have to take into account in establishing the mark-up on their (stochastic) cost estimate. Furthermore, in pricing bids ECs take into account the risk of profit erosion related to the way the project is managed by the owner (e.g. integration of operational requirements into the design, timely and competent commenting on drawings, assistance with respect to importing materials and equipment, obtaining construction permits, etc.). The pre-requisites above are generally not fulfilled and the differences are difficult to quantify, when data originates from different owner organisations. The stable bidding conditions and high degree of project commonality underlying the dataset enable a quantitative comparative analysis. The main dimensions of the dataset are indicated in Table 3.1.

Table 3.1

Dataset Dimensions	
Total number of projects (*P*)	14
Total number of bids (*N*)	30
Number of bids per project (*n*)	1 - 5
Average project cost [2005; EUR mln]	1,150

3.3.2 Winning relative bid prices

The bids were categorised by the number of bids per project (n = 1-5). For $n \geq 2$ the winning (i.e. lowest) bid per project was established and in the case of $n = 1$ the negotiated bid prices were used. Figure 3.2 shows the relative bid prices b as a function of the number of bidders n.

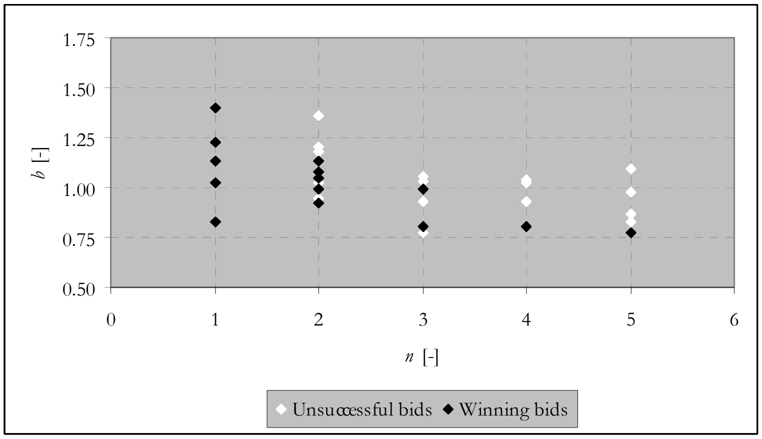


Figure 3.2
Relative bid prices *b* vis-à-vis number of bidder *n*

Subsequently, the median and the mean of the winning/negotiated relative bid prices per category were calculated. Power functions provide good approximations of the median b_n^{a1} and the mean b_n^{a2} winning relative bid prices:

Medians : $b_n^{a1} = 1.21n^{-0.28}$; $R^2 = 0.97$ (3.5)

Means : $b_n^{a2} = 1.20n^{-0.18}$; $R^2 = 0.92$ (3.6)

where : *n* number of bidders

The results show that b_n^{a1} and b_n^{a2} are continuously decreasing functions of *n*, reflecting the price moderating effect of competition. Many LECPs comprise extensions of existing facilities. In these situations it may be attractive to negotiate a contract with the EC involved in the previous project(s), particularly if the functionality of the facility is the same. Also, it may be difficult to solicit interest from other ECs if the incumbent EC participates in the competitive bidding process, due to the inherent information advantage the latter has. In a single source negotiation, the EC can exercise a certain amount of discretion with respect to price setting. This price discretion of the single EC is limited by (i) the boundary condition when there is no value for the owner in the project anymore (i.e. due to the high EPC price the project is not longer viable); and (ii) the threat of a new entrant. In the dataset the price premium associated with a single source situation $n = 1$ (as opposed to competitive tendering $n \geq 2$), calculated as $b_1^{a2} - b_2^{a2}$, amounts to some 14%. The owner can potentially save the premium associated with the lack of competitive market forces by actions such as (partly) reimbursing bid preparation cost to induce other contractors (whose perception is that (*P(b)* < 20%) to participate in a competitive bidding process. One could argue that the (Dual FEED) strategy option (b) described in section 2.4.1 effectively constitutes such a reimbursement of bid preparation cost. Alternatively, owners may consider forms of contracting described as strategy option (c) in section 2.4.1 a CPF remuneration structure for EPCm services. The opportunity cost of a later start of project implementation due to the time required for competitive tendering will also in many cases be a factor that has to be taken into consideration.

As indicated before, in the oil, gas and petrochemical industry the number of (experienced) ECs is limited and bidding events with $n \geq 4$ are relatively rare. The cost estimate of the case study owner organisation (i.e. b = 100%) corresponds with a bidding situation with two bidders; equal to the average number of bidders in the data set (N/P = 2.1; see Table 3.1).

3.4 Model calibration and bid price optimisation

3.4.1 Model calibration

Deriving the required calibration parameters from the dataset, a model for the case study can now be compiled. As discussed in Chapter 2, competition between ECs has been high during the last decades (which covers the period of the dataset).

As indicated in section 3.3.2, the *shape* of the stochastic cost estimate of the work determines the parameter B in equation (3.2). This estimate is predominantly determined by the cost of materials, equipment and construction subcontracts and the associated risks. These parameters are the same for all bidders. In a market with a good dissemination of cost information (see section 2.3.3) it is therefore reasonable to assume that the parameter B is not dependent on the number of bidders n. The characteristics of the stochastic (cumulative) cost estimates of the owner organisation are analysed in chapter 7, indicating[1] (see paragraph 7.2):

B = 3.28.

The linear approximations of the probability of winning for a bidding event with n bidders can than be calculated through equation (3.2):

$$0.50 = A_n - 3.28 b_n^{a1} \qquad (3.7)$$

where : A_n the parameter A for n bidders

In other words, the *median* of the winning bid prices corresponds with a probability of winning equal to 50%. Substituting Equation (3.5) into Equation (3.7) gives:

$$A_n = 3.97 n^{-0.28} + 0.50 \qquad (3.8)$$

The case study owner includes in his estimate E a certain level of profit for the EC based on historical data. Hence a relative bid price b = 1 includes a certain profit element as can been seen from an eyeball's view of Figure 3.2 (for $n \geq 3$ the mean winning relative bid price lies significantly below b=1). The analysis in chapter 7 indicates that under LSFP contracts the mean relative EC profit π=0.10 (see paragraph 7.5). Based on these results it is assumed in this analysis that the actual relative cost of performing the work in Equation (3.1) is: c = 0.90.

Substitution of Equation (3.8) and the above values of the parameters B and c into equation (3.3) gives the concave quadratic approximation of the expected (relative) profit function for various level of competition:

$$\pi_n(b) = -3.28 b^2 + (3.97 n^{-0.28} + 3.45) b - (0.45 + 3.57 n^{-0.28}) \qquad (3.9)$$

3.4.2 Optimum bid prices

The expected relative profit $\pi(b)$ for different numbers of bidders n is depicted in Figure 3.3. The maxima of the expected relative profit (the top of the curves, where $\frac{d\pi_n}{db} = 0$) represent the optimum relative bid prices for various number of bidders (based on bidders displaying risk neutral behaviour). Oviously, $\pi_n(b)$ = 0 at the minium boundary where b = 0.90 discussed above, irrespective of the number of bidders. Furthermore, due to competitive pressures the expected relative profit (at the optimum bid price) for $n = 4$ and $n = 5$ is very small.

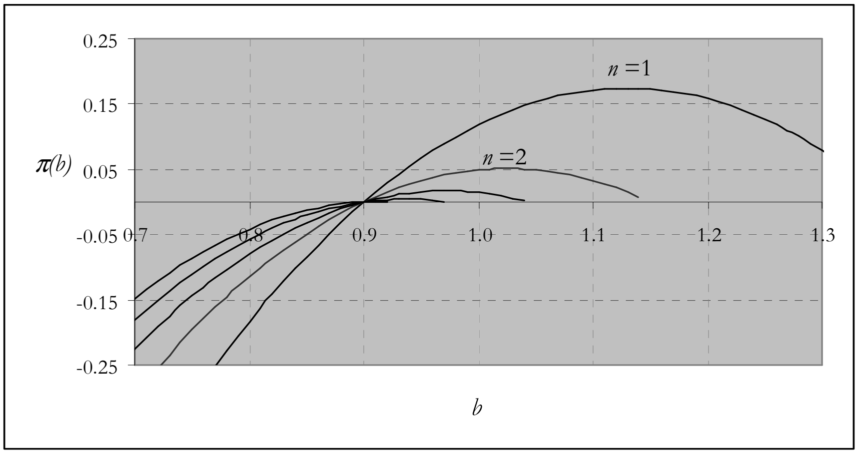


Figure 3.3
Expected relative profit $\pi(b)$ for numbers of bidder n = 1-5

The model optimum relative bid prices (calculated from equation (3..9) as $\frac{d\pi_n}{db} = 0$), as a function of the number of bidders is:

$$b_n^0 = 0.53 + 0.61n^{-0.28} \qquad (3.10)$$

A comparison between the actual (mean) relative bid price given by equation (3.6) and the model optimum relative bid price given by equation (3.10) is shown in Figure 3.4. Overall the model provides a good prediction of the (mean) actual winning bids (R^2 = 1.00) For n = 1 (i.e. a single source negotiated bid) the model result is some 5% lower than the actual (mean) value. In this situation, the EC is able to extract a high level of profit.

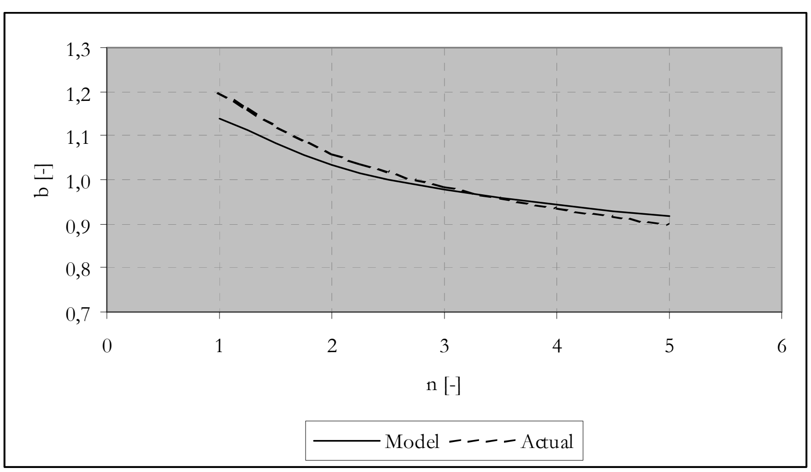


Figure 3.4
Approximation functions of (i) model optimum relative bid prices; and (ii) actual (mean) relative bid prices.

3.5 Conclusions

Competitive tendering for LECPs on the basis of a single LSFP/EPC contract has been analysed through a new model based on an 'applied' approach, theorising the business environment, the bidding process and the drivers behind contractors' bidding behaviour. Calibration parameters for the model are derived from a dataset of the case study owner organisation. The analysis suggests that the model provides a practical proposition to study competitive bidding for LECPs without the large number of published bid prices required by existing models. The model facilitates a quantitative analysis by knowledgeable owner organisations with data required for model calibration.

The results of the provide insights into the competitive tendering process for LECPs, particularly regarding the price premium associated with the lack of (effective) competition. The case study data pertains to a 'buyer's market' with vigorous competition between ECs. Whilst a process in closed form is used, the number of ECs is limited and in many cases they will be able to assess the level of competition. In the case of a single source negotiated LSFP/EPC contract the EC is able to extract a substantial premium (in the case study analysis 14% vis-à-vis a situation with two bidders) even from a knowledgeable owner organisation and in a competitive market. There may be project specific advantages associated with a single source negotiation such as less engineering work and a shorter schedule in the case of a repeat project. Generally however, the benefits of increasing competition (e.g. through a Dual FEED strategy) outweigh the cost[2]. Furthermore owners contracting predominantly on the basis of a single LSFP/EPC contract will in many cases lack the capability required to successfully conduct these negotiations as this requires an in-depth knowledge of the contracting and procurement market.

A sellers' market, such as the one prevailing at the moment (see chapter 2), results in higher bid prices due to:

(a) Higher overall cost levels and delivery times for materials and equipment as well higher cost of construction works;

(b) Higher optimum bid prices due to less competition between ECs; and

(c) A reduced willingness of ECs to accept/price risk.

These changing market conditions should induce owners to explore different strategies and tactics such as cooperative forms of contracting.

Notes

1 The (cumulative) relative owner contract cost used in chapter 7 includes CPIF, CPPF and LSFP contracts. On the LSFP contracts this includes the EC profit. Because the latter is included in both parts of the relative cost fraction (i.e. C_c and E) the resulting error is negligible.

2 The cost of development tends to be 1-3% and the cost of cost of detailed design engineering some 10% of the total installed cost of the facility.

3.6 References

Cagno E., Caron F., Perego A., *Multi-criteria assessment of the probability of winning in the competitive bidding process,* International Journal of Project Management 19 (2001) 313-324.

Carr R., *Paying the price for construction risk,* Journal of the Construction Division, American Society of Civil Engineers, March 1977, 153-161.

Chapman C.B., Ward S.C., Bennell J.A., *Incorporating uncertainty in competitive bidding,* International Journal of Project Management 18 (2000) 337-347.

Clough R.H., Sears G.A., Sears S.K., 2005, *Construction Contracting,* pp 548-558, Seventh Edition, John Wiley & Sons, New York, USA.

Drew D, Skitmore M, Lo HP, *The effect of client and type and size of construction work on a contractor's bidding strategy,* Building and Environment, 36(2001),393-406.

Friedman L., *A competitive bidding strategy,* Operations Research, 4 (1) 1956; 104-112

Gates M., *Bidding strategies and probabilities*, Journal of the Construction Division, American Society of Civil Engineers, Vol.93, No. CO1, Proc. Paper 5159, March, 1967, pp 75-107.

Gates M., *Bidding contingencies and probabilities,* Journal of the Construction Division, Proceedings of the American Society of Civil Engineers, November 1971.

Holt G.D., Olomolaiye P.O., Harris F.C., *A Review of Contractor Selection Practice in the U.K. Construction Industry,* Building and Environment, 30 (4) 1995, 553-561.

King M., Mercer A., *Problems in determining bidding strategies*, Journal Operational Research Society, 36 (10) 1985, 915-923.

King M., Mercer A., *Distributions in competitive bidding*, Journal Operational Research Society, 42 (2) 1991, 151-155

Seydel J., Olson D.L., *Multicriteria support for construction bidding,* Mathematical and Computer Modelling, 34 (2001) 677-702.

Scriven J., Pritchard N., Delmon J., *A contractual guide to major construction projects*, pp 229-232, Sweet & Maxwell Limited, London, 1999.

Stark R.M., 1971, *Competitive bidding: a comprehensive bibliography*, Operational Research Quarterly, 19, pp.484-490.

Stark R.M., Rothkopf M.H., *Competitive bidding: a comprehensive bibliography*, Operations Research 27, 1979, 364-390.

Ward S.C., Chapman C.B., Klein J.H., *Theoretical versus applied models: the Newsboy problem*, Omega, The international Journal of Management Science, (19) 1991; 197-206.

Ward S.C., Chapman C.B., Curtis B., *On the allocation of risk in construction projects*, International Journal of Project Management, Volume 9, 1991, 140-147.

Williams T.P., *Predicting final cost for competitively bid construction projects using regression models*, International Journal of Project Management, 21 (8) 2003, 593-599.

4

Reciprocal dependency of owner and contractor

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The coordination role of ECs in the development, engineering, procurement and construction management of LECPs is crucial to the successful execution of these projects. Effective coordination requires reciprocal dependency in the (contractual) relation between owner and EC. In this chapter the implications of early EC involvement are explored. The research methodology comprises a comparative analysis of three case study projects from the petrochemical industry. Two of the case study projects adopted a CPIF/EPCm based contracting strategy. The third was based on a (traditional) single LSFP/EPC contract. The characteristics of the CPIF/EPCm approach are described in some detail. The results of a quantitative, independently benchmarked analysis of cost and schedule performance are presented in conjunction with the effect of the prevailing contracting and procurement market. On all three projects the adopted contracting strategy created a reciprocal dependency between owner and (implementation) EC at the end of project development, providing a strong incentive for cooperation.

4.1 Introduction

The long project life-cycle of LECPs invariably brings turbulence through changes in project dimensions and/or business environment. In these situations, the contractual relationship between owner and EC is often characterised by confrontation, whereas both parties would benefit from a cooperative modus operandi (Turner, 2003). Forms of contracting aimed at facilitating this cooperation include in most cases risk sharing between owner and EC as well as a remuneration structure with performance related (monetary) incentives. These contracts have been discussed for a long time in the economics literature; e.g. (Scherer, 1964), (Mccall, 1970), (Baron, 1972), (Canes, 1975), (Shavell, 1979), (Demong and Strayer, 1981), (Sappington, 1984), (Berends, 2000), (Bushait, 2003) and (Rose and Manley, 2005). During the last decades, they have also attracted considerable attention from practitioners; e.g. (Brandon, 1991) and (Raayen, 1998). In the USA, the Construction Industry Institute published a report in 1991, exploring the benefits of partnering (CII, 1991), followed by a second report in 1998 (CII, 1998). In the UK, the Latham report (Latham, 1994) has had a profound effect on the (contractual) relationships between owner and EC. However many owners still prefer a single LSFP/EPC contract, unless forced to change by external pressures (Hobbs and Anderson, 2001). Generally, lenders also still have a preference for a single LSFP/EPC approach. The underlying reasons for this risk adverse behaviour is the common belief that alternative forms of contracts will result in loss of single point (EC) responsibility, reduced competition and increased cost.

In this chapter cooperation and reciprocal dependency between owner and EC is discussed. The research methodology comprises a comparative analysis of three case study projects from the petrochemical industry. Normally such empirical studies are difficult due to intrinsic differences between projects, related to the functionality and other project dimensions. Also, in many cases objective performance data is not available. The three case study projects (two executed on a CPIF/EPCm basis and one on an LSFP/EPC basis) are particularly suitable for a comparative analysis, because on all three projects:

(a) The functionality was essentially the same;

(b) The owner organisation was the same;

(c) Independently benchmarked performance data on cost and time is available.

An in-depth analysis was conducted of the three case study projects including interviews with key members of the (owner and EC) project organisation. Through an analysis of objective project performance data and a thorough understanding of the business environment and the way in which the case projects were developed and implemented, it is possible to draw generic conclusions from the study, despite the limited number of projects.

4.2 Case study description

4.2.1 Dimensions

The three case study projects described in this chapter pertain to petrochemical facilities. The capital cost of each of the case study projects was EUR 500 – 1,000 million. All facilities were either part of a larger manufacturing site (projects B and C) and/or interlinked with a number of other petrochemical manufacturing facilities (project A), resulting in complex operational interface issues. Many stakeholders played a part; e.g. shareholders in the (joint venture) owner company, lenders, (construction) contractors, authorities, feedstock suppliers, customers, etc. Some of the main characteristics of the three projects are listed in Table 4.1.

Table 4.1
General project characteristics

	Project A	Project B	Project C
Project type [a]	Greenfield	Brownfield	Brownfield
Location	Singapore	The Netherlands	Singapore
RFSU [b] date	Q2 1997	Q3 1999	Q2 2002
Main Contract	LSFP/EPC	CPIF/EPCm	CPIF/EPCm

Notes to Table 4.1:

[a] Projects related to new manufacturing sites are colloquially referred to as 'greenfield' projects and those related to the construction of new facilities at existing sites as 'brownfield'.

[b] RFSU: Ready For Start-Up

4.2.2 Contractual arrangements

On project A, a Dutch based development EC was engaged on the basis of a CPF contract. Schedule delays during development resulted in pressure from local authorities on the owner organisation to take a positive investment decision. To catch up on the project schedule, it was decided to negotiate a single LSFP/EPC contract for implementation with an EC with demonstrable local construction competence. An unusual feature in the contracting process was that the prospective implementation EC participated in development as an observer to facilitate a smooth transition from development into implementation. This created a reciprocal depency of owner and EC. At the time of FID, the EC had invested considerable time and efforts in the project and for the owner switching would have been time consuming and expensive. The original intention was to involve the development EC in implementation, however this did not materialise (Van Gunsteren and Van Loon, 2001). Through the arrangement described above, the advantages of a negotiated contract for implementation (shorter schedule, retention of implicit knowledge obtained during implementation) were largely captured despite having different contractors for development and implementation. Alignment of the owner and EC organisations was further enhanced through a number of so-called 'common objectives' meetings, early during development and implementation. This is a feature usually associated with partnering arrangements [(Lambert and Knemeyer, 2004) rather than LSFP/EPC contracts. The owner's exposure with respect to the absence of (price moderating) competitive market forces was mitigated by the owner's in-house estimating capability and the specific contracting and procurement market at the time.

On projects B and C, one EC was selected for both development and implementation. The development work was carried out on the basis of a CPF contract. As part of the development contract, a CPIF/EPCm contract for implementation was agreed in principle. The intention of the parties to continue from development into implementation was agreed at the start. The reciprocal depency of owner and EC at the end of development provided 'comfort' to both parties with respect to the risk of opportunistic behaviour of the other party. The owner retained the right to select another EC for implementation, in case final agreement on the implementation contract could not be reached (at the end of development) and/or in case of unsatisfactory performance of the EC during development. Similarlt to Project A however, switching would have been expensive and time consuming. On case study projects B and C the construction contracts were based on LSFP and on 'unit rates' contracts respectively. The latter placed the onus for productivity performance with the construction sub-contractors and the responsibility for managing the quantity of work, with the EC (acting as agent for the owner). Unit rates do however introduce the need for the owner to contract a firm of Quantity Surveyors for (re-)measurement of the construction work.

On case study projects B and C, the development EC and the owner independently compiled cost estimates for the project at the end of development and in an agreed format. Subsequently, a target cost was agreed through a joint owner-EC consolidation process of their respective cost estimates. This provided valuable information regarding the (different) perceptions of project risks and a mechanism to mitigate the owner's exposure associated with not having a 'fixed' contract price for the entire project scope at the end of development.

The option to use a CPIF/EPCm contract was also considered for project A. However, the project manager of project A reports that this option was rejected when two (Japanese) ECs indicated at the time that in Singapore only LSFP/EPC contracting was possible and that a CPIF/EPCm approach was not (Van Gunsteren and Van Loon, 2001). Part of this may be culturally induced. However the fact that five years later one of these ECs worked successfully under a CPIF/EPCm contract on project C suggests that the attitude of ECs towards forms of contract other than the traditional LSFP/EPC approach, had changed. In hindsight this may have been one of the early signs of a reduced willingness of ECs to accept the financial risks associated with LSFP/EPC contracts (and hence of changing market conditions). With a CPIF/EPCm contract the project (cost and completion) risk is placed with the party that is best suited to carry the risk (i.e the owner), providing an efficient contracting solution. The fee structure provides a performance incentive for the EC.

4.3 Cost plus incentive fee contracting

4.3.1 Cost reimbursement and incentive constructs

The CPIF contracts for EPCm services used on projects B and C had a structure based on:

(a) Cost reimbursement comprising a remuneration on EC job-hours plus other costs properly incurred and directly related to the project (e.g. travel cost); and

(b) An incentive construct.

The (economic) efficiency of CPIF/EPCm contract is contingent upon the separation of EPCm cost from the performance related incentive fee. A so-called 'open book' approach is required, with the owner having comprehensive audit rights with respect to all project cost. A prerequisite is that the owner has the capability to exercise these rights.

Cost reimbursement of the EC job-hours took place in accordance with the following formula:

$$Reimbursable\ cost = \frac{SA}{W}\left(1 + PB + O\right) \qquad (4.1)$$

where:
- SA Annual gross salary of eligible EC staff
- W Working hours per annum
- PB Payroll burden (percentage)
- O Overhead (percentage)

The owner carried out ex ante audits to establish the value of the above parameters and subsequent ex post audits to assess compliance. A detailed discussion on the way these parameters can be determined is beyond the scope of this study. In this context it is sufficient to mention that this requires specialist competencies within the owner organisation, to ensure as far as reasonably practicable that the cost reimbursement element does not contain profit. In this study the focus is on the incentive construct.

The incentive construct used on projects B and C comprised an arrangement whereby the actual EC profit Π was a function of the performance p and the available (i.e. potential) EC profit Π_a :

$$\Pi = f(p, \Pi_a) \qquad (4.2)$$

$$\Pi_a = \Pi_{a1} + \Pi_{a2} \qquad (4.3)$$

where: Π_{a1} an ex ante agreed available EC profit element 1
$\Pi_{a2} = \alpha (C_t - C)$ a (cost related) available EC profit element 2

Usually, the element Π_{a2} is zero if the actual cost C exceed the target cost C_t and is subject to a maximum value Π_{a2Max}. The total available EC profit as a function of actual cost is given by:

$$\Pi_a(C) = \begin{cases} \Pi_{a1} + \Pi_{a2max} & \text{for} \quad C < (C_t - \frac{\Pi_{a2\max}}{\alpha}) \\ \Pi_{a1} + \alpha(C_t - C) & \text{for} \quad (C_t - \frac{\Pi_{a2\max}}{\alpha}) < C < C_t \\ \Pi_{a1} & \text{for} \quad C_t < C \end{cases} \qquad (4.4)$$

Included in the actual cost C and the target cost C_t are the cost of EPCm services. In the case of $(C_t - \frac{\Pi_{a2\max}}{\alpha}) < C < C_t$ this provides an inherent incentive to the EC for the efficient use of EPCm job-hours because the profit margin generated through the sharing arrangement will generally be significantly higher than the one available on other jobs. The incentive fee structure is illustrated in Figure 4.1.

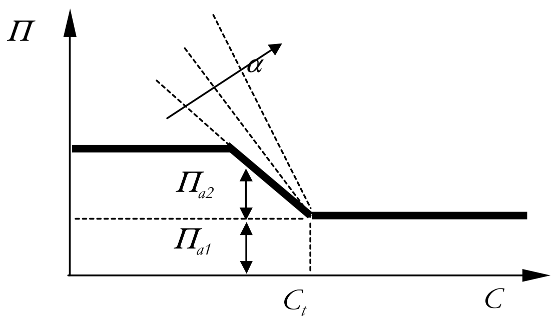
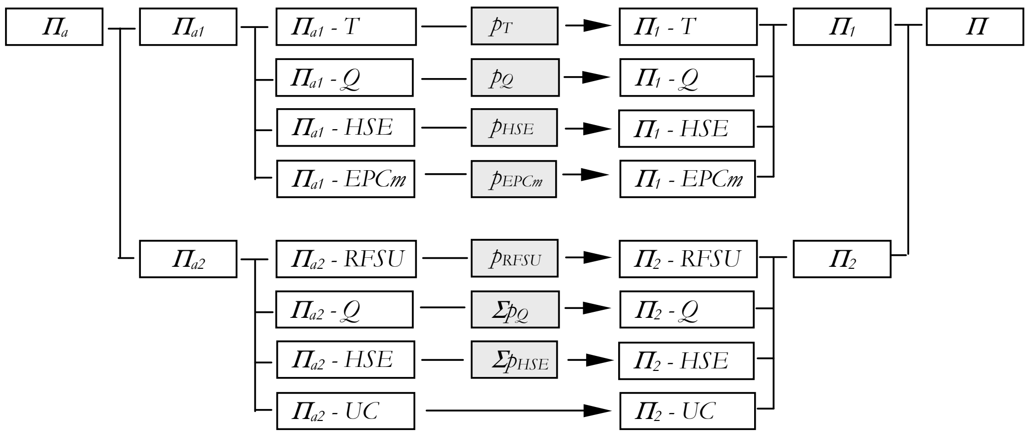


Figure 4.1
Incentive fee structure

Whereas some authors describe 'multiple incentives' contracts, e.g. (Samuelson, 1986) and (Seydel and Olson, 2001), with the form of CPIF contract commonly described in literature, payment of Π_{a1} and Π_{a2} is not subject to performance criteria (other than cost being implicitly included in Π_{a2}), e.g. (Scherer, 1964), (Ward and Chapman, 1991) and (Al-Subhi, 1998). With the form used on Projects B and C, the entire available EC profit Π_a is subject to performance measured against certain criteria; see Figure 4.2. Performance against the criteria linked to Time (milestones), Quality and HESE (i.e. p_T, p_Q and p_{HSE}) is assessed and the associated earned parts of Π_{a1} paid out during execution of the work. Performance with respect to EPCm cost is assessed, and the earned parts of Π_{a1}-*EPCm* paid out, upon completion of the work. The purpose of this criterion is to provide an incentive to the EC for the efficient use of EPCm job-hours if $C > C_t$. Phased payment of 'earned' parts of Π_{a1} during implementation, provides the EC with a certain amount of 'profit cashflow' during the long project life-cycle. Payment of the various parts of Π_2 takes place at the end of implementation (when the actual cost C can be established). For the performance criteria Π_2-*Q* and Π_2-*HSE* the aggregate of the performance scores linked to Π_1 can be used.



where:

T / RFSU	:	Time: (interim) milestones and Ready For Start-Up (RFSU) date
Q	:	Quality of the EPCm work
HSE	:	Health, Safety and Environmental aspects
EPCm	:	EPCm Cost
UC	:	Unconditional; not subject to a performance criterion (other than *C* through Π_2)
p	:	Performance score
Σp	:	Aggregate performance score

Figure 4.2
Incentive fee construct

It can be argued that HSE should not be a performance criterion as this should be a 'given' and that a good HSE performance can be achieved through project management processes (like the ones used on LSFP/EPC contract). Furthermore, it is possible to include a performance criterion regarding the technical availability during a specified period after RFSU. The effectiveness of this with respect to motivating the key decision makers in the EC organisation (e.g. project managers and construction managers) is however questionable as this performance is only established after the (temporary) EC project organisation does not longer exist.

4.3.2 Premises and characteristics

The incentive fee structure described above aims to provide a balanced performance incentive with respect to multiple performance criteria, rather than a focus on cost only as is the case with the form of CPIF commonly used. This way the incentive arrangement acts as a device to align the objectives of owner and the performance incentive of the EC. Key assumptions underlying this approach are:

(a) The owner is able to specify and prioritise (ex ante) project performance criteria (to establish a project specific distribution of the available incentive fee Π_a);

(b) The specified performance criteria are objectively measurable; and

(c) The EC is able to effectively influence overall project performance.

It can be argued that the owner being able to specify and prioritise the project objectives is always a condition for effective project management. In practice however, it is often difficult to specify ex ante unambiguous, quantitative criteria with respect to dimensions such as Quality. Furthermore, qualitative criteria and changing project dimensions during the long project lifecycle of LECPs may diminish the effectiveness of the incentive arrangement with respect to influencing the behaviour of key EC decision makers. Under the arrangement there is no risk of loss for the EC. If the actual cost *C* exceeds or is close to the target cost C_t the element Π_2 is zero (or very small). If this situation becomes apparent during project implementation, a performance incentive remains through Π_1 for time, quality, HSE and the cost of EPCm services, but the incentive for overall cost performance disappears. The impact of the latter on EC behaviour will to a large extent depend on the time at which the situation becomes apparent. If this happens early in the project life-cycle the impact is potentially significant. If it happens after the main construction contracts and purchase orders (for material and equipment) have been awarded, the impact is likely to be small as the actual project cost *C* is largely fixed at that point in time. The obligation of the EC to complete the project remains.

As indicated already in section 2.3.3, on LECPs in the oil, gas and petrochemical industry, the cost of EPCm services (i.e the part of the work carried out by the EC) typically represents some 20% of the capital cost (Berends and Dhillon, 2004). The owner reimburses the EC for its services on the basis of hourly rates; e.g. according the equation (4.1). Materials, equipment and construction work, comprising 80% of the capital cost, are contracted out by the EC 'for-and-on-behalf-of' the owner, or contracted out by the EC and subsequently reimbursed by the owner. Project management is carried out by the EC, acting as the owner's agent. The purchase orders for materials and equipment as well as the construction contracts are awarded after competitive tendering at the appropriate time during project implementation, when the relevant part of detailed engineering has been completed. The high level of definition lower risk means that most of these purchase orders and construction contract can be awarded on the basis of a LSFP or unit rate contract (without the need to establish a complex incentive construct). Furthermore, in many cases a large number of suppliers are available. This facilitates effective competition and an efficient contracting and procurement process.

The implementation EC can be selected through competitive tendering at the end of development. However, with a CPIF/EPCm contract for implementation the selection of an implementation EC is essentially done on the same basis as the EC selection for development (on a CPF contract); i.e. technical capability, (tendered) hourly rates and the tendered fee. Consequently, selection at the start of development of a single EC for both development and implementation provides an efficient solution. The EC selection criteria should include 'implementation capability'. It will not be possible to agree the CPIF/EPCm contract for implementation in full at the start of development. But agreement in principle on the terms and conditions is generally possible with a limited number of outstanding ('square-bracketed') items that are (re-) negotiated at the end of development. This limits the exposure of the owner with respect to being in a 'captive' situation at the end of development and provides a measure of comfort to the development EC with respect to being awarded the implementation contract.

As indicated above, the target cost is an important element of the incentive arrangement. It is usually established at the end of development and its purpose is to provide a cost performance incentive for the EC through the incentive fee element Π_2. The owner pays the actual cost not the target cost. If it becomes clear that the actual cost is going to exceed the target cost, the cost performance incentive for the EC disappears. Therefore, it is in the owner's interest to ensure that the target cost is challenging but not too low and the owner has to have the capability to compile (or procure) its own independent cost estimate to set the target cost at the appropriate level. This process is fundamentally different from a LSFP/EPC contract, where the owner will strive to obtain a contract price that is as low as possible.

With a CPIF/EPCm approach, there is no 'fixed' contract price for the entire project scope, at the time of FID (there is only a target cost). The final cost becomes increasingly firm as project implementation progresses and the various purchase orders and construction contracts are awarded (on the basis of LSFP contracts). With a single LSFP/EPC on the other hand, the EC acts as a 'quasi insurer' (Ward and Chapman, 1991) providing a price guarantee[1] at the start of implementation when the level of (technical) scope definition is insufficient to obtain firm quotations for (many) materials, equipment and construction sub-contracts. Included in the LSFP/EPC bid prices is the premium the owner has to pay for transferring the risk (through a single LSFP/EPC contract) to the EC. Hence, one of the main differences between a (single) LSFP/EPC and a CPIF/EPCm approach lies in the time at which the risk is 'priced' (Berends and Dhillon, 2004).

4.4 Analysis

4.4.1 Cost and schedule performance

The performance with respect to (technical) functionality and organisation was good on all three projects. Project C was initially developed as a 'carbon copy' of project B. However, the latter was a 'schedule driven' project whereas project C was 'cost driven'. As a result, the plant layout was changed to minimise the capital cost (whilst the process technology remained the same). The differing project objectives were reflected in the incentive arrangement, driving the cost and schedule performance. On project B some 50% of Π_I was linked to schedule performance, compared with only 25% on project C. On project C the EC's sharing rate α was 40%, providing a strong cost incentive, compared with only 20% on project B.

Source of the industry benchmark: Independent Project Analysis, Inc.

Figue 4.3
Cost and Schedule Ratios

In Figure 4.3(a), the cost performance on projects A, B and C is depicted as (i) the ratio of actual cost divided by an industry cost benchmark; and (ii) the ratio of the initial owner cost estimate divided by the cost benchmark. In Figure 4.3(b) similar ratios are depicted for schedule. On all three projects the actual cost was within the +/- 10% accuracy band. On ***project A***, the actual cost was just below the independent industry benchmark and significantly below the owner estimate (i.e. the budget). Actual RFSU was a couple of months late. However, if the project would have been finished on time, the plant could not have been started up anyway, due to schedule delays on projects of linked manufacturing plants. This resulted in a focus on cost rather than schedule.

The owner's initial schedule on ***project B*** was extremely aggressive. Construction started when only some 20% of detailed design & engineering had been completed (leading to inefficiencies during construction), whereas on project C by way of comparison, construction started at 40% of detailed design and engineering. Independent benchmarking (carried out prior to implementation) indicated a probability of less than 10% of achieving the initial schedule. The target completion date of project B was indeed not achieved, but the actual duration was still significantly below the industry benchmark (see Figure 4.3(b)). The relatively high cost of project B compared with the industry benchmark can in part be attributed to the fact that the project was schedule driven; i.e. the owner made allowance in the budget for the aggressive schedule. The actual costs were within +/- 2% of the owner's cost estimate. On project C the actual cost was significantly below the owner estimate (budget) as well as the industry benchmark. The project was completed in accordance with the owner's schedule, which was slightly longer than the industry benchmark.

On ***project C*** the EC earned some 95% of the available incentive fee (i.e. $\Pi = 0.95\ \Pi_a$) whereas the EC on project B earned some 30% (i.e. $\Pi = 0.30\ \Pi_a$). To a large extent this is attributable to there being no cost related incentive amount Π_2 on project B ($C > C_t$). Also, due to the aggressive schedule targets on project B only 60% of the schedule related incentives (i.e. Π_{a1}-T) were earned, compared with some 90% on project C (i.e. Π_{a1}-T and Π_{a2}-$RFSU$).

4.4.2 Market conditions

As mentioned above, some 80% of the capital cost is related to the cost of materials, equipment and construction. These cost are determined by the contracting and procurement market when the relevant purchase orders and construction contracts are placed. Due to the long development and implementation time of major engineering and construction projects, this takes place a significant time after the investment decision is taken.

The contracting and procurement market pertains to a large number of different goods and services and it is difficult to establish a composite indicator which provides a direct measure of the state of the market. Here the annual change in Gross Domestic Product (GDP) will be used. GDP is the market value of all goods and services produced in a country during a given time period and is composed of (i) consumption; (ii) investments; and (iii) net exports. An advantage of using GDP is that it is measured frequently and widely. A disadvantage is that GDP not only includes investments but also the consumption and export of final goods. The reason for using GDP here as an indicator for the contracting and procurement market is that the cost of goods and services generally increases when GDP increases. This makes GDP a proxy for the state of the contracting and procurement market (rather than a direct measure of it). Figure 4.4 illustrates the annual changes in GDP in Singapore (projects A and C) and The Netherlands (project B) during 1992 – 2002 together with the duration (from FID until RFSU) for projects A, B and C.

The owner's budget of project A was compiled during the second half of 1993, immediately after a period of economic growth in Singapore. The economic growth in Singapore slowed down during 1994 and subsequently the EPC activities took place in a period of (relatively) stable markets (see Figure 4.4). The market conditions enabled the owner to successfully negotiate a single source LSFP/EPC contract with the EC on project A. Project B was approved after a period of modest, but steady, economic growth in The Netherlands. However when the main construction contracts were awarded, construction cost were high due to a steep increase in economic growth during 1998/1999. The cost of unfavourable market conditions were borne by the owner under the conditions of the prevailing CPIF/EPCm services contract on project B. The incentive arrangement did however facilitate a schedule incentive that would have been difficult to achieve under an LSFP/EPC contract. On project C, contracting and procurement of materials, equipment and construction work took place during a period of a sharp decline in economic growth in Singapore (and the rest of Asia). The lessons learned on 8 previous CPIF contracts were incorporated in project C, including stochastic modelling to optimise the various parameters of the incentive arrangement (see also Figure 4.2). The CPIF/EPCm services contract with the EC enabled the owner to reap the benefits of favourable market conditions.

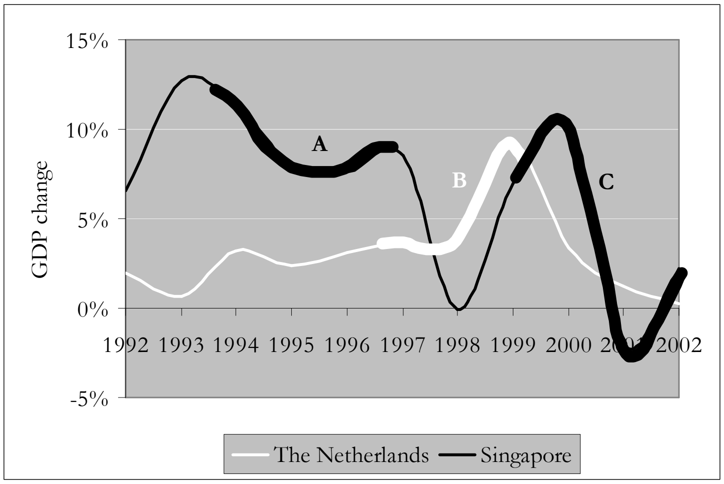


Figure 4.4
Economic Growth Patterns and Project Schedules.

Source: Calculated from (EIA, 2002).

4.5 Conclusions

A crucial element in cooperative contracting (and indeed project management in general) is the composition of the project teams of the owner and EC and the way in which individual and group working relationships are developed. In many cases problems with establishing an effective project organisation occur because availability rather than competence dominates assignments (Groen, Dhillon, Kerkhoven, Janssen and Bout, 2001)[2]. Projects B and C were executed on the basis of a CPIF/EPCm contract, with the EC 'rolling on' from development into implementation. Consequently, ample time was available to align the project teams of the owner and the EC. Both parties had an interest in investing in a cooperative relationship; i.e. a reciprocal dependency existed between owner and EC. The incentive arrangement further enhanced the alignment of owner and EC objectives. Also, the project managers of the owner and the EC both embraced wholeheartedly the cooperative nature of the contractual arrangement, resulting in an integrated project team. With a 'traditional' LSFP/EPC contract, competitively tendered after development, the project management organisations of the owner and implementation EC have to establish formal and informal ways of cooperation in a very short period of time.

On project A, a LSFP/EPC contract for project implementation was negotiated with a selected EC during development. This facilitated a smooth transition from development into implementation. Such an arrangement requires (i) a buyers' market creating sufficient interest among prospective ECs; (ii) a knowledgeable owner organisation, able to establish a credible cost estimate; (iii) an EC willing and able to execute development without participating in the (more attractive) implementation phase; and (iv) a (prospective) implementation EC prepared to invest ex ante significant time and effort without guarantee with respect to contract award. On project A the implementation contract was negotiated after a downturn in overall economic activity, enabling the owner to negotiate (single source) a reasonable LSFP/EPC contract and providing a welcome project workload for the implementation EC. But in most cases it is not possible to create these circumstances on a LSFP/EPC contract.

All three case study projects were successful with respect to the functional effectiveness of the manufacturing facility and the (prioritised) project objectives. On projects B and C the owner carried the project cost risk. The cost performance clearly shows how the CPIF/EPCm shields the EC from the conditions that prevail at the contracting and procurement market at the time during project implementation when purchase orders and construction contracts have to be placed. If an LSFP/EPC contract had been concluded on project B, the EC would have been exposed to adverse market conditions whereas it would have been able to realise a windfall profit in the case of an EPC/LSFP on project C. On risky major engineering and construction projects, with large amount of capital and ECs that are generally not well placed to bear the consequences of the associated risks, CPIF/EPCm contracts provide a credible alternative to the traditional (single) LSFP/EPC approach. This is particularly relevant when the contracting and procurement market is volatile.

On the three projects in this case study, differing contracting strategies and tactics were adopted in differing market conditions. However, on all three projects the adopted strategy created a *reciprocal dependency* between owner and (implementation) EC at the end of project development, providing a strong incentive for cooperation and the basis for project governance and ultimately the success of the project. An essential pre-requisite for such an approach is a willingness of key decision makers in the project organisations of owner and EC to effectively work together.

Notes

1 Many LSFP/EPC contracts nowadays contain exclusions or limitations of the EC's liabilities, particularly with respect to risks that are outside its control (e.g. wage increases). Consequently the contract price is only partly 'fixed'.

2 A frequently raised issue with respect to 'cooperative contracting' is that this requires a larger owner's team, particularly with respect to project (cost and schedule) control and contracting. Whilst this is certainly true, the associated cost associated are limited. An LECP executed under a single LSFP/EPC contract typically requires 2-5 control/contracting professionals whereas a CPIF/EPCm arrangement may require 5-15 people. Assuming an implementation schedule of 3.5 years and an average salary cost of 250,000 Euro/year, this amounts to a delta of Euro 3-10 million. Availability of the right resources rather than cost is mostly the limiting factor.

4.6 References

Al-Subhi Al-Harbi K.M., 1998. *Sharing fractions in cost-plus-incentive-fee contracts.*, International Journal of Project Management, 16 (2): 73-80.

Baron D.P., 1972. *Incentive contracts and competitive bidding,* American Economic Review, 62, pp384-394.

Berends T.C., 2000. *Cost plus incentive fee contracting – experiences and structuring,* International Journal of Project Management, 18(3): 165-171.

Berends T.C., Dhillon J.S., 2004. *An analysis of contract cost phasing on engineering and construction projects*, The Engineering Economist, 2004, 49(4): 327-337.

Brandon B., 1991. *Operator and contractor benefit from incentive contracts*, Oil & Gas Journal, 16 September 1991, pp78-79.

Bushait A.A., 2003. *Incentive/disincentive contracts and its effects on industrial projects,* International Journal of Project Management, 21, pp 63-70.

Canes M.E., 1975. *The simple economics of incentive contracting: Note,* American Economic Review, (65), pp478-616.

Chapman C.B., Ward S.C., Bennell J.A., 2000. *Incorporating uncertainty in competitive bidding.* International Journal of Project Management, 18: 337-347.

Construction Industry Institute , 1991. *In search for partnering excellence.* CII Special Publication 17-1.

Construction Industry Institute, 1998. *Innovative contractor compensation.* CII Research Summary 114-1.

Demong R.F., Strayer D.E., 1981. *The underlying theory of incentive contracting,* Defense management journal, First Quarter 1981, pp42-51.

EIA, 2002. Energy Information Administration, *International Energy Annual 2002*

Groen de T., Dhillon J., Kerkhoven H., Janssen J., Bout J., 2001. *2 X 2 Your choice for projects, twice as cost effective, twice as fast*, NAP, DACE.

Gunsteren L.A. van, Loon P. van, 2001. *Open design & construct management – Managing complex building projects through synthesis of stakeholders' interests*, Eburon Publishers, Delft, The Netherlands.

Hobbs B., Andersen B., 2001. *Different alliance relationships for project design and execution,* International Journal of Project management, 19: 465-469.

Lambert D.M., Knemeyer A.M., 2004. *We're in this together.* Harvard Business Review, December 2004.

Latham M., 1994. *Constructing the team*, Joint Government/Industry review of procurement and contractual arrangements in the U.K. construction industry, Final Report, H.M.S.O., London.

McCall J.J., 1970. *The simple economics of incentive contracting,* The American Economic Review, 60: 837-846.

Raaijen W., 1998. *Lofzang op het alliance model (Praise for the alliance model),* Petrochem, 7/8, 1998, pp16-19.

Rose T., Manley K., 2005. *A conceptual framework to investigate the optimisation of financial incentive mechanisms in construction projects,* 2005 CIB W92/T23/W107 International symposium on procurement systems, The impact of cultural differences and systems on construction performance, February 7-10, 2005, Las Vegas, USA.

Samuelson W., 1986. *Bidding for contracts,* Management Science, Vol.32, No.12, December 1986.

Sappington D. ,1984. *Incentive contracting with asymmetric and imperfect precontractual knowledge*, Journal of Economic Theory, 34: 52:70.

Scherer F.M., 1964. *The theory of contractual incentives for cost reduction*, Quarterly Journal of Economics, 78: 257-280.

Schuyler J., 2001. *Risk and decision analysis in projects*, Project Management Institute Inc, Second edition.

Seydel J., Olson D.L., 2001. *Multicriteria support for construction bidding*, Mathematical and computer modelling, (34), pp677-702.

Shavell S., 1979. *Risk sharing and incentives in the principal agent relationship*, Bell Journal of Economics, 10: 55-73.

Turner J.R., 2003. *Contracting for project management*, Gower Publishing Limited, Aldershot, England.

Ward S., Chapman C., 1991. *On the allocation of risk in construction projects*, International Journal of Project Management, 9(3): 140-147.

5

Relational risk in cooperative contracting

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Effective cooperation requires reciprocal interdependencies between the contract parties. Lack of reciprocity results in relational risk; i.e. the risk of opportunistic behaviour of one or both contract parties. This is particularly relevant for cooperative (incentive) contracting where the owner relies on the EC acting for and on its behalf. The main research questions addressed in this chapter are (i) which factors contribute to asymmetric dependence and opportunistic behaviour and what is the relative importance of these factors; and (ii) how can the resulting relational risk be mitigated? A conceptual model based on transaction cost theory and decision theory is presented. Empirical research in the form of a survey was conducted to test the hypotheses derived from the model. The results of a multivariate analysis indicate that the most effective governance mechanisms to reduce the room for and intent towards opportunistic behaviour are performance monitoring (rather than contract terms) and building trust between owner and EC. Owner organisations can further mitigate relational risk through enhancing their competencies with respect to (market based) cost information and control.

5.1 Introduction

As discussed in Chapter 4, effective cooperation requires *reciprocal* interdependencies between the contract parties. Lack of reciprocity results in relational risk; i.e. the risk of opportunistic behaviour of one or both contract parties (Das and Teng, 2001), with opportunism being "self-interest seeking with guile" (Williamson, 1985). To limit the 'informed' EC taking advantage of the 'under-informed' owner, mechanisms that promote information disclosure and pursuit of project objectives need to be incorporated into the contract. In this chapter the relational risks associated with cooperative (incentive) contracting on LECPs is considered. The main research questions addressed are:

(a) Which factors contribute to asymmetric dependence and opportunistic behaviour and what is the relative importance of these factors; and

(b) How can the resulting relational risk be mitigated?

To answer these types of questions, transaction cost economics needs to be combined with elements that introduce relational aspects in contracting (Kamann, Snijders, Tazelaar and Welling, 2006). First, decision theory and transaction cost theory and its application to the development and implementation of LECPs is discussed. A conceptual model is constructed for empirical research, and three hypotheses are formulated. Subsequently, the research methodology and the dataset used to test the hypotheses are described. As indicated in chapter 4, willingness to work together is a pre-requisite for cooperative contracting and therefore specific attention is paid to trust attributes. Focused interviews complement the analysis of survey results.

5.2 Bounded rationality and relational risk

5.2.1 Decision theory

The principal-agent model (see chapter 2) draws on traditional Walrasian economic theory based on the concept of rational, well-informed parties pursuing self- interest, with expected utility theory as a descriptive model dominating the analysis of decision-making under uncertainty. During the LECP life-cycle however, many decisions have to be taken under uncertainty and on the basis of incomplete information. These decisions constrain and shape the future.

In the field of behavioural economics, Allais (1979) observed risk adverse behaviour on projects when the stakes are high, even when the probability is low. There are many biases that influence choices, such as (i) the availability heuristic - people judging probabilities by thinking of examples (Tversky and Kahneman, 1973); and (ii) the anchoring and adjustment heuristic - people being biased in favour of their present beliefs, ignoring evidence against them (Tversky and Kahneman, 1974). The latter is related to a preference for the status quo, inaction being the default behaviour (Kahneman and Tversky, 1982). The above heuristics do not mean that parties are irrational or random in their behaviour. Rather, their behaviour is governed by *bounded rationality* (Simon, 1982). Parties know that they cannot be substantively rational in the sense of collecting and analysing all the information required for a decision. In most situations, the available information is incomplete, data collection and analysis is constrained by time and the information processing capacity of the human brain is limited. Parties therefore rely on 'standard operating procedures' based on decision heuristics. These decision heuristics are relevant at the micro level of the individual as well as the macro level of the organisation; i.e. individuals interacting in a structured and ordered way in accordance with established rules of behaviour. A project manager acting in accordance with accepted best practices minimises the risk of a wrong decision adversely affecting his career. If things go wrong, it will most likely be blamed on environmental factors. In this way availability heuristics and a preference for the status quo at micro level, result in risk adverse decision-making processes at macro level. On projects, the initial intentions and expectations of the parties involved are critical to project success as anchoring and adjustment heuristics will make it difficult to take corrective action later (Munns, 1995). Research on behaviour in escalating situations shows a tendency at micro and macro level to become overly committed to losing courses of action due to psychological, social and organisational variables. People may commit more resources to a losing cause, for instance, so as to justify or rationalise their previous behaviour. Organisations have imperfect sensory systems, making them relatively impervious to environmental changes. If actions require altering long-standing policies, violating rules, or discarding accepted procedures, change is not likely to happen (Staw and Ross, 1989).

5.2.2 Transaction cost theory

Transaction cost theory (Williamson, 1985) incorporates some of the components of decision theory outlined above into the principal-agent model. It assumes that principal and agent (i) display 'bounded rationality' behaviour; (ii) possess limited calculation abilities; and (iii) operate in an environment where the structure of problems is not known ex ante (Brousseau and Glachant, 2002). Transactions are executed within an uncertain environment and project specific investments, in 'hardware' as well as 'software' (i.e. human resources), are made during a long project life-cycle. Coordination between principal and agent is achieved through a range of governance mechanisms, based on the acknowledgement that transacting is not free; i.e. it takes time and resources of the parties involved.

5.2.3 Relational risk

In chapter 4 it was demonstrated that reciprocal interdependencies can have a positive effect on project governance. Asymmetric dependence on the other hand, increases the relational risk. Asymmetric dependence between principal and agent is created through switching costs; i.e. the costs to replace an existing agent. An example of this is the project specific knowledge of EC resources. Replacing the EC will be costly for the owner, directly (the new EC having to acquire the said project specific knowledge) as well as indirectly (through the time lost). Asymmetric dependence is also created by the perceived value of one party to the other (Nooteboom, 2004). Bounded rationality creates room for opportunistic behaviour. In a ubiquitously uncertain environment, contracts are by definition incomplete and therefore insufficient as governance mechanism. Performance monitoring provides a safeguard to reduce the room for opportunistic behaviour, subject to the owner having the required competencies to perform this activity effectively. Reputation effects attenuate the intention to behave opportunistically, as the gains from opportunism must be weighed against the future cost of reputation loss (Williamson, 1985).

Trust is an important factor regarding the intent of opportunistic behaviour. It is a multidimensional construct and a large number of definitions of trust have been proposed (Cheung, Wong and Suen, 2003). For the purpose of this chapter trust is defined as follows: *Trust is the acceptance of vulnerability and dependence on others, predicated on a positive outcome.* Williamson (1993) claims that trust beyond calculative self-interest will not survive in a market situation and that it is not a reliable safeguard as a response to opportunism. In the field of cognitive sciences however, there is a commonly shared view that trust is viable and can be an important governance element to mitigate relational risk (e.g. Woolthuis, 2002). With respect to project management, some researchers argue that it is unlikely that parties in a transactional relationship will be willing to place themselves voluntarily in a position of dependency because it may be revoked unilaterally (Cox and Thompson, 1997). Others maintain that effective cooperation on projects is not possible without trust and an appropriate balance of formal and informal communication (Turner and Muller, 2004). In an economic context the meaning of trust is also important. According to Ricketts (2001) a significant proportion of transaction costs (e.g. monitoring cost) pertains to lack of trust. Some of these costs are 'hidden' in the form of restricted competitive tendering and an increased potential for claims (Zaghloul and Hartman, 2003). The concept of trust is discussed in more detail below.

5.3 Conceptual model and hypotheses

5.3.1 Conceptual model

The dependent variable is the relational risk on LECPs in the contractual arrangement between owner and EC. Based on the (transaction cost) contract theory discussed above, independent variables can be identified that contribute to this relational risk. The conceptual model and the hypothesised interconnection between the variables are illustrated in Figure 5.1.

Asymmetric dependence between the parties creates relational risks. Under an EPCm arrangement the project specific investments (asset specificity) of the EC pertain only to the 'opportunity profit' of the (human) resources deployed. The tacit, project-specific knowledge of these resources represents however significant value to the owner. Furthermore, the project specific investments (and the asymmetric dependence) of the owner increase dramatically as soon as supply agreements for the facility's products are concluded. This is particularly relevant in an oligopolistic market (see section 2.3.3) where the risks of 'small numbers bargaining' is high. Mechanisms that mitigate relational risk through reducing the *room for opportunism* are the contractual terms & conditions (subject to enforceability) and performance monitoring. Reputation (including the impact on future business opportunities) and mutual trust mitigate the *intent towards opportunism*; i.e. the intent to take advantage of a situation at the expense of the other party. The threat of opportunistic behaviour remains, however, because these mitigations might not be sufficient as safeguards against 'deviant' behaviour.

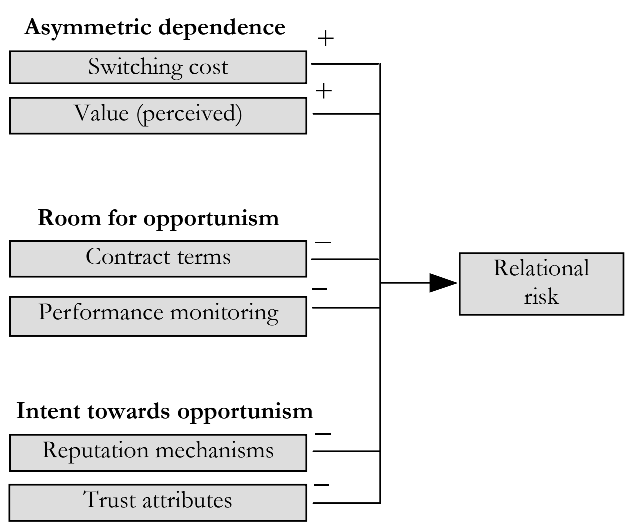

Figure 5.1
Conceptual model

5.3.2 Hypotheses

The following hypotheses can be derived from the conceptual model in Figure 5.1.

Hypotheses:

1. Asymmetric dependence, measured by switching cost and the perceived value of one party to the other, increases relational risk.
2. Contractual terms & conditions and performance monitoring limit the room for opportunism and reduce relational risk.
3. Reputation considerations and trust attributes mitigate the intent of opportunistic behaviour and reduce relational risk.

As discussed in chapter 4, an EPCm arrangement is based on open sharing of information between owner and EC. In this chapter particular attention is given to the role of trust with respect to relational risk. Trust comprises a construct of many different attributes. The University of Salford and the Centre of Construction Innovation (2002) have developed a list of 12 trust attributes based on literature and interviews with industry practitioners. Fukuyama (1996) and Kadefors (2004) propose two additional attributes: (i) equitable terms & conditions of contracts; and (ii) Alternative Dispute Resolution (ADR). Wong and Cheung (2004) have used the resulting 14 trust attributes for research of (long-term) partnering in the civil (residential and office) construction industry in Hong Kong. The same attributes, described in Table 5.1, are used here. The attributes listed are obviously interrelated and there is a significant amount of 'overlap'.

Table 5.1
Trust attributes

Trust Attributes	Description / Comments
Satisfactory terms	Equitable terms & conditions
Problem solving	Early resolution
Long-term relations	Reliability during project life-cycle
Adopt ADR[a]	Avoidance of acrimonious litigation
Communication	Open and frequent communication
Openness	Transparency and integrity
Alignment	Equitable distribution of benefits
Financial	Financial stability
Reputation	Reputation as a valuable asset
Competence	Performance
Information flow	Accuracy of information
Unity	Common understanding
Respect	Management system
Compatibility	Shared cultures and values

[a] ADR: Alternative Dispute Resolution

5.3.3 Research methodology

A survey via Email was used to test the hypotheses and to determine the relative importance of the trust attributes. These factors are difficult to measure, but they can be 'spanned' by quantitative indicators in the form of judgements by people, on a Likert scale. In this survey, a 5-point scale was used for the governance of relational risk in general and a 7-point Likert scale for the trust attributes. The respondents were asked 'how much' they agreed or disagreed with the statements in the survey. These statements were tested for internal consistency before issuing the questionnaire, to ensure they measured the same variable. The survey statements were formulated in 'extremes' as respondents will generally not totally disagree with 'weak' or 'neutral' statements

(Segers, 2002). Test respondents were used to remove any ambiguity in the statements. The survey consisted of:

- 21 general statements;
- 27 statements on generic relational risk variables; and
- 14 statements covering the trust attributes.

A large group of potential respondents could be reached through the Email survey. Anonymous data processing was used to maximise the chance of obtaining 'honest opinions'. The target population consisted of senior project managers; i.e. the key decision makers with respect to choosing project governance mechanisms. Respondents came from the case study owner organisation and all the major ECs in the oil, gas and petrochemical industry. To identify appropriate potential respondents, a pre-investigation via Email, was conducted in which the content of the research and the goal of the survey was explained. The single owner organisation provided homogeneity of the 'tracing sample' population, enhancing the reliability of the results. The involvement of all major ECs in the (global) industry provided the required breadth for the research. The response rate of 28% and 34% for relational risk and trust attributes respectively (see Table 5.2) is considered acceptable in comparison with similar surveys[1]. The responses to the general statements in the survey were used to ensure that data from a homogenous sub-population was analysed. For instance only responses from project managers with EPCm experience on projects with a total installed cost exceeding EUR 200 million were included. A number of responses were incomplete.

Table 5.2
Survey response

	Sample	**Response**	**Data** [a]
Relational risk			
Owner	54	24	16
EC	87	32	23
Total	141	56	39 (28%)
Trust attributes			
Owner	54	26	18
EC	87	39	30
Total	141	65	48 (34%)

[a] The data for analysis excludes incomplete responses and/or respondents without relevant experience.

Four case study projects were selected for an in-depth analysis to verify the outcome of the survey and to obtain a better understanding of the key findings. All four projects were executed under an EPCm arrangement and the capital value of each project exceeded EUR 500 million. The projects covered a period of 15 years; two were located in Europe and two in Asia. The relevant documentation was researched and on each project focused interviews were conducted with the project director/manager of the owner and the EC (i.e. 8 interviews in total). The respondents were interviewed for a relatively short period of time (approximately one hour), using a set of questions derived from the hypothesised relations. Inherent problems with these kind of interviews are bias, poor recall and poor or inaccurate articulation. To counter these problems, the interviews were recorded and case study research was conducted on the selected LECPs to validate the outcome of the interviews.

5.4 Multivariate analysis

5.4.1 Generic relational risk

A multivariate analysis was carried out to analyse the relation between the dependent variable *relational risk* and the independent variables *switching cost, perceived value, contract terms, performance monitoring, reputation mechanisms and trust attributes* in accordance with the conceptual model. For the analysis the (well-known) Statistical Package for the Social Sciences (SPSS) was used.

The survey contains statements that provide a measure for each of the independent variables. Cronbach's alpha (α) is used to measure the internal consistency between the statements/responses pertaining to a specific variable. If $\alpha > 0.9$ the constituent statements/responses are strongly correlated and a construct of the variable under consideration. If $0.7 < \alpha < 0.9$ the correlation is acceptable. Values close to zero would be found for a group of random statements. The results are summarised in Table 5.3.

The responses pertaining to *switching cost* were found to be not consistent. *Reputation mechanisms* were measured on a one-item scale (i.e. only one question in the survey related to this item), so α is not relevant. The other statements/responses were found to be consistent although it should be noted that the value $\alpha = 0.64$ for the variable *contractual terms* is rather low. Subsequently, a multiple regression analysis was carried out (except for the variable *switching cost* on which the responses were inconsistent).

Table 5.3
Results multiple regression analysis

Variable	β	S_e	α	Correlation
Asymmetric dependence				
Switching cost		Responses not consistent		No
Perceived value	0.71	0.19	0.74	Yes
Room for opportunism				
Contractual terms	-0.07	0.28	0.64	No
Performance monitoring	-0.27	0.15	0.72	Yes
Intent of opportunism				
Reputation mechanisms	0.17	0.13	Not applicable.	No
Trust attributes	-0.37	0.17	0.84	Yes

Notes:
β Regression coefficient
S_e Estimated standard deviation of the error terms in the regression model
α Cronbach's alpha: the sum of the individual variances divided by the variance of the entire scale

Calculated using SPSS

The results indicate that the (perceived) *value* of the EC increases the relational risk (with a regression coefficient $\beta = 0.71$), through the owner depending on the EC to provide the required capabilities. This dependence increases over the project life-cycle as the EC becomes increasingly knowledgeable about the project. The effect of *switching cost* could not be proven from the results. The correlation with respect to the *contract terms* is very weak ($\beta = -0.07$) and the value of Cronbach's alpha is also relatively low and the standard deviation large. On the basis of the present results it is therefore difficult to draw any conclusions with respect to the correlation between *contractual terms & conditions* and *relational risk*. The analysis indicates that *performance monitoring* reduces the room for opportunistic behaviour. This is accepted by both owner and EC organisations. *Reputation mechanisms* display a weak positive correlation with a high standard deviation. In our model we assumed that reputation would mitigate relational risk through a reduced intent towards opportunism whereas the analysis indicates that it increases relational risk slightly. Part of the explanation might be that LECPs are regarded as one-off transactions rather than part of a longer-term relationship. This effect will be stronger in a market with many opportunities like the one prevailing at the time of the survey. *Trust attributes* reduce the intent for opportunistic behaviour. The responses have the largest internal consistency and a clear correlation with respect to reducing the intent of opportunistic behaviour.

In summary, the hypotheses are partly confirmed. The results suggest the following correlations:

1. Value increases relational risk;
2. Performance monitoring limits the room for opportunism and reduces relational risk; and
3. Trust mitigates the intent towards opportunism and reduces relational risk.

5.4.2 Trust attributes

The analysis indicates that trust is the most important factor with respect to mitigating relational risk in cooperative forms of (EPCm) contracting on LECPs. Therefore the trust attributes have been analysed in more detail. First the trust attributes were ranked by their relative importance, derived from the mean values of all valid responses (on the 7-point Likert scale used in the survey). The number of cases is not enough to separate the owner and EC responses, which was the original intention, however, the combined results, see Table 5.4, provide an insight in the opinions held by decision makers in the industry.

Table 5.4
Relative importance of trust attributes

Trust attribute	Rank	Mean	SD
Openness	1	6.6	9%
Competence	2	6.3	12%
Communication	3	6.1	15%
Problem solving	4	6.0	14%
Alignment	5	5.8	17%
Information flow	6	5.8	13%
Unity	7	5.5	18%
Long-term relation	8	5.5	21%
Respect	9	5.5	19%
Satisfactory terms	10	5.4	23%
Reputation	11	5.3	20%
Financial	12	5.2	23%
Compatibility	13	5.0	23%
Adopt ADR	14	4.6	33%

Notes:
1. Scores on a scale of 1-7.
2. SD: Standard deviation

Calculated using SPSS

Overall, the mean scores in the current research are very high considering the scale of 1-7. The results suggest that openness (i.e. transparency and integrity) and the competence to perform the work are the most important trust attributes. The adoption of ADR and compatibility (i.e. shared cultures and values) are relatively unimportant.

A statistical analysis called Principal Component Factor Analysis (PCFA) was performed. PCFA is used to study correlations among a large number of interrelated quantitative attributes by categorising them into a small number of 'factors'. The attributes within each factor are more highly correlated with the trust attributes in that factor than with the trust attributes in other factors. In other words, the factors represent a cluster of related attributes, which facilitates a better interpretation of the data (SPSS, 1999). The results are presented in Table 5.5.

Table 5.5
PCFA results

	Factor			
Trust attributes	**1**	**2**	**3**	**4**
Satisfactory terms	0.707	0.009	0.339	-0.250
Problem solving	0.685	0.052	-0.251	0.214
Long-term relations	0.672	0.092	0.186	0.154
Adopt ADR	0.672	0.349	0.206	0.154
Communication	0.316	0.779	0.152	0.136
Openness	-0.089	0.748	0.002	0.329
Alignment	0.185	0.738	0.239	0.117
Financial	0.080	0.161	0.882	0.046
Reputation	0.329	0.390	0.669	0.022
Competence	-0.047	-0.164	0.583	0.568
Information flow	0.469	0.260	0.517	0.275
Unity	0.100	0.321	-0.038	0.767
Respect	0.062	0.271	0.025	0.731
Compatibility	0.311	0.076	0.289	0.603
Variance [%]	34.95	12.74	9.76	8.24
Cronbach's alpha	0.71	0.74	0.76	0.71
KMO[a] measure	0.704			
Bartlett test of sphericity				
Approximate Chi-square	265.986			
Degrees of freedom (df)	91			
Significance[b]	0.000			

Notes:

[a] The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy indicates the proportion of attributes variance that might be caused by underlying factors; values 0.5 - 1.0 are acceptable.

[b] Bartlett's test of sphericity measures the significance level for the level of usefulness of the data. A significance level below 0.05 is acceptable.

Calculated using SPSS

Factor 1 indicates four trust attributes that are significantly correlated: equitable terms & conditions of contract, early resolution of problems, good working relations throughout the project life-cycle and the adoption of ADR processes. These attributes pertain to conditions that enable or constrain actions, such as the *institutional* environment. The trust attributes under factor 2 relate to open and frequent sharing of information, integrity and reciprocity in benefits. Open communication is a pre-requisite to create and maintain confidence in the other party's *integrity*. Factor 3 comprises the ability to execute the work in accordance with the requirements, the provision of accurate information, financial stability and reputation. The latter pertains to a company's track record and the perception of owners regarding the EC's *competence*. The trust attributes under factor 4 pertain to a shared *organisational culture*. A point worth mentioning is that the attribute description 'respect' is somewhat misleading as it does not relate to a normative value concept but to compliance with a management system.

The PCFA score ranking is summarised in Table 5.6. The most important group of attributes (1. Integrity) relate to transparency and integrity fostered by effective and open communication and alignment of effort and reward. A point worthy of note is that on a scale 1-7, the lowest score of 5.3 (Organisation culture) is still considered very high.

Table 5.6
PCFA score ratings regarding trust attributes

Ranking	Description	Score	Factor
1	Integrity	6.2	2
2	Competence	5.7	3
3	Institutional	5.4	1
4	Organisation culture	5.3	4

Note: Scores on a scale of 1-7.

5.4.3 Focused interviews

The focused interviews held with the senior project managers (PMs) of the owner and EC organisations on four case study projects confirmed the results of the multivariate analysis above.

From the survey no correlation could be established between the dependent variable *relational risk* and the independent variable s*witching costs*. The latter were also not mentioned by the PMs. A possible explanation might be the culture associated with the profession. Most PMs consider themselves as 'builders' (i.e. designers and constructors) and have a strong focus on 'getting the job done' and solving problems. Changing EC halfway through a project will not resonate, particularly not with the PMs of the ECs. Furthermore, respondents from the ECs may have been tempted to submit the 'desired answer'. This is also reflected in the survey results (the responses pertaining to switching cost were found to be not consistent). With respect to investments made by the owner and the EC ('asset specificity') the interviewees all stressed the importance of the owner carrying the investment risk with an EPCm arrangement. Investments by the EC are limited and pertain to the human resources tied up during execution of the work. The survey identified *perceived value* as a source of relational risk. The value of an EC as perceived by an owner can be categorised into: (i) technical know-how; and (ii) market knowledge. A particular area of market knowledge mentioned by a number of PMs relates to cost estimating competencies, in relation with establishing a target cost on incentive contracts. When using these forms of contracts, owners need to be able to compile their own independent cost estimates. Owners are generally weak in this area, creating asymmetric dependence on ECs and relational risk.

The conceptual model (see Figure 5.1) includes *contract terms* as a means to reduce the room for opportunism. A correlation between *contract terms* and *relational risk* could not be established from the survey. The interviews seem to confirm this result with a number of PMs proudly stating that 'the contract was left on the bookshelf with the exception of the incentive arrangement'. *Performance monitoring* was generally accepted as good practice. Most PMs explicitly stated, however, that owners should refrain from interfering with the manner in which the EC executes the work. Monitoring activities were also mentioned repeatedly as a way to build trust. Conversely, excessive monitoring can also be perceived as a sign of mistrust. On projects with an incentive arrangement, the latter was mentioned as a useful mechanism to facilitate discussion on the status during the project life-cycle, as this forces the parties to agree which incentive payments are due.

Reputation mechanisms were included in the conceptual model as a means to mitigate the intent of opportunistic behaviour. The survey indicated a weak positive correlation with relational risk; i.e. a source of relational risk rather than a mitigating mechanism. Reputation was repeatedly mentioned by the PMs of the ECs. Apparently this is considered a relevant issue. Part of the explanation of this apparent paradox may be that reputation is a complex construct with a long-term dimension. Most PMs acknowledge the importance of EC reputation, but in reality the short-term (individual incentives and) interests on a project prevail.

Trust was explicitly mentioned by virtually all PMs as critical to a successful EPCm contract. The joint development of a performance related incentive arrangement and the subsequent discussions to agree the level of performance, can act as a mechanism to build trust. Most comments pertained to *openness* (transparency and integrity) attributes starting at the PM (i.e. individual) level and subsequently cascading down through the project organisation. One PM expressed this as the 'emotional bonding' between the responsible PMs of the owner and EC. In a study on partnering, Chen and Chen (2007) also concluded that the composition of the project team is a key success factor, confirming the earlier observation in paragraph 4.5. Also, trust has to be developed ('earned') through open communication and performance. The interviews confirm the survey results with the top three ranked attributes from Table 5.4 (i.e. *openness*, *competence* and *communication*) and the top score of the PCFA in Table 5.5 (i.e. integrity) featuring dominantly in the interviews.

5.5 Conclusions

Contracting inherently involves relational risk, particularly in the case of a CPF/EPCm (services) agreement. This research indicates that:

(a) Relational risk is created by the value of the EC (as perceived by the owner), resulting in an asymmetric dependence of the owner upon the EC;

(b) Performance monitoring (rather than contract terms) is the main governance mechanism to reduce the room for opportunism;

(c) The intent of opportunistic behaviour is primarily influenced by trust attributes; the most important ones being integrity and open communication.

Owners have a propensity to use detailed contractual terms and conditions to control the inherent uncertainty on projects. On LECPs the effectiveness of this safeguard is limited due to ex post changes in the project environment. Our survey results, augmented by a case study analysis, indicate that this view is widely held by experienced practitioners in the oil, gas and petrochemical industry. Furthermore, this research suggests that a good (EC) track record increases the relational risk through owner dependency, rather than mitigating it through reputation mechanisms. Actions that owners can take to mitigate relational risk are:

(d) Knowledge management to reduce information asymmetry, particularly regarding capital cost estimating and market prices. This enables informed owners to establish effective cost targets for cooperative (incentive) contracts.

(e) Enhancement of owner competencies with respect to performance monitoring and contract management in order to limit the room for opportunistic behaviour.

(f) Development of internalised trust building mechanisms focused on the early stages of the owner – EC relationship (getting off on the wrong footing will reverberate throughout the project life-cycle due to anchoring heuristics).

The mechanisms above are of a complementary nature and therefore a combination of the actions and mechanisms indicated above will be most effective in mitigating relational risk and optimizing project performance.

Notes

1 Das and Teng (2001) indicates a typical response rate for Vice-Presidents in US companies of 10-12%. The respondents in this survey work close to this level. Wong and Cheung (2004) report a (valid) response rate of 43% (sample size: 120) for a survey similar to this one amongst different organisational levels in the civil construction industry in Hong Kong. Chen and Chen (2007) report a response rate of 67% in a survey on construction partnering in Taiwan.

5.6 References

Allais M., 1979. *The foundations of a positive theory of choice involving risk and a criticism of the postulates and axioms of the American school*, in *Expected utility hypotheses and the Allais paradox*, Allais M., Hagan O. (ed.), p441, Dordrecht, D.Reidel Publishing.

Brousseau E., Glachant J.M., 2002. *The economics of contracts and the renewal of economics*, in Brousseau E., Glachant J.M. (editors), *The economics of contracts – Theories and applications*, Cambridge University Press, Cmbridge, UK, p12.

Chen W.T., Chen T-T, 2007. *Critical success factors for construction partnering in Taiwan*, International Journal of Project Management, (2007), 25, pp475-484.

Cheung S-O., Ng T.S.T., Wong S-P, Suen H.C.H., 2003. *Behavioral aspects in construction partnering*, International Journal of Project Management, 21, pp333-343.

Cox A., Thompson I., 1997. *'Fit for purpose' contractual relations: determining a theoretical framework for construction projects*, European Journal of Purchasing & Supply Management, Vol.3, No. 3, pp127-135.

Das T.K., Teng B.S., 2001. *Trust, control and risk in strategic alliances: An integrated framework*, Organisational Studies, 22 (2) , pp 251-283.

Fukuyama F., 1996. *Trust – The social virtues and the creation of prosperity*, Free Press, New York.

Kadefors A., 2004. *Trust in project relationships – Inside the black box*, International Journal of Project Management, 22, pp175-182.

Kahneman D., Tversky A., 1982. *The simulation heuristic*, in *Judgement under uncertainty: Heuristics and biases*, pp. 201-208, New York, Cambridge University Press.

Kamann D.J., Snijders C., Tazelaar F., Welling D.Th., 2006. *The ties that bind: Buyer-supplier relations in the construction industry*, Journal of Purchasing and Supply Management, Vol.12, Issue1, pp28-38.

Munns A.K., 1995. *Potential influence of trust on the successful completion of a project*, International Journal of Project Management, Vol.13, No.1, pp19-24.

Nooteboom B., 2004. *Inter-firm collaboration, learning and networks; An integrated approach*, Routledge, London.

Ricketts M., 2001. *Trust and economics organisation,* Economic Affairs, Vol. 21 (1), pp19-22.

Segers J., 2002. *Methoden voor maatschappijwetenschappen*, 'Methods for social sciences', Koninklijke van Gorcum, Assen The Netherlands.

Simon H.A., 1982. *Models of bounded rationality*, Economic Analysis and Public Policy, Vol.1, Cambridge: MIT Press.

SPSS, Statistical Package for the Social Sciences, 1999. *SPSS base 9.0: Applications guide,* Chicago.

Staw B.M., Ross J.,1989. *Understanding behaviour in escalating situations*, Science, 246, pp216-220.

Turner J.R., Muller R., 2004. *Communication and co-operation on projects between the project owner as principal and the project manager as agent*, European Management Journal, Vol. 22, No.3, pp327-336.

Tversky A., Kahneman D., 1973. *Availability: A heuristic for judging frequency and probability*, Cognitive Psychology, 5, pp207-232.

Tversky A., Kahneman D., 1974. *Judgement under uncertainty: Heuristics and biases*, Science, 185, pp1124-1131.

University of Salford and the Centre for Construction Innovation, 2002. *Trust in construction: Achieving cultural change*, http://www.scpm.salford.ac.uk/trust/.

Williamson O.E., 1985. *The economic institutions of capitalism; Firms, markets, relational contracting*, Free Press, New York.

Williamson O.E., 1993. *Calculativeness, trust and economic organisation*, Journal of Law and Economics, 36, pp453-486.

Wong P.S.P, Cheung S.O., 2004. *Trust in construction partnering: views from parties of the partnering dance*, International Journal of Project Management, 22, pp437-446.

Woolthuis R.K., 2002. *Trust and formal control in inter-organisational relationships*, Report series: research in management, Rotterdam: ERIM.

Zaghloul R., Hartman F., 2003. *Construction contracts: The cost of mistrust*, International Journal of Project Management, 21 , pp419-424.

6

Earned value and cost phasing

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In this chapter the Earned Value (EV) concept is used to look at (owner) expenditure phasing under different types of contract. The results of an empirical analysis of payment and EV schedules are presented. Parameterisation of the normalised schedules on the basis of a fourth order polynomial function (in view of the characteristic S-curve) using regression analysis, correlates very well with data found in literature. The analysis indicates that for LECPs in the oil, gas and petrochemical industry: (i) EV provides a description of the actual expenditure phasing and cash flow requirements; (ii) projects typically follow the same generic EV curve; and (iii) there is an established practice of advance payments on LSFP/EPC contracts, following a generic schedule. The cost of advance payments under LSFP/EPC contract vis-à-vis the payments under a CPF/EPCm contract arrangement amount to some 6% on the basis of a Net Present Value calculation. Advance payment schedules may reduce the capital cost to the owner under an LSFP/EPC contract, provided the payment schedule forms an intrinsic part of the bidding process, rather than an afterthought. Downsides are the (potentially) negative effect on EC motivation and the owner exposure in the case of EC bankruptcy.

6.1 Introduction

As discussed above, projects in the oil, gas and petrochemical industry are inherently risky business ventures due to their size, complexity and geographical location. However the most important parameter in this respect is time. Circumstances change with time and so do the risks associated with a project. This is particularly relevant for LECPs which invariably have long development and implementation times. *"Most prone to escalation are the so-called 'long-haul' projects that require huge investment and yield no revenue until the work is finished. Long-haul projects are potentially fraught because: time = risk. Time changes the nature of risk."* (Drummond, 2001).

In this chapter the Earned Value concept is used to look at pricing and expenditure phasing under different types of contract. Particular attention is paid to 'time-related' risks and the results of an empirical analysis of payment and progress schedules are presented. The case study results are validated through a comparison with data from the literature.

6.2 Cost and schedule control

6.2.1 The Earned Value concept

To identify trends early, adequate cost and schedule control mechanisms are an essential part of project management (irrespective of the contracting strategy and the type of contract pricing). To facilitate this, the scope of work is typically broken down into controllable elements in what is known as the Work Breakdown Structure (WBS). Subsequently, money can be used as a common denominator to construct an integrated controls framework, through the Earned Value concept, to track both cost and schedule performance (Vandevoorde and Vanhoucke, 2006). This practice is now generally accepted by project managers (Kim, Wells and Duffey, 2003). Various definitions of Earned Value are in use. Here, Earned Value (EV) is defined as:

The value of goods and services actually received, established by measuring the physical progress per control element, expressed in monetary terms.

The value of materials and equipment consists of the purchase order value, supplementary cost (e.g. freight, insurance, duties, etc.) and storage/handling cost on site. For construction work the physical progress is measured rather than man-hours expended.

The valuation of control elements is usually based on the budget appropriation of the performed work (Cioffi, 2006). In addition to EV, the following measures are used to control cost:

(a) The value of goods and services that have been committed but not yet received;

(b) The (estimated) value of uncommitted work; and

(c) Expenditure.

The project cost estimate (i.e. budget appropriation) against the WBS, scheduled in time, provides an estimated cost phasing. Comparing actual cost with the estimated cost phasing during project execution provides a measure of the project's cost status. This picture, however, is incomplete without an assessment of how much work has been completed in connection with the actual cost. The EV provides the basis for this assessment. EV as defined above is not dependent on expenditure phasing (e.g. invoice timing and payments). A cost control framework based only on the time of invoice payments would provide information too late to take corrective action. Early recording of cost through commitments overcomes this problem (Turner, 1993).

Projects are typically characterised by a relatively slow start, followed by a period of steady progress, gradually levelling off to completion. Initially the number of activities is relatively small, but during the period in the middle a large number of interrelated activities are carried out which determine the shape of the EV and the actual cost and expenditure. The graphical representations of the EV and actual cost/payments as a function of time are commonly referred to as the 'S-curves'. They are usually compiled and reported on a monthly basis.

6.2.2 Expenditure phasing

As indicated in Chapter 3, with an LSFP/EPC contract the price consists of the (estimated) cost and a mark-up. The payment schedules for this price is usually based on (i) milestones; and/or (ii) progress. *Milestone payments* are here defined as those pertaining to (i) time (e.g. monthly payments); and (ii) the achievement of certain events (e.g. main equipment delivered on site). With *progress payments*, the schedule is linked to actual (physical) progress of the work, as for instance measured by the EV. An advantage of a payment schedule based on milestones is that it is relatively easy to administer. A disadvantage is that it is established ex ante; i.e. schedule risk considerations are incorporated in the payment schedule. On the other hand, establishing (actual) progress accurately requires considerable effort and is often difficult, particularly on LSFP/EPC contracts where the information available to the owner is limited. This is potentially a source of conflict between owner and EC. In many cases LSFP/EPC contracts contain provisions to re-negotiate the agreed payment schedule in case actual progress is outside a deviation bandwidth around the scheduled progress. The owner has certain rights to withhold payments, or part thereof, if the project is behind schedule and rights for the EC if the project is ahead of schedule.

With a CPF/EPCm contract, the owner is the contract party[1] on (i) the contract for EPCm services; (ii) all purchase orders for materials & equipment; and (iii) all construction contracts. Consequently, the owner pays the actual cost of the project (plus a fee to the EC) and the owner expenditure phasing is the same as the actual expenditure phasing of the project.

6.3 Basis for empirical analysis and dataset dimensions

The objective of the research described in this chapter is to investigate expenditure phasing under a LSFP/EPC contracting strategy vis-à-vis expenditure phasing under a CPF/EPCm strategy. The empirical analysis is based on a dataset which comprises projects for oil, gas and petrochemicals manufacturing facilities covering a wide geographical area. Some of the key dimensions of the projects are indicated in Table 6.1.

Table 6.1
Dataset dimensions

Capital Cost Mean	Approx. 1,000 [USD million]
Location	Western Europe : 30% ; Africa : 20% ; Middle East : 20% ; Asia : 30%

Of the 17 projects in the dataset, 10 pertained to a LSFP/EPC approach and 7 to a CPF/EPCm approach. From these projects 10 monthly cumulative LSFP/EPC payment schedules and 10 monthly cumulative EV schedules were obtained; adding up to some 800 data points. The subsequent analysis comprised:

(a) Normalisation of the 10 EV schedules and the 10 LSFP/EPC payment schedules using a scale 0.00-1.00 for the independent variable elapsed implementation time and for the dependent variables cumulative payments and cumulative EV;

(b) Calculation of a mean cumulative EV schedule and a mean cumulative EPC/LSFP payment schedule and parameterisation of these schedules on the basis of a fourth order polynomial function (in view of the characteristic S-curve) using regression analysis;

(c) Validation of the results through a comparison with data from literature.

6.4 Results and discussion

6.4.1 Parameterisation of the S-curve

The 10 normalised cumulative LSFP/EPC payment schedules and the 10 normalised cumulative EV schedules are shown in Figure 6.1. The EV schedules are based on LSFP/EPC contracts as well as CPF/EPCm contracts.

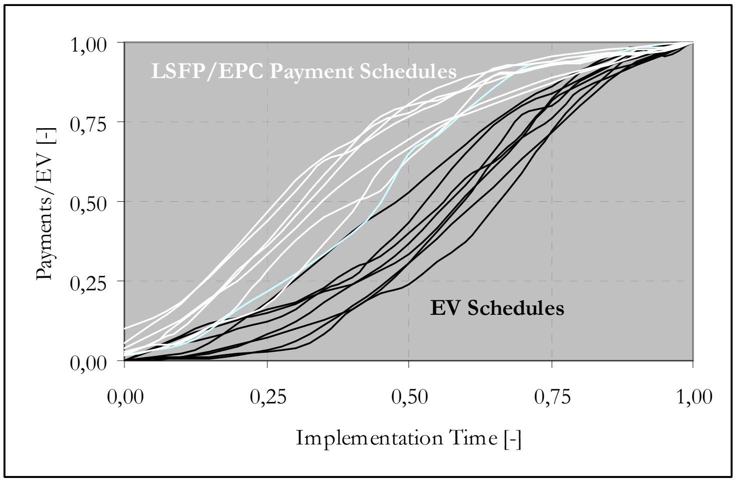


Figure 6.1
Normalised cumulative LSFP/EPC payments schedules and normalised cumulative EV schedules

Subsequently, the following normalised functions of the mean cumulative EV schedule and the mean cumulative LSFP/EPC payments schedule were calculated through regression analysis:

EV: $y(x) = -3.32x^4 + 4.60x^3 - 0.61x^2 + 0.32x$ (6.1)

LSFP/EPC payments schedule: $y(x) = 3.64x^4 - 8.45x^3 + 5.49x^2 + 0.28x + 0.04$ (6.2)

where: x : normalised, elapsed implementation time

The correlation between the approximation functions (6.1) and (6.2) and the respective mean values of the mean cumulative EV schedule and the mean cumulative LSFP/EPC payments schedule is very good with the correlation coefficient[2] $\rho > 0.999$ in both cases. For $0.0 < x < 0.1$ and $0.9 < x < 1.0$ the values are very project specific and consequently the accuracy of the approximation functions (6.1) and (6.2) is strongly reduced in these areas.

An alternative parameterisation of EV is presented by Cioffi (2005):

$$\text{EV:} \quad y(x) = y_\infty \frac{1-\exp(-8xr_{0.67})}{1+\gamma\exp(-8xr_{0.67})} \qquad (6.3)$$

where: y_∞ : normalisation factor

γ : normalisation parameter

$r_{0.67}$: slope factor

A comparison of the S-curves calculated through equation (6.1) and equation (6.3) is given in Figure 6.2 and shows a good correlation with $\rho = 0.999$. The maximum delta (at $x = 0.5$) amounts to 11% of the value calculated through equation (6.1): $y(0.5)=0.38$. A more extensive description of the use of equation (6.3) is given in Appendix 6A. Whereas equation (6.3) provides a lot of flexibility with respect to fitting the curve to a variety of situations, the comparison indicates that for modelling the EV the fourth order polynomial equation (6.1) provides a good approximation of the actual EV.

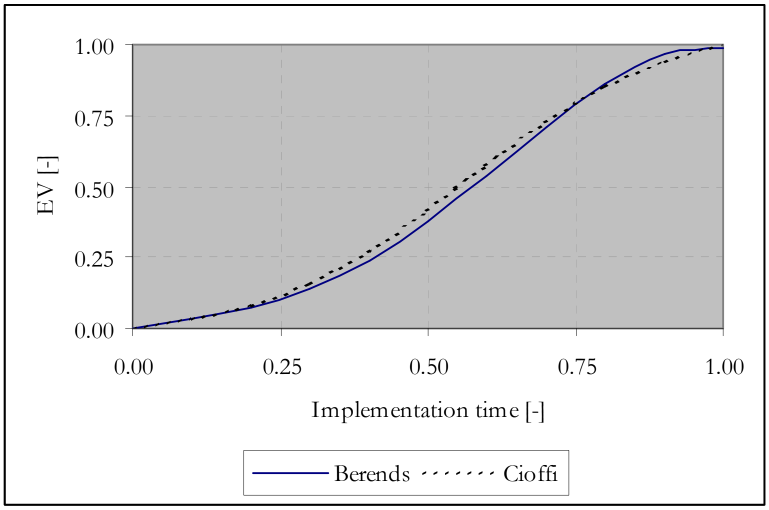


Figure 6.2
Comparison of S-curve parameterisation

6.4.2 Payments schedules

The payments schedule on an LSFP/EPC contract does not represent the actual expenditure profile of the project; rather it is part and parcel of the overall commercial agreement. Under an LSFP/EPC contractual arrangement the owner is uninformed with respect to the actual cash flow requirements of the project. With a CPF/EPCm arrangement on the other hand the owner is by definition fully informed (subject to the owner having the competencies to interpret the available information). The mean cumulative LSFP/EPC payments schedule of equation (6.2) was compared with literature data on expenditure phasing under LSFP contracts for major oil and petrochemical projects (Camps, 1996). Camps reports his findings in the form of a series of discrete values during the implementation time. Figure 6.3 shows the data points of Camps together with function (6.2) of this research.

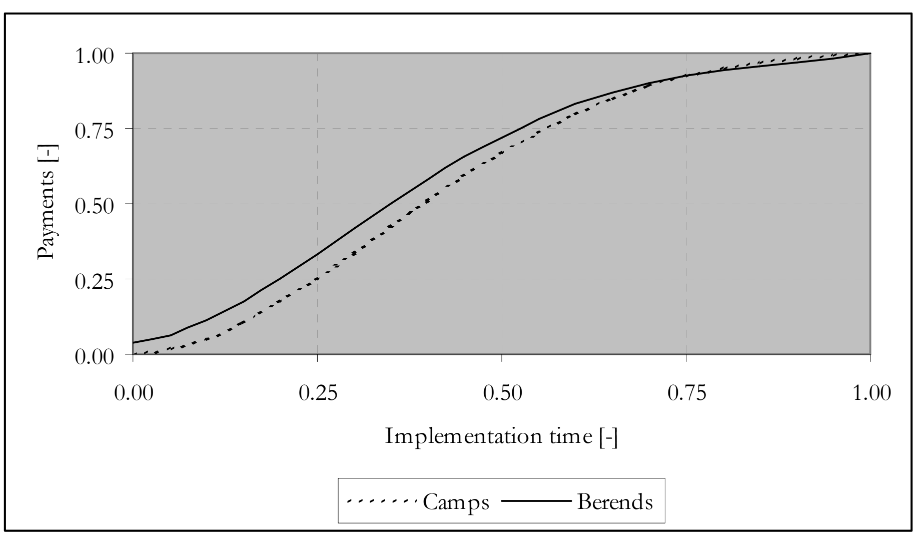


Figure 6.3
Cumulative payments phasing under LSFP/EPC contracts.

There is a very good correlation between the mean cumulative LSFP/EPC payments schedule of equation (6.2) (i.e. 'Berends' in Figure 6.3) and the data of Camps, with the correlation coefficient being ρ = 0.997. At an elapsed implementation time t = 0.5 the mean cumulative payments under LSFP contracts calculated from equation (6.1) is 0.72 compared to 0.67 given by Camps. This indicates that equation (6.2) is not specific to our case study but that it represents the payment schedules typically used in the oil, gas and petrochemical industry.

More remarkable is the very good correlation, illustrated in Figure 6.4, between the mean cumulative EV schedule of equation (6.1) (i.e. 'Berends-EV') on the one hand and the actual expenditure phasing under a CPF/EPCm contract of

(a) Camps (i.e. 'Camps-CPF'); and

(b) this research (i.e. 'Berends-CPF')

with correlation coefficients being ρ = 0.999 and ρ = 0.996 respectively. At an elapsed implementation time t = 0.5 the mean actual expenditure under CPF/EPCm contracts calculated from the case study data is 0.43 compared with 0.38 for the EV according to equation (6.1) and 0.35 for the mean actual expenditure given by Camps.

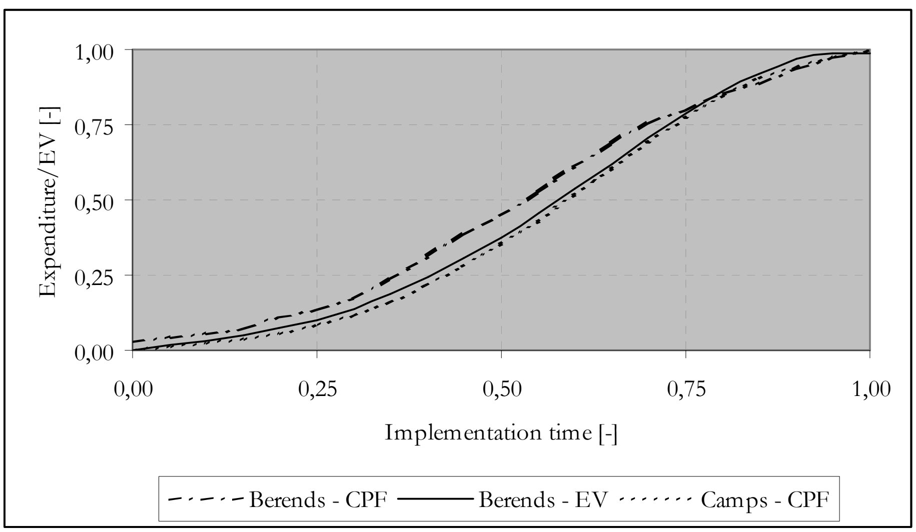


Figure 6.4
Cumulative expenditure phasing under CPF/EPCm contracts; and cumulative EV phasing.

This suggests that EV as defined above and represented by equation (6.1) provides a description of the actual cash flow requirements on LECPs. The actual cash flow requirements of some goods and services takes (partly) place before they are actually received (e.g. 'down payments' for large equipment items) whereas of others it takes place after they are received (e.g. construction work).

6.4.3 The cost of advance payments

The analysis in section 6.4.2 indicates that there is an established practice of advance payments on LSFP/EPC contracts for LECPs. The cost of an advanced payment schedule under a LSFP/EPC contract vis-à-vis the payment schedule under a CPF/EPCm arrangement (i.e. the actual cash flow requirements) depends on:

(a) the level of advanced payment;

(b) the (interest) discount rate used to establish the time value of money; and

(c) the project implementation time.

Using the mean EV and payment schedules of equations (6.1) and (6.2) and assuming an (interest) discount rate of 10% per annum and an implementation time of 3.5 years, the additional cost of advance payment on LSFP/EPC contract, on the basis of a Net Present Value (NPV) calculation, equals some 6% of the total capital cost[3]. In this context the (interest) discount rate is the owner's expected return on investment, adjusted for risk.

A certain level of advance payment on LSFP/EPC contracts may be beneficial. The owner's cost of capital is generally lower than that of the EC and an advance payment schedule may enable an EC to offer a lower contract price. Conversely, bid evaluation may reveal that the EC with a lower LSFP/EPC bid but an advance payment schedule may not be the most economical (Awwal, 1999). To capture these potential benefits, the payment schedule has to be part of the bidding and evaluation process and the owner has to indicate this clearly in the invitation to bid. EV and payment schedules are also important schedule considerations for ECs. Their objective will be to schedule the activities in a way that maximises the NPV of cash inflows subject to constraints with respect to contractual payment provisions and a fixed deadline (Vanhoucke, 2003).

It should also be recognised that high levels of advance payment have a number of drawbacks. At 50% of the implementation time, the mean cumulative EV value is approximately 38% according to equation (6.1) whereas the mean cumulative payments according to equation (6.2) are approximately 72%. This may have a negative impact on the EC's motivation. Also, advance payment constitutes for the owner an increased risk with respect to EC insolvency during the execution of the work. If a (major) capital investment project is carried out by a joint venture of ECs this can (partly) be mitigated by 'parent company guarantees' and 'joint and several liability' provisions in the contract. Finally, the Generally Accepted Accounting Principles (GAAP) and other accounting standards include the principle of accruals/matching; i.e. costs have to be matched with the associated benefits; e.g. (FASB, 1985), (Mills and Robertson, 1995). If a certain capital investment project constitutes a major part of the overall capital expenditure of an owner, the impact of (advanced) payment schedules with respect to GAAP has to be taken into account. An advanced payment schedule may also have an adverse effect on the conditions of any loan agreement.

6.5 Conclusions

LECPs with a long development and implementation time are risky business ventures. Whilst there are many different factors that have to be taken into account when determining the optimal contracting strategy for a specific project, a key consideration is the allocation of risk between owner and (main) EC. Many of these risks are time-related.

The main difference between contracting on the basis of a single LSFP/EPC contract and a CPF/EPCm arrangement lies in the time at which the project risk is priced. Owners with the required project management capability as well as the ability and willingness to accept financial risks can realise projects through a CPF/EPCm contract at lower Total Installed Cost (TIC) than through the traditionally preferred LSFP/EPC contract. Indeed, increasingly owners are forced to accept more risk (both in LSFP/EPC as well as in CPF/EPCm contracts); drivers include: the size, complexity and geographical location of new manufacturing plants, (lack of) financial strength of ECs and the change from a buyers into a sellers market. This requires more involvement of the owner with respect to project management.

On LECPs, the effect of cost phasing can have a significant effect on the capital cost; in this analysis 6% based on an NPV calculation. This research suggests that:

(a) EV provides a measure of actual project cash flow requirements;

(b) Projects typically follow the same generic EV curve; and

(c) Advance payments are common practice on LSFP/EPC contracts in the oil, gas and petrochemical industry and they follow a generic payments schedule.

Advanced payments may reduce the capital cost to the owner under an LSFP/EPC contract, provided the (advanced) payments schedule is timely incorporated in the tendering process. Other aspects that have to be taken into account are: EC motivation, the risk of the EC going bankrupt and GAAP. Both owners and ECs will benefit from making contract cost phasing an integral part of the bidding and contracting process, rather than an afterthought.

Notes

1 The EC may also be the 'formal' contract party with the owner having an obligation to reimburse the EC for all contract cost. In this arrangement the owner is also fully informed.

2 The correlation coefficient $\rho = \frac{Cov(x,y)}{\sigma_x \sigma_y} = \frac{\sum_{i=1}^{n}(x_i - \mu_x)(y_i - \mu_y)}{\sqrt{\sum_{i=1}^{n}(x_i - \mu_x)^2 (y_i - \mu_y)^2}}$

where:

x, y	:	variables
Cov	:	Covariance
σ	:	Standard deviation
μ	:	mean value

3 The calculated cost varies slightly with the payments phasing at the start and the end of the implementation time. These are very project specific and the standard deviation between the case study data is large in these areas.

6.6 References

Awwal A.S., Kansal S., *Examining EPC contracts*, Hydrocarbon Processing, May 1999, pp 69-75

Camps J.A. (1996), *Simple steps help minimise costs, risks in project contracts,* Oil & Gas Journal, 22 January 1996

Cioffi D.F., *Designing project management: A scientific notation and an improved formalism for earned value calculations*, International Journal of Project Management, 24 (2006), pp136-144

Cioffi D.F., *A tool for managing projects: an analytic parameterisation of the S-curve*, International Journal of Project Management, 23 (2005), pp215-222.

Drummond H. (2001), *The art of decision making – Mirrors of imagination, masks of fate*, John Wiley & Sons Ltd.

FASB, Financial Accounting Standards Board, 1985. *Original Pronouncements (as amended through FAS 159)*, CON6 Elements of Financial Statements – FASB Concept Statement, para. 144-152

Kim E., Wells W.G., Duffey M.R., *A model for effective implementation of earned value management methodology*, International Journal of Project Management, 51 (2003), pp375-382

Mills R.W., Robertson J., 1995. *Fundamentals of managerial accounting and finance*, Mars Business Associates Ltd., Lechlade, UK, third edition, p13-14.

Turner J.R., 1999. *The handbook of project based management – Improving the processes for achieving strategic objectives*, McGraw-Hill Book Company, Maidenhead, England, Second Edition.

Vandevoorde S., Vanhoucke M., *A comparison of different project duration forecasting methods using earned value metrics,* International Journal of Project Management, 24 (2006), pp289-302.

Vanhoucke M., Demeulemeester E., Herroelen W., *Progress payments in project scheduling problems*, European Journal of Operational Resaerch, 148 (2003), pp604-620.

Appendix 6A

The EV equation of Cioffi is:

$$y(x) = y_{\infty} \frac{1-\exp(-8r_{0.67})}{1+\gamma\exp(-8r_{0.67})} \qquad (6.3)$$

The parameter *r* describes the magnitude of the rise in the middle third of the S-curve, and defines $r_{0.67}$ through:

$$r = \frac{2}{3} r_{0.67} \,. \qquad (6A.1)$$

When $r_{0.67} = 1$ two thirds of the rise occurs in the middle third of the S-curve; $r_{0.67} < 1$ makes the slope less steep. Using equation (6.1) to calculate the rise in our case study gives:

$$r_{0.67} = \frac{3}{2} \left(y(0.67) - y(0.33) \right) = 0.72$$

The factor γ is calculated through:

$$\gamma = \exp(8\, r_{0.67} x^{0.5}) - 2 \qquad (6A.2)$$

where $x^{0.5}$ is the value of *x* where *y* = 0.50. In our case study $x^{0.5} = 0.58$ which gives γ = 25.95.

Because by definition $y(1.00) = 1.00$ we can now calculate the normalisation factor y_{∞} though equation (6.3) which for our case study gives $y_{\infty} = 1.09$

7

Contract types and performance

In this chapter an empirical analysis of project performance under CPIF/EPCm, LSFP/EPC and CPPF/EPCm contracts is conducted. The stochastic cost estimate underlying the database is shown to be 'credible'; i.e. displaying objectivity and precision. CPIF/EPCm contracts deliver the best cost level performance and LSFP/EPC contracts the best cost predictability. The latter provides the best relative schedule performance for project implementation if the time required for tendering is excluded. Taking the latter into account CPIF/EPCm contracts provide the best schedule performance. Projects with a CPPF/EPCm contract display the worst cost performance and the worst schedule performance. On the CPIF/EPCm contracts a high relative incentive fee is generally associated with low relative cost, but the correlation is weak. The analysis of incentive fee criteria related to performance of quality, HSE and EPCm job-hours, casts doubt on their effectiveness. Suggestions are made for alternative governance mechanisms. A stochastic simulation model is developed and validated. An analysis of the effectiveness of the parameters that determine the incentive construct on CPIF/EPCm contracts, based on the model, indicate that in many cases the initial target cost is set too low. It is suggested that fee limitations are in many cases unduly restrictive.

7.1 Introduction

In the preceding chapters the theory on contracting processes and types commonly used on LECPs in the oil, gas and petrochemical industry is described. This chapter looks at the performance of LSFP/EPC, CPIF/EPCm and CPPF/EPCm through an empirical analysis of projects of the case study owner. As discussed previously, cost uncertainty during the project life-cycle plays a central role in contracting on LECPs. Therefore the stochastic cost estimate at the time of FID vis-à-vis the actual cost at the end of the project is considered first. This forms the basis for the definition of a number of ratio used in the empirical analysis of contract performance levels and predictability. Stochastic modeling has been used by researchers for a considerable time to study systems and processes and increasingly by project practitioners as well (e.g. Wood, 2001). A variety of different modeling techniques are available (Daltelli, Chan and Scott, 2000). Here a 'Monte Carlo' type analysis has been used, based on the earlier mentioned stochastic cost estimate, to investigate the effectiveness of the parameters that determine the incentive construct on CPIF contracts through stochastic simulation.

7.2 Basis for empirical analysis

7.2.1 Dataset dimensions

The dataset comprises LECPs in North America, Europe, Africa and Asia Pacific, spanning a period of 25 years. The main dimensions of the dataset used in this chapter are indicated in Table 7.1. The contractual arrangements with the ECs were based on LSFP, CPIF and CPPF remuneration. The use of CPIF on LECPs is relatively new and the case study owner has initially used them on relatively small projects. Only during the last 15 years have CPIF contracts been used on larger projects which is reflected in the mean project value of 910, 500 and 660 [Euro million] on LSFP, CPIF and CPPF projects respectively. As discussed in section 2.4.2, a disadvantage of CPPF contracts is that there is no (monetary) incentive for the EC with respect to cost (and other project dimensions). Therefore the case study owner organisation has been reluctant to use CPPF contract and the number of CPPF contracts in the dataset is relatively small.

Table 7.1
Dataset Dimensions

Total number of projects	32
Contract types	
LSFP	12
CPIF	13
CPPF	7
Mean value project cost [2005; EUR mln]	700
Median value project cost [2005; EUR mln]	350

7.2.2 Stochastic cost estimates

As discussed in Chapter 2, project cost estimates are important selection criteria for owner organisations to decide whether or not to proceed at the end of project development phases and particularly with respect to FID. Furthermore, stochastic cost estimates also play an important part in the LSFP bidding process and on CPIF contracts in setting the target cost, as indicated in Chapters 3 and 4.

A '*credible stochastic cost estimate*' displays on average, over a number of projects: (i) *objectivity*; i.e. estimates being neither too low nor too high; and (ii) *precision*; i.e. actual cost being within a specified confidence interval around the estimate (Schuyler, 2001). Objectivity means that over the project portfolio, the actual cost are close to the estimate and (statistically) on each project there is a 50/50 probability of 'under/overrunning' the estimate[1]. The precision of a certain cost estimate reflects the uncertainty at a particular moment of project development (e.g. associated with the level of technical scope definition). Typically, after preparing a base estimate, a cost risk analysis is used to establish contingency levels for the various WBS elements and to compile a stochastic cost estimate. The case study owner uses a statistical methodology designed to compile stochastic cost estimates at the end of project development with an 80% confidence interval of +/- 10% around the (single-point) estimate value. In other words, on 80% of the projects, the actual cost is within +/- 10% of the cost estimate. On an individual project there is an 80% probability of actual cost being within +/- 10% of the cost estimate, a 10% probability of overrunning the cost estimate by more than 10% and a 10% probability of underrunning the estimate by more than 10%.

To analyse the objectivity and precision of the cost estimates of the case study owner organisation, on the projects in the database of Table 7.1 the following relative owner contract cost has been analysed

$$c_c = \frac{C_c}{E} \qquad (7.1)$$

where: c_c relative owner contract cost
C_c owner contract cost (see also section 2.4.2)
E associated +/- 10% cost estimate (at FID)

The relative owner contract cost on the projects in the dataset has a mean value μ = 1.01 and a standard deviation σ = 0.11. Figure 7.1 shows the cumulative frequency distribution of c_c and the associated model *Normal*(μ,σ) approximation function. A 'goodness-of-fit test' based on a chi-square distribution and a 'Bowman-Shelton test' for normality, indicate that the model provides a good approximation of the actual distribution. Details of these tests are provided in Appendix 7A. The analysis confirms that stochastic cost estimates of the case study owner display *objectivity*, with the mean value being close to one. The second characteristic of a credible stochastic estimate, *precision*, is not achieved, with only 60% of the observed actual cost data falling in the +/- 10% range around the cost estimate (mean value) compared with the aim of 80%.

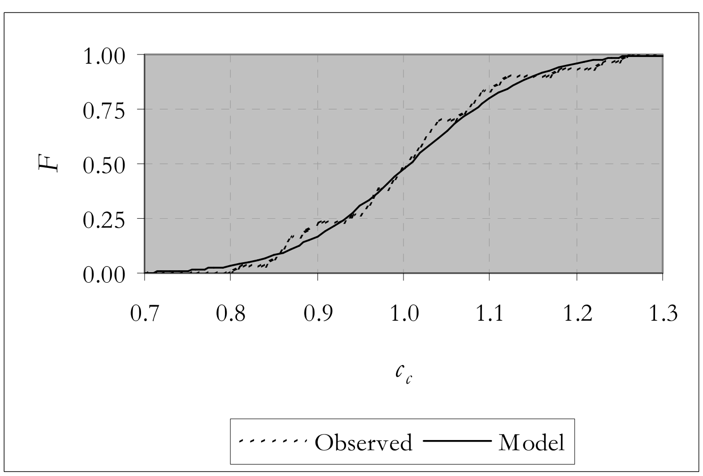


Figure 7.1
Cumulative frequency distribution C_c
Normal(1.01,0.11)

In the range $0.20 < F(c_c) < 0.80$, a linear function provides a good approximation ($R^2 = 0.999$) of the cumulative *Normal(1.01,0.11)* frequency distribution:

$F(c_c) = 3.28c_c - 2.81$ (7.2)

Note: This provides the basis of the function (3.2) describing the probability of winning and the subsequent model of competitive lump sum bidding in section 3.4.1; i.e. in equation (3.2) $B = 3.28$.

7.3 Contract cost and schedule

7.3.1 Cost levels and predictability

In analysing the (owner) contract cost performance on the LECPs in the dataset of Table 7.1, the two main aspects are: (i) the level of cost; and (ii) the predictability of the final cost vis-à-vis the cost envisaged at the time of FID. They are discussed in this order.

When comparing project cost the payment phasing has to be taken into account. *In the analysis, 6% has been added to the mean value of the LSFP distribution to reflect the difference in payment curves discussed in Chapter 6*. The 'goodness-of-fit test' described in section 7.2.2, indicates that the LSFP, CPIF and CPPF contracts in the database can be described by a *Normal*(μ,σ) distribution. The 'Bowman-Shelton test' tests also indicaes 'normality' but the number of data points is too small to be statistically significant. The results of the analysis are shown in Figures 7.2a and 7.2b.

The results indicate that the *relative contract cost level* on projects executed under CPIF arrangements are on average some 8% lower than under LSFP contracts (of which 6% is attributable to the difference in payment schedules). Arrangements based on a CPPF contract are on average some 16% more expensive than CPIF. The standard deviations are very close. The distributions display a second order stochastic dominance as illustrated in Figure 7.2b; i.e. it would be incorrect to conclude that a particular contract type always leads to better cost performance. Rather, at a relative owner contract cost level of $c_c = 1.0$ the *probability* of realising the project below this level is 71%, 35% and 10% for CPIF, LSFP and CPPF contracts respectively.

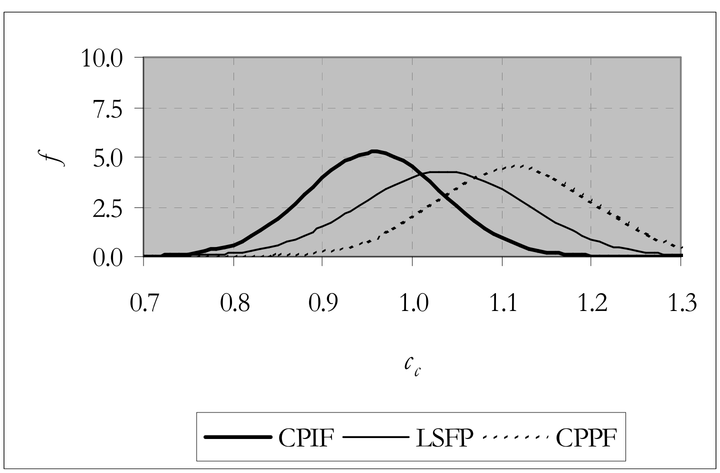


Figure 7.2a
Frequency distributions relative owner contract cost c_c

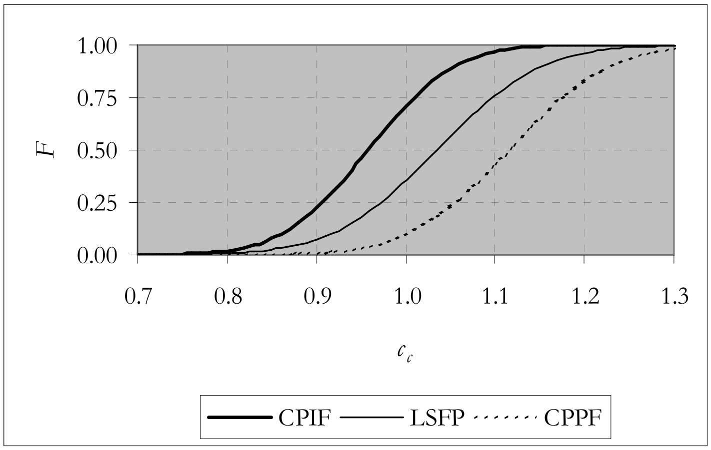


Figure 7.2b
Cumulative frequency distributions relative owner contract cost c_c

CPIF: *Normal(0.96,0.08)*
LSFP: *Normal(1.04,0.09)*
CPPF: *Normal(1.12,0.09)*

The characteristics of LECPs (see section 2.2.1) inherently create large risks due to ex post changes in the project environment and invariably irreversible decisions have to be taken on the basis of incomplete information. Consequently, owners seek to reduce the variability of business drivers where possible, taking into account economic risk pricing. For projects executed on the basis of CPIF and CPPF contracts, FID is based on a *stochastic cost estimate*. With a LSFP contract on the other hand, a *firm bid price* is generally obtained prior to FID (although it should be noted that in the current market environment many LSFP contracts contain escalation provisions related to the price of steel, labour costs, etc.). To investigate *cost predictability*, the final cost vis-à-vis the cost envisaged at the time of FID has been analysed. On CPIF and CPPF contracts where the initially envisaged cost is the cost estimate, this ratio is the relative owner contract cost c_c (see equation (7.1)) and the 'goodness-of-fit' has been discussed in section 7.2.2. On LSFP contracts the *cost predictability* ratio is given by:

$$c_c^{'} = \frac{c_c}{c_{ci}} \qquad (7.2)$$

where: $c_c^{'}$ relative growth owner contract cost

c_{ci} initial relative owner contract cost
(i.e. initial LSFP relative contract sum excluding subsequent scope changes)

The 'goodness-of-fit test' indicates that the $c_c^{'}$ ratio on LSFP contracts in the database can be described by a *Normal(μ,σ)* distribution. The 'Bowman-Shelton test' tests also indicate 'normality' but again the number of data points is too small to be statistically significant. The results of a comparative analysis of CPIF, LSFP and CPPF contracts are depicted in Figure 7.3. Whereas the 'relative cost performance' on CPIF contracts is better than LSFP contracts, the cost predictability (based on the cost envisaged at the time of FID) is better on LSFP contracts. In the case of cost *level* performance the standard deviation of the *Normal(μ,σ)* approximation functions were essentially the same (see Figure 7.2). In the case of cost predictability performance, the standard deviation of the *Normal(μ,σ)* approximation function for LSFP contracts is much lower than for CPIF and CPPF contracts (see Figure 7.3).

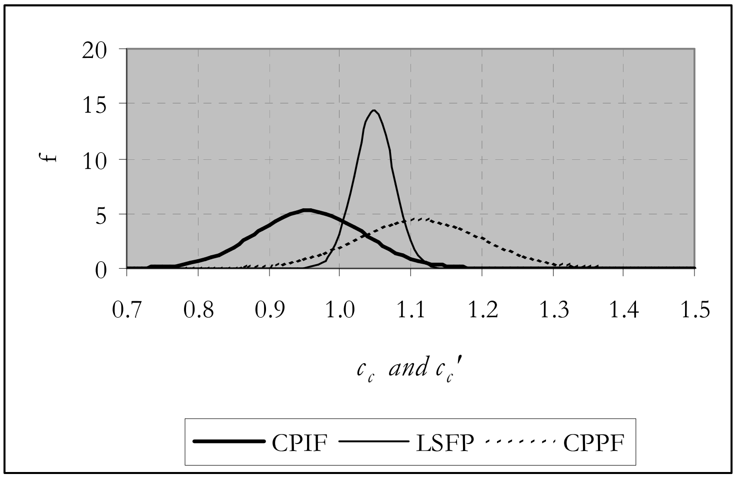


Figure 7.3

Frequency distributions relative owner contract cost c_c (CPIF) and c_c' (LSFP)

CPIF: *Normal(0.96,0.08)*
LSFP: *Normal(1.05,0.03)*
CPPF: *Normal(1.12,0.09)*

7.3.2 Schedule duration and predictability

To investigate the schedule performance on the projects in the database of Table 7.1, the following ratio has been analysed:

$$s = \frac{S}{S_i} \qquad (7.3)$$

where: s relative schedule duration
S actual schedule duration
S_i initial schedule duration (included in the contract)

The actual and initial schedules were measured (in months) from the effective date of contract to RFSU. Similar to cost performance, both the length of a schedule and its predictability are important. As discussed in section 3.2.1, owners of processing facilities in the oil, gas and petrochemical industry generally conclude supply agreements for the facility's end product(s) well before project completion. Consequently, not meeting the scheduled RFSU date is very costly to the owner and predictability is perhaps even more important with respect to schedule performance than it is with respect to cost performance. This may be the underlying reason of an old saying amongst project managers that *'all projects are cost driven prior to FID and schedule driven post FID'*. The relative schedule on the projects in the dataset has a mean value μ = 1.02 and a standard deviation σ =0.08. Figure 7.4 shows the cumulative frequency distribution of the relative schedule s and the associated normal approximation function. A 'goodness-of-fit test' based on a chi-square distribution and a 'Bowman-Shelton test' for normality, indicate that the model provides a good approximation of the actual distribution.

On all three contract types, the initial schedule included in the contract is generally established prior to FID. On LSFP contracts it is included in the payment schedule and in the form of LDs for any delay in completing the project (see also section 3.2.1). On CPIF contracts in the form of incentive performance criteria linked to schedule milestones and RFSU date (see section 4.3.1).

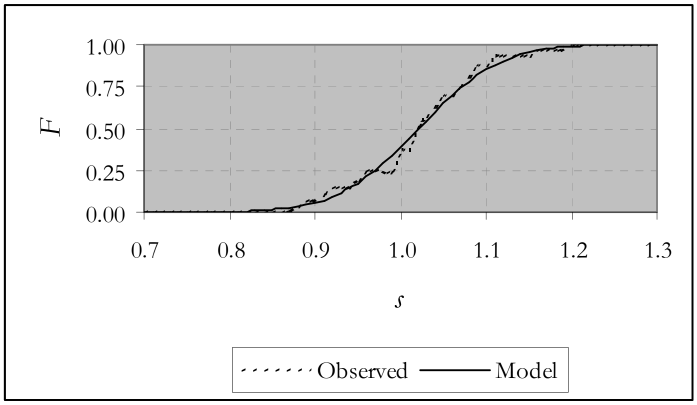


Figure 7.4
Cumulative frequency distribution relative schedule *s*
Normal(1.02,0.08)

On CPPF contracts the schedule is generally also agreed as part of the contract, be it without monetary incentives attached to it. Consequently, the relative schedule *s* provides a measure of schedule performance in absolute terms as well as the schedule predictability. The results of an analysis of the relative schedule on CPIF, LSFP and CPPF contracts are depicted in Figure 7.5.

The relative schedule performance on LSFP contracts is some 3% better than on CPIF contracts and these are in turn some 6% better than CPPF contracts. This does not take into account the time required for competitive tendering which for a single LSFP contract is generally some 3-6 months longer than for a CPIF contract. Based on an implementation time of 3.5 years, this means that the relative schedule performance on CPIF contracts is some 7% better than LSFP contracts, if the cycle time from completion of project development until RFSU is considered. The predictability on CPIF and LSFP is very similar. On projects executed under a CPPF arrangement the predictability is considerably lower, as illustrated by the relatively large standard deviation in the *Normal*(μ,σ) approximation function.

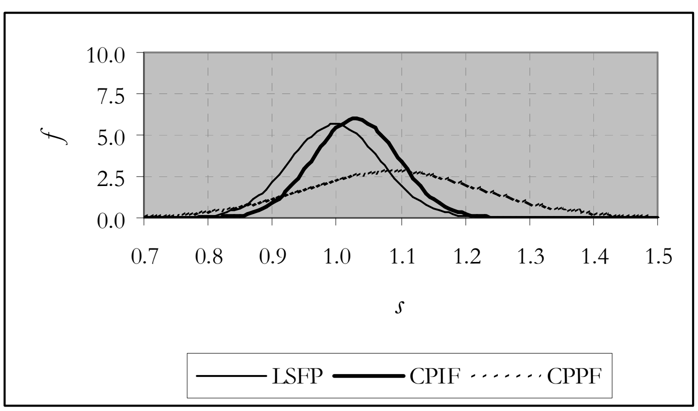


Figure 7.5
Frequency distributions relative schedule *s*

CPIF: *Normal(1.03,0.07)*
LSFP: *Normal(1.00,0.07)*
CPPF: *Normal(1.09,0.14)*

7.4 Effectiveness of multidimensional incentives

7.4.1 Incentives and performance criteria

The CPIF contracts in the database of Table 7.1 essentially had the same structure with respect to EPCm services as described in section 4.3.1:

(a) A cost reimbursable part comprising a remuneration on EC job-hours plus other costs properly incurred and directly related to the project; and

(b) A multidimensional incentive construct.

To investigate the incentives on the CPIF projects in the database of Table 7.1, the following ratio has been analysed:

$$\pi = \frac{\Pi}{E} \qquad (7.4)$$

where: π relative (earned) incentive fee
Π EC earned incentive fee (see also section 4.3.1)
E owner's +/- 10% cost estimate

The results of an analysis of the relationship between the observed relative (earned) incentive fee π and relative cost c are depicted in Figure 7.6. The mean value is μ_π = 0.02 with a high associated standard deviation σ = 0.02. A high relative incentive fee is generally associated with low relative cost, however the correlation is weak (R^2 = 0.29 for a linear regression model). On average some 73% of the earned incentive fee is attributable to the first element of the incentive construct; i.e. π_1 = 0.18. Hence, the cost related incentive fee (i.e. π_2) is only 27%, corresponding with the weak correlation between cost performance and total earned incentive fee.

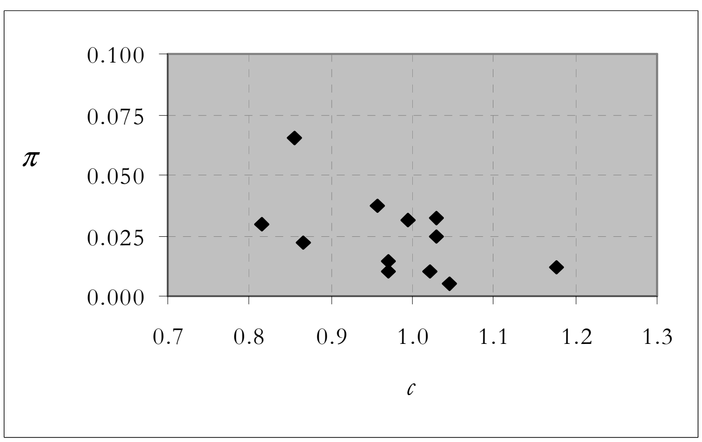
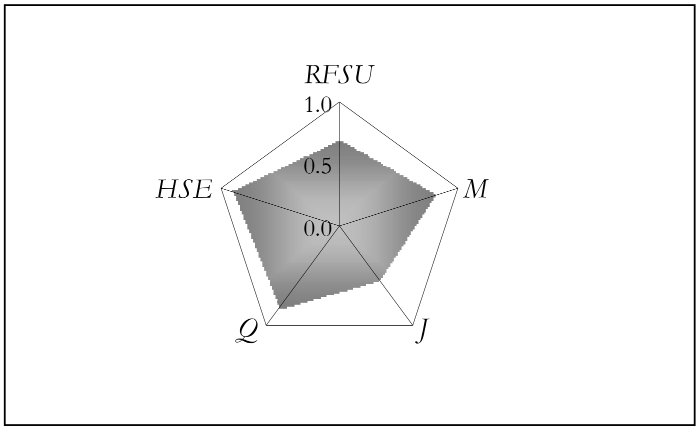


Figure 7.6
Relative (earned) incentive fee π vis-à-vis relative cost c

From the owner's perspective, the success of a project is measured by the overall value generated by the capital investment. This is influenced by a number of interrelated parameters with varying degrees of uncertainty at the time of FID. Risk management plays a critical role in this process (Jaafari, 2001). With CPIF contracts these parameters are translated into performance criteria for project implementation. The criteria in the incentive construct under consideration here are typically used on CPIF contracts (Turner, 2003). The achieved scores (based on the relative incentives fee π_I) on the projects in our database with respect to the multidimensional performance criteria are illustrated in the radar chart of Figure 7.7. This is a measure of the relative performance scores (except cost). Overall the scores are high with a mean value of 0.79 and an (high) associated standard deviation of 0.17.



where:

RFSU	:	Ready For Start-Up date
M	:	intermediate (schedule) Milestones
J	:	EPCm job-hour cost
HSE	:	Health, Safety and Environmental aspects
Q	:	Quality of the EPCm services

Figure 7.7
Relative performance scores

The mean of the scores on the *HSE* and *Q*uality criteria are μ_{HSE} = 0.91 and μ_Q =0.84 (standard deviations 0.10 and 0.11 respectively). A point worthy of note is that in many cases the *Q*uality assessment is rather subjective. A comparative analysis of HSE and quality performance under different types of contract falls outside the scope of this research, but project management heuristics suggests that HSE and quality performance on CPIF contracts are not significantly better than that on LSFP contracts. HSE performance is driven by project management processes and organisational culture. Quality is primarily dependent on the established large codified body of knowledge (see also section 2.2.1); e.g. engineering standards, welding qualifications and test procedures. Hence, it is questionable whether incentives are effective in influencing EC behaviour regarding *HSE* and *Q*uality performance.

The mean values for *RFSU* and *M* are μ_{RFSU} =0.72 and μ_M =0.82 (standard deviations 0.42 and 0.22 respectively). Note that whilst a large proportion of the incentives linked to *RFSU* and *M* are earned, the relative schedule duration on CPIF contracts is s = 1.030 (see Figure 7.5). This is due to: (i) on many contracts a 'sliding incentive reduction scale' is used for RFSU which means the EC can still 'earn' part of the available incentive if the end date is not achieved; and (ii) adjustments to the incentive construct when it becomes apparent that the original RFSU date will not be achieved. This element of subjectivity is reflected in the large standard deviations.

Only half of the CPIF contracts in the database contain an incentive construct with a performance score on the EPCm job-hours target *J*. The mean value of the contracts where it is included is μ_J = 0.54 (σ = 0.47) and in most cases the achievement was 'digital'; either achieved in full or not at all. As the cost of EPCm services is included in the target cost C_T, the incentive construct already includes an inherent incentive with respect to *J* if $C < C_T$. Furthermore a number of CPIF contracts included a mechanism whereby the cost reimbursement of EPCm job-hours is reduced through a sliding scale if the agreed target is exceeded.

7.4.2 Target cost and fee limitation

The available cost related incentive element π_{a2} is dependent on the parameters target cost C_t and the EC sharing rate α (see equation (4.3) in section 4.3.1). They are discussed in this order.

The *target cost* C_t plays a crucial role in the incentive construct described before in terms of providing a cost incentive as well as an incentive with respect to *RFSU*, *Q* and *HSE* (see Figure 4.2 in section 4.3.1). To investigate the influence of the target cost on the CPIF projects in the database of Table 7.1, the following ratio has been analysed:

$$c_{ti} = \frac{C_{ti}}{E} \qquad (7.5)$$

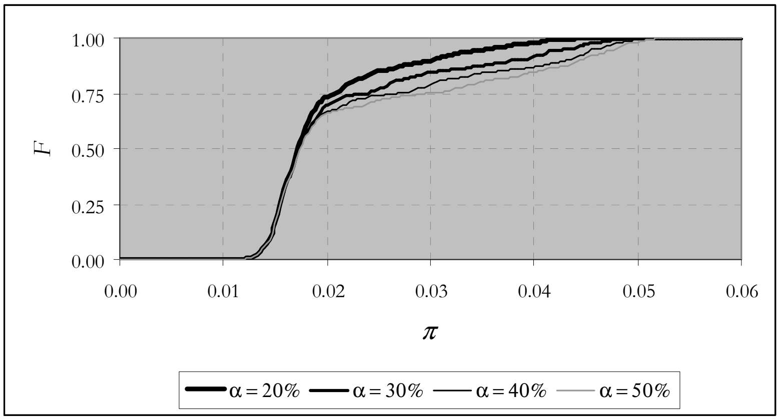
where: c_{ti} relative initial target cost established at the start of contract
C_{ti} initial target cost established at the start of contract
E owner's +/- 10% cost estimate

The results of the analysis indicate a mean value of the relative initial target cost μ =0.96 (σ = 0.05). In other words, on average the target cost is initially set at a level 4% below the owner's cost estimate. Using the *Normal(1.01, 0.11)* distribution of section 7.2.2, which translates into (cumulative) probability equal to 34% of actual cost being below the target cost. Consequently, the probability of 'creating' a cost related EC incentive fee element Π_2 (see section 4.3.1) is rather low. On all projects where $c_{ti} < 1$ the target cost was adjusted upwards during execution; on average from c_{ti} = 0.94 to 0.99; this includes the three worst *'cost performance'* projects. Starting with a low target cost and adjusting it later may seem attractive but is counterproductive. At the time of adjustment, the possibility of materially influencing the project cost outcome are small as most of the purchase orders for materials & equipment and the sub-contracts for construction have been awarded by then. The purpose of the target cost in CPIF contracts is to provide a cost performance incentive for the EC. A commonly made mistake amongst owners is that the target cost is intuitively associated with the contract sum under a LSFP contract. Indeed, this is most likely the underlying reason for c_t = 0.96 in the database. On projects where $c_{ti} \geq 1$ the target cost was maintained at the original level until completion; this includes two of the three best *'cost performance'* projects.

To investigate the influence of the EC sharing rate α on the relative profit, a stochastic simulation has been carried out for the range of values in the database α = 0.2 - 0.5, based on the *Normal(1.01,0.11)* relative cost distribution of section 7.2.2 and a target cost c_t = 0.96. The other model parameters and settings are based on the average distribution in the database of incentive fees across performance parameters and on the performance distribution described in section 7.4.1. The results are depicted in Figure 7.8.

The first parts of the graphs are almost identical for all values of α and represent the element π_1 of the incentive construct. Only for π > 0.018 is there a significant difference between the different vales of α. This point in the stochastic model corresponds with the 73% of observed relative incentive fee (i.e. π = 0.24) attributable to π_1 as referred to in section 7.4.1. For α = 20% there is cumulative probability of 75% that π < 0.02; i.e. there is a 25% probability that π > 0.02. For α = 50% on the other hand there is a 33% probability that π > 0.02 and a 25% probability that π > 0.03. Hence, increasing α increases the expected profit. On average the CPIF contracts in the database contained an incentive construct with α = 40%. Increasing the value of α above

0.40 increases the incentive fee only marginally (Berends, 2000). The stochastic model predicts a value μ_π = 0.23 for α = 0.40 compared with an observed value of π = 0.24, confirming the validity of the model.



α	20%	30%	40%	50%
μ	0.020	0.022	0.023	0.024

Figure 7.8

Cumulative probability distribution of achieving a relative profit π at various levels of the EC sharing rate α
Calculated by using @RISK, advanced risk analysis for spreadsheets (Palisade Corporation, 2001).

Most CPIF contracts include a maximum value for the cost related incentive fee Π_2 (see equation (4.4) and Figure 4.1 in section 4.3.1) because the owner is in many cases concerned that the EC might earn an inappropriately high fee due to the target cost being set at too high a level. To investigate the effect of a high target cost and of fee limitation, a stochastic simulation has been carried out, based on a high relative target cost c_t = 1.10 (i.e. 10% above the estimate) with and without fee limitation. The simulation settings are the same as in the earlier simulation and the results are depicted in Figure 7.9.

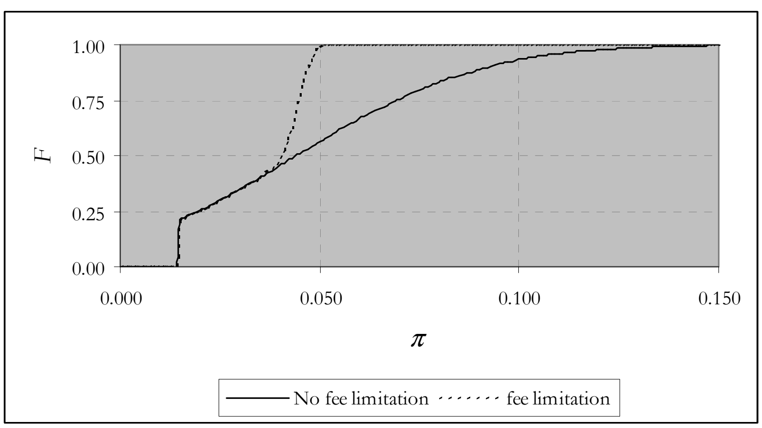


Figure 7.9

Cumulative probability distribution of achieving a relative incentive fee π with and without fee limitation
Calculated by using @RISK, advanced risk analysis for spreadsheets (Palisade Corporation, 2001).

In the case without fee limitation the model indicates a mean value of the relative incentive fee of $\mu_\pi = 0.05$. In the case with fee maximisation, the maximum fee has been set at $\pi_{2max} = 0.04$. This corresponds with the lower boundary of a +/- 10% confidence interval around the (single point) stochastic cost estimate and is the value generally used on the CPIF contracts in the database. The model indicates in this case a mean value of the relative incentive fee of $\mu_\pi = 0.04$. The effect of limiting π_2 on the overall relative fee π (i.e. including π_1) is clearly noticeable in Figure 7.9. Whereas there is the opportunity of a high relative profit (e.g. $\pi = 0.05$-0.10) the probability of achieving it is small. Hence, even with a target cost set at a level which is 10% above the cost estimate, the 'exposure' of the owner is limited.

7.5 Conclusions

In this chapter project performance under CPIF, LSFP and CPPF contract types has been investigated. The stochastic cost estimate underlying the database used for empirical analysis was shown to be *'credible'*; i.e. displaying objectivity and precision. The *Normal*(μ,σ) approximation function of relative cost has been used to analyse cost and schedule performance level/duration and predictability. The results indicate that CPIF contracts deliver the best cost level performance but that LSFP contracts deliver the best cost predictability (vis-à-vis the owner contract cost envisaged at the time of FID). With respect to schedule predictability there is no significant difference between CPIF and LSFP contracts. The latter provides the best relative schedule performance for project implementation, excluding the time required for tendering. If the latter is included CPIF contracts offer a better proposition. Projects with a CPPF contract display the worst cost and schedule performance in terms of level/duration as well as predictability.

The analysis indicates that the cost level under a CPIF contract is some 16% lower than under a CPPF contract and some 8% lower than under an LSFP contract. This suggests that on average the incentive constructs are effective with respect to minimising overall project cost. On the CPIF contracts a high relative incentive fee is generally associated with low relative cost, however, the correlation is weak which suggests inconsistencies in the way CPIF contracts are structured and used.

On all CPIF contracts where the initial target cost was set below the cost estimate, the target cost was subsequently adjusted upward during implementation to approximately the level of the cost estimate. Setting a low target cost can also be construed as a lack of trust on the part of the owner whereas it was concluded in Chapter 5 that this comprises a critical element in cooperative forms of contracting like CPIF. Concerns about the EC earning an inappropriate fee may also be the underlying reason for maximising the cost related part of the incentive construct. A stochastic simulation model was developed and validated through an empirical analysis of the projects in the dataset. Based on a credible stochastic estimate, the model provides a good prediction of the expected earned incentive fee. The model indicates that the concerns with respect to the EC earning an 'undue' fee are largely unfounded, provided the target cost does not exceed the cost estimate by more than 10%. Most owner organisations do not have a structured approach for designing incentive constructs (Bushait, 2003). But uneasiness about CPIF contracting should be mitigated through enhancing owner's competencies with respect to contracting and cost estimating (i.e. the ability to set a credible target cost) rather than through unduly limiting the incentive fee. The cost related part of the incentive construct is only effective with respect to cost performance if there is significant probability at the outset of actual cost being significantly below the target cost. This suggests that further improvements to these contracts can be made. Stochastic modelling as described in this chapter can assist in this process.

The analysis of incentive fee criteria related to performance of quality, HSE and EPCm job-hours, casts doubt on their effectiveness. It is suggested that governance with respect to quality and HSE is more efficiently achieved through established project management processes rather than through an incentive construct and that job-hours can be managed through the cost reimbursable part of the contract. This suggests that the same performance on CPIF contracts can be achieved by not including *HSE* and *Q* criteria in the incentive construct.

The relative fees achieved on CPIF contracts may appear to be small; the mean of the achieved relative fee is π=0.02. This translates, however, into an EC profit margin of 12% (based on EPCm job-hour cost being 20% of the overall cost). Hence the relative owner contract cost under a CPIF contract is the actual cost of executing the project (including EPCm services) plus a relative EC fee of π=0.02. The relative owner contract cost under a LSFP contract is 0.08 higher than under a CPIF contract. This suggests that on the (historical) projects in the dataset executed under a LSFP contract, the mean EC profit is π=0.10 [2].

Notes

1 This concept only works for a portfolio of many projects of a similar size, where the owner seeks to minimise the amount of capital tied up to cover project uncertainties . With LECPs this is usually not the case and a large over- or under-run on one LECP will distort the overall balance. Therefore these should generally be budgeted more conservatively in view of the large risks and financial exposure.

2 In section 3.4.1, this is the basis for setting the actual relative cost of performing the work at c = 0.90.

7.6 References

Berends T.C., 2000. *Cost plus incentive fee contracting – Experiences and structuring*, International Journal of Project Management, 18, pp165-171.

Bushait A.A., 2003. *Incentive/disincentive contracts and its effects on industrial projects*, International Journal of Project Management, 21, pp63-70.

Campolongo F., Saltelli A., Sorensen T., Tarantola S., *Hitchhiker's guide to sensitivity analysis*, 2000, pp15-47. In Saltelli A., Chan K., Scott E.M. (editors), *Sensitivity analysis*, John Wiley & Sons Ltd, Chichester, England.

Jaafari A., 2001. *Management of risks, uncertainties and opportunities on projects: time for a fundamental shift*, International Journal of Project Management, 19, pp89-101.

Newbold P., 1995. *Statistics for business and economics*, Prentice Hall International Inc., New Jersey, fourth edition, 1995, pp405-414.

Palisade Corporation, @RISK, 2001. *Advanced risk analysis for spreadsheets*, Version 4, February 2001.

Schuyler J., 2001. *Risk and decision analysis in projects*, Project Management Institute Inc., Pennsylvania, USA, second edition, 2001, p5.

Turner J.R. (2003). *Contracting for project management*, p41-42, Gower Publishing Limited, Aldershot, England.

Vose D., 2001. *Risk analysis – A quantitative guide*, John Wiley & Sons Ltd., Chichester, England, second edition, 2001, p243.

Wood D.A., 2001. *Probabilistic methods with simulation help predict timing, cost of projects*, Oil & Gas Journal, Nov.12, 2001, pp79-83.

Appendix 7A

The dataset contains two extreme c_c values (1.526 and 1.576; both projects executed under a CPPF contract) that have been discarded of the distribution analysis as they would influence the outcome disproportionally. This means the number of data points n = 30.

7.A.1 Number of intervals

The goodness-of-fit χ^2 statistic is dependent on the number of intervals N used. Whilst there are no definitive rules for selecting N, Scott's Normal approximation generally works very well (Vose, 2001); this gives:

$$N = (4n)^{2/5} = (4*30)^{2/5} \approx 7$$

7.A.2 Chi-square 'goodness-of-fit test'

Hypotheses:

H_0 : The data come from a *Normal(1.007,0.112)* distribution
H_1 : The data do not come from a *Normal(1.007,0.112)* distribution

The null hypothesis specifies category probabilities that depend on the estimation from the data of m = 2 parameters; i.e. the mean value μ and the standard deviation σ. This means that the number of degrees of freedom for the chi-square random variable is (Newbold, 1995):

$$\nu = N - m - 1 = 4$$

This gives $\chi^2 = 4.34$ which is much lower than $\chi^2_{4,0.005} = 14.86$ indicating that the data provide strong evidence that distribution of the observed data is indeed Normal.

7.A.3 Bowman-Shelton test of normality

The Bowman-Shelton test statistic for normality is:

$$B = n\left[\frac{(Skewness)^2}{6} + \frac{(Kurtosis - 3)^2}{24}\right] = 30\left[\frac{(0.336)^2}{6} + \frac{(2.574 - 3)^2}{24}\right] = 0.791$$

The significance point at 5% level for a sample size of n = 30 is 3.71 (Newbold, 1995) and consequently the test result provides very little ground for questioning the hypothesis that the distribution of observed data is Normal.

8

Concluding observations

8.1 Conclusions of preceding chapters

Chapter 2 shows how the strong growth in LECPs for processing facilities in the oil, gas and petrochemical industry stopped abruptly after the oil shocks in the 1970s. Owner capabilities related to the development and implementation of LECPs shifted to a limited number of ECs resulting in a market with oligopolistic characteristics. During the 1980s and 1990s owners transferred the cost and completion risk of LECPs to ECs through strategies based on a single LSFP/EPC contract. Strong competition between ECs limited the price premium to owners for the economic inefficiencies associated with this approach. In the current 'sellers market' with limited competition, owners need to look for other ways to mitigate these inefficiencies.

The analysis presented in ***Chapter 3*** indicates that in a competitive market, the relative EC profit (including risk premium) on single LSFP/EPC contracts is, in the case of a single bidder, some 14% higher than with two bidders. The developed (risk neutral) model, based on a stochastic cost estimate and an in-depth understanding of the contracting market, provides a good prediction of actual bid prices and an insight into the effect of competitive forces. The financial risks associated with LECPs are high and in a market with limited competition, owners will be less able to transfer these risks to ECs (through LSFP/EPC contracts) at an acceptable price, than they were in the 1980s and 1990s.

On the three case study projects analysed in ***Chapter 4,*** significant changes occurred in the construction contracting and (equipment & materials) procurement market. With a CPIF/EPCm contract as used on two of the case study projects, the EC is responsible for execution of the project but its liabilities (e.g. with respect to the cost of completing the work) are limited to the (incentive) fee. The owner accepts the risk of procurement and construction and tries to achieve optimum EC performance through a (performance related) incentive arrangement. This 'cooperative contracting' approach mitigates the economic inefficiencies referred to in chapter 2, by creating a reciprocal dependency between owner and EC. The analysis illustrates the effect of changing market conditions on the owner contract cost under various types of contract.

The relational risk in 'cooperative contracts' such as CPIF/EPCm is inherently greater than with LSFP/EPC contracts. The multivariate analysis in ***Chapter 5*** indicates that with cooperative contracts, the most important relational variable is trust (particularly integrity and open communication), at company level as well as at the level of individual decision makers. This is not obvious, because both owners and ECs are (historically) used to work on the basis of LSFP/EPC contracts whereby the owner has limited insight in the cost of executing LECPs and both parties try to safeguard their interests through stringent terms and conditions of contract. The use of 'cooperative contracting' requires a behavioural and organisational change process, with a higher demand on owner capabilities, particularly with respect to contracting and procurement and project (schedule and cost) controls.

The time value of money plays a central role in the economic evaluation of LECPs, but is often underexposed in the analysis of contract cost performance. In **Chapter 6**, the expenditure phasing under ten LSFP/EPC contracts and ten CPIF/EPCm contracts is investigated. The findings, validated through a comparison with the results from similar studies, indicate that there is an established practice of advance payments on LSFP/EPC contracts. On the basis of an NPV calculation, the cost of these advanced payment schedules vis-à-vis the actual expenditure phasing (i.e. the owner contract cost under a CPIF/EPCm contract) is some 6% of TIC.

The comparative analysis described in ***Chapter 7*** indicates that the owner contract cost under LSFP/EPC and CPPF/EPCm contracts of the case study owner organisation, was (in a competitive market) some 8% and 16% higher, respectively, than under CPIF/EPCm contracts. *A large part of this contract cost difference is 'hidden' in the differences in expenditure phasing.* This suggests that the incentive arrangements have been effective. LSFP/EPC contracts provide the best relative schedule duration from contract award to RFSU but if the time required for tendering is taken into consideration as well, CPIF/EPCm contracts deliver the shortest duration. Areas for improvement of the multidimensional incentive constructs are (i) the level of the target cost (typically the initial level is too low, undermining the effectiveness of cost incentives); and (ii) the definition and number of performance criteria. The incentive constructs investigated are complicated and the effectiveness with respect to Quality and HSE performance is questionable. Governance with respect to these aspects is better achieved through established project management processes.

8.2 Outlook

Uncertainty and risk are the ruling paradigms on LECPs. Managing these effectively, i.e. efficiently with the ability to adapt to changing circumstances (Carnall, 1990), requires governance: *"The complex process of steering multiple firms, agencies and organisations that are both operationally autonomous and structurally coupled in projects through various terms of reciprocal interdependencies"* (Miller and Lessard, 2000). The contract between owner and EC formalises their relationship, specifying the obligations and liabilities of the parties as well as the allocation of risk. The awarding of the contract, however, merely comprises an intermediate milestone in the contracting process of strategy development, pre-qualification, tendering, evaluation/award and contract management. This *contracting process* (covering the entire project life-cycle) comprises one of the most important project governance mechanisms on LECPs. Its effectiveness is contingent upon information transmission, particularly signaling (see section 2.4.3) between owner and EC.

The execution of LECPs requires contracting strategies and tactics, designed for and tailored to specific project needs. In this thesis strategies/tactics based on a (single) LSFP/EPC and an CPIF/EPCm approach have been used as archetypical extremes of the contracting spectrum. In essence the difference between the two boils down to procuring a product (i.e. the processing facility) with an LSFP/EPC contract and procuring services with a CPIF/EPCm contract. In reality a large number of different types of contract is deployed, including many variations to these two archetypes and new concepts continue to be developed and implemented (e.g. tendering a suite of contract types, offering ECs the opportunity to select the optimum contract).

The last 5 - 10 years have seen a dramatic turn in the contracting markets for LECPs, from a buyers' market into a sellers' market. This situation and the oligopolistic market characteristics are unlikely to change in the short term. Increasingly owners are faced with high price premiums associated with the traditional single LSFP/EPC approach, forcing them to consider alternative (cooperative) contracting approaches that place a greater demand on their in-house competencies. Particularly important in this respect is the ability of the owner to establish a credible cost estimate of a project, enabling:

(a) Analysis of competitive bidding on a LSFP/EPC basis; and

(b) Setting of appropriate cost target on CPIF/EPCm contracts.

In the future, contracting will be a core competency[1] of any successful owner organisation involved in the development and implementation of LECPs. Owners with the required in-house project management and contracting competencies and the ability and willingness to accept financial risks, will be able to realise LECPs faster and at lower capital cost than companies that do not possess these attributes. Furthermore, an inability to deploy a range of different contracting strategies and tactics will result in viable projects not being implemented.

The development and implementation of LECPs is an exciting process at a company level as well as at the level of the project professionals. Many people derive satisfaction from being part of transforming a conceptual idea into a large, functional artefact. In the 1960s and 1970s the growth in LECPs for processing facilities in the oil, gas and petrochemical industry attracted many professionals. The influx of young talent into the industry declined strongly in the 1980s and 1990s. Currently, the shortage of experienced professionals to realise, during the next decades, the unprecedented amount of processing capacity required to meet the world's energy needs, is felt throughout the industry. Historically, contracting practitioners 'learned the ropes' on the job and from experienced peers. The demographics outlined above and changed market situation make this increasingly difficult. At the same time the attention for strategic thinking about 'capital contracting' and the amount of empirical research at universities is limited. In the Netherlands for instance, there is one part-time chair (at Delft University of Technology) pertaining to project management for the process industry, where contracting for processing facilities forms a small part of the curriculum. Furthermore the information exchange between contracting practitioners and theorists is limited. In this respect the field of contracting is not unique as there is a widely shared concern that management science is insufficiently used by practitioners (Van Aken, 2004). Also, the number 'outside PhD scholars' (i.e. practitioners doing PhD research) is limited (Schnabel, 2007).

The economics of contracts provide a rich source of ideas for innovative contracting approaches that is hardly used by practitioners. To enable practitioners to use this source, theoretical contracting (economics) concepts need to be translated into practical experience-based models. Theorists need to have access to data for empirical research, to expand and validate existing models and develop new ones. Closer cooperation between theorists and practitioners will enable both to play their part in addressing the challenges and opportunities associated with LECPs in the future.

Notes

1 Core competencies are the sum of knowledge, experience, capabilities and the attitude of people that has become an inherent part of an organization (Boekhof, 1997).

8.3 References

Boekhof T., 1997. *Managen van kennis, ('Managing knowledge')*, p40, Kluwer bedrijfsinformatie, Deventer, The Netherlands.

Carnall C.A., 1990. *Managing change in organisations*, p1-11, Prentice Hall International, Hemel Hempstead, UK.

Miller R., Lessard D.R., 2000. *The strategic management of large engineering projects,* p135, Massachusetts Institute of Technology (MIT).

Schnabel P., 2007. *Van boekenwijsheid naar empirie ('From book knowledge to empirical research')*, NRC Handelsblad, 24 February 2007, p22-23.

Van Aken J.E., 2004. *Management research based on the paradigm of the design sciences: the quest for tested and grounded technological rules*, Journal of Management Studies, 41 (2): pp219-46.

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Kees Berends

The Hague, November 2007.

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Education

MSc Mechanical Engineering, Eindhoven University of Technology, 1987.
Thesis: *Convection induced fluid flow and heat transfer – A finite element model and experimental validation*

MBA Henley Management College / Brunel University, 1998
Thesis: *A Study of Incentive Contracting on Capital Investment Projects – Practices in a Chemicals Company*

PhD Project Management, Delft University of Technology, 2007
Thesis: *Contracting Economics of Large Engineering and Construction Projects*,

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2002/2005	*Contracting on Engineering and Construction Projects* Annual course Project Engineering and Management, Delft University of Technology
2005	*Contracting Strategies for Engineering and Construction Projects* Dutch State Business, Atradius, Amsterdam
2007	*Novel Contracting Strategies* Shell Engineering Conference
2000/2007	Numerous lectures and contracting strategy workshops in the context of LECPs of the Royal Dutch Shell group.

Employment

1987/1988	Military service
1989/1991	Project Engineer/Manager Shell UK Downstream Ltd.
1992/1994	Commercial Services Manager Shell UK Downstream Ltd.
1995/1999	Senior Project Consultant Shell International Chemicals B.V.
2000/2005	Senior Contracts Advisor Shell Global Solutions International B.V.
2006/2007	Capital Contracting Services Manager Shell Global Solutions International B.V.

Publications

Berends T.C. (2000). *Cost plus incentive fee contracting – experiences and structuring,* International Journal of Project Management, 18(3): 165-171.

Berends T.C., Dhillon J.S., 2004. *An analysis of contract cost phasing on engineering and construction projects*, The Engineering Economist, 49(4), pp 327-337.

Berends T.C., *Cooperative contracting on major engineering and construction projects*, The Engineering Economist, 51 (2006), pp35-51.

Berends T.C., *Engineering and construction projects for oil and gas processing facilities: Contracting, uncertainty and the economics of information*, Energy Policy 35 (2007), pp 4260-4270

Berends T.C., Poley J., *Relational risk in contracting for large engineering and construction projects – An application of decision and transaction cost theory,* Submitted to The Journal of Purchasing and Supply Management.

Notations

General

MMbc/d	million barrels of crude per day
MMtpy	million tonnes per year

Contracts

C_t	target project cost
C	actual project cost (including EPCm service cost)
C_c	owner contract cost
C_{ti}	initial target cost established at the start of contract
E	owner project cost estimate
H_0 , H_1	hypotheses
HSE	Health, Safety and Environmental (performance criterion)
J	EPCm job-hour cost (performance criterion)
M	schedule Milestones (performance criterion)
$P(b)$	probability of winning with a relative bid price b
$P(b)_n$	probability of winning with a relative bid price b and n bidders.
Q	Quality (performance criterion)
RFSU	Ready For Start-Up date (performance criterion)
S	actual schedule duration
S_i	initial schedule duration
b	relative bid price; $b = B/E$
c	relative cost of performing the work; $c = C/E$
c_c	relative owner contract cost
$c_c^{'}$	relative growth owner contract cost
c_{ci}	initial relative owner contract cost
c_{ti}	relative initial target cost established (at the start of contract)
s	relative schedule duration
Π	EC fee/profit
Π_t	target fee/profit
Π_{a1}	an ex ante agreed available EC incentive fee (element 1)
Π_{a2}	cost related available EC incentive fee (element 2)
α	EC sharing rate (cost related incentive fee)
$\pi(b)$	relative fee; $\pi = \Pi/E$

Statistics

F	*frequency*
F	*cumulative frequency*
R^2	variance
Cov	covariance
$Normal(\mu,\sigma)$	Normal distribution with mean μ and standard deviation σ
χ^2	chi-square random variable
μ	mean value
σ	standard deviation
ρ	correlation coefficient
ν	number of degrees of freedom for χ^2

Abbreviations

ADR	Alternative Dispute Resolution
CAR	Construction All Risk (insurance)
CPF	Cost Plus Fee (contract)
CPIF	Cost Plus Incentive Fee (contract)
CPPF	Cost Plus Percentage Fee (contract)
ECs	(international) Engineering and Construction contractors
ECA	Export Credit Agency
EIA	Energy Information Administration
EPC	Engineering, Procurement and Construction
EPCm	Engineering, Procurement and Construction management (services)
EV	Earned Value
FED	Front End Development
FEED	Front End Engineering Design
FID	Final Investment Decision
FPI	Fixed Price Incentive (contract)
GAAP	Generally Accepted Accounting Principles
GDP	Gross Domestic Product
GTL	Gas-To- Liquids
HSE	Health, Safety and Environment
IOC	International Oil Company
ITB	Invitation To Bid
JV	Joint Venture
LDs	Liquidated Damages
LECPs	Large Engineering and Construction Projects
LNG	Liquefied Natural Gas
LSFP	Lump Sum / Fixed Price (contract)
NOC	National Oil Company
NPV	Net Present Value
PCFA	Principal Component factor Analysis
PM	Project Manager
RFSU	Ready For Start-Up (date)
TIC	Total Installed Cost
TCO	Total Cost of Ownership
WBS	Work Breakdown Structure