THESIS ON CIVIL ENGINEERING F34

Risk Transfer and Construction Project Delivery Efficiency - Implications for Public Private Partnerships

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Declaration:
Hereby I declare that this doctoral thesis, my original investigation and achievement, submitted for the doctoral degree at Tallinn University of Technology has not been submitted for any academic degree.

/Emlyn D.Q. Witt /

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EHITUS F34

Riskijuhtimise delegeerimise mõju avaliku ja erasektori ühiste ehitusprojektide tõhusale juhtimisele

EMLYN D. Q. WITT

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KIRJASTUS

With thanks to my supervisor, Professor Roode Liias, and to Professor Irene Lill for their support and encouragement and to my family for their patience.

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LIST OF ABBREVIATIONS

CIB	International Council for Research and Innovation in Building and Construction
DBFO	Design Build Finance Operate
EIB	European Investment Bank
ERR	Eesti Rahvusringhääling (Estonian Public Broadcasting)
EU	European Union
IMF	International Monetary Fund
NPM	New Public Management
P3	Public-Private Partnership or Public/Private Partnering
PF	Private Finance
PFI	Private Finance Initiative
PFP	Privately Financed Project
PPI	Private Participation in Infrastructure
PPP	Public Private Partnership
PSC	Public Sector Comparator
SPV	Special Purpose Vehicle
UK	United Kingdom (of Great Britain and Northern Ireland)
US	United States (of America)

1. INTRODUCTION

1.1 Overview of Chapter

This chapter serves to introduce the subject of the research and to provide an explanation for the approach adopted.

A description of the background to the research, its relevance to current issues and its evolution as it progressed is followed by an outline of the dissertation.

1.2 Background to the Research

The financial crisis from 2007 may be considered a crisis of risk measurement and understanding – whether with regard to 'subprime' mortgage-backed securities or European sovereign bonds, risk assessments were heavily relied upon by investors and their trust in these assessments appears to have been misplaced.

The years leading up to 2007 coincided with the rise of Public Private Partnerships (PPPs) in Europe. PPPs emerged in the 1990s as an alternative to directly government-funded procurement of infrastructure on one hand and privatisation on the other. The approach gained momentum as public budget constraints were tightened while access to relatively cheap private credit eased. Into the early 2000s, public policy in much of Europe was actively promoting PPPs.

Pro-PPP policies translated into a great deal of effort being expended in creating an 'enabling environment' for PPPs in terms of legislation and dissemination of 'best practice' type information. Publications from major accounting firms, legal firms, engineering firms – typical participants in PPPs and consultants to both public and private 'partners' also abounded. Some of the academic literature, however, has been directly critical of the fundamental concepts underlying PPPs. More recently, even government publications from the United Kingdom – the European 'home' of the PPP - have become markedly less enthusiastic about the approach, and have suggested that PPPs have not delivered on initial value for money expectations. (UK Public Accounts Committee, 2011; UK Treasury Committee, 2011)

This returns us to the crisis in risk measurement and understanding on two counts: firstly, as a direct consequence of the financial crisis there has been a general contraction in the availability of credit and a rise in its cost (one might say 'a revised pricing of risk') since 2007 and, secondly, that the justification for PPPs has at its core a notion that the private sector is able to achieve greater efficiency than the public sector when its capital is 'at risk' – but the substance of this conception now appears remarkably less tangible than it once did.

With PPPs relating to a broad range of disciplines (public administration, finance, economics, accounting, law, construction, health, education, etc.) there is a tendency for any PPP research to be multidisciplinary. However, particularly in the context of a doctoral dissertation such as this, there is also a need to set out the area within PPPs which is under investigation so as to provide confidence that it falls within the remit of the core discipline. In this regard it is argued that this research broadly falls within the competence of construction management and economics research.

The specialist field of construction management and economics does have a currently active research programme concerning PPPs which has resulted in a considerable body of literature. However, the construction-related research programme has generally been focused at the project level and has tended to accept PPPs as simply another type of procurement arrangement. From this perspective, having legislation in place which enables PPPs may be considered to be beneficial in that it makes another procurement option available for any particular project. With a general acceptance that different projects will be suited to different procurement arrangements, much of the construction-related research has assumed (or, at least, has not challenged) that, where PPP procurement is employed, its choice has been justified and the research has rather focused on investigating specific details within the PPP procurement context with the intention of improving PPP project delivery efficiency. The policy-level question: "is PPP a comparatively efficient procurement approach" has thus seen less consideration in the construction-related literature than, for example, it has in public administration, economics and accounting research.

Yet the question is pertinent – should all national governments take the trouble and expense of enabling this type of procurement arrangement? For example, with regard to Estonia, which has relatively little PPP experience, on what basis can it be determined whether PPPs represent an efficient approach to Estonian public procurement? On the advice of the major accounting, legal and engineering firms all of whom have a direct commercial interest in promoting PPPs? Should enabling legislation be passed, should some multi-million euro pilot projects be undertaken as experiments and should a 'PPP unit' be set up and staffed in the Finance Ministry? Would this not merely encourage the sort of political commitment to a preferred procurement option, which, for instance, has seen certain public sector agencies in the United Kingdom find that PPPs are "the only show in town" when the need for capital investment has arisen? (Heald, 2003) These suggestions would rather tend to prevent the rational choice of the most appropriate procurement arrangement than to encourage it.

Thus, there is a need to establish the relative efficiency of the PPP approach at a multi-project, policy level. Construction management and economics as an academic discipline has an obvious research role to play here in that a considerable proportion of the value of a typical PPP relates to the design, building, operation and maintenance of a constructed asset. Yet, at the same time, there are certainly aspects of the PPP approach which extend beyond the

construction discipline and into the realms of accounting, finance, public administration, law, etc. A construction-related perspective suggests both a particular, construction-based research approach to the measurement of relative PPP efficiency and a corresponding contribution to construction management and economics 'knowledge' in developing and implementing the research approach.

Consideration of 'knowledge' and, particularly, the acceptance of our knowledge as being incomplete draws us once again into a consideration of risk. If our knowledge were comprehensive, then our expectations (unless these were irrational) would simply be met. It is the fallibility of our expectations, the consequence of our incomplete knowledge that gives rise to the notion of risk.

Plato's *Theaetetus* portrays knowledge as justified, true belief which may be constructed by perception and reason upon some elemental, self-evident truths. (Chappel, 2005) The *empiricist* tradition, after Locke, accords priority to perceptions so that an empirical, construction-based research approach implies that knowledge would be acquired through inductive inferences drawn on the basis of perceptions or observations of construction projects. (Uzgalis, 2007) But this would be insufficient to establish such knowledge as being either 'objective' or 'scientific'. To be accorded such status, the philosophy of science contributions of Karl Popper and Thomas Kuhn are instructive. Popper suggests that it is rather the ongoing critical effort to refute a proposition than its correct formulation that works towards its establishment as being objective. (Corvi, 1996) Kuhn implies that its being scientific relates to its acceptance as such by the scientific community. (Kuhn, 1970)

In this way the 'knowledge contribution' of this research may be seen to relate to two distinct efforts – firstly in the critical evaluation of the construction-related knowledge to which it refers (and upon which it is based and which it sets out to extend), and secondly in proposing inductive conjectures relating to PPP efficiency for the critical evaluation of others (the relevant scientific community).

In light of these limitations, a conception of knowledge as absolute is impractical - a relative conception of knowledge (and hence risk) is appropriate. For this, the construction project provides a convenient unit of consideration since, at the completion of any project, the project's outcome can be considered to be known with certainty. Prior to that, there is incomplete knowledge with respect to the project's outcome – the conditions under which expectations are fallible and risk is experienced.

Similarly, whether knowledge relates to truth (of an absolute sort) is not of immediate consequence. Greater importance is attached to knowledge having utility in its application (for example, in improving the accuracy of our expectations or predictions). This utility relates to a social context, a society which itself imposes restrictions on the admissibility of knowledge and its acceptable use.

By way of a knowledge contribution then, this research is not anticipated to bathe a previously shaded part of the construction management and economics field in the bright light of new knowledge. Rather, it aims to lighten some parts of the shading while arguing that others are darker than they have previously been taken to be.

1.3 Evolution of the Research

This research effort commenced in 2006 and was inspired by the promotion of PPPs by European Union policy. The author's familiarity with the United Kingdom's construction industry where the vast majority of European PPP projects had been procured and location in Estonia, where very little PPP activity had taken place but where there were distinct indications of an emerging interest in this procurement approach coincided to suggest *the potential efficiency of PPPs in Estonia* as an obvious topic for research.

The initial approach adopted was qualitative and sought to draw a comparison between the United Kingdom and Estonian procurement contexts. However, once it became clear that the justification for PPPs was largely reliant on a risk-based argument and the possibility of directly measuring risk transfers in construction projects occurred to the author, the initial approach was revised in favour of a more quantitative one.

With a suitable measure of risk transfer, an acceptable proxy for value for money was sought. The fulfillment of expectations referenced this once again to the measure of risk and provided a convenient solution to the problem. However, for both risk transfer and project delivery efficiency measures, the data required were detailed financial data and obtaining them was crucial to research success.

Data collection was made possible through the kind cooperation of industry professionals some of whom, justifiably, expressed doubts as to the reasonableness of the research intentions and approach. The attainment of this remarkably commercially sensitive and detailed data set allowed the research project to proceed. It is indeed an unusually rich data set which allows for numerous insights into the Estonian construction industry over the past decade.

With the key to the development of a quantitative approach centred on a measure of risk transfer, a defensible conception of risk was called for. In light of the confusion surrounding the use of this term in the literature of most disciplines, this called for a considerable research effort on its own account.

The model developed to reflect the expected risk transfer – project delivery efficiency relationship and the analysis based upon it provides an original view of historical Estonian project performance which challenges the assumptions underlying the PPP approach. It also challenges the way in which risk is conceived of and, by extension, attempts made to 'manage' it.

1.4 Outline of the Dissertation

Having presented an overview of the research and its wider context in the introductory chapter, Chapter 2 describes in detail what is meant by "Public Private Partnership" (PPP). It provides an overview of the historical context in which PPPs emerged, an explanation of the principal justifications for adopting this form of procurement arrangement and its increasing role in Europe to illustrate the current relevance of PPPs. The PPP-related literature is then reviewed – first generally and then specifically with regard to the construction-related literature – to outline the context in which this research is positioned. The chapter closes with an explanation of how this research is intended to contribute to both construction-related research and to the wider PPP-research programme.

Primarily, Chapter 2 establishes that the principal justification for using PPPs is an argument that optimal risk transfer puts in place incentives which invoke the greater efficiency of the private sector and this leads to better value for money. In Chapter 3, this argument is refined and the focus is shifted from PPP arrangements to the more general context of construction procurement.

The relationship between risk transfer and project delivery efficiency and its implications for construction procurement are then considered from a design science perspective from which it may be seen as constituting design theory. Methodological implications for the research are drawn and the knowledge contribution of the research is described within a design science framework.

Chapter 4 focuses on developing an understanding of the risk concept appropriate to construction projects. The chapter's purpose is to establish a conception of risk with particular relevance to the construction project context which enables risk transfer to be understood and measured. An historical overview is taken to capture the main ideas from probability theory, insurance, economics and finance since the notions of risk from all of these disciplines inform the construction industry's conceptions of risk. Emphasis is given to revealing the diversity of opinions regarding the conception of risk within and between these fields of knowledge. The construction literature on risk is then critically reviewed before an attempt is made to draw together principal aspects into a generalized conception of risk in projects.

The focus is on the nature of risk and does not extend to the considerable volume of literature associated with dealing with risk (whether risk management or decision-making under uncertainty).

Having determined that the risk transfer – project delivery efficiency relationship can be tested on the basis of historical project data (in Chapter 3) and established a suitable conception of risk, Chapter 5 proposes quantitative indicators for both risk transfer and for project delivery efficiency and a geometrical representation of the risk transfer - project delivery efficiency relationship. This enables the idealized relationship of greater risk transfer leading to improved project delivery efficiency to be modeled.

Chapter 6 defines the objectives of the data collection exercise in order to determine the testing intentions and hence the specific data collection requirements. The sampling and data collection methodology is discussed and the collected data are presented and described.

A series of analyses and statistical tests are carried out to investigate the relationships between the project variables under consideration and the main findings with respect to the risk transfer - project delivery efficiency relationship are discussed.

In the concluding chapter (Chapter 7), the findings of the data analysis are further discussed in relation to their implications for construction procurement in general and for the potential use of the PPP approach for infrastructure procurement in the Estonian context. The limitations of this research and its significance for construction management and economics are then considered. Possible modifications to underlying theory are explored from a design science perspective on theory development. Finally, recommendations for further research are indicated.

2. PUBLIC PRIVATE PARTNERSHIPS

2.1 Overview of Chapter

This chapter describes what is meant by "Public Private Partnership" (PPP). It provides an overview of the historical context in which PPPs emerged, an explanation of the principal justifications for adopting this form of procurement arrangement and its increasing role in Europe to illustrate the current relevance of PPPs to the wider European and the more specific Estonian contexts. The PPP-related literature is then reviewed – first generally and then specifically with regard to the construction-related literature – to outline the context in which this research is positioned. The chapter closes with an explanation of how this research is intended to contribute to both construction-related research and to the wider PPP-research programme.

2.2 What are Public Private Partnerships?

2.2.1 Historical Context

Private sector provision of infrastructure is not a new phenomenon. Klein and Roger (1994) note that railways, canals, roads, gas, power and water systems were all initially privately financed, owned and operated in most countries. The first concessions, for water supply and for the construction of roads, were awarded in England in the 1600s. (Arndt, 2000 p.5-6; Auriol and Picard, 2011) Once infrastructure networks were established, however, the need to impose performance standards and rent limits on the operators of these natural monopolies arose and public authorities began to regulate them. Wars and economic depression in the first half of the 20th century served to further strengthen government control over infrastructure and much of it was nationalized. (Klein and Roger, 1994; Inderst, 2009)

In parallel with increased public control over infrastructure was a tendency towards separating the design, construction and operation functions which had originally been integrated. Operation and construction became disconnected largely as a consequence of the change in ownership. The separation of design from construction is related to the increasing influence of professional institutions (specifically of design professionals – architects and engineers) and was seen as a response to the high incidence of infrastructure-related structural failures which occurred in the late 1800s allegedly due to under-design in the pursuit of profit (by 1875, railway bridge failures were occurring at a rate of about 25 per year in the US alone). (Pietroforte and Miller, 2002)

From the 1970s, disenchantment with the performance of publicly managed infrastructure led again to deregulation and privatisation, suggesting a continuous cycle of private ownership – regulation – nationalization - deregulation. (Klein and Roger, 1994) Pietroforte and Miller (2002) argue that

the segmented procurement and direct public funding of infrastructure projects had led to underinvestment, inefficiencies, a focus on initial delivery only and an inflated public administration.

Public sector reforms (in developing, transitional and developed countries) beginning in the 1980s saw a drive to redress these problems through privatisation and contracting out within the framework that became known as the "new public management" (NPM). (Less charitably, Rhodes (1994) refers to it as the 'hollowing out of the state'). The emergence of the NPM parallels a shift from a Keynesian to a monetarist paradigm and the rise of free market economics. (Larbi, 1999 p.2)

The NPM approach involves the increased use of markets and competition in the provision of public services. It disaggregates public bureaucracies through decentralization, redefines the role and institutional character of the public sector as market- and private sector-oriented and it sees the public sector embracing private sector management practices. (Rhodes, 1994; Larbi, 1999 pp. iv-2; Broadbent and Laughlin, 1999) The new managerialism is reflected in the acronym "3Es"– efficiency, economy, effectiveness and in the key phrase "value for money". (Rhodes, 1994; English and Guthrie, 2003)

Within this context, government programmes to promote the use of private finance in the delivery of infrastructure-based public services emerged as part of wider privatisation strategies - notably in Chile in the 1970s and the United Kingdom in the 1980s - and, by the late 1990s had become an established means of securing private capital and management expertise in infrastructure investment. (IMF, 2004; Estache, 2005; Sadka, 2006)

2.2.2 Defining Public Private Partnerships

The term "Public Private Partnership" (PPP) has been used in reference to a variety of cooperation arrangements relating to a wide range of infrastructure projects. According to Alfen (2010), it was first used in the 1960's in the United States referring to urban development projects which involved private sector participation. While no single, accepted definition of PPPs exists, the attributes which characterize PPPs and the general concepts which underlie PPP arrangements may readily be drawn from the literature. (European Commission, 2003a; IMF, 2004; Price Waterhouse Coopers, 2005 p.12; Renda and Schrefler, 2006)

The terminology used to describe such arrangements varies between countries and organizations. The European Union tends to prefer "Public-Private Partnership" (PPP). (European Commission, 2003a; European Commission, 2003b) In the United States and Canada the terms used include "Public-Private Partnership" and "Public/Private Partnering" and both the abbreviations P3 and PPP are common. (Arndt, 2000; Vining and Boardman, 2008) In the United Kingdom, the term "Public Private Partnership" (PPP) refers to a range of different types of partnership including:

• the Private Finance Initiative (PFI) *"where a private sector partner takes on the responsibility for providing a public service, including maintaining, enhancing or constructing the necessary infrastructure"*;

• introduction of private sector partners as minority or majority shareholders in state-owned businesses;

• the use of private sector expertise and finance to *"exploit the commercial potential of government assets"*. (United Kingdom Government, 2000)

In Australia, the terms "Private Finance" (PF), "Privately Financed Project" (PFP) and "Public Private Partnership" (PPP) apply. (English and Guthrie, 2003; New South Wales Government, 2007) The World Bank refers to this type of arrangement as "Private Participation in Infrastructure" (PPI). (Estache, 2005)

In this monograph, the term Public Private Partnership (PPP), being the most widely recognized, is used in all cases and the other terms (PFI, P3, PFP, PPI) are all considered to be equivalent to it. So that, for example, a definition of PFI or PFP, etc. is accepted as being a relevant definition of PPP and cited literature which specifically refers to any of the terms is deemed to apply to PPPs.

In considering some of the more general PPP definitions from the literature, the centrality of public sector reforms, of infrastructure and of a tendency towards the integration of the design, construction and operation elements for delivering infrastructure-based services are evident:

[PPPs are] *"Partnerships between the public and private sector to construct and operate infrastructure"*. (English and Guthrie, 2003)

"Public-private partnerships (PPPs) refer to arrangements where the private sector supplies infrastructure assets and services that traditionally have been provided by the government". (IMF, 2004)

"PPPs transform ... public sector clients from being owners and operators of infrastructure projects into purchasers of long-term services from the private sector that is responsible for designing, building, financing, and operating the assets." (Zhang, 2005b)

"Public Private Partnership – arrangement where the Public Sector enters into a contract with the private sector to deliver public infrastructure based services where significant upfront capital investment in assets is required." (New South Wales Government, 2007)

A more detailed description of PPPs may be derived by elaborating on the constituent elements of these definitions in turn.

The partnership

The 'partnership' is typically a contractual agreement between a public institution and a private sector commercial entity. (Reagan, 2005) A considerable variety of arrangements have been adopted and these are continuously being developed to suit new project characteristics. (IMF, 2004; European Commission, 2003b p.16) Examples of contractual arrangements which tend to be referred to as PPPs include (in order of increasing private sector responsibility):

- Service contracts
- Operation and management contracts
- Leasing
- Concessions
- Divestiture (both partial and complete)

with "DBFO" concession agreements where the private sector partner is responsible for designing, building, financing and operating the asset for a fixed period of time (typically 15 – 35 years) being the most common. Ownership of the assets is often transferred to the public sector (usually for less than their true residual value) at the end of the concession period. (European Commission, 2003b p.18-25; IMF, 2004; European Commission, 2005; Deloitte, 2006)

At the next level of detail there is an impressive array of more specifically defined types of concession agreements with acronyms like BOO, BOOT, BOT, BLOT, BROT, LOT, LOTS, ROT, etc. (The letters refer to: B-build, O-own or operate, L-lease, R-rehabilitate or refurbish, S-sell, T-transfer). For the purpose of this monograph, it is unnecessary to delve into these. However, it is curious to note that there appears to be considerable disagreement between sources regarding their nature. For example, the European Commission's Guidelines for successful PPPs (European Commission, 2003b p.16) assert that BOT contracts are not concession agreements but are equivalent to "turnkey" arrangements. This interpretation of "turnkey" is at odds with that of most authors on construction procurement including Ireland (1985) and Skitmore and Marsden (1988) who do not consider that such arrangements entail any element of operation whereas BOT certainly does. Arndt (2000) and the IMF Fiscal Affairs Department (2004) both classify BOT arrangements as concessions but are in disagreement with each other regarding other details, for example, the nature of BTO contracts. Finally, both Arndt (2000) and Deloitte (2006) note that there are country differences regarding the interpretation and use of these acronyms.

It should also be noted here that the term 'partnership' may sound attractive particularly to politicians and business leaders and this would tend to lead to a wider application of the PPP label. (For example, Freshfields Bruckhaus Deringer (2005) notes this with regard to PPPs in Austria). Similarly, perhaps in the aftermath of the recent financial crisis, it is conceivable that a change in opinion regarding the perceived attractiveness of 'partnerships' would lead to a rapid decline in the number of PPPs being entered into and could even see some existing PPPs being relabeled.

The role of the public sector

The public sector partner assumes the role of principal purchaser of the PPP deliverables. (European Commission, 2003a) It defines the objectives to be obtained by the PPP in terms of the public interest and monitors and enforces compliance with these objectives. (European Commission, 2004a)

This amounts to increased enabling and regulatory roles for the public sector - firstly to put in place the necessary reforms to allow greater private sector

participation, secondly to ensure that the contracts with private partners reflect the public interest and thirdly to efficiently provide the necessary management and oversight of these contracts. (Montague, 1999) This role differs from the public sector's 'traditional' role and it must be borne in mind that, since only a limited number of projects will be suitable as PPPs, the public sector's capacity to fulfill its 'traditional' role must remain in parallel to this additional capacity. Estache (1999) argues that governments have tended to focus on getting deals done and have typically underestimated the difficulties in successfully fulfilling their additional roles.

Takashima et al (2010) point out that the revenue stream associated with selling the infrastructure-based services is often insufficient to attract private sector financing of potential PPP projects. In order to overcome this, the public sector then provides additional support by way of capital grants, tax incentives, or guarantees. This represents yet another role of the public sector in PPPs – that of co-financer or guarantor.

The public sector roles may also be split between levels of government, for example the public sector client for the services to be delivered and with responsibility for contractual oversight may be a state agency or local authority, whereas central government will typically be the provider of any guarantees (these may relate to the creditworthiness of public agencies or local authorities – for example, Asenova and Beck (2010) comment on the contractual standing of UK local authorities with regard to PPP schemes).

The role of the private sector

The private sector partner is the principal operator - typically financing, designing, constructing and operating an infrastructure asset to meet objectives defined by the public sector. (European Commission, 2003a)

The private sector's involvement is usually organized around a Special Purpose Vehicle (SPV) - a limited liability company specifically set up to carry out the PPP project. The SPV provides the legal and commercial focus for the relationship between the private sector provider and the public sector authority. (UK Audit Commission, 2003 p.52)

The SPV enters into the primary PPP contract with the public partner on one side and matching contracts with suppliers for providing (designing and constructing) the assets and the services (through the operation of the assets) on the other. The intention is to fully transfer the service delivery responsibilities of the primary PPP contract from the SPV to the suppliers. The SPV must pay the asset providers once these have been constructed and the service provider for the services as they are delivered. To fund these, the SPV is primarily debt financed (up to 90% debt with 10% equity is common) with the remaining finance provided in the form of equity by the SPV shareholders. The SPV shareholders are principally the contractors supplying the assets and services but may include other investors. Syndicated bank loans are typical sources of debt. However, bond issues have also been successfully used for financing larger projects. The

SPV pays down the debt, interest and dividends entirely from project revenues which are received from the public sector partner or collected directly from users as the services are delivered. (Palmer, 2000; Spackman, 2002)

Similarly to the multiple roles which are discernible within that of the 'public sector partner', we can also draw a clear distinction between the asset and service provision roles of (some of) the SPV shareholders (dominated by construction-industry businesses) and the main providers of finance (financial institutions and institutional investors).

In addition, legal, financial and technical advisers from the private sector are typically engaged by both public and private 'partners' in the course of setting up a PPP deal. (Edwards et al, 2004)

Infrastructure-based services

Definitions of "infrastructure" tend to be broad and somewhat ambiguous. (Moteff and Parfomak, 2004) Infrastructure assets are commonly categorized according to their physical characteristics into economic infrastructure (relating to, for example, transport networks, utilities, communication, energy, etc.) and social infrastructure (e.g. education, health, prisons, etc.) Financial analysts tend to use the term "infrastructure" to define a particular class of asset and, in doing so, allude to the financial, economic and investment characteristics of infrastructure (e.g. high barriers to entry, inelastic demand for services, stable and predictable cash flows, inflation-linked returns, etc.) (Inderst, 2009)

Post "9/11", consideration of "critical infrastructure" (that ought to be secured against potential terrorist attacks) has seen a broadening of the term to include systems of banking and finance, continuity of government and cyber-based systems. (Moteff and Parfomak, 2004).

In light of this considerable breadth of use, it is arguable that the delivery of any public service relies on the existence of assets and these assets may reasonably be described as "infrastructure". It is in this broad sense that the term "infrastructure" is used in this monograph.

PPPs usually involve the development and operation of infrastructure assets on the basis of an output- or performance-specification prepared by the public sector. (European Commission, 2003b; Hurst and Reeves, 2004) These infrastructure assets are typically in areas characterized by a strong public function, e.g. transport, urban development, security, etc. (European Commission, 2003a) The public sector purchases only the services as they are generated through the asset's operation but enters into a long-term commitment to do so. (Grout, 1997) The public partner may or may not assume ownership of the infrastructure asset itself at the end of the contract period. (IMF, 2004)

The distinction between PPPs and 'traditional' public sector procurement

As already noted in section 2.2.1 above, the historical period in which infrastructure tended to fall within the remit of the public sector spanned most of

the 20th century (being consolidated by about 1930 and remaining largely unchallenged until the 1970s but with considerable variations between different countries) and it still continues in many countries today. It is to this state of affairs that the term 'traditional' is applied here. The quotation marks are retained because, prior to that, the state of affairs that existed bears greater similarity to that which is envisaged under a PPP type arrangement than to the 'traditional' public procurement model. (Pietroforte and Miller, 2002)

Under 'traditional' public procurement the public sector contracts with the private sector to construct an asset, as defined by a detailed specification, which will be owned and controlled by the public sector to provide a flow of public services. (Grout, 1997) The project is funded through public debt which is largely incurred before or during the asset's construction phase. By contrast, PPP arrangements involve the full or partial private financing of the asset's provision and operation (the public sector defining and purchasing only the delivered public services as they occur, as stated above). (European Commission, 2004a) The investment in infrastructure is therefore achieved without immediate recourse to public debt or, at least, with a substantially reduced initial incurrence thereof. (Grout, 1997; European Commission, 2003a; IMF, 2004)

A principal feature of PPPs in comparison to 'traditional' public procurement is that they integrate or "bundle" together the elements of asset construction and asset operation. The benefit of this lies in the potential effect that the quality of design and construction have on operating costs. Provided the services arising from operation can be well-specified and easily verified, then such "bundling" could be advantageous and it provides an incentive for the supplier to consider whole life costs. (Martimort and Pouyet, 2006 p.2; Sadka, 2006; Grimsey and Lewis, 2007)

2.2.3 A Generic PPP Arrangement

The simplified, generic PPP scheme illustrated in Figure 2.1 (below) draws on the generic arrangements of Raisbeck (2009) and Palmer (2000).

Raisbeck (2009) points out that such representations are deceptively simple as they do not capture the complexity of financial instruments and contracts which surround the financing of such projects. As indicated in section 2.2.2 above, they also do not fully reflect the interrelationships between the parties or between the public and private sector involvement.

However, for the purpose of this monograph, a generalised conception of a typical PPP together with an appreciation of the greater complexity of specific projects is sufficient for the development of the thesis.

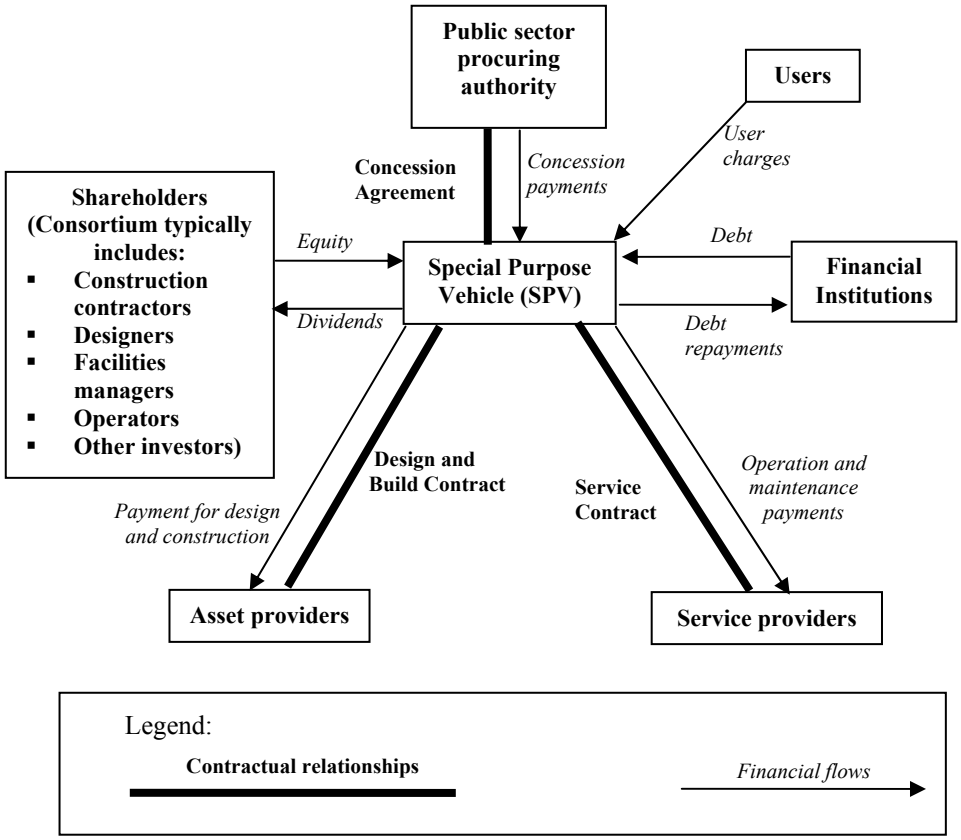

Figure 2.1: Generic PPP Scheme (adapted from Palmer, 2000 and Raisbeck, 2009)

2.3 The Justification for using PPPs

The market-oriented public sector reform context in which the PPP approach arose has already been described in section 2.2.1 and this is reflected in the references to "value for money" and "private sector efficiency" which PPP proponents have made in their arguments for its adoption. A further primary driver of PPP adoption has been budgetary constraints. (European Commission, 2003b p.14)

PPPs are promoted as increasing private sector participation in public service provision which boosts investment in public infrastructure, creates new business and investment opportunities and improves efficiency and value for money while still retaining public sector control. The competitive market environment in which the private sector operates is considered to promote better management and to instill in it a greater capacity to innovate and to take advantage of business opportunities than is possible for the public sector. The private sector's

greater efficiency allows it to provide goods and services of better quality at lower cost. The public sector, on the other hand, represents the public interest and thus is uniquely competent to determine which public services are to be provided and at what cost to the taxpayer. (Montague, 1999; UK Government, 2000; IMF, 2004)

These sentiments have crystallized into two principal justifications for adopting the PPP approach. Edwards et al. (2004 p.17) characterize these as:

1. a macroeconomic argument that:

PPP provides finance for investment which the public sector could not afford. (Broadbent and Laughlin, 2002; European Commission, 2003b; Auriol and Picard, 2011); and,

2. a microeconomic argument that:

PPP projects provide greater value for money than 'traditionally' procured projects. (Montague, 1999; UK Government, 2000; Heald, 2003)

The former, macroeconomic argument has largely been dismissed since the public sector's obligation to pay for the assets and services remains whether this is upfront as direct capital spending as in 'traditional' procurement or later, as the services are delivered, under PPP arrangements. (Grout, 1997; Palmer, 2000; Spackman, 2002; Engel et al, 2008; Vining and Boardman, 2008) However, greater restrictions on public capital expenditure compared to those on future service payments together with public accounting treatment which enables PPP-related payment obligations to be omitted from national debt statistics have provided considerable incentives for the selection of the PPP route ahead of other procurement options. In some cases this has led to PPP being the only procurement option available. (English and Guthrie, 2003; IMF, 2004; Vining and Boardman, 2008; UK Treasury Committee, 2011 p.8-9, p.35; UK Public Accounts Committee, 2011 p.7)

Even the pro-PPP literature seems to have come to accept that a macroeconomic advantage is illusory (at least for developed economies) and the claim that PPP increases investment in public infrastructure tends to be omitted. The second, value for money argument has become dominant. (Institute for Public Policy Research, 2001; European Commission, 2003a p.92; Edwards et al, 2004; European Commission, 2004a; Sadka, 2006)

According to the UK Government (2000), it is the fact that private sector capital is at risk that provides the necessary incentives to invoke the private sector discipline and innovation which leads to greater value for money. In this way, value for money is achieved through risk transfer and the optimal allocation of risk between the public and private sectors. (English and Guthrie, 2003; EC-PPPresource book, 2004 p.9; Pitt et al, 2006)

In transferring risk to the private sector, the public partner seeks to put in place the necessary incentives for the private contractor to perform efficiently but also endeavors to minimize the price of risk bearing by limiting risk transfers to those risks which the private sector is best placed to manage. Thus, the optimal allocation of risk is usually taken to mean allocating each risk to the

party best able to manage it at lowest cost. (EC PPP guidelines, 2003 p.79; Pitt et al, 2006; Irwin, 2007 p.56)

Further complicating the issue of risk allocation, however, has been the central role that the extent of risk transfer (particularly of risks associated with asset ownership) has played in the accounting treatment of PPP schemes. PPP projects have tended not to count towards public debt statistics provided that a minimum level of risk transfer to the private sector has been surpassed and, in some cases, this has been considered to conflict with the pursuit of optimal risk transfer for value for money. (Grout, 1997; Heald, 2003; Edwards et al, 2004; UK Treasury Committee, 2011 p.70)

In this way, risk transfer is central to both the value for money justification for PPPs and to their accounting treatment. But assessments of risk transfer and its pricing have proved controversial – where details of these have been made public, they have often been criticised as attempts to 'fudge' the value for money calculations. (Terry, 1996; Edwards et al, 2004 p.213-215; Hood et al, 2006; Pitt et al, 2006; UK Audit Commission, 2003 p.37; UK Transport Committee, 2008; Khadaroo, 2008) Yet this criticism is often accompanied by calls for greater accuracy under what seems to be a widely held assumption that the extent of risk transfer and a fair price for bearing risk is calculable in some absolute sense. (UK Transport Committee, 2008 p.15-16; UK Public Accounts Committee, 2011)

2.4 PPP projects in Europe

2.4.1 PPPs to 2007

The European Commission can be seen to have embraced the PPP concept and, from 1999, there has been a clear policy to increase the level of private funding in infrastructure procurement. (European Investment Bank, 2005; European Parliament, 2006) In March 2003 it published "Guidelines for Successful Public-Private Partnerships" (European Commission, 2003b) to highlight the benefits that it perceived private sector investment in infrastructure could offer the then Accession Countries with their requirements for improved infrastructure. This was followed up in June 2004 with further guidance in the form of the "Resource Book on PPP Case Studies". (European Commission, 2004b) In the same year, a "Green Paper on Public-Private Partnerships and Community Law on Public Contracts and Concessions" was issued followed by consultation on its contents with stakeholders from member states which concluded in May 2005. (European Commission, 2004a; European Commission, 2005)

In January 2007, the author undertook a desktop survey of the PPP deals which had reached financial close in the member states of the European Union by the beginning of 2007. (The survey refers to the EU-25, it excludes the two states (Romania and Bulgaria) which acceeded to the European Union in 2007. The findings of this survey are shown in Table 2.1 and in Figure 2.2 below.

Table 2.1: Summary of PPP Market Activity in European Union Member States to 2007

Member State	Number of Projects[1] (by January 2007)		Age of PPP Programme[2] (by January 2007)	Institutional Capacity Indicators in Place[3] (by January 2007)	
	In Procurement	Construction / Operation	(approx. nr. of years)	PPP Unit / Taskforce	PPP Legislation in Place[3]
Austria	5	1	3	Yes	No
Belgium	6	1	5	No	No
Cyprus		1	-	No	No
Czech Republic	9	0	2	Yes	No
Denmark	3	0	1	Yes	No
Estonia		2	-	No	No
Finland	1	2	5	No	No
France	18	10	5	Yes	Yes
Germany	20 (approx., phase uncertain)		5	Yes	No
Greece	15 (approx., phase uncertain)		5	Yes	No
Hungary	3	6	15	No	No
Ireland	46	17	10	Yes	Yes
Italy	25 (approx., phase uncertain)		6	Yes	Yes
Latvia	0	0	1	Yes	No
Lithuania	3 (phase uncertain)		1	No	No
Luxemburg		1	-	No	No
Malta	4	4	1	Yes	No
Netherlands	9	4	15	Yes	Yes
Poland		4	15	Yes	Yes
Portugal	6	17	12	Yes	Yes
Slovakia	1		2	No	No
Slovenia		1	1	No	No
Spain	30 (very approximate)		15 (approx.)	No	Yes
Sweden	5 (phase uncertain)		-	No	No
United Kingdom		748	15	Yes	No

[1] Sources: Price Waterhouse Coopers (2005), ASFiNAG (2006), Standard & Poor's (2006), European Urban Knowledge Network (2006), PPP Centrum – Czech Republic (2006), Vestergaard, T. (2005), Burgienė, D., Näslund, V. and Švemberga, A. (2006), Public Private Partnership Task Force – Germany (2006), Timar, A. (1999), Public Private Partnership – Ireland (2006), Kyvelou, S. and Karaiskou, E. (2006), Liepins, A. (2006), Ludviks, A. (2006), Fenech, T. (2005), Freshfields Bruckhaus Deringer (2005), Netherlands – Ministry of Finance (2006), Monteiro, R.S. (2005), Partnerships UK (2006)

[2] Source: UNDP (2004) table updated as appropriate from further sources
[3] Refers to specific PPP legislation, in some member states e.g. United Kingdom, the need for such legislation has not arisen

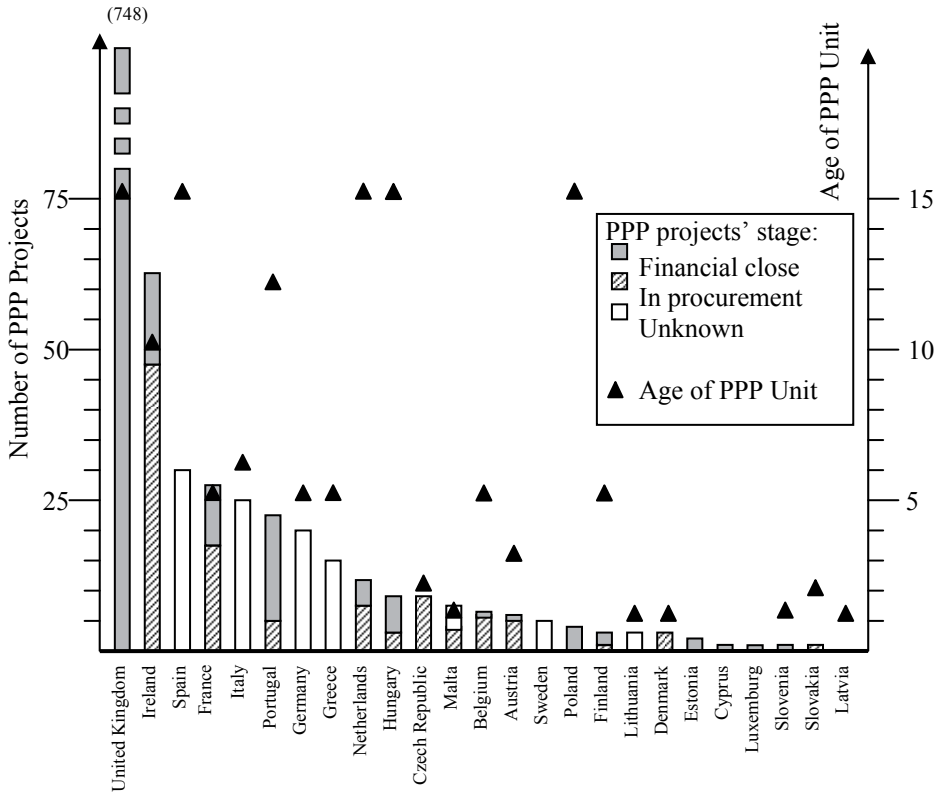

Figure 2.2 – Number of PPP Projects and Age of PPP Units in EU-25 by January 2007

This data was used as the basis for categorising (somewhat crudely) the relative status of PPPs within the member states according to projects in implementation and institutional capacity as follows:

1. Member states with established PPP programmes by January 2007 – where a high proportion of projects were in operation and the number of projects in procurement had stabilized.
    - United Kingdom
    - Ireland
    - Spain
    - Portugal
2. Member states with PPP programmes by January 2007 which were at a stage where the first projects were now operational and where the number of projects in procurement was rapidly increasing.
    - Italy
    - Germany
    - Greece
    - France
3. Member states whose PPP programmes by January 2007 were in their initial stages (few if any projects in an operational phase at that time) but which had political backing primarily evidenced by whether PPP units or task forces had been established:
    - Austria
    - Belgium
    - Czech Republic
    - Denmark
    - Latvia
    - Lithuania
    - Malta
    - Slovakia
    - Slovenia
4. Member states which, by January 2007, had an indeterminate policy with regard to PPPs including both:

i) Member states which had a long-standing PPP programme or had trialed PPPs but where the approach had not been scaled up, including:
    - Netherlands
    - Sweden
    - Finland
    - Poland
    - Luxemburg
    - Hungary

ii) Member states which had little or no PPP experience and no clearly defined national policy on PPPs, including:
    - Cyprus
    - Estonia

It is interesting to note that a similar survey carried out for the European Investment Bank (EIB) also in 2007 (Blanc-Brude et al, 2007) shows slightly

different numbers of projects although the overall relative proportions for each member state are similar. There is considerable scope for differences – firstly within the definition of what constitutes a PPP project in order for it to be counted and secondly the extent to which projects, especially those of local governments, are captured.

In terms of a PPP 'league table', the United Kingdom alone was responsible for about three-quarters of all PPPs in Europe and thus strongly dominated the market. Estonia lay at the opposite end of the scale – the EIB survey denying that any PPPs had been procured in Estonia while the author's survey identified 2 PPPs by this time.

2.4.2 PPPs since 2007

In 2007, the future for PPP procurement appeared to be very bright indeed. However, 2007 turned out to be the global highpoint of the PPP market ($68.6 billion) with the credit crunch reducing that to $55.5 billion by the end of 2009. (Demirag et al, 2011) We still await the effects of the current European sovereign debt crisis on PPPs which may well see further contraction in the market. Yet, it is also instructive to consider these numbers within the historical context, as Klein and Roger (1994) note: *"In the nineteenth century, annual cross-border flows for private infrastructure projects amounted to the equivalent of several hundred billion dollars (adjusting for output growth and inflation)".*

This suggests the potential for private sector infrastructure investment is very large compared to current levels. Though this is very dependent on what exactly is being measured – Inderst (2009) reports an estimate that $100bn - $150bn of fund money had been raised waiting to be placed in suitable infrastructure investments in 2006 and cites Thomson Financial as asserting that the value of infrastructure-related deals exceeded $300bn both in 2006 and 2007.

Fitzgerald and Duffield (2009), Raisbeck (2009), UK Treasury (2009), UK Treasury Committee (2011 p.17) and UK Public Accounts Committee (2011 p.7) all note that the post 'credit crunch' economic conditions have driven up the cost of PPP procurement and made it extremely difficult to secure private finance. Yet Inderst (2009) suggests that it has also seen an increase in investor interest in the infrastructure market and a consequent driving down of returns on infrastructure investments. The United Kingdom government's Treasury Committee (2011 p.18) estimated (by simple comparison) that the higher cost of private capital over the cost of government debt following the credit crunch would make PPP projects 70% more expensive than publicly funded equivalents (everything else being equal). However, assumptions concerning the low cost of government debt may not be reasonable in many European countries following the onset of the more recent sovereign debt crisis. The United Kingdom government's Treasury went so far as to set up a public facility to co-finance PPP projects where insufficient private finance could be sourced. (UK Treasury, 2009) With government intervention in the UK financial sector including the nationalisation and acquisition of public shareholdings in banks, some of which

play substantial roles in financing PPP projects (both with debt and as equity holders in SPVs), the concept of private – public separation has become considerably more opaque. (UK National Audit Office, 2009; UK Treasury, 2010 p.74; UK Public Accounts Committee, 2011 p.Ev39-Ev47) In addition to bank failures, the demise of the monoline insurers has also led to increased public funding of PPPs. (Raisbeck, 2009) In some cases then, the post-2007 PPP has become a remarkably elaborate arrangement for the procurement of public infrastructure with public funds. In this form it seems very unlikely to yield efficiency gains and value for money against more direct forms of public procurement.

It is curious then that the Estonian government is currently (November 2011) considering undertaking its first major national highways PPP – an approximately 200 million euro scheme - apparently because the government could not otherwise afford it! (ERR, 2011; Sorainen, 2011)

2.5 PPP Research

A great deal of the PPP literature has been produced by or for organisations that have a direct stake in the success of the global PPP enterprise. At one end of the scale are those which are actively promoting PPPs as part of furthering their policy agenda - these include the European Union and its institutions, national, state and local governments and their agencies. Notably, the United Kingdom government's Treasury has even been active in advertising the approach beyond the borders of the UK. (Montague, 1999) Influential examples of such literature include Public Private Partnerships – The Governments Approach (UK Gov, 2000) and The European Union's Green Paper on Public-Private Partnerships (EU Green Paper, 2004).

The Bretton Woods institutions (i.e. the International Monetary Fund (IMF) and the World Bank Group) have similarly produced largely pro-PPP publications in line with their support for the PPP approach (for example: PPIAF, 2006; IMF, 2004) However, it should also be noted that the IMF has continuously expressed concern at the accounting treatment of PPPs and their use to circumvent public debt limits. (IMF, 2004)

Consulting accountancy and legal firms which provide advisory services to both public and private sector parties to PPPs have also published widely on PPPs. (Examples include: "Delivering the PPP Promise" (Price Waterhouse Coopers, 2005), "Closing the Infrastructure Gap" (Deloitte, 2006), "PPP in Europe – An Overview" (Freshfields Bruckhaus Deringer, 2005)).

Slightly removed from directly investing in PPP projects are the various public watchdogs which monitor public spending. Examples from the United Kingdom which have extensively reported on PPPs include the National Audit Office (which has produced more than 70 reports relating to the PFI to date) and parliamentary committees (Transport Committee, Public Accounts Committee, Treasury Committee, etc.) These publications do not tend to question the

underlying (pro-PPP) policies but rather investigate their implementation. However, the most recent UK Treasury Committee and Public Accounts Committee reports (UK Treasury Committee (2011) and UK Public Accounts Committee (2011)) have both been strongly critical of the PPP approach. In a similar, investigation-oriented role, the credit-rating agencies (Standard and Poors, Moody's and Fitch) have also contributed to the PPP literature.

While most of the literature from these sources is likely to be fundamentally in favour of the PPP approach (because of their stake in its success) it has made a genuinely useful contribution to academic discussion through its explanatory role of developing the definition and describing the nature of PPPs. It has also had a potentially more dangerous influence on academic debate because the access to first-hand PPP data enjoyed by these sources is considerably better than that of academics. Most PPP data are unavailable to the public – and with-held on the grounds of their commercial sensitivity. (Heald, 2003; Hood et al, 2006; Pitt et al, 2006) The contractual parties to PPPs and their advisers have direct access to data and public watchdogs and parliamentary committees are usually equipped with the necessary powers to obtain the data they desire. Similarly, the credit-ratings agencies are given access to commercially sensitive data in order to rate credit risk. In the absence of such leverage academics have largely had to rely on second-hand data mediated by these sources.

For completeness, it should also be noted that organisations which are largely opposed to the PPP approach do exist and they too produce literature albeit in far smaller quantities than PPP proponents. An example of this is Unison's "Reclaiming the Initiative – Putting the Public Back into PFI" (Unison, 2009).

PPPs bring a number of disciplines together and thus tend to hold some relevance to many fields of research. Arndt (2000 p.2) suggests that economics, law, accounting, engineering and finance are amongst these. The source journals and authorship of individual articles tend to suggest a particular disciplinary perspective and it is with regard to this general affiliation which the literature may be classified as 'economics literature' or 'accounting literature' in the discussion below. However, most of the PPP literature is multidisciplinary by its nature, authors rarely adhere to any strict subject boundaries and their findings tend to be relevant to all other PPP researchers regardless of their disciplines.

Much of the accounting literature is critical of the PPP approach - Pitt et al (2006) note that a 2002 UK survey of 200 chartered accountants found that only 1% of them strongly agreed that PFI provided value for money. To an extent, this reflects the controversy surrounding the accounting treatment of PPPs which has seen the accountancy profession at odds with government departments and divisions within the profession itself (Broadbent and Laughlin, 2002; Heald, 2003). The value for money testing, typically involving comparison with the hypothetical cost of procuring the same project by 'traditional' public-funded means using a Public Sector Comparator (PSC), is also the focus of a great deal of criticism. (e.g. Edwards et al, 2004; Khadaroo, 2008) Asenova and Beck (2010) provide an argument that the PPP approach is primarily driven by a

desire to satisfy private sector investment needs and is not about pragmatic choice between procurement routes.

Economics and finance authors who have also commented on the inadequacy of the PSC calculations include Grout (1997 and 2003), Spackman (2002) and Pitt et al. (2006).

Much of the economics and finance literature may be considered as seeking to inform PPP versus traditional procurement decisions. These include the modelling of residual control rights (Hart et al, 1997), building and operation bundling (Martimort and Pouyet, 2006; Iossa and Martimort, 2008), public accounting rules (Maskin and Tirole, 2007), BOT concessions (Auriol and Picard, 2011) and cost reduction incentives (Hoppe et al, 2011). The findings tend to take the form: if certain conditions exist, then the PPP option / 'traditional' procurement is preferrable. However, Grimsey and Lewis (2007) suggest that the distinction between PPPs and traditional procurement is becoming ever more blurred and irrelevant.

Models of more detailed aspects of PPPs are offered by, for example, Alonso-Conde et al. (2007) and Takashima et al. (2010) with regard to government guarantees and the timing of investment decisions repectively both in a real options framework. However, at this greater level of detail, the research is less relevant to a PPP / 'traditional' procurement decision as the PPP context is already assumed.

The public management literature has also provided commentary on both sides of the PPP debate – for example, Nisar (2007) provides evidence that risk transfer to the private sector has been successful in prison projects while Gaffney and Pollock (1999) and Hellowell and Pollock (2007) find PPPs to be an inefficient form of provision in the health sector.

Hodge and Greve (2009) reflect on the PPP research and conclude that:

"Todays debates over...PPPs are characterised by language games and either loud criticism or gushing praise rather than evidence-based learning and synthesis.... the most optimistic reading of the evidence thus far is that it is mixed.... Much remains to be done to improve the reliability of these findings."

At the broadest level, theory-building with regard to PPPs has been attempted – for example Vining and Boardman (2008) develop a positive theory of PPPs.

2.6 Construction-related PPP Research

A considerable amount of PPP literature has been developed within construction research programmes. The acceptance of PPP as a legitimate topic for research by the construction research community is evident from the establishment of a Task Group on Public Private Partnerships (TG72) by the International Council for Research and Innovation in Building and Construction (CIB) in August 2008 (whose mandate has recently been extended until 2015). (CIB, 2008; CIB, 2012)

That construction research should contribute significantly to our understanding of PPPs follows from the fact that construction costs largely account for PPP capital costs and costs associated with facilities management (which again is generally considered to fall within the remit of construction research) typically make up a significant proportion of PPP operational costs. Financing costs, which are often the most significant costs of PPP projects, make up the majority of the remaining costs. Over and above the costs of finance which the public sector itself would face, these financing costs are justified in terms of risk transfer to the private sector and this risk transfer, in turn, is primarily considered to relate to 'construction risk'. (Edwards et al, 2004 p.95, p.217; UK Public Accounts Committee, 2011 p.8)

Yet, despite the centrality of construction to PPP, there has been little reference to the construction-related literature in non-construction PPP research whereas it is typical for construction researchers to cite PPP literature from outside the field of construction. The few exceptions to this include Edwards et al (2004) who refer to Akintoye et al (1998) with regard to the specific risk analysis techniques in use in PFI projects and Grimsey and Lewis (2007) - research in the area of 'finance' – who draw on both the economics and construction research literature. In addition, construction research (specifically, Merna and Smith, 1999) is often cited in PPP literature when explaining the principles of project risk allocation (e.g. Pitt et al; 2006).

The reason for the apparent lack of interest in construction PPP research beyond the construction field seems to be that PPP research within the construction field tends not to address the broader issues concerning the relative efficiency of the PPP approach compared to that of 'traditional' approaches to infrastructure procurement. (There are some exceptions, e.g. De Lemos et al, 2003) Rather, construction authors tend to consider PPP as one among a range of procurement options and much of the construction research presupposes the decision to adopt PPP and focuses instead on the detailed consideration of specific aspects within the PPP approach with a view to improving the performance of PPP projects – examples include Ranasinghe (1999), Ye and Tiong (2000), Akintoye et al (2003), Zhang (2004a, 2004b, 2005a, 2005b, 2005c, 2006b), Eaton et al (2006), Edkins and Smyth (2006), Kumaraswamy and Anvuur (2008), Moir and Bowles (2010), Grisham and Srinavasan (2009), Ramboutsos and Chiara (2009), Yuan et al (2009), Zhang (2009), Lam et al (2010), Xie and Ng (2010) and Yang et al (2010).

Similarly, the construction literature often focuses on capturing specific lessons learned from PPP implementation - Zhang and Kumaraswamy (2001), Ahadzi and Bowles (2004), Li et al (2005a, 2005b), Jefferies (2006), Zhang (2006a), Lousberg and Wamelink (2007), Liyanage et al (2009) and Adrias (2010) while examples of reports on country-specific PPP adoption issues and experiences include Ismail et al (2009), Kristiansen (2009), Cheung et al (2010) and Khaderi and Aziz (2010).

Most of the above references include a general description of PPPs but there are also construction research papers which focus on describing the approach or a specific aspect of it - Stainback and Donahue (2005), Aziz (2007), Roohé (2007), Alfen (2010), Ismail et al (2010).

Tang et al (2010) provide an overview of PPP-related construction research.

Much of the construction-related PPP research addresses the issue of risk – primarily the specifics of risk allocation and the identification of specific risks. Examples include Arndt (2000), De Lemos et al (2004), Li et al (2005c), Akintoye and Chinyio (2005), Xenidis and Angelides (2005), Thomas et al (2006), Medda (2007), Ng and Loosemore (2007), Jin and Doloi (2008), Roumboutsos and Anagnostopolous (2008), Chan et al (2010), Chung et al (2010), Frank-Jungbecker and Alfen (2010), Jin (2010), Ke et al (2010), Ng et al (2010), Pohle and Girmscheid (2010), Ramboutsos (2010), Wibowo and Mohamed (2010) and Xu et al (2010). It is the author's contention that the interest in risk generated by PPP-related research has been a key driver of the resurgence of risk as a construction research topic in recent years. (This point is made in more detail in Chapter 4 of this monograph).

Probably the most influential construction research in terms of its impact on PPP research beyond the construction field has related to studies of construction costs particularly those comparing PPP with 'traditional' procurement - examples of such studies include Mott MacDonald (2002), Flyvberg et al (2002), Fitzgerald and Duffield (2009), Raisbeck et al (2010). Studies of this nature have been heavily relied on for empirical indications of the value for money performance of PPPs.

2.7 Intended Contribution of this Research

Construction research has a key role to play in the wider debate regarding the efficiency of PPPs because the PPP costs associated directly and indirectly with construction represent a considerable proportion of total cost and therefore impact significantly on overall value for money. Conversely, understanding the relative efficiency of PPPs in delivering construction projects compared to alternative forms of procurement also provides an important research topic for construction management.

The key to the efficiency question is said to lie in risk allocation since the principle justification for PPPs is the assertion that they deliver better value for money than 'traditionally' procured projects and this is achieved through the optimal allocation of risk between the public and private sector partners since the necessary incentives for improved efficiency are enabled by virtue of the private sector's own capital being at risk (as noted in Section 2.3 above). However, this has been hotly debated and there is a lack of empirical evidence to support or refute such assertions. (Hodge and Greve, 2009)

This research sets out to empirically test the influence of risk allocation between the parties to a construction contract on the efficiency of the project's

delivery. By doing this, both the claims of PPP value for money and the effects of risk transfer on project delivery efficiency may be investigated. The empirical data for this research has been obtained solely from the Estonian construction market and is therefore specific to the Estonian context. However, the findings are not only intended to inform future value for money calculations relating to risk allocation in Estonia. They are also seen as an original and timely contribution to the understanding of risk allocation and transfer in the context of construction projects and hence to the PPP value for money debate.

2.8 Chapter Summary and Conclusions

PPPs emerged in the 1990s as an alternative to public debt-funded procurement of infrastructure on the one hand and privatization on the other. As a form of public procurement, they are considered as related to contracting-out / privatization and the private sector- / market-oriented reforms associated with the New Public Management (NPM).

The term 'PPP' applies to a wide and evolving variety of contractual arrangements between public and private sector 'partners' in which infrastructure assets are developed and operated to deliver public services. The role of the public partner typically encompasses that of enabler and principal purchaser of the resulting services. The private sector is the principal operator – typically financing, designing, constructing and operating an infrastructure asset to sell infrastructure-based services (which are defined by the public sector) to the public sector.

The primary justification for adopting the PPP approach is the assertion that, through optimal risk transfer, incentives are put in place to invoke the greater efficiency of the private sector and this leads to better value for money. In this way the issue of risk transfer is central to a consideration of PPP.

The PPP approach has been promoted by the European Union as an infrastructure procurement option and, despite criticism of PPPs (particularly concerning the accounting treatment of the public sector's future liabilities and their value for money calculations) and the effects of financial crises since 2007, PPPs continue to be attractive to public sector clients throughout Europe. Most of the European PPP experience has been gained in the United Kingdom. In contrast, Estonia has little PPP experience and does not seem to have a clearly defined policy towards PPP. However, as the PPP approach apparently begins to lose favour with the United Kingdom government, Estonia appears to be seeking to adopt it to a greater degree.

Much of the PPP literature is generated by public sector institutions and private sector entities which have a direct interest in the success of the PPP enterprise and it is generally, and unsurprisingly, pro-PPP. The academic literature tends to be more critical (particularly that relating to the accounting discipline) but it also fails to convince - there are difficulties with the vagueness of both the terms 'PPP' and 'traditional', the generalized label of all non-PPP

forms of public procurement to which it is typically compared and a need for more empirical evidence.

The construction-related PPP literature provides some of the existing evidence in the form of PPP project construction cost analyses but it is more often focused on specific details of PPP projects – aiming to improve implementation while pre-supposing the choice of procurement arrangement.

This research investigates the relationship between risk allocaion / transfer and the efficiency of project delivery on the basis of empirical evidence obtained from Estonian construction projects. Such an investigation is seen as an original and timely contribution to the understanding of risk allocation in the context of construction projects and hence to the PPP value for money debate.

3. TOWARDS A DESIGN SCIENCE THEORY OF CONSTRUCTION PROCUREMENT

3.1 Overview of Chapter

In Chapter 2 it was established that the principal justification for using PPPs is an argument that optimal risk transfer puts in place incentives which invoke the greater efficiency of the private sector and this leads to better value for money. In this chapter, this argument is refined and the focus is shifted from PPP arrangements to the context of construction procurement in general.

The relationship between risk transfer and project delivery efficiency and its implications for construction procurement are then considered from a design science perspective from which it may be seen as constituting design theory. Methodological implications for this research are thus drawn and the knowledge contribution of the research is then explicitly described within a design science framework.

3.2 Refining the 'Value for Money through Risk Transfer' argument

In Section 2.3, it was argued that the primary justification for pursuing the PPP approach has been that greater value for money is achieved through optimal risk transfer to the private sector. By transferring to the private sector all that risk which the private sector is better placed to manage, the public sector is considered to put in place incentives for the private contractor to perform efficiently. This is intuitively appealing because it apparently aligns responsibilities with rewards (or consequences) but it is also conditional upon several presumptions, including that:

1. a suitable allocation of risk can be determined *ex ante*; and that
2. the intention to transfer risk is effective in practice.

3.2.1 Focusing on the Construction Component

Fulfilling these conditions is simplified if consideration is limited to the construction element of projects. The PPP literature justifies such a focus in that it suggests a general consensus that:

- the risks associated with construction are among the most significant risks to which PPP projects are subject (Akintoye et al, 1998; Edwards et al, 2004 p.95; Ng and Loosemore, 2007; UK Public Accounts Committee, 2011 p.8);
- it is intended to fully transfer construction-related risk to the private sector partner under PPP arrangements (Li et al, 2005c; Aziz, 2007);
- the transfer of construction-related risk in PPP projects is, at least partly, effective in practice. There is considerable evidence supporting the notion that the construction elements of PPP projects have a greater tendency to be

completed within budget (and on time) than 'traditional' projects. (Mott MacDonald, 2002; Pitt et al, 2006; Grimsey and Lewis, 2007; Nisar, 2007; UK Public Accounts Committee, 2011 p.8) Though better performing than 'traditional' projects, risk transfer in terms of out-turn construction cost is not always achieved under PPP arrangements either – the UK government's National Audit Office reports that 35% of PPP projects exceed their contracted price. (UK Public Accounts Committee, 2011 p.25).

However, it should be noted that the extent to which this successful risk transfer amounts to improved value for money is debatable because the construction cost estimates for PPP projects are reportedly substantially higher than for 'traditional' construction projects and they also tend to be made at a time when considerably more detailed design information is available. With regard to European Union highways projects, Blanc-Brude et al (2006) estimate that construction cost estimates are 24% higher for PPP than for 'traditional' projects and Edwards et al (2004) report that the construction costs of the UK PPP road and hospital schemes they surveyed included premiums of 25% and 31% respectively to ensure they finished within budget. (Grimsey and Lewis, 2007; Chung et al, 2010; Hodge and Greve, 2009).

The greater certainty of outcome which arises from risk transfer is generally assumed in the literature to constitute a benefit to the public sector. There are, however, complications in this regard: firstly, the value of this increased certainty is obscure - it relates to the relative risk aversion of the public sector and, from a financial perspective on risk, to how the transferred risks are correlated with overall market risk and with other risks to which the public investment portfolio is exposed. This, in turn, leads into a wider debate regarding the comparative costs of public and private project finance - further consideration of such details is given by, for example, Klein (1996), Grout (1997) and Iossa and Martimort (2008).

Secondly, as indicated in Section 2.2.2, the notion of a singular 'public sector partner' is a construct of convenience. In fact, it comprises numerous stakeholders (typically including government agencies, central government, taxpayers and users) all of whom may hold unique perspectives on the desirability of risk transfer and cost certainty. (For example, Edwards et al, 2004 p.65 refer to cases of PPP projects in which risks have been transferred from the public client organization not to the private sector contractor but to the public as individual users of the procured public facilities.) For the purposes of this research, the convenient consideration of a public sector 'client' and a private sector 'contractor' is maintained but it is also acknowledged that the nature of both public and private sector 'partners' is typically rather more complex.

Finally, a focus on the construction element enables the direct comparison of PPP with any other procurement arrangement which involves construction. Such approaches already have a strong precedence in PPP research in that, simply from necessity, many empirical studies which attempt to compare PPP with non-PPP procurement focus on the construction element as data for this component is

more readily and more quickly available to researchers – Hodge and Greve (2009) note that, of the 25 studies into the efficiency of PPP in their survey, most refer to estimates made before contracts are signed or rely on data relating to the early stages of project life.

3.2.2 PPP in a wider Construction Procurement Context

There has been a tendency to compare PPP procurement with 'traditional' procurement. While this may appear to be a logical response to the introduction of PPP as a new procurement approach and the attendant debate concerning whether or not it is relatively efficient, the vagueness of both 'traditional' and 'PPP' concepts limits the efficacy of such analysis. Hodge and Greve (2009) describe the concept of 'traditional' procurement as "*both horribly vague and largely unquantifiable*". Grimsey and Lewis (2007) note that any distinction between the two has become increasingly blurred as hybrid procurement forms have developed and they suggest (as do several other authors including Arndt, 2000; Smith 2003; Alfen, 2010) that procurement options should be considered in the sense of a procurement continuum rather than from a bipolar (PPP / 'traditional') perspective.

A procurement continuum appears to be largely compatible with the conception of procurement implied by most construction authors in which PPP constitutes one option (or several options) within a wider range of procurement options, as indicated in Section 2.6.

From a construction perspective, the procurement route for a project describes its overall management arrangement. According to Ireland (1985), procurement routes differ in terms of the following variables:

- the roles and relationships of the parties involved,
- the process structure (i.e. the level of integration or 'packaging' of project elements (design, finance, construct, operate, maintain, etc.),
- the basis for selection of contractors,
- the basis for payment of contractors,
- the contractual details.

Procurement route choice for a particular project depends on both:

- project characteristics – for example, the relative importance of time, cost, quality or performance levels, associated uncertainty or risk; and on
- client characteristics – including time and cost requirements, financial possibilities and limitations, expertise, experience and traditions, policies.

Since projects are unique and clients differ, this implies that no single procurement route would be the most suitable choice in all cases (Nahapiet and Nahapiet, 1985). However, we should also note here that this does not necessarily imply a free choice of one procurement route from the complete range of possible routes depending on project and client characteristics. The wider project context tends to greatly influence (and limit) choice - for example, Bowen et al (1999) report considerable client preferences for particular

procurement routes and limited knowledge of alternative options. Political and legislative constraints as well as local procurement traditions may also constrain choice. In this way, the notion of a preferred procurement route for most, if not all, projects cannot be ruled out.

In addition, procurement routes are not accurately definable as a consequence of their many inherent variables, each of which may take any value whereas only a few of these variables are unique to any particular procurement route. Ireland (1985), for example, advocates defining the values taken by each variable in preference to attempting to generalize by adopting overall procurement route descriptions (such as Design-Bid-Build or Build-Own-Operate).

3.2.3 Procurement Route Variables pertinent to Risk Transfer

Some of the variables that 'define' a procurement route are directly relevant to risk transfer, in particular:

1. The degree of 'bundling'; and,
2. The payment mechanism.

The "degree of 'bundling'" refers to the extent to which the contractor is given responsibility for other components of infrastructure procurement (design, finance, operation, maintenance, asset ownership) in addition to the construction component. As procurement routes become more integrated and the responsibility for more elements of project delivery is passed to the contractor, the scope for risk transfer to the private sector (the contractor) increases.

By expressing the procurement process as a sequence of common elements, any procurement arrangement may then be described in terms of who takes responsibility for delivering each element. Since risk factors may be classified in accordance with these same elements and the interfaces between them, the corresponding scope for risk transfer may be determined. Thus, if a package of elements is allocated by a client organization to an external contractor, we might assume that some or all of the risks associated with these elements and the interfaces between them would be best managed by the contractor and the client would therefore be in a position to transfer some or all of these risks to the contractor. Conversely, the transfer of risks associated with a particular element which is not included within the contractor's responsibility would not be efficient. (Witt, 2008)

It is important to note that only the 'scope for risk transfer' may be thus indicated rather than the individual risk factors which are allocated to a particular party as this depends not only on who is responsible for delivering the associated element in question but also the contractual relationship between the parties involved and the effectiveness of this relationship in transferring risk (Smith, 1995). Actually achieving risk transfer to a contractor requires overcoming further constraints including difficulties relating to the definition and quantification of risks and the typical reluctance of contractors to accept transferred risk. (Gao and Handley-Schachler, 2004)

Similarly, as the basis for payment of contractors becomes less input- (or cost-) based and more output- (or price-) based, the contractor is intended to assume greater responsibility for cost variation and the degree of risk transference from client to contractor is expected to increase. (A more detailed discussion of this point is provided by, for example, Bajari and Tadelis, 2001)

In this way, a procurement continuum of the form shown in Figure 3.1 may be considered. The more integrated and output-based the payment mechanism becomes, then, in general, the more risk is transferred to the private sector contractor. (Graphs of a similar form have been provided by Arndt, 2000; Smith 2003; Alfen, 2010 among others showing increased risk transfer with increased 'bundling' while Patterson, 2009 offers an example of a similar relationship between risk transfer and the payment mechanism).

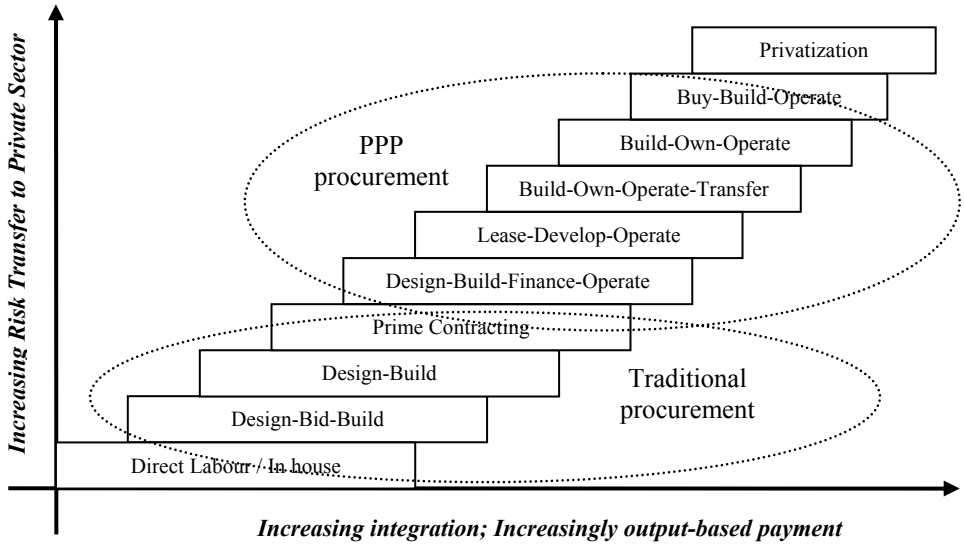

Figure 3.1: Procurement continuum showing the conceptualized "traditional" and PPP procurement regions

In an attempt to portray a sense of scale in terms of increased 'bundling', generalized procurement route descriptors (e.g. 'design-build', 'prime contracting', etc.) have been included. In addition, a notional indication of what might constitute the ranges which could typically be regarded as 'PPP' and 'traditional' procurement are superimposed on these and, in acknowledging their vagueness, these regions are shown as overlapping. The degree of output-based payment does not necessarily correspond fully with such a representation, but, in a general sense, PPPs would typically be both highly integrated and entail an extreme form of output-based payment (the basis for payment tending to be the price of the services arising from the operation of the capital assets) and

'traditional' forms would tend to be less integrated and have more input-based payment mechanisms.

Importantly, Figure 3.1 does represent a general conception of (construction) procurement in terms of risk transfer from client to contractor which both avoids the vague categorization into PPP / 'traditional' and also sets PPP projects within the context of all construction projects.

Such a conception enables findings from all forms of construction projects to be related to PPP projects and vice versa. This is of particular relevance to the Estonian context of this research because, in Estonia, PPP projects are extremely rare in comparison to non-PPP projects. It is also notable that, on a scale of risk transfer, PPP projects occupy a range which is not entirely at one end but is rather bounded on either side by more common construction procurement arrangements. While 'traditional' projects tend to be on the lower end of the risk transfer scale, construction projects where both contractor and client are the same private sector entity (that is, construction projects undertaken on a contractor's own account) retain all the risk associated with the project (though it is, of course, not *transferred* from a public sector client). In this way, such projects represent complete 'allocation' of risk to the private sector.

The resulting conceptual framework provides not only the possibility to contribute to the PPP debate but also for a consideration of one of the fundamental issues of construction procurement in general – *the relationship between risk transfer and value for money*.

However, the notion of 'value for money' with regard to constructed infrastructure assets typically extends over a broader conception of asset performance than is determinable from a consideration of the construction phase alone. The United Kingdom government's Treasury, which has been particularly influential in promoting PPPs and insisting upon a 'value for money' justification for their employment, defines their value for money as: *"the optimum combination of whole life cost and quality (or fitness for purpose) to meet the user's requirement"* UK National Audit Office (2007). To differentiate between this wider sense of value for money and a construction phase-specific consideration of value for money, (construction) 'project delivery efficiency' is adopted as the appropriate equivalent. Thus, the central relationship of interest in this research may be rephrased as that between *risk transfer and project delivery efficiency*.

3.3 A Design Science perspective on Construction Procurement

The risk transfer – project delivery efficiency relationship both underpins the justification for the PPP approach and is also a central concept for construction procurement in general. If the project context is idealized as consisting of a 'client' who seeks to benefit from the realization of the project and its agent, a 'contractor' who carries out the construction works (and, perhaps, additional

functions) for the client, then, with respect to the construction component of the project, this relationship may be expressed as:

The greater the transfer of (construction) risk from the client to the contractor then the greater the efficiency of (construction) project delivery (all else being equal).

Koskela (2008) and Voordijk (2009) both argue that construction management may be conveniently characterized as a design science. Van Aken (2007) defines *design science* as the: *"body of knowledge of a particular discipline on designs and design methods".* A design being *"a representation, a model of an entity to be realized and intended as an instruction for the next step in the creation process".*

The design science paradigm is generally cited as having emerged from Simon's seminal work *The Sciences of the Artificial* although Koskela (2008) argues that its roots lie in Aristotle's science of production. It draws fundamental distinctions between knowledge in relation to nature (the natural sciences), to society (the social sciences) and to man-made objects. The defining characteristics of design science are its focus on the derivation of interventions and systems for the solution of field problems (as opposed to the natural and social sciences' focus on explanation). (Hevner et al, 2004; van Aken, 2007; Koskela, 2008)

Knowledge-intensive design is at the heart of engineering, architecture and, indeed, all construction-related disciplines. They are fundamentally concerned with the design of solutions and the realization of these in physical and / or social 'reality'. Design 'craft' is combined with *design science* – the "*valid procedural knowledge concerning how to design solutions for field problems in a professional way".* (van Aken, 2007) Yet the explanatory sciences still have an important role in terms of providing the requisite knowledge inputs for understanding the phenomena which the design embodies and the physical and social contexts in which it is to be realized. (Voordijk, 2009)

According to Hevner et al (2004), these natural and social science inputs take the form of supporting 'kernel' theories which are then "*applied, tested, modified, and extended"* by the design science researcher in order to develop the knowledge base for design. "*The goal of* [explanatory] *science research is truth. The goal of design science research is utility... truth and utility are inseparable....Truth informs design and utility informs theory."* Hevner et al (2004)

Within the design science paradigm, *design theories* and *technological rules* are approximately equivalent. (Koskela, 2008) Voordijk (2009) suggests that these are the typical research products of the design sciences just as causal models are for the explanatory sciences.

Venable (2006) asserts that theorizing and theory building are central to all the principal activities of design science research as shown in Figure 3.2. Walls et al (1992) note 7 characteristics of design theories as follows - design theories:

1. *are goal-oriented*
2. *do not involve pure explanation or pure prediction*
3. *are prescriptive*
4. *are composite theories which encompass kernel theories from natural science, social science and mathematics.*
5. *tell us "how to / because" (as opposed to "what is"- explanatory theories, or "what will be"- predictive theories, or "what should be" – normative theories)*
6. *show how explanatory, predictive, or normative theories can be put to practical use*
7. *prescribe both the properties which an artifact is to exhibit and the process of artifact construction*

Venable (2006) contends that an appropriate form for a design theory is a utility theory which makes the assertion that: *"a meta-design (e.g. a particular type of technology or approach) has utility in solving or improving a problematic situation."*

It is immediately apparent that our earlier statement of the relationship between risk transfer and project delivery efficiency with regard to construction procurement closely corresponds to these descriptions of design theories in that:

- the determination of a suitable procurement arrangement for a construction project may be considered as a design process;
- goal-orientation is obvious – the purpose is clearly intended to be improved project delivery efficiency;
- the relationship is prescriptive – it prescribes maximizing (construction) risk transfer;
- kernel theories are apparent, for example, in relation to the understanding of 'risk' and the efficiency of project delivery and are applied in pursuing the given goal.

However, there is certainly an element of prediction though this is not 'pure' in that the stated relationship predicts relative to a particular instance of construction procurement (i.e. a singular construction procurement artifact). The relationship also contains little information regarding the properties of a successfully designed construction procurement artifact nor any indication of the process by which the construction procurement arrangement comes about. It follows that while the stated relationship certainly contributes to a design theory of construction procurement, it does not fully satisfy the requirements for such a design theory in the sense that it informs rather than entirely enables construction procurement arrangements to be designed.

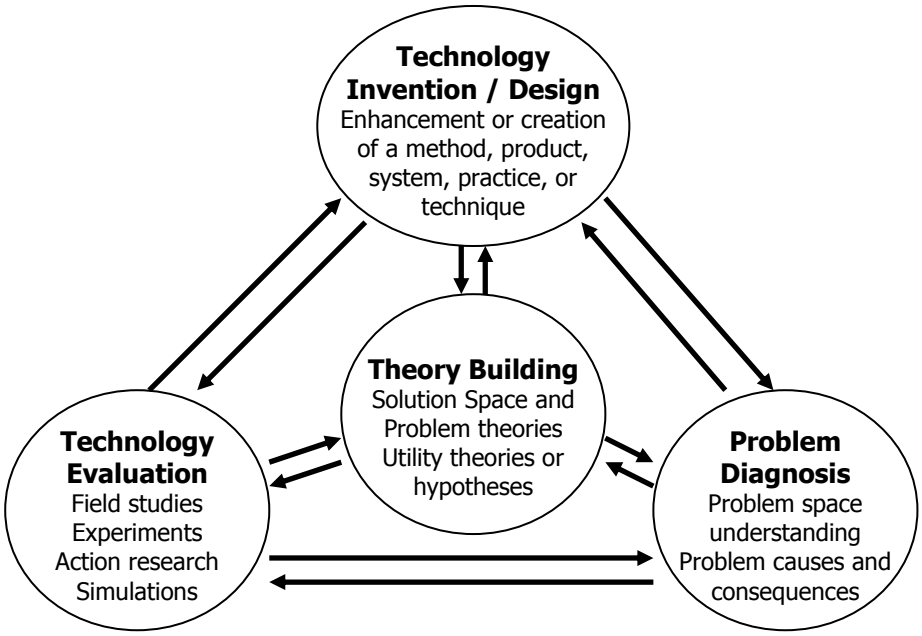

Figure 3.2: Depiction of an Activity Framework for Design Science Research
Source: Venable (2006)

Kuechler and Vaishnavi (2008) reflect a similar notion in their illustration of the logical relations between prescription and explanation in the design process with their inclusion of 'mid-range' theories which span the explanatory 'kernel' theories and highly prescriptive design theories. (The original version of this diagram is attributed to Goldkhul (2004)). This is shown in Figure 3.3.

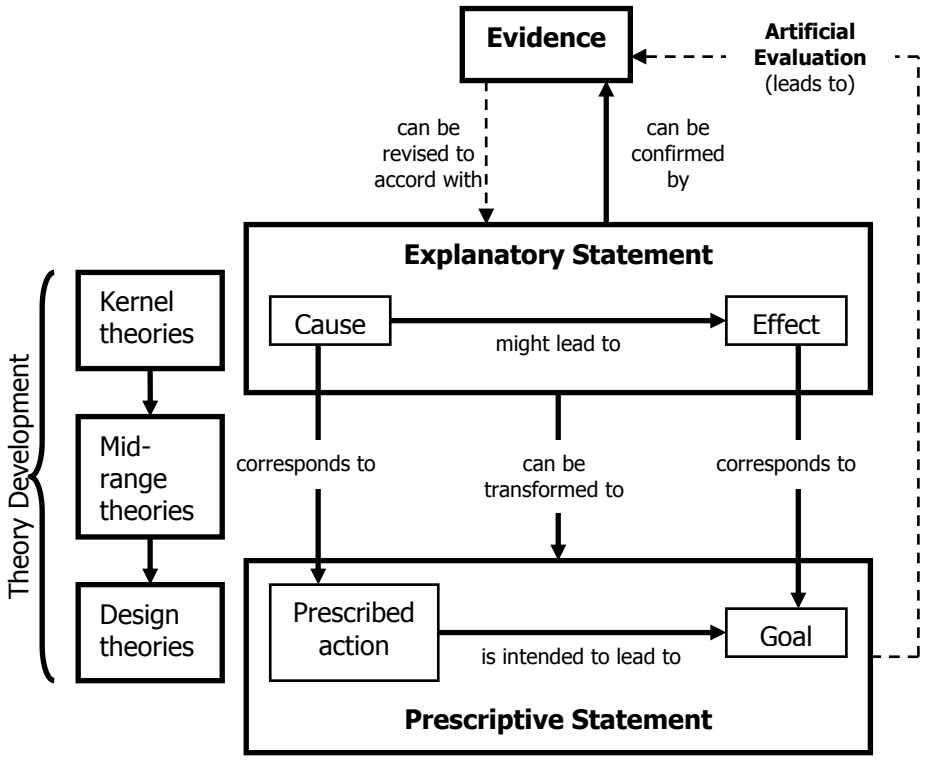

Figure 3.3: Theory Development in the Design Process
Source: Kuechler and Vaishnavi (2008)

Within this framework, theory development and, hence, contribution to the underlying knowledge base which supports construction procurement (designs), occurs in the process of the design of artifacts (construction procurement arrangements). Subsequent to their realization (in the form of procured construction projects), artifacts may be evaluated and the evidence arising from this evaluation (and from the design process) serves to refine the kernel theories as well as the mid-range and, ultimately, the highly prescriptive design theories.

Specifically considering this research within the design science process suggested here, the starting point may be thought of as the relationship between risk transfer and project delivery efficiency. As discussed above, this relationship resembles (mid-range) design theory and it rests upon kernel theories, for example, one of which would relate to an understanding of the nature of 'risk'. The evaluation of artifacts (i.e. procured construction projects)

provides the evidence for the verification or modification of the kernel and design theories.

It is also notable that it was indeed the evaluation of such artifacts which led to the generalization of this risk transfer – project delivery efficiency relationship in the first place. Thus, we return to the iteration of truth informing design and utility informing theory from Hevner et al (2004).

3.4 Methodological Implications

If the relationship between risk transfer and project delivery efficiency is taken to constitute (mid-range) design theory which serves to inform the design of procurement arrangements for construction projects, then the design science framework indicates that the utility of this relationship and its underlying kernel theories may be tested through the evaluation of the designed artifacts (procured construction projects). Such evaluation would also provide evidence in relation to the supporting kernel theories and thus the possibility of testing and/or modifying them.

In the author's view, it seems that, whether or not the specific kernel or design theories under scrutiny were actually employed in the design of the evaluated artifacts is immaterial. The evaluation would still yield evidence pertinent to the validity of the kernel theories and/or utility of the design theories under consideration.

What is specifically called for in order to verify, modify or otherwise inform the given relationship on the basis of artifact evaluation is a means of measuring both risk transfer and project delivery efficiency in procured construction projects. It is apparent that a measure of risk transfer will assume a particular conception of 'risk' – whatever that conception, it will provide supporting kernel theory to the design theory.

From this point, the method for proceeding with this research is clear:

1. the determination of a means of measuring / evaluating risk transfer and project delivery efficiency in procured construction projects;
2. the collection of data for undertaking the evaluation;
3. carrying out the evaluation (data analysis in accordance with the determined means of evaluation);
4. interpreting the evidence arising from the evaluation to reflect on the kernel and design theories under consideration;
5. theory development - verifying and/or making recommendations to modify the theories in light of the evidence obtained.

3.5 Chapter Summary and Conclusions

The PPP literature justifies a focus on the construction component of infrastructure procurement and this serves to both simplify the quantification of risk transfer and also enables the consideration of PPP procurement within the context of construction procurement in general. This raises the possibility of an investigation which potentially informs both the debate concerning the relative efficiency of PPPs and contributes to the underlying body of knowledge which is drawn on for solving construction procurement field problems.

The key relationship under investigation is that greater (construction) risk transfer from a client to a contractor leads to greater (construction) project delivery (when all else is equal). Construction-related research corresponds well with a design science paradigm and, from this perspective, the identified relationship resembles design theory. By considering it as such, the theory-building potential of this research is clarified and its contribution to the construction management body of knowledge is made explicit.

The adoption of a design science approach carries methodological implications in that it suggests iteration along a loop of:

design theory -> design process -> evaluation of design artifacts -> verify / modify design theory

is a legitimate, scientific approach to theory development. A design theory to subject to testing (the risk transfer – project delivery efficiency relationship) has been identified in this chapter. It may be considered that the design process is embodied within all historically procured construction projects so that these constitute the artifacts which should be evaluated in order to determine the validity or otherwise of the design theory. An appropriate basis for evaluation (i.e. the measurement of risk transfer and project delivery efficiency) must now be determined before historical project data can be collected and analyzed to provide the evidence towards theory verification and/or development.

However, the concept of 'risk' is vague and this challenges the validity of an attempt to measure risk transfer. The next chapter, Chapter 4, is therefore dedicated to investigating the conception of risk so that an appropriate measure of risk transfer may be determined. The means of evaluation is established in Chapter 5. Chapter 6 describes the data set and data analyses which constitute the evaluation of design artifacts. Chapter 7 concludes with the implications of the evidence derived from the evaluation both for the development of the design theory and for the wider issue of the use of PPP procurement in the Estonian context.

4. THE CONCEPTION OF RISK

4.1 Overview of Chapter

In order to investigate the relationship that greater (construction) risk transfer from a client to a contractor leads to greater (construction) project delivery efficiency, the term 'risk transfer' must be defined with respect to the construction project context to the extent that its measurement is made possible. This requires an explicit and robust understanding of the risk concept appropriate to construction projects.

Therefore, this chapter's purpose is to establish a conception of risk with particular relevance to the construction project context which enables risk transfer to be understood and measured. An historical overview is taken to capture the main ideas from probability theory, insurance, economics and finance since the notions of risk from all of these disciplines inform the construction industry's conceptions of risk. Emphasis is given to revealing the diversity of opinions regarding the conception of risk within and between these fields of knowledge. The construction literature on risk is then critically reviewed before an attempt is made to draw together principal aspects into a generalized conception of risk in projects.

The focus is on the nature of risk and does not extend to the considerable volume of literature associated with dealing with risk (whether risk management or decision-making under uncertainty).

4.2 General Conceptions of Risk

4.2.1 Multiple Definitions

The term 'risk' has numerous meanings and connotations in its contemporary usage. Dictionary definitions include:

1. *a hazard or dangerous chance* (Webster's Encyclopedic Unabridged Dictionary of the English Language, 1989)
2. *the possibility of financial loss* (Oxford Dictionary of English, 2003)
3. *the possibility that something unpleasant or unwelcome will happen* (Oxford Dictionary of English, 2003)
4. *exposure to mischance or peril* (Oxford English Dictionary, 1989)
5. *In relation to insurance contracts (a) the hazard or chance of loss; (b) the degree of probability of such loss; and (c) the amount that the insurance company may lose* (Webster's Encyclopedic Unabridged Dictionary of the English Language, 1989)
6. *the chance that is accepted in economic enterprise and considered the source of (an entrepreneur's) profit.* (Oxford English Dictionary, 1989)

'Risk' may thus variously describe:

(a) that which has the potential to cause harm or loss {1},

(b) the possibility (or chance or probability) that the loss (or injury or unpleasant / unwelcome consequence) will occur {2, 3, 5a, 5b},

(c) the (personal or financial) exposure to such a possibility {4} as well as,

(d) the loss itself {5c (though note that this is the loss to the insurance company)}.

(e) In addition, 'risk' may have positive connotations in the sense of suggesting profit or gain {6}.

Dowie (1999) argues that the *"multiple, confusing and ambiguous usages"* are an impediment to decision-making and the term should be abandoned. Kaplan (1997) suggests that each author define it in their own way - but appeals to them to make clear what 'way' that is. However, he also notes that the Society for Risk Analysis formed a committee to define the word 'risk' and, having deliberated for four years, finally gave up and reported that it may be better not to define risk.

4.2.2 Origins and Significance

Controversy regarding the term might be considered to 'begin' with disagreement concerning its origins. One view suggests that the concept of risk arose in the early modern era and signifies the emancipation of society from fatalism. Examples include Bernstein (1996):

"The revolutionary idea that defines the boundary between modern times and the past is the mastery of risk: the notion that the future is more than a whim of the gods and that men and women are not passive before nature."

Giddens (1999):

"Life in the Middle Ages was hazardous; but there was no notion of risk and there doesn't seem in fact to be a notion of risk in any traditional culture. The reason for this is that dangers are experienced as given. Either they come from God, or they come simply from a world which one takes for granted. The idea of risk is bound up with the aspiration to control and particularly with the idea of controlling the future."

Luhmann (1993 p.8-9):

"Older civilizations...had no need for a word covering what we now understand by the term risk. Mankind had naturally always been preoccupied by uncertainty about the future....Thus the term 'risk' first appears in the transitional period between the late Middle Ages and the early modern era."

Alternative views include those of Beck (1992):

"risks are not an invention of modernity. Anyone who set out to discover new countries and continents – like Columbus – certainly accepted 'risks'."

and Covello and Mumpower (1985) who argue that problems involving risk have been dealt with since ancient times *"often in a sophisticated and quantitative way"* .

It is conceivable that much of the basis for this apparent divergence in views can be attributed to differences in the authors' specific conceptions of risk. Note in the above quotations that Giddens differentiates between 'risk' and 'hazard' and Luhmann between 'risk' and 'uncertainty'. Does Beck mean by 'acceptance of risk' something altogether different to what Bernstein refers to as 'mastery of risk'? Appreciation of the contexts from which these quotations are drawn is also pertinent, particularly in light of recent events – Bernstein's *Against the Gods*, an 'ode' to the 'titans of Wall Street' and their 'mastery of risk', rings somewhat hollow after the global financial crisis of recent years. Beck's *Risk Society*, and the consternation it expresses at the extent to which mankind has become increasingly exposed to perils consequent to a short-sighted pursuit of economic objectives, gains credence from the 2011 Fukushima nuclear disaster:

"Sciences rationality claim to be able to investigate objectively the hazardousness of a risk permanently refutes itself. It is based, firstly, on a house of cards of speculative assumptions, and moves exclusively in a framework of ***probability statements****, whose prognoses of safety cannot even be refuted, strictly speaking, by* ***actual*** *accidents."* (Beck 1992) (Emphases are shown as in the original text).

Whereas Beck's notion of risk is purely negative, Bernstein's risk is positively brimming with opportunities.

4.3 Risk in Probability Theory

Whether the concept was or wasn't in its infancy, the emergence of the mathematical theory of probability in the 17th century saw many of the foremost Western intellectuals engaged in the consideration and mathematical treatment of situations where the outcome was not certain (Todhunter, 1865 p.619-620 gives a chronological list of these) and most of the tools and concepts which find employment in risk analysis today were developed as part of probability theory between 1650 and 1800. (Covello and Mumpower, 1985)

Covello and Mumpower (1985) indicate that prior to this time religious sensitivities provided a strong disincentive to openly speculate on future events. They cite Grier (B. Grier, *The Early History of the Theory of the Management of Risk* – paper presented at the Judgement and Decision Making Group Meeting, Philadelphia, Pennsylvania, 1981) as suggesting that the preconditions for the development of probability theory lay in a 16th century change in the Catholic Church's definition of usury so that the charging of interest on loans became permissible provided that the lender incurred risk. And that, although this decision was, decades later, rescinded, risk had by then become a legitimate topic for discussion.

If speculating as to the outcomes of future events touched on religious sensitivities, then the framework in which most probability problems were considered – games of chance and, particularly, gambling – had the potential to give rise to moral issues. It is notable that a considerable contribution to the seminal work on probability is associated with a religious institution, the Abbey of Port Royal – the recluses (usually considered to be Arnauld and Nicole) of which wrote *Logic* (Port Royal, 1693 transl.) and where Pascal became a recluse in 1655. (Boutroux, 1902 transl.) Further, of the most eminent of the earliest contributors to the theory of probability, Galileo, Kepler and Pascal had some of their publications banned by the Catholic Church. (Index Librorum Prohibitorum, 1758) Yet, it appears that it was not their work on the mathematics of probability that caused friction with the religious authorities, but rather their other intellectual pursuits. In the case of Pascal, it is his *Pensées* which appears in the Index Librorum Prohibitorum (Index Librorum Prohibitorum, 1758) and which is largely concerned with his thoughts on religion, rather than his correspondence with Fermat (published mainly in Fermat's *Varia Opera Mathematica*) which established the theory of probability. (Todhunter, 1865 p.8) So that, whereas the religious authorities at the time of the 'birth' of the mathematical theory of probability may indeed be seen to be intolerant to challenges to the official views, it does not appear that the mathematical theory of probability *per se* induced much ire.

Moral sensitivities are evident in the literature to a small degree, for example, De Moivre, writing in 1756, begins the second edition of his treatise with a letter to his patron explaining that his work is not intended to promote gambling. (De Moivre, 1756) But, in general, the 18th century works in this field indicate neither religious nor moral scruples regarding their subject. (Examples include D. Bernoulli, 1738; T. Bayes, 1763 and De Moivre, 1756 (with the exception of the preface to the second edition)).

4.3.1 Conception of Risk in the Mathematical Theory of Probability

Pascal's famous 'wager', with which he convinces himself of the rationality of accepting the existence of God, succinctly combines both religious and moral themes and gives insight into his understanding of the concept of 'risk':

"In this hazard, as in every other, there are two things to be considered: the degree of probability and the amount of risk. The question of the existence of God being infinitely beyond the scope of reason, the probability is the same for the affirmative as for the negative. This term then is cancelled. There remains the risk. On the one hand there is the finite to be ventured, on the other hand the infinite to be gained. Now, however great may be the finite, it becomes as nothing before the infinite. Strictly speaking then, it becomes a question of venturing the infinitely little in order to gain the infinitely great. Hence we are clearly bound to wager in favour of the existence of God. The reasoning is conclusive. If I am capable of discerning any truth, this is one". (Boutroux, 1902 transl. p.70)

Thus Pascal's 'risk' in this passage is clearly not probability or likelihood. It is a function of the potential loss and the potential gain - but the information given is insufficient to confirm precisely what function this is. Of particular interest in this description is the allusion to the Principle of Indifference. That is, because he considers the question of the existence of God to be beyond the scope of reason, (i.e. he is in perfect ignorance) he accords the same probability to God's existing as to God's not existing.

So, Pascal's risk = f{A, B}
where A = potential gain
B = potential loss

The wager or action may then be advantageously taken if A>B (given equal probability of both).

De Moivre defines risk in the context of games of chance thus *"the risk of losing any sum is the reverse of expectation; and the true measure of it is, the product of the sum adventured multiplied by the probability of the loss*". (De Moivre, 1756 p.4)

With the same notation, this would be:
(Mathematical) Expectation = pA;

De Moivre's risk = qB
where q = the probability of loss = 1-p
and B = the sum which is potentially lost, i.e. the stake.

De Moivre goes on to show that a wager or action is advantageous to take provided that mathematical Expectation (pA) exceeds Risk (qB). (De Moivre, 1756 p.4-5)

Laplace uses the term differently again, *"there is a moral advantage in distributing the risks of a benefit which one expects over several of its parts. Thus in order to send a sum of money to a distant part it is much better to send it on several vessels than to expose it on one."* Here the context is not a game of chance but rather an activity with an expectation which might not be fulfilled. The term 'risk' is used in the sense of "exposure to the possibility of loss" (Laplace, 1902 transl. p.154)

In the notation we have adopted, Laplace's risk = q

Keynes, in his *Treatise on Probability*, gives the following definition of risk:
(the notation is the same as in the examples above)

"If A is the amount of good which may result, p its probability (p + q = 1), and E the value of the 'mathematical expectation,' so that E=pA, then the 'risk' is R,

where R=p(A-E) = p(1-p)A = pqA = qE

This may be put in another way: E measures the net immediate sacrifice which should be made in the hope of obtaining A; q is the probability that this sacrifice will be made in vain ; so that qE is the ' risk.'" (Keynes, 1921 p.315)

Which gives Keyne's risk = qE

In the first case, it is evident that, in a precise sense:

Pascal's risk ≠ De Moivre's risk ≠ Laplace's risk ≠ Keynes' risk

and it is reasonable to conclude from this that the conception of risk within the mathematical theory of probability literature is somewhat confused.

However, there appears to be a problem with Keynes' conception of risk given above. It seems to the author that, in his last statement (of the quotation from his *Treatise on Probability* given above), Keynes highlights an error in his formula:

If E really does measure *'the net immediate sacrifice which should be made in the hope of obtaining A'* then:

$E \neq pA$

rather, the quantity E ('mathematical expectation' in our notation) should be replaced with B defined (as above) as the sum which is potentially lost, i.e. the stake.

It would follow that Keynes' result would, in fact, be risk = qB which is the same as De Moivre's and we would have precise agreement between the two authors who specifically attempted to define 'risk'. (It should be noted here that Keynes was fully aware of De Moivre's work and that, in deriving his expression for risk, he clearly considered that it was something which had not been done previously.)

In light of this we can revisit Laplace's statement and show that, since the context is not one of a game of chance with a stake as such, then the 'benefit' he refers to is in fact the sum which is potentially lost (i.e. 'benefit' = B) and the magnitude of the risk (now in the same sense as Keynes and De Moivre use the term, not simply the degree of exposure to (= probability of) loss (= q)) in question is again qB (the probability of the loss multiplied by the magnitude of the loss). Likewise Pascal's wager involves the comparison of A with B given the probability of both being equal. This is also compatible with risk = qB, since the comparison could as well be expressed as:

pA compared to qB

where pA is the mathematical expectation and, again, qB is the risk.

We could therefore conclude that, from the literature on the mathematical theory of probability, there arises a generally acceptable mathematical probability conception of risk which is:

Risk = qB
or:
(Mathematical Theory of Probability) Risk = the product of the magnitude of the potential loss and the probability that this loss will occur and we may fairly attribute this definition to De Moivre.

Pascal and De Moivre suggest that the decision to participate in a game or to take a particular action is rational where mathematical expectation exceeds risk, i.e:

pA > qB

This is illustrated in a second reference to Pascal's wager where there is no specific mention of 'risk' but there is a clear expression of a basis for rational choice under conditions of uncertainty: *"In every wager, there are two things to be considered: the number of the chances, and the importance of the gain or loss. Our reason for choosing this or that side is expressed by the product of these two factors."* (Boutroux, 1902 transl. p.183; De Moivre, 1756 p.5)

4.3.2 Mathematical Expectation - an Insufficient Basis for Decisions

However, as soon as probability theory is applied in a social context, the notion of rational choice on the basis of mathematical expectation (i.e. pA > qB) can be seen to be insufficient. This is elegantly illustrated by the *Petersburg problem* which was posed to the mathematician Montmort by Nicolas Bernoulli thus:

Peter tosses a coin and continues to do so until 'heads' appears. He agrees to give Paul one ducat if the coin lands on 'heads' at the first throw, two ducats if 'heads' appears at the second throw, four ducats if 'heads' appears at the third throw and so on. What is the value of Paul's expectation?

The paradox being that, although the mathematical expectation (pA) is infinite, common sense tells us that Paul would only stake a small amount to participate in this game. (Todhunter, 1865 p.133-134; Bernoulli, 1738)

Daniel Bernoulli (cousin of Nicolas Bernoulli) proposed a Theory of Moral Expectation in suggesting a solution to the Petersburg problem. In his 1738 paper *Exposition of a New Theory on the Measurement of Risk* he points out that consideration of the value of a risky proposition by reference only to its terms (i.e. the expected value (mathematical expectation) and, by implication, the risk in the manner shown above) is insufficient. The value or *utility* of the proposition to the particular person who is deciding whether or not to participate is also relevant. This 'utility' or 'moral expectation' depends on the particular circumstances of the individual in question. (Bernoulli, 1738)

Daniel Bernoulli's proposal, which is notable as the first expression of the concept of the diminishing marginal utility of money (according to Keynes), indicates that the value of a given sum to a particular person is inversely proportional to the sum which that person already possesses and it therefore implies that people are risk averse, i.e. a given sum lost carries a larger value than the same sum gained. In terms of the Petersburg problem, it shows that the utility or 'moral expectation' of Paul (under Bernoulli's specific assumptions regarding his utility function) and therefore the amount which he would reasonably stake on such a game is rather small (approximately 3 ducats if he possessed 10 ducats, 4 if he possessed 100 ducats and 6 if he possessed 1000 ducats). (Bernoulli, 1738) Keynes argues that this solution (together with Cramer's which is also a utility-based solution which pre-dates Bernoulli's but is less sophisticated) is only partially satisfactory as it is the great *risk* of the game which deters Paul from staking an infinite or even a large, finite sum. Yet these solutions ignore risk and concentrate only on the utility of the mathematical expectation. Numerically, Daniel Bernoulli's suggestions for Paul's stake give the probability of losing something as ¾ if Paul stakes 3 or 4 ducats and 7/8 if he stakes 6 ducats. Keynes suggests that the paradox could be resolved through the development of the theory of risk. He argues that ethical calculation demands that the high risk be taken account of. (Keynes, 1921 p.318-319) Contemporary authors concerned with the sociology of risk, particularly Beck, have greatly elaborated on the implications of this point. (Beck, 1992; Luhmann, 1993)

With this we have a first insight into the complexity of practical problems involving risk - in order to be practical, they must extend beyond the risky proposition itself into the social domain. Then consideration must be given to the social context of the stakeholders to whom the risky propositions pertain. In that context, their values to any given stakeholder depend on the particular circumstances of that stakeholder. In addition, we must appreciate that risk and its acceptance or the 'taking' of it has an ethical dimension.

4.3.3 Risk and Ethics

The ethical aspect of risk comes particularly to the fore when the (mathematical) theory of probability finds application to human conduct. It should be noted here that, whereas the typical framework for a discussion of probability, for convenience, is a game of chance, from the outset the authors who developed the theory were giving consideration to the many applications of their discoveries beyond games. So that, even in the earliest references, applications to practical problems included general life choices (Port Royal, 1693 transl. p.474) and the mathematics of life expectancy, annuities and life insurance. (Todhunter, 1865 p.37-43) Further examples of attempts at application include problems of astronomy (Todhunter, 1865 p.222 – 227) and problems of disease, notably Laplace's calculation of the impact on mean life expectancy that the elimination of small-pox would effect. (Todhunter, 1865 p.602)

The application of probability theory to conduct is recommended in the Port Royal Logic: *"that we may judge what is fit to be done, to obtain the good and avoid the evil, we ought not only consider the good and evil in itself; but also the probability whether it may happen or not and geometrically to consider the proportion which the things holds* [sic] *together"*. (Port Royal, 1693 transl. p.476)

Keynes notes that a number of difficulties arise when probability theory and, in particular, a 'mathematical expectation' approach (*"we ought so to act as to make the sum of the goodness of each of the possible consequences of our action multiplied by its probability a maximum")* is applied to conduct. These include:

1. that risk is ignored;
2. the assumption that degrees of goodness are numerically measurable and arithmetically additive;
3. the assumption that degrees of probability are numerically measurable and arithmetically additive;
4. that the weight of evidence on which each of the probabilities are founded is ignored. (Keynes, 1921 p.307-323)

That risk is ignored under a mathematical expectation approach has already been referred to above with regard to Daniel Bernoulli's proposed solution to the Petersburg problem. If we accept Bernoulli's assertion that the value of a sum of money to a person varies in inverse proportion to the amount of money that the person already possesses, then, Keynes suggests, it may well be true that the value of goodness varies in a similar fashion and that the undesirability of risk might increase more than in proportion to its uncertainty. (Keynes, 1921 p.313-320) The modern work relating to the observed violations of expected utility theory, particularly that of Tversky and Kahneman, appears to bear out these doubts. (Tversky and Kahneman, 1986)

4.3.4 The Meaning of Probability

The remaining two difficulties relate to the meaning of 'probability'. It is widely held that this is a subject of intense disagreement between one group who consider probability in terms of degree of belief and another who have adopted a much narrower statistical frequency interpretation (for discussions of this point see, for example, Arrow, 1951; De Finetti, 1974. Additionally, Kaplan, 1997 includes a further type of 'traditional' meaning (a conception of probability as a mathematical abstraction independent of what it stands for) and also a series of 'new' meanings together with their corresponding groups of followers). The former arises from a philosophical consideration of probability as a branch of Logic, the second expresses probability in purely algebraic terms. A cursory investigation from the point of view of the conception of risk in a construction project context reveals that the wider, logical meaning should be adopted and this does not appear to be incompatible with the mathematical manipulation of probabilities quantified. In contrast, the adoption of the narrower, purely

quantified meaning renders the result inapplicable to most real-life situations where a singular proposition is under consideration.

The notion that probability is first and foremost a branch of Logic is attributed to Leibniz. (Keynes, 1921 p.v; Leibniz, 1890 transl. p.55). Probability relates to knowledge – Butler, in his *Analogy*, observes from a deterministic stance that, to an infinite intelligence, nothing which is the possible object of knowledge would be probable since it would be known with certainty. *"But, to us, probability is the very guide of life"*. (Butler, 1860 transl. p.84) Jevons argues the same point: only infinite knowledge would provide certainty. Infinite knowledge is beyond us, so we must contend with partial knowledge and, therefore, the realm of probability. (Jevons, 1900 p.197)

De Morgan defines probability thus: *"by degree of probability we really mean, or ought to mean, degree of belief"*. (De Morgan, 1847 p.172) Jevons objects to the term *belief* on the grounds that it is no less obscure than *probability*, preferring to relate probability to the *quantity of knowledge* and he suggests that probability theory *"defines rational expectation by measuring the comparative amounts of knowledge and ignorance, and teaches us to regulate our actions with regard to future events in a way which will, in the long run, lead to the least disappointment"*. (Jevons, 1900 p.199-200) Noting here that the stated intentions of probability theory (regarding rational expectation with respect to the future) are very closely aligned to those associated with a modern consideration of risk.

Keynes' articulation is particularly clear: *"The terms 'certain' and 'probable' describe the various degrees of rational belief about a proposition which different amounts of knowledge authorise us to entertain. All propositions are true or false, but the knowledge we have of them depends on our circumstances"*. He uses the term 'rational belief' here in order to distinguish between mere belief (which may be irrational) and belief based upon evidence. To Keynes, *knowledge* corresponds to the highest degree of rational belief or *certain* rational belief in a proposition and, therefore, to the proposition being true. So that Keynes accepts degrees of belief but not degrees of knowledge. He makes the further point that, in referring to propositions as being certain or probable, this does not refer to the propositions themselves but strictly pertains to the relationship between a proposition and a corpus of knowledge concerning it and that: *"A proposition is capable at the same time of varying degrees of this relationship, depending upon the knowledge to which it is related"*. So that the probability of a proposition is *subjective* in the sense that it is relative to a given corpus of knowledge but probability is not subject to *"human caprice"* – *"a proposition is not probable because we think it so'*. Given the facts that make up the corpus of knowledge concerning it, the probability of a proposition is fixed *objectively*. (Keynes, p.3-10) Kaplan adopts a very similar stance and suggests that *"probability is that degree of credibility or confidence dictated by the evidence"*. (Kaplan 1997)

By way of comparison, a purely algebraic formulation of probability is offered by De Moivre: *"if we constitute a Fraction whereof the Numerator be the number of Chances whereby an Event may happen, and the Denominator the number of all the Chances whereby it may either happen or fail, that Fraction will be a proper designation of the Probability".* (De Moivre, p.1)

Venn suggests an alternative, 'material' view of probability – referring to laws of things - to contrast with what he terms the 'formal' or 'conceptualist' viewpoint (which, according to Venn, refers to laws of thought) as, for example, proposed by De Morgan. (Venn, 1888 p.ix-x) His definition of probability is based on the conception of a series of events. This series is composed of two classes - the indefinitely numerous class of (all) events and, within this, a smaller class of events which happen in a particular way so that the probability of an event happening in a particular way is: *"the numerical fraction which represents the proportion between the two different classes in the long run".* (Venn, 1888 p.162-163)

Although such 'frequency' definitions often purport to provide entirely objective conceptions of probability they also confine probability to being an abstraction useful only in the realm of mathematical manipulation. Any practical application would require supporting assumptions such as, for example:

- the validity of the so-called Law of Large Numbers – so that even if a series were not exhaustive, it would at least tend to the 'true' probability if it represented an adequately large sample (note the reference to "in the long run" in Venn's definition above);
- that an historically observed ratio of happenings to total trials would be maintained into the future;
- fair coin or fair die type assumptions – by which we would imply that we were in a state of perfect ignorance regarding any preference for the coin or die to fall upon any given face;

and these would reduce the 'objectivity' of the probability to precisely the same level as that of Keynes' definition derived from logic so that probability would still be relative to a (limited) corpus of knowledge. Arrow (1951) notes that the von Neumann – Morgenstern theorem (i.e. "Game Theory") gives rise to the same conclusion: "any definition of probability leads to a degree-of-belief interpretation".

De Finetti (1974) argues that a 'frequency' interpretation of probability cannot be 'objective' on the grounds that any probability must refer to a single, well-specified event (or, more accurately, proposition). 'Frequencies' may only enter the framework of analysis where events of known outcomes have, subjectively, been deemed by the analyst to be (more or less) similar to the proposition under consideration.

Referring once again to the difficulties Keynes identified in the application of probability theory to conduct, the 3rd and 4th difficulties are now clear: with regard to the 4th difficulty, that the weight of evidence on which each of the probabilities are founded is ignored, it may as well be that a great deal of

evidence or a very small amount of evidence supports a particular, rational belief and it is the consideration of this which is typically ignored in a mathematical expectation approach.

In consideration of Keynes' 3rd point regarding the assumption that degrees of probability are numerically measurable and arithmetically additive, a mathematical treatment of probability requires that stringent conditions regarding scale and independence of probabilities as well as their numerical measurability be met. Alternatives exist to the scale of probabilities (typically referred to as 'Pascalian') in which 1 designates certainty and 0, impossibility (according to Keynes (Keynes, 1921 p.155) this scale was, in fact, first introduced by Leibniz). Coleman (2001) notes that Baconian probability uses an altogether different lower bound of non-provability on a scale which is ordinate but not mathematical in the sense of the Pascalian model. It is worthwhile to point out here that a contemporary debate between the merits of differing approaches to the weighing of uncertain evidence within the legal process has emerged (see, for example, Jackson 1996) and consideration of a Baconian probability scale in a construction project risk analysis context has also attracted interest. (An example is Mak (1995) with regard to his fuzzy sets theory approach to risk analysis. Yet it is unclear from his paper how or, indeed, if he actually adopts a Baconian scale in his (fuzzy logic) treatment of risk and whether his consequent conceptions of 'likelihood' and 'risk' differ from interpretations which follow a Pascalian model.)

4.3.5 Inverse Probability and Bayes' Result

Probability theory thus provides us with a conception of 'risk' as "*the product of the magnitude of the potential loss and the probability that this loss will occur"* and an understanding of 'probability' as the degree of rational belief in a proposition relative to a corpus of knowledge concerning that proposition. So that, in order to accord a magnitude or value to a given instance of risk, the derivation of a value of probability in relation to a given corpus of knowledge is required. This has been referred to as the problem of 'inverse probability' i.e. *"questions respecting the probability of causes as deduced from observed events"* (Todhunter, 1865 p.475) or, as Jevons puts it (somewhat inaccurately): *"the grand object of seeking to estimate the probability of future events from past experience"* (Jevons, 1900, p.261). Whereas many of the mathematicians associated with the theory of probability concerned themselves with problems of this nature – both James and Daniel Bernoulli, De Moivre, Condorcet, Laplace – it was the work of Thomas Bayes' which first set down explicit rules for the calculation of inverse probabilities. (Jevons, 1900 p.261, Keynes, 1921 p.174)

Bayes' result specifically refers to estimating the probabilities of the causes of compound events from their observed outcomes (Bayes, 1763; Todhunter, 1865 p.290) and follows directly from the more fundamental principles of probability (de Finetti, 1974; Keynes, 1921 p.175). In essence, it provides a method for modifying prior probabilities in the light of additional evidence or information.

De Finetti distinguishes between *Bayesian techniques* – which he notes have been developed into 'imposing mathematical machinery' and which are often applied in a standardized format without due regard for the specific features of the case in question and the opinions of the person making the underlying judgments – and what he refers to as the *Bayesian standpoint.* The latter referring to the conception of probabilities as relating to degrees of belief supported by evidence and subject to modification (in accordance with Bayes' theorem) as further evidence is obtained – which, in de Finetti's view, amounts to the logical framework for the theory of probabilistic inference (de Finetti, 1974). In Kaplan's words, Bayes' theorem is *"the fundamental law governing the evaluation of evidence"*. (Kaplan, 1997)

The principal objection to Bayes' method for modifying prior probabilities based on further evidence lies in the legitimacy of the prior probabilities themselves which are often assumed on the basis of the principle of indifference. (Keynes, 1921 p.182) Mak (1995) notes 3 further objections to the practical use of Bayes' theorem:

1. assumptions of mutual exclusivity, exhaustive hypotheses and conditional independence of evidence seldom hold in practice;
2. an inability to distinguish ignorance from uncertainty (this is similar to Keynes' 4th objection to the application of probability to conduct noted in section 4.3.3 above)
3. the single degree of belief output is expressed as a point estimate (the output is more accurately expressed in terms of a probability distribution function (see, for example, Kaplan, 1997) but this does not overcome the more fundamental issue of justifying action on the basis of probability rather than certainty.)

From the perspective of this investigation into the conception of risk, it is rather the widespread adoption of the Bayesian standpoint in approaching problems involving risk (Kaplan, 1997; Arrow, 1951; Mak, 1995) than the detailed application of Bayesian techniques to specific problems (and their limitations) that is of interest. It affords us the opportunity to summarise the principal features of probability as fundamental to a conception of risk, if not in the unanimous view of all authors on the subject (I refer specifically to those who hold a 'frequency' interpretation of probability as discussed above) then at least in agreement with some of the foremost authorities in the field of applied probability (such as Arrow, de Finetti and Keynes) as follows:

- Probability relates to the degree of rational belief in a proposition relative to a given corpus of knowledge.
- This is a subjective measure of probability in the sense that the probability of a proposition can vary depending on the knowledge to which it is related and, thus, different stakeholders may legitimately assess the same proposition to have different probabilities because the knowledge from which they draw

their conclusions differs. (Yet this measure of probability is objective in the sense that it objectively follows from any particular corpus of knowledge).

- As additional information or evidence becomes available, the corpus of knowledge changes and the probability (i.e. the rational degree of belief in the truth) of a proposition should be modified.

4.4 Risk in Insurance

Todhunter notes that investigations into mortality and life insurance were underway by the late-17th century by Graunt, van Hudden, de Witt and Halley. (Todhunter, 1865 p.37-41) So that, in an historical sense, insurance developed in parallel with probability theory.

An insurance perspective on the conception of risk is pertinent since there is a well-defined and generally accepted meaning of 'risk' in an actuarial sense and the importance of risk measurement and the concepts of 'risk bearing', 'compensation for bearing risk' and 'risk transfer' are particularly obvious and well-defined in an insurance context. In addition, the insurance-related academic literature, especially that from the 1960s, is a rich source of information regarding debate about the meaning of the term 'risk'. This owes to a surge in interest in 'risk management' at that time leading to a proliferation of university courses dealing with 'risk management', the associated creation of a risk management function in many commercial enterprises and attempts by insurance academics to provide a coherent conception of risk to underpin this new application while still holding for 'risk' in a traditional, insurance sense. (Crowe and Horn, 1967; Denenberg and Ferrari, 1966; Rennie, 1961)

A specific parallel to what the author notes in the construction-related literature of today (see section 4.7 below) is the lack of agreement on a definition of risk and, more worryingly, even when authors specifically define what they mean by risk, they then do not consistently adhere to their own definition. (Crowe and Horn, 1967)

Before considering the broader interpretations of risk intended by insurance academics, to embrace risk beyond insurance, it is instructive to summarise what constitutes 'insurable risk'. Bunni (2003, p.189) notes that not all risks are insurable and that, to be insurable, the following limitations need to be satisfied:

1. the insured event must be fortuitous;
2. an insurable risk should be quantitatively measurable ("*in such a way that the theory of probability and the law of large numbers may be used*");
3. the objects insured must be adequately numerous and homogenous for sufficient selection;
4. the extent of loss and the cause of damage must be assessable.

Risk in this sense is considered from the *insurer's* perspective rather than the individual's and, from this point of view, in some cases (i.e. for 'insurable risks') a 'frequency' interpretation of probability appears more applicable in that the

context is one of large numbers of repetitions of a relatively well-defined type of event.

Denenberg and Ferrari (1966) refer to *"actuarial risk theory"* as being *"concerned with the variability of an insurer's pure premium distribution"* and therefore *"not directly applicable to an individual's decisions"*.

Borch (1967) suggests that the actuarial theory of risk was developed and remained largely independent of the theory of probability and mathematical statistics because insurance was one of the only practical applications of probability for many years and actuaries saw their results as solutions to insurance problems while outsiders found it difficult to use these results as they were obscured by the jargon of insurance terms. Keynes (1921 p.22) expresses a lower opinion of the ability of insurance practitioners to evaluate risk pointing out that *"it is sufficient for the underwriter if the premium he names **exceeds** the probable risk"*.

Yet, even if actuarial risk theory is not readily applicable to the conduct of individuals or one-off events for that matter, the underlying conception of 'risk' which it relates to is of importance to our discussion and Borch provides insight into this. He notes that while *"the foundation of insurance is the Law of Large Numbers"*, the number of insurance contracts within any actual insurance company's portfolio is not so 'large' that deviation from the expected (long run) outcome value can be neglected. (It could similarly be argued that, even if an insurance company did hold an infinite number of contracts and the Law of Large Numbers was valid, deviation would still be expected to occur within any particular, discreet time period). The actuarial theory of risk is concerned with the analysis of these deviations and, specifically, the derivation of the 'probability of ruin' for the insurance company on the basis of the portfolio of insurance contracts including reinsurance contracts it holds. Borch suggests that the theory can be traced back to an early definition of risk which he attributes to Tetens (in a paper of 1786) and which refers to *"the expected loss to the insurance company if the insurance contract leads to a loss"*. According to Borch, Tetens formally defined risk as *"one half of the mean deviation"* but this definition has been obsolete from the mid-20th century as 'mean deviation' has been replaced by 'standard deviation' for convenience. 'Risk' in this sense is a measure of the (expected) deviation or variance from the expected value (of net income to the insurance company). (Borch , 1967)

A number of insurance authors (including Ratcliffe, 1963; Denenberg and Ferrari, 1966; Crowe and Horn, 1967) emphasize the difference between the established and consistent definition of risk arising from actuarial risk theory (as above) representing the traditional, insurance company's perspective on risk and a more general conception of 'risk as uncertainty' associated with the rise of 'risk management' and attempts to broaden the concept to embrace the conduct of individuals and firms in situations involving risk. The resolution of this discrepancy has been proposed in various ways and these proposals give rise to several conceptions of the underlying 'nature of risk'.

To Denenberg and Ferrari (1966), the central issue lies in the clarification of *whose* risk is under consideration. If it is an insurer's risk, then this is readily quantifiable and (re)insurance reduces risk through the pooling process (i.e. the Law of Large Numbers applies). Conversely, if an individual's risk is under consideration, subjective and psychological factors are of greater importance and insurance is a 'risk transfer device'. They object to defining risk as uncertainty on the grounds that this emphasizes the subjective and psychological aspects of risk over its objective and quantifiable properties and it ignores the role of increased knowledge as a risk reduction measure.

In this way a definition of risk as uncertainty is incompatible with a decision theory conception of risk as well as with actuarial risk theory and is inferior to both. They suggest that, if a more general conception of risk is to be advanced from an insurance perspective, then it would be more appropriately based upon risk as variability from expectation: *"utilizing the relative dispersion of actual from expected results, or the probability that actual results will differ from expectations"*. In a separate passage from the same article, they refer to risk as being simply, *"the difference between actual and expected outcomes"*. (Denenberg and Ferrari, 1966)

Athearn (1971) reaches a similar conclusion: *"the nature of risk is best understood in terms of expectations...it is worthwhile to bring this out in the definition of risk because it reveals the relationship between risk theory and decision theory"*.

Ratcliffe (1963) also objects to the 'risk as uncertainty' conception but resolves this by differentiating between 'subjective uncertainty' and 'objectified uncertainty'. He defines 'subjective uncertainty' (with a quotation from p.7 of Pfeffer's *Insurance and Economic Theory*) as:

"a state of mind relative to a specific fact situation. It reflects the state of a person's knowledge, his feelings, and his strength of conviction about any given matter. [Subjective] *Uncertainty varies from person to person and for any given person, from time to time."*

'Objectified uncertainty', on the other hand, is 'risk' according to Ratcliffe who recommends that it should be defined as follows:

"Risk is the possibility that actual results may differ from predicted average results."

Most interestingly from Ratcliffe's discussion of risk is his explanation of the implications of the Law of Large Numbers – that the *"degree of risk varies only with the number of exposure units"*- so that, where there is only one exposure (i.e. with regard to a one-off event), then the degree of risk is 100% and, as the number of exposures becomes large, so the actual results approach the predicted average results and the degree of risk tends towards zero. (Ratcliffe, 1963) Here we have an interpretation of risk which encompasses both the perspective of the individual and that of the insurer.

Crowe and Horn (1967) similarly cannot accept the equating of risk to uncertainty. Their objections lie in uncertainty being a state of mind and, thus,

subjective (similar to Ratcliffe's 'subjective uncertainty') whereas they consider risk to be primarily an objective phenomenon. They propose a definition of risk as:

"the possibility that a sentient entity will incur loss". They consider 'possibility' to capture the essence of risk in that it conveys *"the idea that something can happen, but not go beyond this point to suggest either that there are necessarily degrees of risk or that risk can be measured"*.

The inconsistency of such sentiments with the traditional, actuarial perspective on the measurability of risk is obvious but Carlson (1963) objects to the imprecision of the term 'possibility' (specifically with reference to Ratcliffe's proposed definition) since, in rolling a die, for example, there is *certainty* that the actual result will differ from the average. Similarly, with regard to the Crowe and Horn definition, in a life insurance context for example, death, and therefore loss, is certain rather than possible.

Consideration of the insurance literature also highlights the use of risk classifications in guiding the determination of approaches to dealing with risk (i.e. the 'management' of risk). A classification into 'insurable' and 'uninsurable' risk has already been noted above. A similar distinction is that of 'pure' risk (which may lead only to loss) versus 'speculative' risk (which may lead to loss or gain) with the former mostly being efficiently insurable. (Denenberg and Ferrari, 1966) However, Athearn argues that any deviation from expectation may be construed as a loss, whether directly or indirectly as in an opportunity cost sense. (Athearn, 1971)

Finally, the notion of an additional (risk) premium for bearing risk must be mentioned. If the net insurance premium is understood to equate to the insured parties' average expected loss (with additions for the insurer's overhead costs and profit), it is thus independent of risk (as defined in an actuarial sense). As stated above, since the Law of Large Numbers only partially applies due to the limited number of similar contracts the insurer holds and within a bounded time-frame then, the pooling of risk will be expected to reduce but not fully eliminate risk. According to Borch (1967), (historically) *"There seems to have been a vague feeling that some amount, proportional to the risk, should be added to the net premium as a "safety loading", but this was first explicitly suggested by Wold (in 1936)."* It follows that, where risk is transferred from one party to another, a 'risk premium' should be paid in compensation for risk-bearing. And that this 'risk premium' is separate from and should not be confused with the 'pure premium' which refers only to the average expected loss (plus the insurer's overhead costs and profit).

In summary, the insurance literature indicates a fundamental difference between 'risk' in an actuarial sense – where it specifically relates to an insurer's probability of ruin – and 'risk' in a general sense, where it relates to individuals' decisions and actions. However, there is common ground between these senses of 'risk' and this lies in their both being relative to expectations. This gives rise to

a general conception of risk as relating to the variance of actual outcomes from expected ones.

4.5 Risk in Economics

The importance of inclusion of the economics and finance literature to our discussion relates primarily to the consideration of risk with respect to profit (or return) but it also serves to draw together within the context of commercial activity many of the threads already discussed. Adam Smith provides an appropriate starting point in his Wealth of Nations.

In the first place, Smith's conception of risk is strongly associated with insurance. He considers the 'real value of a risk' to be equal to the 'common premium' payable to an insurer to insure the risk in question. Where the 'common premium' *"must be sufficient to cover the common losses, to pay the expense of management, and to afford such a profit as might have been drawn from an equal capital employed in any common trade."* (Smith, 1776 p.103)

Smith's 'common premium' is precisely equivalent to the term 'pure premium' employed above but his reference to this as the 'real value of risk' appears naive since it does not consider the differences between risk to the insured and risk to the insurer in the fashion of Ratcliffe (1963) or Denenberg and Ferrari (1966). In further discussion of this point however, Smith (1776 p.104-105) refines his position. He notes that a 'great company' or 'great merchant' with many (20 to 30) ships might be better off retaining 'sea risk' as: *"The premium saved upon them all, may more than compensate such losses as they are likely to meet with in the common course of chances."* He also considers that the widespread neglect of insuring shipping as well as the great majority of people failing to insure their houses against fire (in his day) is rather reflective of a 'presumptuous contempt of risk' than any insightful calculations on their part. He thus indicates his appreciation that the value of risk varies according to the particular circumstances of the parties concerned. (Though it does seem unlikely that an insurance company (even in the 1700s) would hold so few policies and be diversified and reinsured to such a minimal extent that it could be advantageous for a company or merchant with only 20 to 30 ships to opt for self-insurance especially given Smith's insistence that profit margins for insurers were not high.)

Smith also provides us with insight into the relationship of risk to profit: *"The ordinary rate of profit rises more or less with the risk. It does not, however, seem to rise in proportion to it, or so as to compensate it completely. Bankruptcies are most frequent in the most hazardous trades."*(Smith, 1776 p.106)

Exactly what Smith means by 'risk' is undefined but the context of this passage suggests an equivalence of the term 'risk' to 'uncertainty of returns' and also to 'hazardousness' of trades.

Smith ascribes what he sees as incomplete compensation for risk to unreasonable optimism: *"The chance of gain is by every man more or less overvalued, and the chance of loss is by most men undervalued"*. This irrational belief in the success of their enterprises draws so many to risky commercial ventures that *"their competition reduces their profit below what is sufficient to compensate the risk."* (Smith p. 103-106)

It is with regard to precisely this interrelationship of competition, profit and risk that Knight's famous contribution to the conception of risk is made. Knight firstly argues that competition tends to eliminate profits and bring the value of economic goods into equality with their cost. But, in practice, this is only a tendency with precise equality rarely achieved. The difference between perfect and actual competition results in a margin of profit which may be either positive or negative. (Knight, 1921 p.18-20)

In agreement with Smith, Knight draws attention to the irrationally high confidence that most individuals have in their personal abilities and good fortune, the greater tendency to such traits among entrepreneurs than the population at large and the additional stimulation of competition in suggesting that the available evidence indicates, albeit inconclusively, that profits are, in aggregate, negative.

Knight also objects to the characterization of profit as a reward or inducement for risk-taking because of the temporal dislocation of the decision to engage in a venture from its outcome: it is the *expectation of profit* rather than *actual profit* which induces the entrepreneur to engage. (Knight, 1921 p.361-366)

Yet it is for the differentiation between 'uncertainty' and 'risk' that Knight's work is most often cited. He argues that:

"The term "risk," as loosely used in everyday speech and in economic discussion, really covers two things... in some cases a quantity susceptible of measurement, while at other times it is something distinctly not of this character". (Knight, 1921 p.19-20)

The former meaning ('measurable uncertainty') he designates *"risk proper"* and he states that this *"is so far different from an **unmeasurable** [quantity] that it is not in effect an uncertainty at all"*. Knight asserts that the 'uncertainty' associated with 'risk proper' can be eliminated through grouping or consolidation of instances of exposure since the distribution of the outcome in a group of instances is known (either by *a priori* calculation or statistics from past experience) and thus 'risk proper' cannot *"prevent the complete realization of the tendencies of competitive forces, or give rise to profit"*. (Knight, 1921 p.20-21 and p.233-234)

The second, non-quantitative meaning, he refers to as *"true uncertainty"* and *"It is this "true" uncertainty, and not risk, as has been argued, which forms the basis of a valid theory of profit and accounts for the divergence between actual and theoretical competition."* (Knight, 1921 p.20)

He associates 'risk proper' and 'true uncertainty' with 'objective probability' and 'subjective probability' respectively. (Knight, 1921 p.233) This distinction may appear to imply a 'frequency' or 'Law of Large Numbers' conception of probability but this would be a gross oversimplification of Knight's stance since, when he discusses the practical considerations of his distinction, he reveals a far more nuanced rendering in which uncertainty reflects a state of knowledge:

"It is a world of change in which we live, and a world of uncertainty. We live only by knowing something about the future; while the problems of life, or of conduct at least, arise from the fact that we know so little....The action of the situation is action according to opinion, of greater or less foundation and value, neither entire ignorance nor complete and perfect information, but partial knowledge."(Knight, 1921 p.199)

But, in embracing the more complex and nuanced position with regard to the nature of uncertainty, he undermines his own clear distinction between 'risk proper' and 'true uncertainty'. The impression he leaves is that of a continuum between these two extremes with neither being met in practice and with limited practical applicability in business:

"The conception of an objectively measurable probability or chance is simply inapplicable" (Knight, 1921 p.231)*..."when an individual instance only is at issue, there is no difference for conduct between a measurable risk and an unmeasurable uncertainty"*(Knight, 1921 p.234) particularly in light of de Finetti's observation (noted above) that a probability always refers to a single, well-specified event. (de Finetti 1974)

Whereas a considerable body of literature associated with the field of economics pertains to dealing with risk and uncertainty – particularly that regarding rational choice and decision-making under uncertainty from celebrated authors such as Wald, Arrow, von Neumann and Morgenstern, Tversky and Kahneman, etc. – it has limited relevance to our discussion of the nature of risk and, therefore, is not reviewed here.

4.6 Risk in Finance

Perhaps the most commonly referred to conception of risk with regard to economic enterprise in today's global media refers to the financial markets and owes particularly to the work of Markowitz and Sharpe with regard to Modern Portfolio Theory and the Capital Asset Pricing Model respectively. According to Bernstein (1996 p.252-260), Markowitz identified variance of return as undesirable to investors and found it to be a suitable proxy for risk. Variance subsequently became synonymous with risk.

In his 1952 article on portfolio selection, Markowitz's starting point is that investment portfolio diversification reflects both the observed and sensible behaviour for investors. He finds that this is compatible with a rule whereby investors *"consider expected return a desirable thing and variance of return an undesirable thing"*. By combining diverse, risky assets into portfolios, their

individual variances of return tend to cancel each other out to an extent and the portfolio tends to exhibit lower variance of return for a given expected return than would its component assets individually. In addition, he notes that the portfolio with the maximum expected return is not necessarily that with the minimum variance so that, rather than a single, ultimate, portfolio, there exists a set of efficient portfolios and the possibility to increase expected return by accepting greater variance and to reduce variance by accepting a lower expected return. (Markowitz, 1952) This is illustrated in Figure 4.1 below.

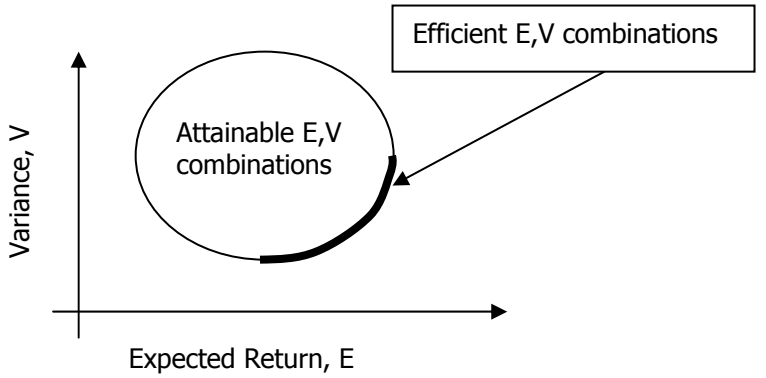

Figure 4.1: Efficient Asset Portfolios
source: Markowitz (1952)

Markowitz (1952) makes plain that he considers the term 'risk' to be equivalent to 'variance of return'. He suggests that: *"if the term "yield" were replaced by ... "expected return," and "risk" by "variance of return," little change of apparent meaning would result"*. Yet the implications go beyond this since variance of (expected) return is relative to expected return so that risk is conceived of as a function of the outcome expectation.

Markowitz's ideas were developed by Sharpe into the Capital Asset Pricing Model (shown in figure 4.2). Whereas in Sharpe's conception, risk equates to the standard deviation of expected return, it is his refinement of risk into components that is of particular interest to this discussion. Sharpe (1964) contends that there is a linear relationship between the expected return and the standard deviation of return for *"efficient combinations of risky assets"*. But, for individual assets (as opposed to efficient combinations or portfolios of assets), there is no consistent relationship between their expected return and their 'total risk' (measured as the standard deviation of expected return). Rather, it is only with regard to what he calls *'systematic risk'* that a relationship holds where systematic risk is that component of risk which cannot be reduced through diversification because it is correlated with the risk (standard deviation of returns) of any efficient combination of assets. In other words:

Total risk = systematic risk + risk which can be eliminated through diversification

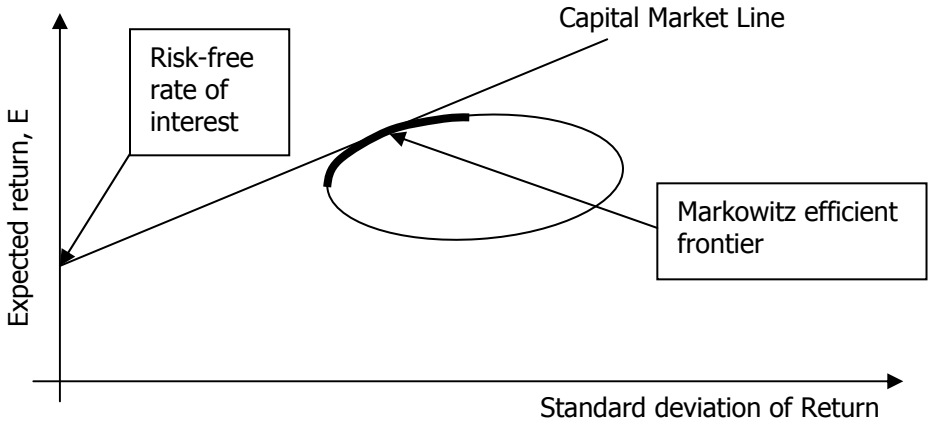

Figure 4.2: The Capital Asset Pricing Model
source: Sharpe (1964)

In Figure 4.2 the Capital Market Line represents all efficient investments (in the sense of 'risk versus return') at market equilibrium. It can be practically established by taking a broad-based stock price index such as the S&P 500 for the NYSE as a proxy for the market portfolio and the rate of interest on treasury

bills or similar effectively 'zero risk' assets to establish the risk-free rate of return (i.e. the price of time). Within this model, only the systematic risk component is considered (since the remaining risk can be cancelled out through diversification).

We have here echoes of Knight's assertion that measurable uncertainty (or 'risk proper') can be eliminated through diversification or combination. Both Knight and Sharpe (as well as Markowitz before him) adopt a fundamentally probabilistic formulation of the concept of risk. Knight considers (and struggles with) the logical basis of such an approach but Markowitz and Sharpe simply assume the mathematical formulations resulting from (mathematical) probability theory (and, indeed, a Gaussian distribution of returns).

Sharpe, by providing a measure of risk (historically determined standard deviation of return) which may be applied to all securities, offers in the CAPM a logical framework in which risk may be avoided or sought almost at will. Yet Knight's and Sharpe's (together with Markowitz's) conceptions of risk differ with regard to their relationship with profit (or return). Knight's assertion is that, because 'risk proper' can be measured, it can be diversified and eliminated and, therefore, it is not the basis for profit – 'true uncertainty' is. For Sharpe, it is the diversifiable risk ('total risk' less 'systematic risk') which does not provide a basis for additional return (i.e. profit) because it can be eliminated through diversification. (Sharpe's diversifiable risk is thus equivalent to Knight's 'risk proper'.) But, Sharpe's 'systematic risk' *is* measurable yet it cannot be diversified (at least within the bounds of his CAPM framework) and, therefore, it provides a basis for additional return which Knight's classification would deny it.

4.7 Risk in the Construction and Project Management Literature

We turn now to the context of construction projects in which it is intended to consider the concept of risk and particularly to investigate the notion of risk allocation or transfer. It is firstly noteworthy that, rather than setting out to uncover a deep understanding of the concept of risk, the majority of construction management-related literature is 'light' on theoretical concepts and focused upon application. It tends to borrow its concepts from other (purer / more established) fields and apply these to specific construction industry problems. But, in doing so, it also seems to the author that it tends to be unfaithful to any particular conception of risk and is often inconsistent between and even within particular texts.

The author's intention is not to imply that a single, robust and unchanging definition of risk is either possible or desirable. Rather it is to show that the word 'risk' is used in a remarkably wide variety of ways within the literature and that there is considerable ambiguity and confusion as to what it is referring in many cases. Therefore, the notion that 'risk' (whatever 'risk' is) may be 'allocated' or 'transferred' is fundamentally problematic.

Voordijk (2009) characterizes 'construction management and economics' as a 'multidisciplinary design science' with no single theory but numerous frameworks and concepts. Knowledge and results from a wide range of scientific disciplines are related to the built environment in order to produce technological laws, functional rules and socio-technological understanding aimed at optimizing or improving the design, production and operation of the built environment. It follows not only that a discussion of risk in the context of construction management will draw on numerous more specialized fields (mathematics, economics, insurance, finance, etc.), but that the controversies within these disciplines' risk-related debates may tend to be compounded further when these differing and problematic conceptions of risk are amalgamated.

There is a body of literature which relates to the generalisation of risk and its management – examples include Kaplan (1997), Verbano and Venturini (2011) who set out to integrate these conceptions. On the hand, sociologists such as Beck (1992) and Luhmann (1993) adopt highly generalised conceptions of risk which they apply to all fields of human endeavour. The construction and project management literature cannot be said to have a generally accepted conception of risk.

In their review of construction-related risk and risk management research, Edwards and Bowen (1998) note that substantive treatment of the topic of risk in construction dates from the 1960s. Quantitative applications of risk analysis techniques dominate the earlier publications reviewed. Later, from the 1980s, risk management systems and human involvement with these became predominant. In addition, the authors draw attention to an apparent geographical shift in the research effort from the United States in the earlier period (1960-1980) to the United Kingdom (from 1981 onwards).

To gain an indication of the trends in the construction risk literature since 1997, the author undertook a survey of the risk-related articles from the two journals identified in Edwards and Bowen (1998) as being the most prolific in the period 1981 – 1997 (i.e. *Construction Management and Economics* and *International Journal of Project Management*). In terms of the annual number of articles published, the combined total from these two journals has shown a slight overall increase over the period from 1998 to 2010. (Refer to Figure 4.3 below.) There is an indication of a further shift eastwards with regard to the major source of articles as it appears that the proportion of contributions from Australia and Asia have slightly increased during this period while articles originating in the UK have shown a slight decline as a proportion of the total – though neither trend is convincingly robust. In addition, whereas the 1980s and 1990s saw an increase in the number of articles dealing with risk management systems and 'soft' construction risk management, the rise of the Public Private Partnership (PPP) and construction risk issues associated with PPPs, particularly risk allocation, appear to have become increasingly important themes in recent years.

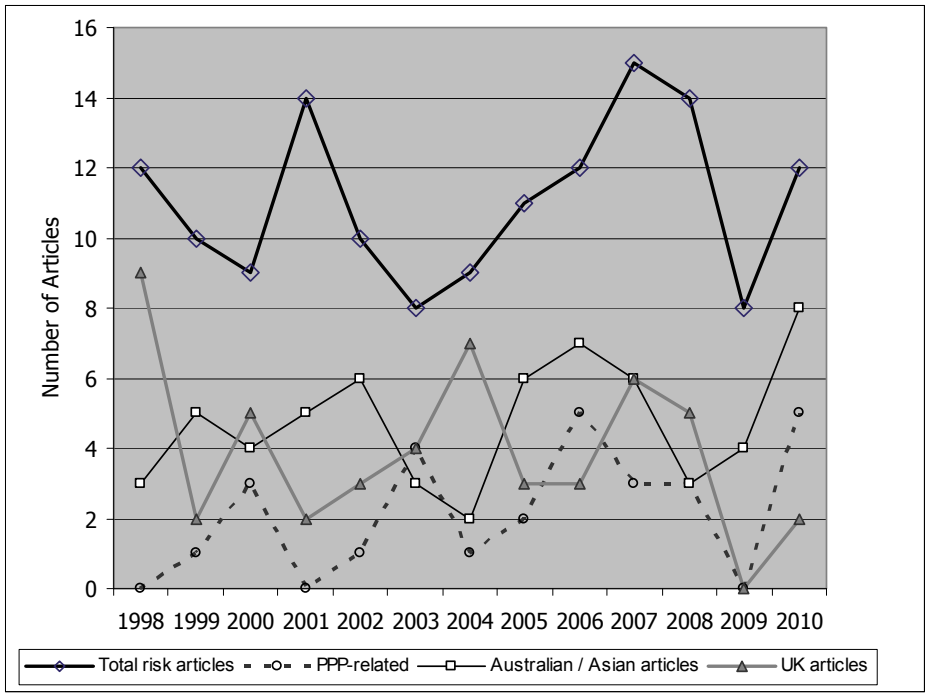

Figure 4.3: Risk-related Articles in Construction Management and Economics and the International Journal of Project Management 1998-2010

4.7.1 Definitional Imprecision and Inconsistencies in Use

A considerable range of incompatible risk definitions has been adopted in the construction and project management literature by different authors. This has been noted and commented upon. (Abdelgawad, 2011; Jha and Devaya, 2008; Raz and Hillson, 2005; Institution of Civil Engineers et al, 2002) What is rather less reported is the low level of enlightenment offered by many of the 'definitions' proffered and that authors are often unfaithful to their own particular definitions of 'risk' both over time and even within single publications. In contrast, the level of agreement in terms of how risk should be dealt with in 'risk management systems', is comparatively high though differences and discrepancies do exist between these too (Raz and Hillson, 2005; Wiguna and Scott, 2005; Chapman, 2006).

The definitional imprecision seems in some cases to be a consequence of authors' focus on developing practical approaches to dealing with risk. For example, Perry and Hayes (1986) argue that:

"We have chosen, so far, not to concern ourselves with the problems of precise definition and semantics, preferring to concentrate on the more practical aspects."

In other cases, authors manage to avoid specifically defining risk in their texts, for example, Flanagan and Norman (1993, p.22) and Raftery (1994, p.5).

Yet, it is questionable whether the 'risk' management systems developed can be particularly useful if the object of their processes (i.e. risk) is unclear or ambiguous and it is particularly difficult to accept 'risk allocation' as a rational basis for procurement method selection (as asserted, for example, by Love et al, 2008) if the precise nature of 'risk' is undefined. Chapman (2006) concurs:

"In the author's view clarity about what risk management is about has to include clarity about what is meant by the word 'risk'."

Yet a selection of the risk definitions attributable to Chapman, one of the more prolific authors on the subject of risk and its management in the construction and project management literature, provides a useful starting point to illustrate the problems that definitions are often unenlightening and individual authors' definitions may substantially change from publication to publication:

Definition 1.*"an undesirable implication of uncertainty"* (Cooper and Chapman, 1987)

Definition 2.*"Exposure to the possibility of economic and financial loss or gain, physical damage or injury, or delay as a consequence of the uncertainty associated with pursuing a particular course of action"* Chapman, C.B. (1991) Risk, in ***Investment, Procurement and Performance in Construction*** (eds P. Venmore-Rowland, P. Brandon and T. Mole), E. & F.N. Spon (Chapman & Hall), London, pp. 259-75. (Quoted in Raftery, 1994)

Definition 3."the implications of the existence of significant uncertainty about the level of project performance achievable" (Chapman and Ward, 1997)

Definition 4. *"the possibility of departures from expectations which matter"* Chapman (2006)

Definition 5.*'the implications of uncertainty about the level of project performance achievable'* Ward and Chapman (2008)

As definitions, these are weak and inconsistent. Chapman does advocate broad definitions of risk (see Chapman, 2006 and Ward and Chapman, 2008) yet these definitions appear *overbroad.*

In the first place, all these definitions except Definition 4 are framed on the basis of uncertainty. So that, if the assertion of numerous authors (including, Perry and Hayes, 1986; Raftery, 1994; Wood, 2003) that risk and uncertainty are effectively synonymous is accepted (which, apparently, Chapman does not - except perhaps in Chapman (2006), see the consideration of Definition 4 below) then these definitions are circular and thus unenlightening. A further drawback to defining risk in terms of uncertainty lies in the pervasiveness of the latter (*"I know of nothing with any certainty but the sight of the stars makes me dream"* – Vincent van Gogh).

Definition 1 is ambiguous on two levels. It could mean that there are multiple undesirable implications of uncertainty and one of these is *risk*, yet it does not enlighten the reader as to *which* undesirable implication of uncertainty *risk* is. In terms of Aristotle's formulation of definition by genus (for example, implication of uncertainty) and differentia (for example, undesirable), both genus and differentia here are insufficient (Moore, 2009); it is akin to defining a cat as "a type of living thing". Alternatively, Definition 1 could be understood to mean that *all* undesirable implications of uncertainty are *risk* (or *risks*) in which case "incomplete knowledge" which would appear to be an obvious implication of uncertainty (Edwards and Bowen (2003) also refer to uncertainty as implying *"a lack of complete knowledge"),* provided that it is 'undesirable', would be an example of risk. Yet few people would consider 'incomplete knowledge' as being 'risk' (not least because of its near certainty).

Definitions 3 and 5 are more detailed variations of Definition 1. Note that the focus on 'undesirable' or negative connotations has been discarded allowing for the consideration of positive connotations or 'up-side' risk. While this is obviously inconsistent with Definition 1, it illustrates a development of thinking within the area of risk management over the years and it is paralleled by similar inclusion of up-side risk in definitions adopted elsewhere in the literature. (Hillson, 2002) (A curious exception is noted here in a quotation from Flanagan and Norman, 1993: *"the risk of success and the cost of failure can be calculated by using the probability of failure"* suggesting an early, highly positive conception of risk!)

The narrowing of these definitions in comparison with Definition 1 relates to these referring to *"project risk"* as opposed to a more general 'risk' so the *genus* is further defined as *"implications of uncertainty about the level of project performance achievable"* but the *differentia* remain insufficient if it is accepted

that not all *"implications of uncertainty about the level of project performance achievable"* can reasonably be termed 'risk'.

Definition 4 differs notably from the others in that it does not distinguish between risk and uncertainty. In fact, in proposing it, Chapman (2006) argues that *"a modern position on probability renders this distinction irrelevant because whether or not we associate probabilities with uncertainty is simply a question of whether or not this is a useful thing to do"*. Yet this directly contradicts the same author's arguments for replacing 'risk management' with 'uncertainty management' because the meanings of these two terms significantly differ. (Ward and Chapman, 2003)

Definition 4 is also the only of these in which risk is defined *relative* to expectations. The other definitions suggest that risk may exist in the absence of expectations.

Additionally there are significant qualitative distinctions between risk being *"exposure to the possibilities"* (as in Definition 2), *"the possibility"'* (as in Definition 4) and *"implication"* (as in Definitions 1, 3 and 5).

4.7.2 Non-adherence to Stated Definitions

Similar problems bedevil many of the definitions offered by other authors, for example, Akintoye and Chinyio (2005) adopt a definition ascribed to McKim:

"Risk involves an activity or decision where either the outcome or consequence is less than certain, and at times, both of these are uncertain".

This definition is neither 'precising' since it would label as 'risk' almost any conceivable endeavour involving either an activity or a decision (going for a drive; choosing a hat; etc.) nor does it match the sense in which the term 'risk' is used in their article. For instance, later in the article, the following example of a particular 'risk' appears: *"a risk that vehicles could get stuck in mud during the construction period"*. Here 'risk' seems to be being used in the sense of 'possibility' and a specific outcome is referred to. There is no indication of the 'risk' in the sense of the given definition as a myriad of activities and / or decisions and / or combinations of these could lead to scenarios in which possible outcomes might include vehicles getting stuck in mud during the construction period.

Edwards and Bowen (1998 and 2003) assert their adoption of a Royal Society, 1991 definition of risk but this definition does not encompass the breadth of the term 'risk' as it is used in these two articles. The Royal Society, 1991 definition reads as follows:

"Risk is the 'probability that an adverse event occurs during a stated period of time'" (quoted in Edwards and Bowen, 1998 and 2003)

In explaining why this particular definition appeals to them, they state that: *"it incorporates concisely the three essential elements of risk: chance of occurrence; unfavourable or harmful impact; and duration of exposure."*

This is a loose interpretation since a more precise reading of the Royal Society definition above equates risk to probability, that is, only "chance of occurrence" so that this 'risk' is not an 'adverse event' and, being merely the probability of an adverse event occurring, it does not have an unfavourable or harmful impact (at least in the sense implied).

The loose interpretation is evident in the examples the authors give of particular risks. For instance, 'criminal acts on construction sites' are cited as an example of "social risks' in Edwards and Bowen (1998) along with many others where risk descriptions are clearly descriptions of events (and not necessarily adverse ones, e.g. 'equipment availability') or descriptions of variable factors (such as 'interest rates' as an example of 'financial risks') and not probabilities.

In this way, although a particular definition is proffered, a different, colloquial usage of the term 'risk' which does not match the given definition emerges in the course of articles. This colloquial usage often encompasses more than one of the wide range of meanings risk commonly takes (refer to the various dictionary definitions of risk given above in section 4.2.1). The effect is that the term is ambiguous.

The intention here is not merely to criticise the efforts of others with regard to defining risk. Rather, it is to emphasize the difficulties in (and, perhaps, even the impossibility of) formulating a generally consistent and acceptable definition of the term. It is also apparent that this problem is reflected throughout the history of consideration of risk well beyond the confines of the construction and project management literature.

4.8 Common Ground and a General Conception of Risk in Projects

The project framework offers a conveniently bounded system with well-defined investment inputs and outputs within which to consider risk. Yet the conception of risk within a construction project context will tend to encompass some or all of the conceptions of risk which are held in 'purer' disciplines so that the term 'risk' as it is used in the contexts of insurance, financial markets, economics, public health, psychology, and so on, are all relevant. It has been demonstrated that no single, precise definition is likely to hold for this context but there is also considerable common ground amongst these differing conceptions and, in the author's view, the principal common characteristics regarding the nature of risk can be drawn together into a generalised conception of risk. This is unlikely to be a 'correct' representation of risk in an absolute sense but its purpose is to establish a concept of risk which allows the explanation and measurement of risk allocation and transfer and enables the interpretation of empirical data regarding these. For this purpose, an approximate representation may still be useful.

Common characteristics include:

- a relationship with uncertainty;
- framing in probabilistic terms;

- reference to conduct;
- reference to expectation;
- reference to time;
- reference to profit.

4.8.1 Uncertainty

Reference to uncertainty is noted as a common thread throughout the literature in all manner of relationships:

- risk arising from uncertainty (e.g. Thompson, 1995),
- its being an implication of uncertainty (e.g. Cooper and Chapman, 1987),
- uncertainty causing risk (e.g. Flanagan (2002) p.26),
- equivalence of risk to uncertainty (e.g. Perry and Hayes, 1986),
- risk and uncertainty being at either end of a continuum (e.g. Raftery, 1994 p.8),
- risk being 'objectified' or defined uncertainty (e.g. Ratcliffe, 1963),
- risk encompassing uncertainty (Flanagan and Norman, 1993 p.22),
- risk being separate from uncertainty (Knight, 1921 p.20).

Perminova et al (2008) in a broadly based investigation into precisely this relationship suggest that uncertainty is the context for risks and this appears to be a widely acceptable proposition.

Butler and De Morgan relate uncertainty to a lack of complete knowledge which, in the context of (formal) logic, draws us into the realm of probability (and belief). (Butler, 1860 p.84; De Morgan 1847 p.172)

4.8.2 Probability

Jevons and Keynes refine this to a consideration of 'rational belief' relating to a corpus of knowledge so that we have a notion of probability based upon available knowledge or evidence. (Jevons, 1900; Keynes, 1921)

There appears to be a general adoption of a Pascalian conception of probability (where 1 represents certainty and 0 represents impossibility) and a Bayesian standpoint (with regard to probability reflecting the evidence-based degree of belief with the degree of belief being subject to revision in light of further evidence) (De Finetti, 1974; Kaplan, 1997; Mak 1995). However, there are also challenges to this approach and the assumptions underlying a mathematical treatment of probability in risk analysis – for example, the independence of variables, the principle of indifference, etc. - may not be met (Mak, 1995). (Some authors in the construction and project management literature even suggest their own unique alternatives! For example, Jaafari (2001) states (presumably in error) that:

"Events are said to be certain if the probability of their occurrence is 100% or totally uncertain if the probability of occurrence is 0%.")

4.8.3 Reference to Conduct

Probability could perhaps be a benign and abstract numerical property but, when applied to conduct, it acquires a distinctly different nature. Risk, on the other hand, always relates to activity. In order to engage with risk it is necessary to *do* something, even if that is something as passive as living. In addition, by relating probability to degree of belief and hence knowledge, human perception and agency combine with any notion of risk as being inherent or absolute. Here, ideas of social mediation and relativity arise – for example, the reference of Crowe and Horn (1967) to a 'sentient entity' incurring loss and, more extreme, the assertion of Edwards and Bowen (2003) that *"risk is a social construct"*. Though this latter example may reflect a more extreme view than that generally held, since, as Keynes (1921 p.4) notes: *"a proposition is not probable because we think it so"* yet it also cannot be dismissed as Knight (1921 p.201) observes: *"We **perceive** the world before we react to it, and we react not to what we perceive but always to what we **infer**."* In this way we cannot reasonably abstract risk from its social context.

4.8.4 Reference to Expectation

The initial definitions of risk given in this chapter (from Bernstein, 1996; Giddens, 1999 and Luhmann, 1993) all suggest the emergence of risk as emancipation from fate – arising in the anticipation and active prediction of the future state of affairs. The notion that risk is relative to expectation is apparent in all areas of consideration – whether explicit as in insurance and finance where risk is measured as a function of deviation from expectation, or implied as it is in many construction and project management references which consider risk in terms of the impact or consequences on the outcome or objectives of a project (see, for example, Raz and Hillson, 2005).

4.8.5 Reference to Time

Conceiving of risk relative to expectation requires acceptance of a temporal dislocation between the consideration of risk and realization of outcome (fulfillment or otherwise of expectation). The time function applies directly to the underlying context of uncertainty – ultimately a proposition is either true or false. The state characterized by 'risk' occurs when an expectation exists but the outcome is, as yet, unknown.

This is clearly exemplified in a financial market context: if the same security could be simultaneously both bought and sold (by one party), there would be no risk in the transaction.

It is also important to note that risk perceptions with respect to any particular proposition are not stable over this time period. Just as the odds shorten as to which number of a roulette wheel the ball will settle on in the final moments of the spin, outcomes tend to become more narrowly defined in time.

Similarly, it can be argued that expectations are fixed in time – ultimate consequences at infinite time are quite obviously not usually the focus of a risk assessment. The project context is convenient in this regard since its clear time boundaries are imposed upon expectations and outcomes alike.

4.8.6 Reference to Profit

In finance a relationship between 'risk' and 'return' is often referred to. This is complicated by terminology since the 'expectation' takes the form of 'expected return' (Markowitz, 1952). It also refers only to non-diversifiable risk (Sharpe, 1964) so that a direct relationship between risk or risk bearing and profit or expected profit is simplistic. Further complications are suggested by Knight's insistence that 'risk proper' is not a valid basis for profit and his suggestion that profit margins are, on balance, negative. Knight, 1921)

The insurance industry provides some insight into this problem – the concept of a 'pure premium' relating to the average cost of expected claims and an additional 'risk premium' referring to compensation for the risk-bearing relating to the *distribution* of the pure premium from its expected value.

In the case of one-off events as typically experienced in the project context, Ratcliffe (1963) notes that the degree of risk is 100% (i.e. there can be no risk-spreading), thus there is no equivalent of the 'pure premium'. The 'loss' (the context here being insurable risk but this could as well be 'gain' but this is irrelevant) will either occur or will not occur and there is only a 'risk premium' to consider.

It does not seem reasonable to consider a 'risk premium' in this sense to be equivalent to 'profit' but the project context seems again to be convenient for its consideration.

Consider a proposition with a likelihood of occurrence, p (where $0<p<1$) and a given (possible) effect, E, on the project's (monetized) outcome. If this proposition was to eventuate, then this eventuation would be reflected in the project's monetized outcome. If, on the other hand, it did not eventuate, then it would not be reflected.

If such a proposition were to affect a number of projects with specified expected profits, P so that in some cases it did eventuate and in other cases it did not, then, everything else being equal, the projects' profits would either be P in the case of the proposition not eventuating or P + E in the case of the proposition eventuating.

Thus, in the project context, we would expect the profit realized to reflect the eventuation of risk.

4.8.7 Generalized Conception of Risk in Projects

Based on these considerations, a conception of risk as shown in Figure 4.4 seems justifiable.

With reference to the figure, initial project outcome expectations are formed with reference to a set of risky propositions affecting the project. The set is neither necessarily comprehensive (further risky propositions which may affect the outcome may have been ignored), nor are the risky propositions fully defined so their 'boundaries' may overlap.

Four further clarifications should be added here which bear on issues of risk allocation and risk assessment:

1. different stakeholders are not assumed to hold a common understanding of the risky propositions;
2. the mutual independence of risky propositions is not assumed;
3. correlations between propositions may be variable;
4. underlying causal factors cannot be fully accounted for in any analysis (for example, the project context will tend to be altered beyond acceptable levels by major events like catastrophic natural disasters).

The initial expectation is expressed in terms of project outcome values and refers to an initially accessed corpus of knowledge which relates to the set of risky propositions, to all other project factors and to all interrelationships between all of these.

The initial expectation, formed at time t_0 is necessarily disconnected in time with the outcome (considered to arise at time t_1 for convenience). Time t_0 might be, for example, approximately the time of contract agreement and time t_1 the time of completion of construction or final account settlement for a typical construction project. Between t_0 and t_1, the corpus of knowledge available for generating expectations varies and interim expectations may be formed which may, in many cases, be increasingly accurate as time approaches t_1. In the case that the expectations are expressed as a range rather than a single point estimate, the range might be expected to narrow from the initial expectation to disappearing altogether at time t_1 (as shown by the dotted lines either side of the expectation in Figure 4.4).

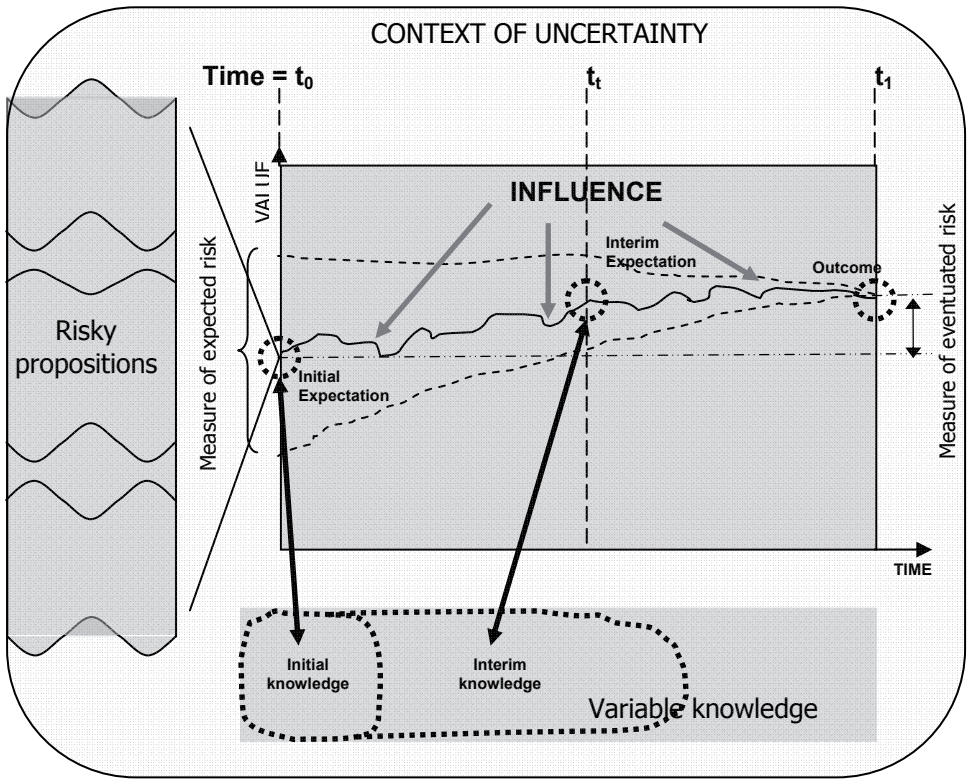

Figure 4.4: Conception of Risk in Projects

The knowledge accessed or referred to by different stakeholders will tend to differ. Precise agreement over what constitutes the set of risky propositions, the meanings of specific propositions, the 'other project factors' and the interrelations of all of these is beyond practical possibility. Thus, ultimately, stakeholder expectations will differ. Yet this does not preclude agreement in a practical or contractual sense – the totality of the expectation may be negotiated and agreed between stakeholders even if agreement does not extend to the bases of the stakeholders' expectations. Here, competition seems also to play a role in adjusting expectations (and, perhaps, 'over-ruling' expectations which are justified on a more rational basis with respect to knowledge).

Two possibilities present themselves as quantitative measures for risk – firstly, if an expectation is expressed as a range (as opposed to a fixed point estimate), the magnitude of the range provides an indication of *expected* (or anticipated or estimated) risk. However, such a measure does not bear any relationship to the actual outcome and, if it is not entirely arbitrary, it is certainly based on the perception from a particular stakeholder's standpoint and will be perceived differently by other stakeholders. The second possibility is to measure the difference between the expectation and the outcome in a manner similar to that suggested by Denenberg and Ferrari (1966) (refer to section 4.4 above).

Here the measurement reflects *eventuated* risk – that is, the aggregate value of the effects which occurred producing a difference between expectation and outcome. In itself, such a measure bears only a tentative relationship to the risk to which the project may have been *exposed* (maybe the project was just 'lucky' in achieving an outcome close to expectation *despite* great exposure to risk). Thus, (eventuated risk) ≤ (total exposure to risk). But eventuated risk provides an extremely useful measure for consideration of risk transfer in the contractual context of construction projects as follows:

Consider two parties – a client and a contractor – who agree, at time t_0, to an initial price for the client to pay on project completion (which pertains to an underlying estimate of cost to and profit for the contractor) and then, at t_1, the parties agree an outcome price (which pertains to an underlying outcome cost to and profit for the contractor). The difference between the underlying cost at time t_0 and the underlying cost at time t_1 provides the measure of 'eventuated risk' (with respect to project costs). By comparing the relative changes in price to the client (and, therefore, in profit to the contractor) it becomes clear which party has 'paid for' the eventuated risk and, thus, the extent of *risk transfer* from the client to the contractor which has occurred.

It is an unnecessary condition for the timescale to extend into the future – time here is relative to knowledge and it is only required that the outcome is not known at t_0 and is known at t_1. Similarly, the traditional separation of 'loss' and 'gain' is largely irrelevant in this conception. Loss and gain refer only to the value of the outcome relative to the expectation and therefore reflect only how optimistic or pessimistic the expectation turns out to be. Both may be considered to be inefficient.

It is apparent that project parameters may be altered between t_0 and t_1 so that the outcome is susceptible to influence. (This could just as well take the form of motivating labour to make up for lost time as illegally manipulating a stock market – the possibility to influence the outcome exists in both cases).

Finally, the entire system may be considered from a social constructivist perspective: the outcome may not be absolute but rather socially determined. Likewise, knowledge may refer only to that permissible knowledge which is socially acceptable in the particular context (this is plainly observable in the inadmissibility of some types of genetic information in life insurance and criminal justice contexts) and the selection of risky propositions may be socially influenced.

4.9 Chapter Summary and Conclusions

Definitions of risk are many and varied. Different fields of knowledge have their own conceptions of risk but, even within these fields, there tends to be controversy with regard to the meaning of the term.

The construction and project management field draws its concepts from a broad range of 'purer' disciplines but, with regard to 'risk', the controversies also

get imported and confusion is further compounded by attempts to refer to risk in a general sense intended to encompass many of the (different) conceptions from the purer disciplines (such as insurance, economics, finance, health, and so on).

Unsurprisingly, the construction and project management literature contains many examples of incompatible definitions of risk and authors are inconsistent in adhering to their own chosen definitions both over time and, in some cases, even within the same article.

The research problem addressed in this dissertation relates specifically to risk transfer between client and contractor organizations in the context of projects involving construction. In order to investigate risk transfer, a conception of risk which enables the measurement of risk transfer in some form is required.

This chapter has drawn together the principal notions and common ground which underlie risk conceptions historically, with regard to probability theory, insurance, economics and finance as well as in the construction and project management literature and combined these in the form of a generalized conception of risk appropriate to the project context.

On the basis of this generalized conception of risk, the 'eventuated risk' measured as the difference between the initially expected project outcome and the actually realized project outcome provides a convenient metric for aggregate 'risk transfer' measurement. The extent to which both parties (client and contractor) to a construction contract pay for the eventuated risk (for the client: by way of a change in contract price; for the contractor: by way of a change in contract margin) directly indicates the risk transfer from client to contractor that has been effected in the particular contract.

5. AN EVENTUATED RISK TRANSFER MODEL

5.1 Overview of Chapter

In Chapter 3 it was determined that the risk transfer – project delivery efficiency relationship could be considered in the sense of a design theory and tested on the basis of historical project data. In Chapter 4 a conception of risk was established which enabled the measurement of (eventuated) risk transfer from the client to the contractor of a construction project.

This chapter proposes quantitative indicators for both risk transfer and for project delivery efficiency and a geometrical representation of the risk transfer - project delivery efficiency relationship. This enables the idealized relationship of greater risk transfer leading to improved project delivery efficiency to be modeled.

5.2 Risk Transfer and Project Delivery Efficiency Indicators

5.2.1 The (Eventuated) Risk Transfer Indicator

In Section 3.2.1 it was established that the tendency for construction projects to be completed within budget has been widely adopted as an indicator of risk transfer - if construction risk is successfully transferred to a contractor, then the client would not be affected by variations in construction cost as the contractor would take responsibility for these. It was also noted that there is evidence that budgets have been substantially increased (by an estimated 24-31% in specific cases) in order to accommodate cost increases which cannot be passed on to the client. This is problematic because, if budgets are inflated, then they are less likely to be overspent and this gives the impression of greater risk transfer having occurred regardless of whether any risk eventuated.

In Section 4.8.7 it was argued that the risk which had 'eventuated' in the course of a construction project could be measured as the difference between the out-turn and the estimated values of the underlying cost of construction to the contractor. In addition, by comparing the relative changes in price to the client and, therefore, in profit to the contractor, it becomes clear which party has 'paid for' the eventuated risk and, thus, the extent of *risk transfer* from the client to the contractor which has occurred.

In considering variation between estimates and out-turn values of both the price to the client and the contractor's profit margin, the problem of inflated estimates (i.e. the problem of establishing whether risk transfer occurred or did not) is resolved. It becomes evident whether the contractor anticipated a high margin and relatively little risk eventuated or whether the contractor's anticipated margin was modest and 'upside' risk eventuated which was transferred to (i.e. accepted by) the contractor.

The traditional dimensions of construction project success are cost, time and quality. For the purposes of this study, only the financial dimension (cost) is taken into consideration. Time and quality are taken to be subordinate to cost and adequately accounted for within the cost dimension. If time and quality are of particular importance to a given project, then this should be reflected in the cost through time- or quality-related penalties, incentives and their corresponding contingencies.

5.2.2 The Project Delivery Efficiency Indicator

If we accept that any variation in the construction cost can be seen to represent risk eventuating during the course of construction and that the eventuation of risk is always undesirable because it implies the inefficient allocation of resources, it follows that both client and contractor seek to fulfill their initial financial expectations in terms of price and margin respectively. Construction cost certainty reflects the fulfillment of both parties' expectations and this may be taken as an indicator of project delivery efficiency. It must be noted, however, that this does not give any indication as to whether the construction cost, price and margin corresponding to any particular project reflects value for money in any absolute or whole life-cycle sense. This is somewhat ameliorated by the context in which construction contracts are agreed – often with price competition in the selection of the contractor and, typically, between a knowledgeable contractor and a knowledgeable client. Yet, since this project delivery efficiency measure is relative, it enables the convenient comparison of projects which differ in size, type, and any other characteristics.

Taken together with the eventuated risk transfer indicator, the basis for modeling the relationship between risk transfer and project delivery efficiency is now established.

5.3. Modeling the Risk Transfer – Project Delivery Efficiency relationship

5.3.1 Defining the Terms

The terms under consideration are the cost variance, ΔC and its two components: price variance, ΔP and margin variance, ΔM for the construction phase of projects involving construction.

Where $\Delta C \neq 0$ then the change in cost must be accommodated either by a change in the price paid for the construction by the client (i.e. a change in price, ΔP) or by a change in the margin earned by the contractor (i.e. a change in margin, ΔM) or by both. This is simply another way of expressing the relationship:

$$price, P = \cos t, C + margin, M \tag{5.1}$$

so that:

$$P_0 - C_0 = M_0 \tag{5.2}$$

and:

$$P_1 - C_1 = M_1 \tag{5.3}$$

where: P_0, C_0, M_0 represent respectively the construction price, cost and margin prior to the start of construction (at time, t_0) and P_1, C_1, M_1 the price, cost and margin as determined (and agreed) after the completion of construction (at time, t_1).

$$\Delta C = C_1 - C_0 = (P_1 - M_1) - (P_0 - M_0) = \Delta P - \Delta M \tag{5.4}$$

To allow the comparison of different projects $\Delta C, \Delta P, \Delta M$ are most conveniently expressed as percentages of the initially expected cost:

$$\Delta C = \frac{C_1 - C_0}{C_0} \times 100\ \% \tag{5.5}$$

$$\Delta P = \frac{P_1 - P_0}{C_0} \times 100\ \% \tag{5.6}$$

$$\Delta M = \frac{M_1 - M_0}{C_0} \times 100\ \% \tag{5.7}$$

5.3.2 Representation of construction projects

In terms of these quantities, any conceivable project performance may be represented by a point with coordinates $(\Delta M; \Delta P)$ on the graph shown in Figure 5.1

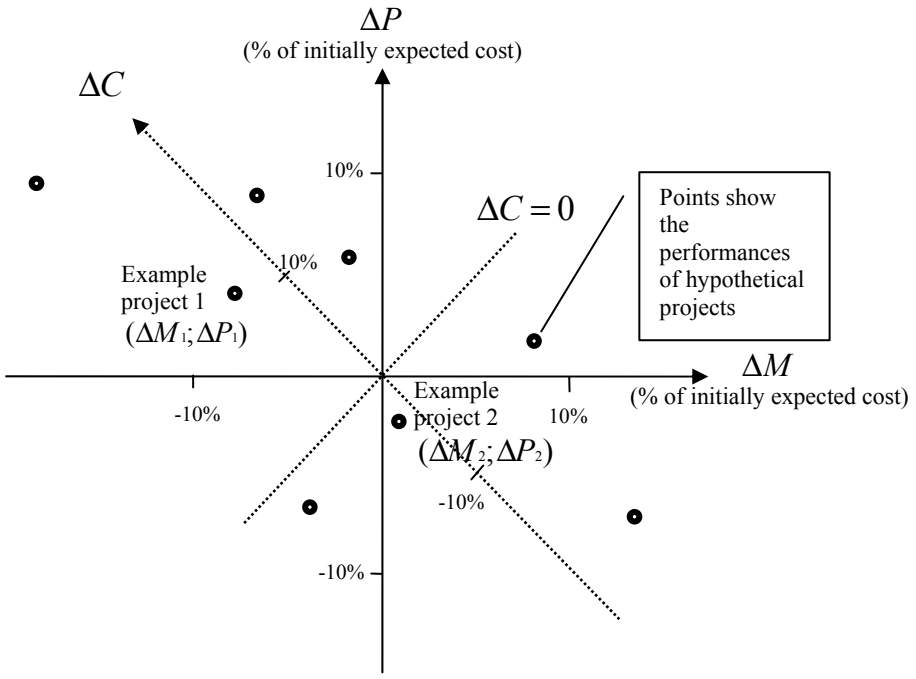

Figure 5.1: Graph of ΔM versus ΔP showing ΔC and hypothetical project performances

5.3.3 Project delivery efficiency

Project delivery efficiency is indicated by a project's coordinates in relation to the origin. An efficiently delivered project is one which satisfies both parties' expectations by achieving its anticipated price, cost and margin so that $\Delta P = \Delta M = \Delta C = 0$ and the project coordinates are $(0;0)$ that is, they are at the origin of the axes shown in Figure 5.1.

Therefore, in a general sense, the greater the distance of a project's coordinates from the origin, then the less efficient was its delivery.

For example, "Example project 2" in Figure 5.1 is more efficiently delivered than "Example project 1". And, despite its anticipated margin being exceeded ('bettered') and the anticipated price being undercut ('bettered'), "Example project 2" is less efficiently delivered than a hypothetical project located at the origin.

5.3.4 Eventuated risk

The aggregate eventuated risk (the arithmetic sum of the cost impacts of all the risk events which actually occur) is reflected by the cost variance, ΔC. In general and with other factors being equal, a relatively 'risky' project would be one with large ΔC and 'less risky' project would exhibit a small ΔC value. In this way, "Example project 1" on the graph exhibits greater eventuated risk than "Example project 2".

5.3.5 Eventuated risk transfer

(Eventuated) risk transfer is indicated by a project's coordinates in relation to the ΔP and ΔM axes.

If all of a change in a project's cost, ΔC is accommodated by a change in price and there is no associated change to the contractor's margin (i.e. $\Delta C = \Delta P$ and $\Delta M = 0$) then it follows that no transfer of risk from the client to the contractor has occurred. On the other hand, if all of ΔC is accommodated by a change in the contractor's margin and the price remains unchanged ($\Delta C = \Delta M$ and $\Delta P = 0$) then all of the risk that eventuated in the project has been transferred to the contractor.

In this way, for any given value of ΔC there is a line which represents all the possible $(\Delta M ; \Delta P)$ coordinates which could arise from such a value of ΔC. The dashed diagonal lines passing through the coordinates of "Example project 1" and "Example project 2" in Figure 5.2 indicate all the risk transfer combinations possible under these respective values of ΔC. The further towards the top and right of the diagonal the more the contractor benefits and the further to the bottom and left the more the client benefits.

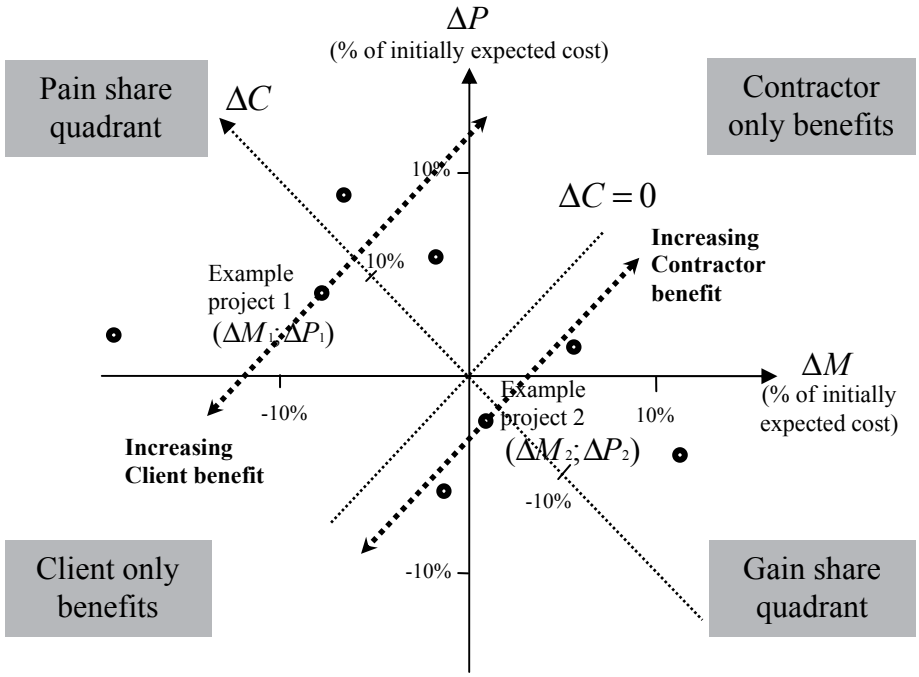

Figure 5.2: Geometrical representation of benefits from risk transfer and the meaning carried by a project's location on the graph

The quadrant of the graph in which the project is positioned according to its $(\Delta M; \Delta P)$ coordinates is also noteworthy. Where a cost increase causes the price to rise and the margin to fall, both parties share in the adverse effects and a project located within this quadrant would therefore be indicative of "pain share". Conversely, shared benefits of cost decreases would locate the project in the "gain share" quadrant. However, two further quadrants exist – the "contractor only benefits" quadrant where a margin increase occurs in the context of a price increase; and a "client only benefits" quadrant where a price decrease is achieved in the context of a reduced margin. These are shown on the graph in Figure 5.2.

5.3.6 Modeling the Risk Transfer – Project Delivery Efficiency idealization

In Section 3.3 the idealized relationship: *the greater the transfer of (construction) risk from the client to the contractor, then the greater the efficiency of (construction) project delivery (all else being equal)* was noted as central to both the PPP approach and to construction procurement in general.

This may be conveniently expressed in terms of the geometrical representation proposed above.

Consider a set of equivalent construction projects. In the first place let us divide these into two groups:

1. the projects for which the out-turn costs (to the contractor) exceed the initial expectations ($\Delta C > 0$); and,
2. the projects for which the initial expectations exceed the out-turn costs ($\Delta C < 0$).

For both groups, if the idealized relationship holds, then the more risk that is transferred from the client to the contractor, the more efficiently the project will be delivered. Graphically, this means the closer the project coordinate is to the ΔM axis (higher risk transfer), the closer the project coordinate will be to the origin (greater project delivery efficiency). The closer the project coordinate is to the ΔP axis (lower risk transfer), the further away it will be from the origin (lower project delivery efficiency).

This arrangement is illustrated in Figure 5.3.

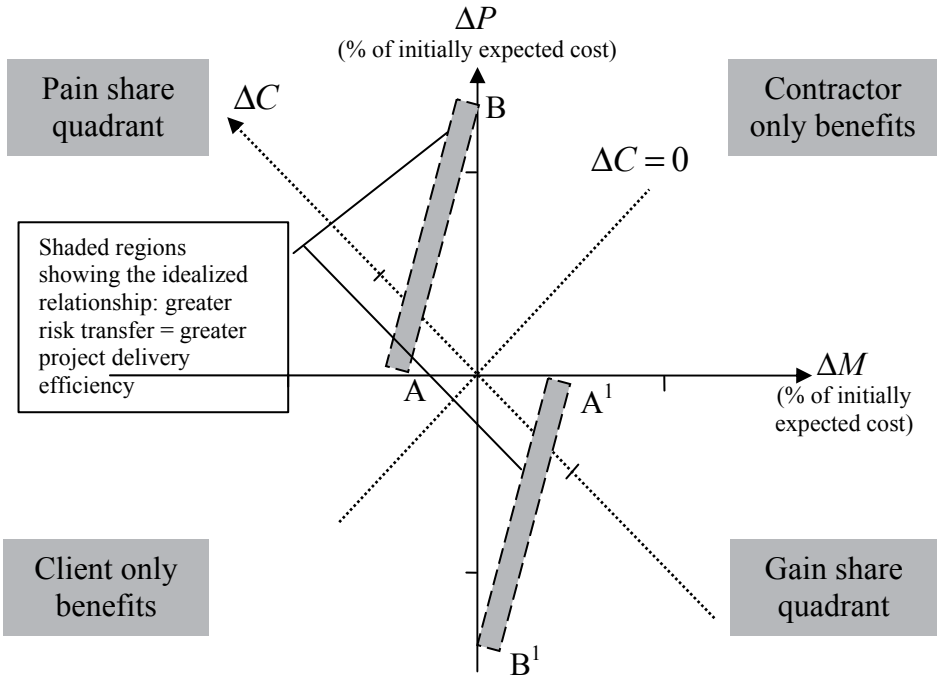

Figure 5.3: Idealization of the Greater Risk Transfer = Greater Project Delivery Efficiency Relationship

With reference to Section 3.2.2 in which it was noted that both the degree of bundling and the extent of output-based payment affect risk transfer, and assuming that the intention to transfer risk is realized in practice, it could be considered that a project located on the graph at position A (or A^1) would be characterized by a high degree of bundling and an output-based payment mechanism whereas a project located at B (or B^1) would be characterized by a relatively low degree of bundling and an input-based payment mechanism. It is

apparent that positions B and B^1 approximately correspond to what would be expected in the case of lump sum type payment mechanisms while A and A^1 correspond to cost plus fixed fee payment arrangements.

In the case of projects with cost plus percentage fee payment mechanisms, project coordinates would slightly cross over to the other side of the ΔP axis – this is a consequence of the chosen metrics (being expressed as a function of C_0, ΔM is positive if it remains a constant percentage of cost when the cost escalates and becomes negative if the cost reduces). Such arrangements potentially invoke incentives for contractors to incur increased costs in order to increase their profit margins and for clients to simultaneously reduce both construction costs and fee payments to the contractor and these somewhat perverse effects are reflected in their location encroaching into the "contractor only benefits" or into the "client only benefits" quadrants. With this exception, no projects would be located in either the "client only benefits" or the "contractor only benefits" quadrants as, in the two extremes:

1. if all the eventuating risk is transferred to the contractor then only the margin changes and there is no price change;
2. if none of the eventuating risk is transferred to the contractor, then only the price changes and the margin remains unchanged.

Thus a margin decrease should not occur in conjunction with a price decrease nor should a margin increase occur in the context of a price increase - both would be unreasonable within this idealized system.

5.4 Chapter Summary and Conclusions

It has been established that (eventuated) risk transfer may be measured in terms of the relative proportions of cost variance which are paid for / accepted by the contractor (by means of a change in margin) and by the client (by means of a change in price). In addition, the degree to which both the client's and contractor's initial expectations are met provides an indicator of project delivery efficiency. Together, and with all measurements expressed in terms relative to the initial estimated construction cost of the project, these provide the basis for a convenient geometric representation of the relationship between (eventuated) risk transfer and project delivery efficiency.

This representation enables the idealized relationship: *the greater the transfer of (construction) risk from the client to the contractor, then the greater the efficiency of (construction) project delivery (all else being equal)* which is central to both justifying the PPP approach and to construction procurement in general to be modeled.

The resulting model indicates the expected distribution of historical project data if the idealized relationship holds for the given set of projects and therefore provides a basis for testing the relationship's validity.

6. DATA COLLECTION, ANALYSIS AND FINDINGS

6.1 Overview of Chapter

In the preceding chapters a basis for empirically testing the risk transfer – project delivery efficiency relationship central to the justification of the PPP approach and to construction procurement in general has been developed.

This chapter defines the objectives of the data collection exercise in order to determine the testing intentions and hence the specific data collection requirements. The sampling and data collection methodology is discussed and the collected data is presented and described.

Focusing on an attempt to justify or refute the validity of the risk transfer – project delivery efficiency relationship on the basis of the collected data, a series of analyses and statistical tests are carried out to investigate the relationships between the project variables.

The chapter concludes with a discussion of the main findings of the investigation with regard to risk transfer in the construction project context and its relationship with project delivery efficiency.

6.2 Data Collection Objectives

The notion that the private sector is more efficient than the public sector when its capital is at risk is fundamental to the PPP approach. As discussed in Section 2.3, the justification for using PPPs rests on invoking this greater efficiency through the greater transfer of risk from the public sector. In Section 2.7 the need for empirical evidence to ascertain whether PPPs actually deliver better value for money through better risk allocation between public and private sector partners was identified. In addition, it was noted that, if the relationship between risk transfer and project delivery efficiency were empirically tested with data from Estonian projects, the findings would not only inform value for money calculations relating to risk allocation in Estonia but also, more generally, they would contribute to the understanding of risk transfer in the project context and hence to the wider PPP value for money debate.

The argument that a focus on the construction component of any project is justified was made in Section 3.2.1. Such a focus simplifies the consideration of risk transfer and also enables the direct comparison of PPP with any other procurement arrangement which involves construction.

Specific project attributes influencing the degree of risk transfer were identified (in Section 3.2.2) to include:

1) 'bundling' - i.e. the degree of integration of (i.e. single contractor responsibility for) the construction component together with other project elements (design, finance, operation, etc.); and,
2) the mechanism by which the contractor is paid by the client;

so that the *intended* allocation of risk may be approximately determined on the basis of these indicators.

In Section 3.3 the risk transfer – project delivery efficiency relationship was further refined and characterised as design theory in the form: *the greater the transfer of (construction) risk from the client to the contractor, then the greater the efficiency of (construction) project delivery (all else being equal).*

The design science approach suggests that testing the utility of this relationship and its underlying 'kernel' theories may be achieved through the evaluation of designed artifacts (in this case, historically procured construction projects). As such, the design science framework conveniently fits the empirical testing envisaged and provides insight into how this testing can inform subsequent theory-building.

A generalized conception of risk and a corresponding measure of (eventuated) risk transfer were derived in Chapter 4 on the basis of initially estimated and out-turn project values. In Chapter 5 a project finance-based measure of project delivery efficiency and a geometric representation of the relationship between risk transfer and project delivery efficiency were proposed which enabled the idealized relationship: greater risk transfer = greater project delivery efficiency to be modeled. The proposed geometric representation provides for the convenient consideration of financial data from any construction project with regard to risk transfer and project delivery efficiency and allows all construction projects regardless of their specific characteristics to be represented and directly compared.

6.2.1 Empirical Testing Intentions

For this research, it is intended to limit the testing to data from projects which have been undertaken in Estonia.

The principal test for which project data is required concerns the relationship between risk transfer and project delivery efficiency and, if such a relationship is observed, the magnitude of this effect in terms of the associated efficiency gain.

The supporting assertions, that:

- greater 'bundling' leads to greater risk transfer; and,
- the more output-based the payment mechanism, the greater the risk transfer;

also require testing.

In addition, tests relevant to related arguments for the adoption of the PPP approach may be carried out on the same data, such as:

- the comparison of project delivery efficiencies achieved by public and private sector clients; and,
- the degree to which the price of construction to the client changes over the course of projects.

Finally, it is acknowledged that the great variation between individual projects' characteristics, implementation processes and financial outcomes

suggests that discernible relationships with respect to risk transfer and project delivery efficiency will require the data from a large number of projects.

6.2.2 Data Requirements

From these testing intentions, it follows that the project data to be collected should include:

- financial data – both initially estimated and out-turn construction costs (to the contractor), profit margins (for the contractor) and prices (to the client);
- the degree of 'bundling' – which other elements (e.g. design, finance, operation, etc.) are integrated with the construction component;
- details of the payment mechanism; and,
- client type.

In addition, other project characteristics – the project start year and the type of construction project – may also be considered desirable to collect in order to provide the possibility of further disaggregating and assessing the data in more detail.

Project financial data of this nature (which includes both cost to contractor and price to client) is only available from construction contractors and, as previously noted, there is a need to capture the data from as many projects as possible. The source of data is, therefore, large construction contractors operating in the Estonian construction market.

6.3 Sampling and Data Collection

The ten largest construction contractors operating in the Estonian construction market were identified and a written request for data was sent to each of them. It was considered that these would together account for a considerable proportion of Estonian construction activity and it would be practical to collect data relating to as many projects as possible from a small number of firms. This request included an explanation of the research and details of how the anonymity of the data was to be maintained. The latter was considered necessary as the profit margin data for specific projects is commercially sensitive and this was resolved by avoiding the collection of individual project specific information (such as the names of projects, clients, etc.) and through the expression of all financial data as ratios (specifically, as functions of initially estimated cost, C_0) in publications.

By way of feedback to participating companies and as an incentive for construction firms to provide data, participating firms were offered a feedback report containing an analysis of the firm's data and a comparison of each firm's project performance indicators against 'market averages' based on all the data collected from all other participating firms. (These reports were produced in July 2011 once the data collection exercise had been completed).

Four of the ten firms approached responded positively to the data request and project data for a total of 296 construction projects were obtained.

6.4 Data Description

The full data set appears in Appendix A – Project Data. Note that the financial data are all shown in the table as ratios of the initially estimated cost, C_0, but that the actual monetary values were obtained and, in some cases, these values are used in the data analysis.

For all projects, the complete financial data were obtained but for 181 of these projects the degree of 'bundling' ('responsibilities of contractor' on the input form) and the payment basis were not provided. All projects were started and completed in Estonia between the years 2001 – 2010 and represent a total value of 7.8 bn EEK (approximately 500m €) of construction works. (All of the projects were completed prior to Estonia's adoption of the euro and, therefore, monetary values are expressed in EEK). To put this into perspective, Statistics Estonia gives the total value of construction activities which took place in Estonia over the same time period as 22607m € which suggests that the sample of projects obtained represents approximately 2% by value of all construction activities.

The projects ranged in size from less than 1m EEK (64000 €) to more than 400m EEK (25.6m €) and covered both building (163 projects, 5.3 bn EEK) and civil engineering (97 projects, 2.2 bn EEK) projects (the remainder being classified as 'other') for both private sector clients (135 projects, 4.7 bn EEK) and public sector clients (112 projects, 2.2 bn EEK) as well as projects undertaken by contractors on their own accounts (49 projects, 0.9 bn EEK).

Procurement arrangement information was available for 115 projects of which 95 were lump sum (fixed price) contracts, 8 were target cost, 7 were cost plus and 5 had other payment mechanisms. In 61 projects, the involvement of the contractor was limited to construction only while in 49 the contractor also had responsibility for the design (including, in a small number of these cases, responsibilities for financing and operation as well). Table 6.1 contains a summary of the collected data.

Table 6.1: Data Description Summary

Client Type	**No. of projects**	**Project Type**	**No. of projects**
Private sector client	135	Building	163
Public sector client	112	Civil engineering	97
Own organization as client	49	Other	36
Total	**296**	**Total**	**296**
Level of 'bundling'	**No. of projects**	**Payment mechanism**	**No. of projects**
Build only	61	Cost plus % fee	4
Design & Build	49	Cost plus fixed fee	3
Design, Build & Operate	4	Target cost	8
Design, Build, Finance & Operate	1	Unit rate	3
No information	181	Lump sum	95
		Guaranteed Max Price	1
		Other (unspecified)	1
		No information	181
Total	**296**	**Total**	**296**
Project size range*	**No. of projects**		
Very small (<1m EEK)	56		
Small (1m-3m EEK)	65		
Medium (3m-10m EEK)	57		
Large (10m-35m EEK)	56		
Very large (>35m EEK)	62		
Total	**296**		

***** *Project size ranges chosen to divide the sample into 5 groups with approximately the same number of projects in each.*

6.5 Data Analysis

6.5.1 Testing the Risk Transfer - Project Delivery Efficiency Relationship

In adopting the geometric representation described in Chapter 5, risk transfer is indicated by a project's coordinates in relation to the ΔP and ΔM axes. The degree of risk transfer achieved in any project is indicated by the relative proximity of the $(\Delta M;\Delta P)$ coordinates of that project to either the ΔP axis or the ΔM axis. A project with coordinates closer to the ΔP axis than the ΔM axis would therefore exhibit relatively low risk transfer and project coordinates closer to the ΔM axis than the ΔP axis would indicate relatively high risk transfer.

Project delivery efficiency is indicated by a project's coordinates in relation to the origin. The greater the distance of a project's coordinates from the origin, then the less efficient was its delivery (as discussed in Section 5.3.3).

A graphical representation of the project data collected is shown in Figure 6.1. It should be noted that 27 of the projects have $(\Delta M;\Delta P)$ values which locate them outside the range (-40% to +40%) shown in Figure 6.1. The majority of these (20 out of 27 projects) show an increase in margin in the context of a price increase so that they are also positioned in the same quadrant of the graph (i.e. the 'contractor only benefits' quadrant) which is most densely populated by the projects with $(\Delta M;\Delta P)$ coordinates within the -40% to +40% range.

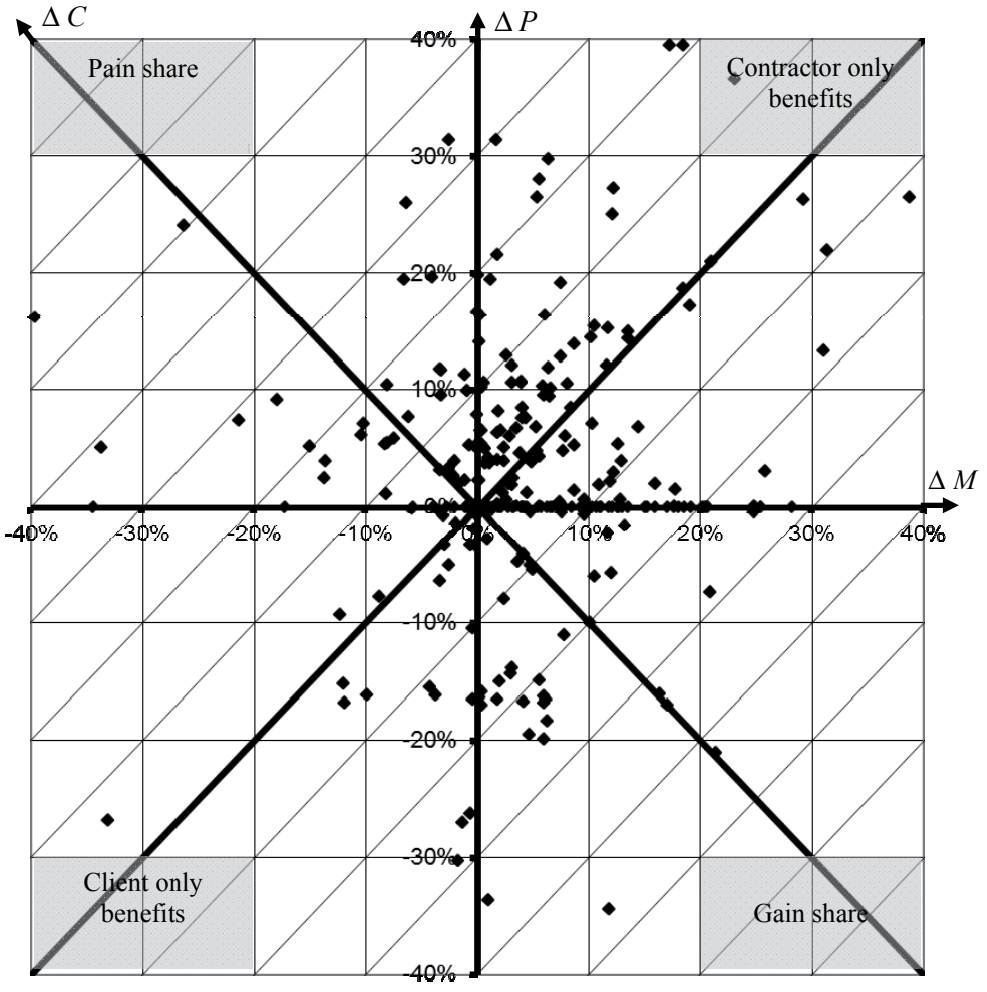

Figure 6.1: Graphical Representation of the Collected Project Data

It is immediately evident that the distribution pattern of the collected project data does not correspond with the idealized risk transfer – project delivery

efficiency relationship as modeled in Section 5.3.6. The project data in the sample clearly show a tendency for both price increase (the majority of project coordinates being located above the ΔM axis) and margin increase (the majority of project coordinates being located to the right of the ΔP axis) to occur in conjunction with each other. This was argued to be unreasonable within the idealized system because, should risk (in the form of unanticipated cost or saving) eventuate, then this would be 'paid down' by either the client (as a price change) or the contractor (as a margin change) or some combination of the two.

The distribution of project coordinates in Figure 6.1 is less clear with respect to the comparison of cost increases (project coordinates located above and to the left of the diagonal $\Delta C = 0$ line) compared to cost decreases (project coordinates located below and to the right of the diagonal $\Delta C = 0$ line). The degree of cost estimating accuracy will be more rigorously tested below.

Whether higher risk transfer is associated with greater project delivery is not clear from Figure 6.1 - this would imply a distribution such that project coordinates closer to the ΔM axis would also tend to be closer to the origin whereas project coordinates closer to the ΔP axis would tend to be further away from the origin. However, this can be statistically tested if numerical indicators for the degree of risk transfer (relative proximity to the ΔM axis) and project delivery efficiency (relative proximity to the origin) are derived. Such indicators are:

$$\text{Degree of risk transfer} = \frac{|\Delta M|}{|\Delta M| + |\Delta P|} \tag{6.1}$$

A degree of risk transfer value of 1 or 100% would indicate complete (eventuated) risk transfer from the client to the contractor while a value of 0 would indicate that no (eventuated) risk transfer had occurred. Values above 0.5 or 50% indicate that a project's coordinates locate it closer to the ΔM axis (i.e. they indicate 'higher' risk transfer) while values below 0.5 or 50% would apply where the project's coordinates locate it closer to the ΔP axis (indicating 'lower' risk transfer). Note that, if both ΔM and ΔP values are zero for a project, i.e. its coordinates locate it at the origin of the graph, then it is not possible to determine a degree of risk transfer and it is assumed to be 50% (i.e. evenly shared).

$$\text{Project delivery inefficiency} = \sqrt{(\Delta M)^2 + (\Delta P)^2} \tag{6.2}$$

Note that the quantity 'project delivery *inefficiency*' measured as the distance from the origin is used here as it is more convenient to calculate than a direct measure of *proximity* to the origin.

Testing hypothesis (1) that: *'Greater risk transfer from the client to the contractor is associated with greater project delivery efficiency.'*

Risk transfer is found to be weakly, though significantly, correlated with project delivery efficiency. (Refer to Table 6.2) The Pearson correlation coefficient between the indicators 'degree of risk transfer' and 'project delivery inefficiency' is calculated to be -0.22 which, for 294 degrees of freedom, corresponds to a significance level of $\alpha = 0.01\%$ for a one-tailed test. The one-tailed test option is selected since the test is specific with respect to *greater* risk transfer being correlated with *greater* project delivery efficiency.

However, correlation testing is affected by outliers in a data series and, in order to confirm this result, the same test was carried out on the data series firstly excluding 'extreme outliers' and then excluding all 'outliers'. For the purpose of this testing, *extreme outliers* are arbitrarily defined as the data for those projects which experienced a price change, ΔP of 100% or more, i.e. the reduced data series for which $-100\% < \Delta P < 100\%$ was tested. *Outliers* are defined as the data for those projects which experienced a price change, ΔP of 40% or more, i.e. the reduced data series for which $-40\% < \Delta P < 40\%$ was tested.

Initially, therefore, it may be asserted that the data appears to support hypothesis (1) in showing that greater risk transfer is positively (though weakly) correlated with greater project delivery efficiency (this result being significant at $\alpha = 5\%$ even where all outliers are excluded).

6.5.2 Testing the assumptions underlying the Risk Transfer – Project Delivery Efficiency Relationship

The weakness of this correlation together with the considerable deviation of the actual project data distribution from that anticipated and the obvious concentration of project coordinates in the 'contractor only benefits' quadrant of the graphical representation in Figure 6.1 all suggest that other, more influential relationships underlie the distribution of the collected project data. To investigate this, correlations between project values of ΔC, ΔM and ΔP were tested for. Framing these as hypothesis tests, the corresponding hypotheses may be stated as:

Hypothesis (2): *An increase in cost is associated with an increase in price.*
Hypothesis (3): *An increase in cost is associated with a decrease in margin.*

Together, hypotheses (2) and (3) imply:
Hypothesis (4): *An increase in price is associated with a decrease in margin.*

This last hypothesis reflects the notion that underlying cost changes are 'shared' between the client and contractor as a function of risk transfer.

Referring to the results shown in Table 6.2, hypothesis (2) is supported by a strong positive correlation which remains significant at an α-level of 0.1% even as all outliers are excluded from the tested sample. Thus, a cost increase tends to be associated with a price increase and a cost decrease with a price decrease.

Hypothesis (3), that an increase in cost is associated with a decrease in margin is also supported, albeit only once outliers have been excluded from the correlation test. The need to exclude the outliers results from a small number of extreme projects in which very large cost increases (the largest being 407%) occurred in conjunction with very large margin increases (the corresponding margin increase in the given example being 94%). With outliers excluded, a strong, negative correlation is found to exist so that cost increases are typically associated with margin decreases and vice versa.

An unexpected result arises in testing hypothesis (4). Though weak, once all outliers have been excluded, there exists, nonetheless, a positive correlation (with a probability of 99% that the effect is not due to chance) between price change and margin change so that a price increase tends to occur in conjunction with a margin increase. This result does not support hypothesis (4) and is incompatible with the assumption that underlying cost changes are 'shared' between the client and the contractor.

Table 6.2: Correlation Tests Summary

Data range descriptions for correlation testing	Pearson product-moment correlation coefficient, r	Data sample range description	No. of projects in sample range	Significance, P (probability that correlation is due to chance)
Hypothesis (1) *Greater risk transfer from the client to the contractor is associated with greater project delivery efficiency.*				
Degree of risk transfer $= \frac{\lvert\Delta M\rvert}{\lvert\Delta M\rvert + \lvert\Delta P\rvert}$ AND Project delivery inefficiency $\sqrt{(\Delta M)^2 + (\Delta P)^2}$	-0.22	All	296	P<0.0001
	-0.20	Excluding extreme outliers: -100% < ΔP < 100%	286	P=0.0003
	-0.13	Excluding all outliers: -40% < ΔP < 40%	272	P=0.0160
Hypothesis (2) *An increase in cost is associated with an increase in price.*				
ΔC AND ΔP	0.93	All	296	P<0.0001
	0.71	Excluding extreme outliers: -100% < ΔP < 100%	286	P<0.0001
	0.65	Excluding all outliers: -40% < ΔP < 40%	272	P<0.0001
Hypothesis (3) *An increase in cost is associated with a decrease in margin.*				
ΔC AND ΔM	0.25	All	296	P<0.0001
	-0.44	Excluding extreme outliers: -100% < ΔP < 100%	286	P<0.0001
	-0.66	Excluding all outliers: -40% < ΔP < 40%	272	P<0.0001
Hypothesis (4) *An increase in price is associated with a decrease in margin.*				
ΔP AND ΔM	0.58	All	296	P<0.0001
	0.32	Excluding extreme outliers: -100% < ΔP < 100%	286	P<0.0001
	0.14	Excluding all outliers: -40% < ΔP < 40%	272	P=0.0105

6.5.3 Investigating the Price Increase – Margin Increase Correlation

Consideration of the arithmetic means of the ΔC, ΔM and ΔP data series in the sample reveals that, on average, price increases and margin increases are similar and are greater than cost increases (Refer to Table 6.3). In fact, once extreme outliers are removed, the average cost change for the sample is found to be a cost decrease, while both the average price and margin changes are increases. (It is notable, however, that standard deviations are generally very high though of a similar magnitude for all ΔC, ΔM and ΔP. While expected,

given the considerable differences between different projects, the high standard deviations would tend to reduce confidence in the revealed relationship).

This result does not contradict (nor does it support, for that matter) the finding of a positive correlation between ΔC and ΔP as the Pearson product-moment correlation coefficient, r, is not suggestive of any specific geometric properties beyond its general inclination (positive or negative) of the linear trend-line to which the data 'fit' but only to the degree of 'fit' itself. It is thus reasonable for a negative value of ΔC to correspond with a positive ΔP and so on. However, it does imply that the relationship between ΔM and ΔP is not merely one of 'sharing' increases and decreases in the underlying cost, rather, it seems that some of the margin increase is achieved at the expense of a price increase. Such an interpretation would help explain the positive correlation between ΔM and ΔP values.

In further investigating this phenomenon, project data which exhibit an increase in the underlying cost are of particular interest and these are compared with data for those projects which experience a cost decrease. If the arithmetic means for ΔC, ΔM and ΔP for projects showing an overall cost increase are compared with those for ΔC, ΔM and ΔP for projects showing an overall cost decrease (see Table 6.3) then, regardless of the inclusion or exclusion of outliers and in general terms, cost increases appear to be borne largely by the client in the form of price increases (margins remaining largely unchanged) while cost decreases are largely captured by the contractor as margin increases (prices remaining largely unchanged).

This suggests that the degree of risk transfer differs under conditions of cost increase as compared to conditions of cost decrease. Specifically this may be stated as:

Hypothesis (5) *the degree of risk transfer associated with cost increases is less than the degree of risk transfer associated with cost decreases*.

This hypothesis is supported when tested with a one-tailed Student's t-test - values for the degree of risk transfer under cost increases are found to be substantially and significantly ($P < 0.01\%$) lower than under cost decreases. (Refer to Table 6.4 for details). However, the testing does not imply causality in the sense that, while there is a very strong indication that the degree of risk transfer is greater in conjunction with a cost decrease than it is in conjunction with a cost increase, it remains unclear whether the cost change determines the degree of risk transfer or whether the degree of risk transfer is influencing the cost change (or whether some other factor(s) is (are) responsible for both effects).

Table 6.3: Arithmetic Means of ΔC, ΔM and ΔP

Data descriptions	All projects			Excluding extreme outliers: -100% < ΔP < 100%			Excluding all outliers: -40% < ΔP < 40%		
	No.	mean	S.D.	No.	mean	S.D.	No.	mean	S.D.
All projects									
ΔC	296	**4%**	40%	286	**-1%**	19%	272	**-2%**	15%
ΔP	296	**11%**	47%	286	**5%**	18%	272	**3%**	12%
ΔM	296	**7%**	18%	286	**5%**	14%	272	**4%**	12%
Projects which exhibit an overall cost increase only									
ΔC	140	**23%**	50%	131	**13%**	17%	121	**11%**	12%
ΔP	140	**27%**	63%	131	**13%**	18%	121	**9%**	10%
ΔM	140	**4%**	21%	131	**0%**	14%	121	**-2%**	12%
Projects which exhibit an overall cost decrease only									
ΔC	156	**-13%**	13%	155	**-12%**	11%	151	**-12%**	9%
ΔP	156	**-3%**	17%	155	**-3%**	15%	151	**-3%**	10%
ΔM	156	**10%**	13%	155	**10%**	13%	151	**9%**	10%

6.5.4 Testing the Realization of Intentions to Transfer Risk

The issue of causality may be partially addressed if consideration is given to the indications of the intention to transfer risk. It has been discussed in Section 3.2.2 that the level of integration or 'bundling' and the degree to which the payment mechanism is output-based are indicative of the intended risk transfer from the client to the contractor. If the intention to transfer risk is assumed, for now, to be effective in practice (it will be specifically tested below), it would then be expected that more integrated projects with more output-based payment mechanisms would show a higher degree of risk transfer than the others. Since the relative effects of more integration compared to a more output-based payment mechanism are unknown at this stage, it is not possible to rank the projects in terms of intended risk transfer more accurately than 'higher risk transfer' projects (fixed price payment + integration) and 'the rest' (all projects which are either not fixed price or not integrated).

Table 6.4: Cost Increase / Cost Decrease scenarios – Student's t-tests Summary

Data descriptions	Cost Increase		Cost Decrease		Significance (probability of the difference occurring by chance)
	No. of projects	Arithmetic mean degree of (eventuated) risk transfer $= \frac{\lvert\Delta M\rvert}{\lvert\Delta M\rvert + \lvert\Delta P\rvert}$	No. of projects	Arithmetic mean degree of (eventuated) risk transfer $= \frac{\lvert\Delta M\rvert}{\lvert\Delta M\rvert + \lvert\Delta P\rvert}$	(Unpaired, one-tailed Student's t-test)
Hypothesis (5) The degree of risk transfer associated with cost increases is less than the degree of risk transfer associated with cost decreases.					
All projects	140	0.39	156	0.68	P < 0.0001
Excluding extreme outliers: -100%< ΔP < 100%	131	0.40	155	0.68	P < 0.0001
Excluding all outliers: -40%< ΔP < 40%	121	0.42	151	0.69	P < 0.0001
Hypothesis (5) tested for projects with higher intended risk transfer.					
Higher intended risk transfer projects (fixed price & integrated)	19	0.34	23	0.74	P < 0.0001
All other projects	41	0.40	32	0.47	P = 0.1974

Considering these two groups (higher intended risk transfer group; the rest) separately, there is a substantial (and significant, P<0.01%) difference between the degree of risk transfer values under cost decrease compared to those under cost increase for the higher intended risk transfer group. In contrast, the difference is neither so large nor is it significant under cost increase / decrease scenarios for the other projects (refer to Table 6.4). In addition, the mean values of (eventuated) risk transfer calculated for the higher intended risk transfer projects are of interest in that, for cost increase scenarios, they average 0.34 i.e. considerably less than 0.5 (which represents 50-50 sharing of the eventuated risk) and could be termed low risk transfer. (On average, the client pays for 66% of cost increases.)

For cost decreases, on the other hand, the average (eventuated) risk transfer is 0.74 reflecting a high degree of risk transfer (the contractor retaining 74% of cost decreases).

Turning now to testing the effectiveness of risk transfer intentions with respect to 'bundling' and to payment mechanisms, two further hypotheses are proposed:

Hypothesis (6) *More integrated procurement routes are associated with more risk transfer to the contractor.*

Hypothesis (7) *More output-based contractor payment mechanisms are associated with more risk transfer to the contractor.*

The results of the statistical testing of these hypotheses appear in Table 6.5.

Table 6.5: Effectiveness of Risk Transfer Intentions – Student's t-test Summary

Data range descriptions	No. of projects	Degree of risk transfer $= \frac{\lvert\Delta M\rvert}{\lvert\Delta M\rvert + \lvert\Delta P\rvert}$	Significance (probability of difference occurring by chance)	Mean project delivery inefficiency $\sqrt{(\Delta M)^2 + (\Delta P)^2}$	Significance (probability of difference occurring by chance)
Hypothesis (6) More integrated procurement routes are associated with more risk transfer to the contractor.					
Less integrated projects (Build only)	61	**0.45**	**P=0.1751**	0.23	P=0.1674
More integrated projects (More than Build only)	54	**0.51**		0.34	
Hypothesis (7) More output-based contractor payment mechanisms are associated with more risk transfer to the contractor.					
Less output-based contractor payment (other than Fixed Price)	18	**0.27**	**P=0.0002**	0.30	P=0.4391
More output-based contractor payment (Fixed Price)	96	**0.52**		0.28	

The analyses summarized in Table 6.5 suggest that only hypothesis (7): *more output-based contractor payment mechanisms are associated with more risk transfer to the contractor* is supported. Yet the degree of risk transfer values associated with more output-based contractor payment (0.52) are similar to the

overall arithmetic mean value for degree of risk transfer for all projects (0.48). This suggests that it is more accurate to assert that more input-based contractor payment is associated with *lower* risk transfer to the contractor. In any case, the relatively higher degree of risk transfer associated with more output-based contractor payment is not reflected in any statistically significant improvement in project delivery efficiency although the analysis does show a slightly lower project delivery inefficiency value for the higher risk transferring group.

The evidence in support of hypothesis (6): *more integrated procurement routes are associated with more risk transfer to the contractor* is not statistically significant (even at $\alpha = 10\%$). The mean project delivery inefficiency values in this case are higher for the more integrated projects (though also not at an acceptable level of statistical significance to draw any conclusions regarding their correspondence).

6.5.5 Comparing the Performances of Different Client Types

Mean values for the performance indicators ΔC, ΔP, ΔM, degree of risk transfer and project delivery inefficiency according to client type are shown in Table 6.6. For this sample, the public sector clients can be seen to be more consistent and to achieve greater project delivery efficiency (less inefficiency) than their private sector counterparts. The greater consistency of public sector clients' performance is indicated by both the generally lower standard deviation values for all indicators and by the comparatively low number of projects which are identified as outliers where the change in price is equal to or more than 40% of the initial cost estimate (2% of projects for public sector clients compared to 10% for private sector clients and 16% for projects undertaken by the contractor's own organisation).

The lower values for project delivery inefficiency achieved by public sector clients reflect public sector clients' comparative success at restraining both price and margin increases.

The values calculated for the degree of (eventuated) risk transfer are not particularly sensitive to the inclusion or exclusion of outliers since outliers will tend not to influence (eventuated) risk transfer values to a great extent as the risk transfer value is a ratio with maximum value 1 and minimum value 0 regardless of how extreme the project's ΔC, ΔP and ΔM values may be. The pattern which emerges is one where private sector clients tend to succeed in transferring the most risk to contractors. Public sector clients achieve an approximate 50 – 50 sharing of eventuated risk with their contractors while contractors working for their own organizations accept least eventuated risk (this being merely notional risk transfer since it reflects interdepartmental distributions within single firms).

However, in light of the finding in support of Hypothesis (5) *the degree of risk transfer associated with cost increases is less than the degree of risk transfer associated with cost decreases,* it must be noted that the higher average risk transfer values for private sector clients occur in the context of overall cost decreases (when outliers are excluded as they have a profound effect on mean

ΔC values). If the private sector clients' values for degree of risk transfer are calculated separately for both data subsets "under cost increases, i.e $\Delta C > 0$ " and "under cost decreases, i.e. $\Delta C < 0$" then the corresponding mean values for (eventuated) risk transfer are 0.42 and 0.80 respectively!

Table 6.6: Performance Indicators by Client Type

Client Type	No. of projects	ΔC	ΔP	ΔM	Degree of risk transfer $\frac{\lvert\Delta M\rvert}{\lvert\Delta M\rvert + \lvert\Delta P\rvert}$	Project delivery inefficiency $\sqrt{(\Delta M)^2 + (\Delta P)^2}$
All projects						
Own organisation (internal project)	49	mean = 2% s.d. = 27%	mean = 17% s.d. = 38%	mean = 15% s.d. = 29%	mean = 0.43 s.d. = 0.26	mean = 0.35 s.d. = 0.40
Private sector client	135	mean = 6% s.d. = 52%	mean = 13% s.d. = 61%	mean = 7% s.d. = 15%	mean = 0.62 s.d. = 0.37	mean = 0.28 s.d. = 0.58
Public sector client	112	mean = 3% s.d. = 24%	mean = 6% s.d. = 29%	mean = 3% s.d. = 12%	mean = 0.50 s.d. = 0.34	mean = 0.13 s.d. = 0.29
Excluding extreme outliers: -100% < ΔP < 100%						
Own organisation (internal project)	46	mean = -2% s.d. = 21%	mean = 10% s.d. = 26%	mean = 12% s.d. = 26%	mean = 0.43 s.d. = 0.27	mean = 0.28 s.d. = 0.27
Private sector client	129	mean = -2% s.d. = 22%	mean = 4% s.d. = 20%	mean = 5% s.d. = 12%	mean = 0.64 s.d. = 0.36	mean = 0.17 s.d. = 0.17
Public sector client	111	mean = 1% s.d. = 14%	mean = 3% s.d. = 10%	mean = 2% s.d. = 9%	mean = 0.51 s.d. = 0.34	mean = 0.11 s.d. = 0.09
Excluding all outliers: -40% < ΔP < 40%						
Own organisation (internal project)	41	mean = -2% s.d. = 22%	mean = 4% s.d. = 17%	mean = 6% s.d. = 18%	mean = 0.43 s.d. = 0.28	mean = 0.20 s.d. = 0.15
Private sector client	121	mean = -4% s.d. = 14%	mean = 2% s.d. = 12%	mean = 5% s.d. = 11%	mean = 0.67 s.d. = 0.35	mean = 0.14 s.d. = 0.10
Public sector client	110	mean = 1% s.d. = 13%	mean = 3% s.d. = 9%	mean = 3% s.d. = 9%	mean = 0.51 s.d. = 0.34	mean = 0.11 s.d. = 0.08

6.6 Discussion of Findings

The principal findings from the data analysis of this sample of Estonian construction projects may be summarised as follows:

1) Greater risk transfer from the client to the contractor is associated with greater project delivery efficiency;
2) Cost increases are associated with price increases;
3) Cost increases are associated with margin decreases;

4) Price increases are associated with margin increases;
5) Risk transfers under conditions of cost increases are smaller than risk transfers under conditions of cost decreases;
6) More integrated procurement routes (more 'bundling') does not correspond to any significant difference in risk transfer nor any significant difference in project delivery efficiency;
7) More input-based contractor payment mechanisms are associated with lower risk transfers but do not correspond to any significant difference in project delivery efficiency;
8) Public sector clients achieve greater project delivery efficiency more consistently than private sector clients. Contractors acting as their own clients achieve lower project delivery efficiency than either external private sector clients or public sector clients.
9) On average, and if outliers ($-40\% < \Delta P < 40\%$) among the projects are ignored, prices increase by 3%, margins increase by 4% and costs decrease by 2% (all expressed as % of initial cost expectation, C_0)

It has been argued throughout this monograph that the greater risk transfer – greater project delivery efficiency relationship is central to the justification for the PPP approach and should be empirically tested. The data analysis undertaken (refer to Table 6.2) has shown that, for the data collected, such a relationship can be said to exist but the correlation is extremely weak (see Figure 6.2).

If an attempt at abstracting an approximate magnitude of the improved project delivery efficiency effect of risk transfer is made from this relationship, then the linear trendline in Figure 6.2 suggests that the average project delivery inefficiency of projects with zero risk transfer is in the order of 0.05 greater than that corresponding to projects with 100% risk transfer.

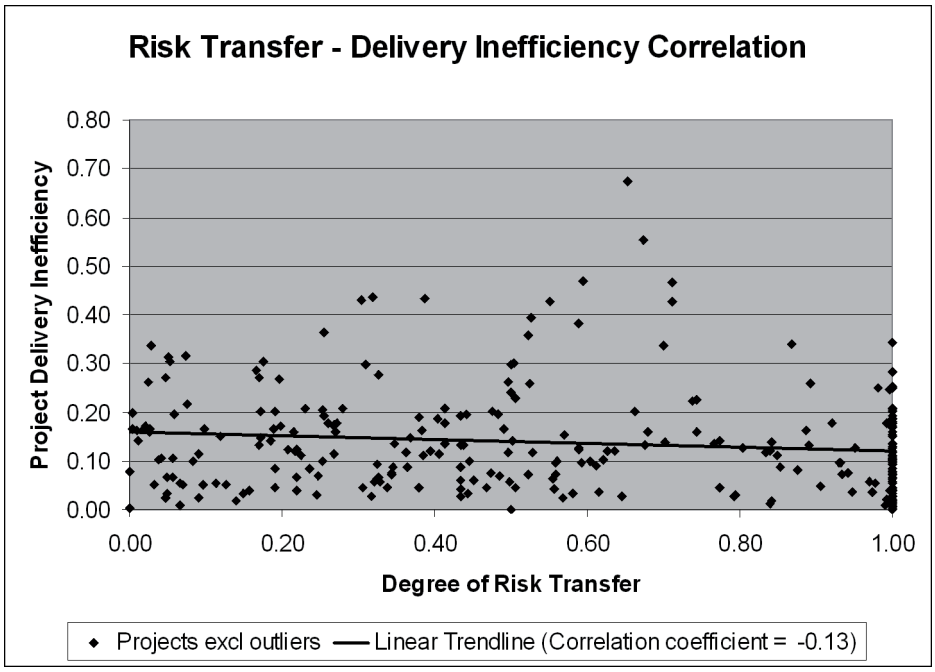

Figure 6.2: The Risk Transfer – Project Delivery Efficiency Correlation

Since for 100% risk transfer there is no corresponding change in price (only a margin change) and for 0% risk transfer only price change occurs, this difference could be expressed simply as a relative price change, as follows:

$$0.05 = \sqrt{(\Delta M)^2 + (\Delta P)^2}$$

$$\Delta M = 0$$

$$\Delta P = \pm 0.05$$

so that, the project delivery inefficiency difference translates into a price difference of 5% (of the initial cost estimate, C_0).

This 'result' is both small and highly contrived. Firstly, as the intention to transfer risk is only partially effective - output-based payment mechanisms and 'bundling' appear to result, on average, in changes to (eventuated) risk transfer of the order of 0.54 for output-based compared to 0.27 for non-output-based and 0.51 for 'bundled' compared to 0.45 for 'unbundled' (refer to Table 6.5). This is a considerably narrower range than the 0 to 1.0 range used in the calculation above and it falls well short of the 100% risk transfer that the PPP approach envisages. Secondly, it is undermined by the finding that risk transfers under conditions of cost increase are smaller than those under conditions of cost decrease. The evidence in Table 6.4 even suggests that higher intended risk transfers result in lower eventuated risk transfers under conditions of increased

cost. This implies that the intention to transfer risk tends only to be effective when it is undesirable for the client (i.e. under cost decreases). Conversely, when the client would benefit from high risk transfers (i.e. under conditions of cost increases) risk transfer intentions are relatively ineffective. The finding that neither 'bundling' nor output-based payment seem to significantly affect project delivery efficiency (Table 6.5) also suggests that the risk transfer – project delivery efficiency relationship is not suitably robust for practical application.

Table 6.4 indicates that the number of projects which experience an overall cost increase is similar to the number with an overall cost decrease. This, together with the average cost change (when extreme outliers are excluded) of -1% (refer to Table 6.3), suggests that contractors' cost estimation is relatively accurate within the data sample and that there is neither systematic bias towards cost increases nor towards cost decreases. Yet there clearly is a tendency for prices to rise and for margins to rise with them which implies that contractors have the possibility to 'steer' the financial outcome of projects in their favour and that they do so. This might be envisaged as occurring by way of two general, simplified mechanisms:

1) Where an overall cost decrease occurs the contractor succeeds in maximizing the share of the saving which is captured as increased margin. (Price remains largely unchanged).
2) Where an overall cost increase occurs the contractor succeeds in minimizing the impact of this increase in terms of decreased margin. (Price rises in proportion to cost increase).

In this way, the contractor appears to be able to exert a degree of control over risk transfer.

It was noted in Section 3.2.1 that one report into UK PPPs had suggested that premiums of 25% (in the case of road projects) and 31% (in the case of hospital projects) had been added to ensure that projects would complete within budget. Firstly, the magnitude of such risk premiums is clearly out of proportion to average price increases in the Estonian sample context (where the average price increase is in the order of 5%, see Table 6.3). But, secondly, such an addition of a risk premium will, by this analysis, effectively increase the risk transfer to the contractor since the likely cost decrease outcome will translate into higher risk transfer to the contractor (i.e. will serve to increase margin rather than any cost saving being reflected in a reduced price). The addition of contingency is not a response to higher risk transfer, rather, higher risk transfer results from the addition of contingency (and the likely consequent cost decrease if everything else is equal and cost estimates are typically accurate). The 100% risk transfer sought by PPP advocates indeed appears to be achievable if the budget is inflated to a sufficiently great extent. (Though this would certainly not be financially efficient from the client's point of view).

Finally, the analysis found that public sector clients achieve greater project delivery efficiency more consistently than private sector clients or contractors acting as their own clients. This finding appears to suggest comparatively greater

competence in terms of managing the procurement of construction projects by the public sector. It may reflect a relatively greater experience and adherence to good practice procedures by public sector clients. It certainly challenges the assertion that the competitive market environment in which the private sector operates promotes better management and instills in it a greater capacity to innovate and to take advantage of business opportunities than is possible for the public sector leading to the private sector's greater efficiency. With regard to the Estonian data collected, such a notion of greater private sector efficiency is clearly unsupported.

Noting that contractors' own organizations were found to be even less effective than other private sector clients, it seems unlikely that consortia comprising similar contractors in joint venture with other private sector entities (as in typical PPP arrangements) would be remarkably more effective than public sector clients in delivering construction projects.

6.7 Chapter Summary and Conclusions

On the basis of the project data collected for 296 Estonian construction projects completed in the years 2001 to 2010 and which represented approximately 2% of all national construction activity in the same period, a series of analyses were undertaken. These revealed that, although there is a negative correlation between values for the degree of risk transfer and those for project delivery inefficiency, the relationship between risk transfer and project delivery efficiency is very weak and it is unlikely that achieving greater risk transfer to the contractor will tend to result in appreciable project delivery efficiency gain.

Rather than reflecting risk transfer intentions such as indicated by the degree of 'bundling' and the degree to which the contractor payment mechanism is output-based, eventuated risk transfer was found to be higher in conjunction with cost decreases and lower in conjunction with cost increases. This result held where intended risk transfer was high in terms of both 'bundling' and output-based payment suggesting that risk transfer is not pre-determined but changes or is manipulated or 'steered', to some degree, over the course of a project. The data indicate that this 'steering' tends to benefit contractors rather than clients.

Graphically, this may be represented as a distribution where project coordinates are concentrated in the "contractor only benefits" quadrant of the graph. Projects with cost increases tend to be located in closer proximity to the ΔP axis (lower risk transfer) while projects with cost decreases tend to locate in closer proximity to the ΔM axis (higher risk transfer). This distribution is evident in Figure 6.1.

Public sector clients were shown to be more consistent and effective in efficiently delivering construction projects. This result challenges the notion that the competitive private sector environment promotes greater efficiency in terms of managing the procurement of construction projects.

7. CONCLUSIONS

7.1 Overview of Chapter

Chapters 2 to 5 have established the need for the empirical validation or refutation of the optimal risk transfer – value for money relationship which underpins the justification of the PPP approach, reformulated this relationship to render it generally applicable to construction procurement, drawn together a common, project-based interpretation of the conception of risk and developed the associated representations and metrics to enable risk transfer and project delivery efficiency to be measured and the postulated relationship between these to be modeled. The empirical testing of the developed model and thus the risk transfer – project delivery efficiency relationship have been carried out on the basis of data from historical Estonian construction projects in the data analysis reported in Chapter 6.

In this chapter, the findings of the data analysis are further discussed in relation to their implications for construction procurement in general and for the potential use of the PPP approach for infrastructure procurement in the Estonian context. In addition, possible modifications to underlying theory are explored from the design science perspective on theory development.

The limitations of this research and its significance for construction management are then considered and recommendations for further research are indicated.

7.2 Implications of the Findings

7.2.1 Implications for Construction Procurement

According to the data analysis in Section 6.5.4, neither bundling (integrating the construction element with other elements such as design, operation, finance, etc.) nor selecting an output-based contractor payment strategy appear to achieve any substantial increase in risk transfer to the contractor. (Conversely, selecting an input-based contractor payment mechanism does appear to result in significantly reduced risk transfer to the contractor). However, risk transfers under conditions of cost increases are significantly smaller than risk transfers under conditions of cost decreases. Assuming that cost estimates are genuine (and the evidence shown in Tables 6.3 and 6.4 indicates that there is no obvious systematic bias in the cost estimating with respect to this particular data sample) then cost increases or decreases (which are measured relative to the cost estimates) cannot be predetermined at the start of a construction project. This suggests that contractors are able to influence or 'steer' risk transfer to their benefit during the course of the project (as discussed in Sections 6.6 and 6.7).

The precise mechanism of such 'steering' is not accessible from such a broad, aggregated measure of risk transfer but it appears to be consistent with a

tendency for contractors to maximize their profit margins over the course of a project with the result (as shown by Table 6.3) that:

1) prices remain largely unchanged when an overall cost decrease occurs,
2) prices rise when an overall cost increase occurs.

This may be simply the selective management of costs by the contractor or a formal strategy to pursue price rises or any combination of both. In all cases, the implication is that risk eventuation is being influenced during the course of the project by the contractor. This is in line with the conception of risk put forward in Section 4.8.

Additionally, the correlation between risk transfer and project delivery efficiency is weak and, even if actual risk transfers closely matched risk transfer intentions (which they do not), the average, extrapolated project delivery efficiency gains from greater risk transfers would be small (approximately, in the order of a 5% price change corresponding to an increase in risk transfer from 0% risk transfer to 100% risk transfer).

Thus, if:

- the predetermination of risk transfer from client to contractor is ineffective in practice;
- the efficiency gains arising from increased risk transfer to the contractor are small; and,
- the influence that may be exerted on risk transfer during the course of the project is considerable,

then it appears that there is little benefit to a client in attempting to transfer risk to a contractor, particularly if this attracts an additional price premium.

The current arrangement, where risk transfers are low under cost increases and high under cost decrease scenarios, is obviously not in the client's interest. If performance incentives could be maintained at similar levels (which is, of course, a questionable assumption) then a zero risk transfer arrangement would translate into an overall decrease in price of 2% (measured as a % of the initial cost estimate, C_0) compared with the actually achieved 3% overall price increase. (Refer to the figures (all projects, excluding all outliers) in Table 6.3). That is, a 5% improvement. Alternatively, a procurement approach which ensured equitable gain-share or pain-share (eventuated risk transfer of 0.5) would still be preferable for the client as it would enable the client to share in the benefits of influencing risk eventuation. Again referring to the (all projects, excluding all outliers) figures in Table 6.3, this would provide an approximately 4% improvement in price (from a 3% price increase to a 1% price decrease). Such an arrangement might have greater possibilities to maintain performance incentives but, as previously discussed, the data suggest that achieving any specific degree of desired risk transfer is unlikely.

It should also be noted here that since ΔC, ΔP and ΔM are all expressed as percentages of the initial estimated cost, the ΔM values appearing in Table 6.3 represent very substantial changes in profit margin. Given that the average

estimated profit margin for the projects in the sample is about 8% of the initial cost estimate by value or about 10% by project (as smaller projects tend to have higher estimated profit margins), a value of $\Delta M = 9\%$ roughly represents a doubling of the profit margin. With this in mind, an eventuated risk transfer of 0.5 is perhaps unnecessarily extreme and a considerably lower eventuated risk transfer of about 0.2 would still provide substantial performance incentives for the contractor if it could be adhered to.

There appears to be no appreciable benefit from bundling – though not statistically significant, the indications are rather that project delivery efficiency is better for the less integrated projects in the sample.

The overall impression given is that the procurement route characteristics (specifically the degree of 'bundling' and the contractor payment mechanism) have a limited effect on project delivery efficiency. The great variability between individual projects (noticeable in the high standard deviation values in Tables 6.3 and 6.6) suggests that other project parameters exert a greater influence on project outcomes. In other words, projects may be delivered efficiently or otherwise whatever their procurement arrangement.

7.2.2 Implications for the PPP approach in Estonia

The Estonian evidence does not appear to support the justification for the PPP approach. Neither the high degree of integration nor the extreme output-based payment mechanism is likely to translate into effective (i.e. eventuated) risk transfer to the contractor. And, even if it did, the corresponding project delivery efficiency gain is unlikely to be substantial (<5%) – certainly not of an adequate order of magnitude to offset the higher financing costs (as high as 70% more expensive than public finance - see Section 2.4.2) and arrangement costs associated with PPPs.

In addition, the case for PPP procurement in Estonia is undermined by the finding that public sector clients achieve greater project delivery efficiency more consistently than do private sector clients and that contractors acting as their own clients achieve lower project delivery efficiency than either external private sector clients or public sector clients.

7.2.3 The Design Theory perspective – Theory Development Considerations

In Section 3.3 it was argued that the relationship: *the greater the transfer of (construction) risk from the client to the contractor then the greater the efficiency of (construction) project delivery (all else being equal)* resembled mid-range design theory. The findings of the data analysis in Chapter 6 show that, from an evaluation of the corresponding design artifacts (procured projects), this relationship has low utility as design theory (at least in the Estonian context). While the evidence does provide validation that greater risk transfer is (weakly) correlated with greater project delivery efficiency, it also

indicates that the intention to transfer risk does not tend to result in the desired risk transfer - hence the low utility.

Additionally to validating or otherwise the design theory, it was suggested (in Section 3.4) that the data analysis would enable reflection on underlying kernel theories and thus would provide a basis for theory development in terms of both design and kernel theories.

The New Public Management paradigm of relatively greater private sector efficiency, which may be considered to constitute supporting, kernel theory in this case, does not appear to be borne out by the evidence of the better performance of public sector construction clients in Estonia. The implication being that the greater private sector efficiency assumption should either be modified or is simply not applicable in this context.

In a similar way, a conception of risk supporting the relationship under investigation must allow for risk to be allocated by the client to the contractor. This equates to a requirement that risk transfer can be predetermined by the client – though this is not a necessary precondition for the relationship to be 'true', it certainly is for the relationship to be useful. However, the evidence suggests that risk transfer is not predetermined and tends to be influenced by the contractor over the course of the project. This can be readily explained in terms of a changing knowledge context as the project proceeds. (It may be helpful for the reader to refer once again to Figure 4.4 in which the general project risk concept is illustrated.) At the end of the project (t_1), the outcome is known with certainty and may be conveniently equated to a state of complete knowledge (with respect to the project outcome). At the beginning of the project, the context is one of partial knowledge. The predetermination of risk transfer or, in other words, the allocation of risk at this time (t_0), takes place in the absence of some relevant knowledge. The missing knowledge relates to the inability to define all of the assumptions supporting the outcome expectation, which of their assumed values will be incorrect and to what extent these will affect the outcome.

As the project progresses the missing knowledge is incrementally revealed until, at t_1, complete knowledge is attained. Thus, risk allocation, since it can only reflect partial knowledge, cannot be fully defined. In addition, since it is typically the contractor who is directly engaged in the work and therefore largely in control of it, it is rather the contractor than the client to whom the missing knowledge is first revealed and who is better placed to react so as to maximize unanticipated gains and avoid unanticipated losses as they arise and thus influence risk transfer.

The suggestion here is not that there is necessarily any withholding of information from the client nor any delay in sharing new knowledge as it is revealed. It is simply the observation that, if the partial knowledge on which the initial risk allocation is based (at t_0) were to represent a relatively great proportion of the complete knowledge available at project completion (at t_1) then relatively little missing knowledge would be revealed in the course of the project, little influence on risk transfer could be exercised by the contractor and

risk allocation and eventuated risk transfer would be relatively similar. Conversely, if the initial risk allocation were to reflect a relatively small proportion of the complete knowledge with a great amount of additional knowledge being revealed during the course of the project, then risk allocation (or intended risk transfer) would tend to be substantially different from eventuated risk transfer with an associated increase in the possibility for risk transfer to be influenced. The data analysis suggests that this latter scenario more closely resembles the typical situation for the projects in the sample.

By way of analogy, consider the project as a field at night which the client and contractor intend to cross. If the field were to be intensely flood-lit (with the bright light of complete knowledge), the client could, at the start of the journey, indicate the precise line to be followed so as to avoid all obstacles and the destination point on the far side of the field could be accurately predetermined. However, the typical construction project context seems to more closely resemble a scenario where only a torch is providing the illumination. The general direction may be indicated from the start but the obstacles must be dealt with as they emerge from the darkness. Now, since it is the contractor who is carrying the torch, the choice of which way to go around the obstacles and thus the destination point on the far side of the field tends to be subject to his influence.

The implication seems to be that risk allocation decisions made at the start of a project are characterized by a context of relative ignorance. Whether this reflects upon the absolute availability of knowledge at this time is unclear, but the extent to which knowledge is applied (and perhaps the accuracy with which knowledge may be discerned from that which is not knowledge) is limited.

In addition, there is a definitional problem which has been alluded to above – as complete knowledge regarding a project outcome is only available on its realization and not before, the assumptions upon which any particular outcome expectation is based cannot be fully defined. Similarly, at a more detailed level, it seems that a risky proposition may not be fully defined and still be 'risky'. (A coin toss makes a convenient example – if the mechanics of the toss, coin characteristics, starting position, landing position, landing surface properties, etc. are all fully defined, then the outcome is certain. The 'riskiness' lies in the incompleteness of the relevant knowledge and, consequently, the vagueness of the definition). This research has avoided the problem of identifying or defining specific risky propositions by considering only the aggregate effect of all risky propositions on the sample projects' outcomes. However, the utility of its findings are undermined by precisely the same effect because, by aggregating the results from a large number of projects, general trends have been identified but the application of such general trends to a single, specific project has very limited use. The vagueness of probability remains inescapable.

In terms of providing validation or refutation of the generalized relationship between risk transfer and project delivery efficiency, the multi-project level approach can be seen to be appropriate since the relationship under investigation

is defined at the same (multi-project, procurement policy) level of aggregation. However, with regard to utility, specifically the development of design theory with respect to procurement arrangement 'design' for individual projects, this high level of aggregation reduces its applicability and rather indicates obstacles to the useful application of the risk concept to the project context than providing constructive input to the development or modification of the supporting theory.

7.3 Limitations of the Research

Thus, while appropriate for informing procurement policy, the high degree of generalization which necessarily ignores the uniqueness of projects and their specific details imposes a limitation on the application of the research to individual projects.

It is clear from the relatively great project to project variability of the parameters under consideration that the degree of 'bundling' and the contractor payment mechanism are not the only determinants of project delivery efficiency and / or risk transfer. Numerous other factors, for example, economic, contractual and other contextual conditions, motivation levels among personnel, project team communications, etc. appear to be influential and their effects have been assumed to 'balance out' over the project sample provided that the sample is sufficiently large.

However, since the sample project data were drawn from a small number of construction firms (four in total) some of these factors, particularly 'soft' factors such as the motivation levels of personnel, may be firm-specific and thus could potentially affect the extent to which the research findings reflect overall market conditions.

Further potential sample selection-related limitations arise from the self-selection by firms in terms of whether to participate in the survey and to what extent to participate in it. With regard to the former, the decision by some of the firms approached to decline to participate in the survey may have been in consideration of how their project values (for example, perhaps what they considered to be unusually high or low profit margins) might differ from other firms'. Similarly, only two of the four construction firms which did participate shared the entirety of their project data within a given date range – in the case of the other two firms, only the data for selected projects were divulged. Again, the representativeness of the data with respect to the overall Estonian construction market may thus be limited.

Similarly, the extent to which the Estonian construction context may be taken to be representative of the wider, international construction environment constrains the applicability of these results beyond the Estonian construction industry.

As noted in Section 5.2.2, the relative measure of project delivery success employed – the achievement of both the client's price expectation and the contractor's margin expectation – does not give any indication as to whether the

price corresponding to any particular project reflects value for money in an absolute sense. This effect is somewhat counteracted by the context in which the contracts are agreed – often with price competition in the selection of the contractor and, typically, between a knowledgeable contractor and a knowledgeable client. A second limiting consequence of this choice of metric is that only successfully completed historical projects may be considered and, if a significant proportion of projects in the overall market tend not to be completed, then this would constitute a sampling bias.

Project delivery efficiency is taken to be a suitable proxy for value for money with respect to the construction phase. However, the value for money definition referred to in Section 3.2.3 specifically relates to whole life cost and quality which encompasses a broader range of possibilities particularly with respect to potential efficiency effects materializing later on in the life of the constructed facility (primarily in the operation phase). In this way, value for money which occurs outside the construction phase may be seen to be discounted in this research.

As indicated in Section 5.2.1, the time and quality dimensions of project outcomes are subordinated to cost in this analysis with the assumption that if time and / or quality were considered of particular importance, then this would be reflected in the cost dimension (through time- or quality-related penalties and incentives). However, it is conceivable that a non-cost dimension emphasis could be chosen by the client and that this could affect the representativeness of the project delivery efficiency and risk transfer values.

7.4 Significance for Construction Management and Wider Research

This research represents an original and pioneering attempt to model and quantitatively test the risk transfer – project delivery efficiency relationship that underpins the justification for the PPP approach and is assumed to apply to construction procurement in general. Specific contributions to our understanding in this respect arise in three areas: with regard to the concept of risk and its allocation, with regard to the selection of procurement routes for projects as well as specific implications for the appropriateness of the PPP approach.

In terms of the conception of risk, the research has drawn attention to the considerable inconsistencies between the concepts of risk which have been adopted in the construction literature and the corresponding doubt which this casts upon all of its applications (for instance in terms of generalizations relating to the 'allocation of risk' or the 'management of risk', etc.) Though the research has proposed a generally applicable conception of risk, it has stopped short of developing this into alternative applications. Rather, it has emphasized the shortcomings of such applications.

Regarding procurement route selection, the research findings are supportive of the construction-related literature which tends to consider procurement methods as project dependent rather than there being a single, preferred

procurement route. There is obviously a slight conflict between this stance and the practical formulation of public procurement policy which favours standardization. Specifically, the research findings suggest a limited significance of client choices in terms of initial procurement decisions and imply that procurement approaches which include greater flexibility so as to enable efficient responses to unanticipated events will generally have greater utility given the apparently high level of ignorance at the project start.

Beyond the field of construction management, this research provides much-needed empirical evidence in terms of the justification for the Public Private Partnership approach to public procurement of infrastructure. While the findings reflect only the Estonian context, they do directly and significantly challenge the risk transfer and private sector efficiency assumptions which are basic to the justification of the PPP approach and the research methodology and the adopted measures of project delivery efficiency and (eventuated) risk transfer are of general applicability and therefore provide a contribution to the wider, multidisciplinary PPP research effort.

7.5 Recommendations for Further Research

Whether risk transfer cannot be predetermined with some success or whether it *could* be but simply *is* not remains unclear from this research. There is a need to ascertain in greater detail the extent to which attempts are made to predict the eventuation of risks (i.e. to identify risks) at the start of and during construction projects, how accurate these attempts tend to be and the level of accuracy which may potentially be attained.

To further pursue the issues of risk identification and risk transfer in construction projects – longitudinal studies tracking selected, 'specific' risks through construction projects to determine by what mechanism the apparent influencing of risk transfer occurs could be undertaken. Such research is somewhat complicated by the observation made earlier that risky propositions may not be fully defined.

Equally, the strong indication that risk-based approaches may not be effective in practice which arose in this research should be further explored both in terms of more accurately determining their effectiveness (as above) and also investigating the possibility of alternative, non-risk-based approaches to the consistent achievement of efficient project delivery and the procurement arrangements which support these.

Longitudinal studies could also provide insight into how the risk transfer and project delivery efficiency measurements change as projects progress and to what extent this might assist in enabling the early prediction of project outcomes.

Finally, there is scope for country comparisons of data – to determine how generally applicable the findings are and the extent to which the Estonian context differs from others.

7.6 Chapter Summary and Conclusions

The principal findings of the data anaylsis were:

- that the predetermination of risk transfer from client to contractor is ineffective in practice;
- that the efficiency gains arising from increased risk transfer to the contractor are small; and,
- that the influence that may be exerted on risk transfer during the course of the project is considerable.

It appears, consequently, that there is limited benefit to a client in attempting to transfer risk to a contractor at the start of a project.

For the historical Estonian projects analyzed, risk transfers tended to be low under cost increases and high under cost decrease scenarios, and this arrangement does not serve the client's interests.

The Estonian evidence does not support the justification for the PPP approach – a high degree of integration and an output-based payment mechanism tend not to translate into greater risk transfer to the contractor and neither does greater risk transfer correspond to an adequately substantial project delivery efficiency gain to offset the higher financing and arrangement costs associated with PPPs. In addition, Estonian public sector clients tend to achieve greater project delivery efficiency more consistently than do private sector clients.

Thus, the relationship: the greater the transfer of (construction) risk from the client to the contractor then the greater the efficiency of (construction) project delivery (all else being equal) is found to have low utility as design theory. Similarly, the kernel theory (associated with New Public Management) regarding greater private sector efficiency, is not supported by the evidence.

It appears that risk allocation decisions made at the start of a project are characterized by a context of relative ignorance. Though it remains unclear to what extent this reflects the absolute availability of knowledge at this time, coupled with the inconsistent meaning of the term 'risk' as it is applied in the construction context, this may present a challenge to the effectiveness of risk-based approaches to project management.

The primary limitations of the research relate to its multi-project aggregation of data (in order to overcome the large differences between projects) and the relatively narrow sampling. While appropriate for an investigation aimed at empirically testing the justifications for public procurement policies, the multi-project level findings are not directly applicable to individual projects. Likewise, the narrow sampling – all the data having been provided by four Estonian construction firms – limits the findings to the Estonian context on one hand and may have affected how representative the findings are even with regard to the Estonian construction market.

Recommendations for further research include the conducting of detailed, longitudinal studies to track risk eventuation within projects in order to better

understand the context in which risk transfer choices are made in practice and the mechanism by which (eventuated) risk transfer develops over the course of projects as well as to further explore possibilities of non-risk-based approaches to achieving project delivery efficiency. In addition, country comparisons of the same (eventuated) risk transfer and project delivery efficiency measurements as determined in this research for Estonian projects would be of interest in ascertaining international market differences.

This research project was conceived of in order to empirically test the validity of the PPP approach to public infrastructure procurement in Estonia and, in doing so, to contribute to the development of the science of construction management. The justification for the PPP approach was identified as being a relationship between risk transfer and project delivery efficiency which was considered to apply to all projects involving construction. A generally applicable conception of risk in construction projects and an eventuated risk model of construction procurement which directly related risk transfers to project delivery efficiency were developed for the purpose of testing the relationship. On this basis, data from a sample of Estonian construction projects were collected and analyzed. The analysis indicated that, in the Estonian context, risk transfers were not predetermined and that efficiency gains attributable to increased risk transfer were not sufficient to off-set the higher finance and arrangement costs commonly associated with PPP procurement. In addition, it was found that public sector construction clients tend to consistently deliver projects more efficiently than private sector clients in Estonia. The immediate research objective was therefore met in that the principal justification of the PPP approach was found to be invalid with respect to the Estonian context.

From a design science perspective, the risk transfer – project delivery efficiency relationship was found to have low utility as design theory for construction project procurement and supporting kernel theories relating to both the relative efficiency of the private sector and to the predetermination of risk transfer at the start of projects were challenged.

The contribution of this research to scientific knowledge is considered to be two-fold: firstly, in terms of the critical effort with which the existing construction-related and wider literature has been evaluated in this work (particularly in relation to the 'risk' and the 'Public Private Partnerships' literature) and, secondly, with regard to the formulation of original propositions concerning the conception of risk, the measurement of both risk transfer and project delivery efficiency, the modeling of their inter-relationship and the interpretation of empirical evidence with respect to the relative efficiency of the PPP approach. These propositions await the critical evaluation of the scientific community.

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APPENDIX A – PROJECT DATA

Project #	Start Year	Project Type	Client Organization Type	Initial Estimate (As a ratio of C0)			Actual Out-turn (As a ratio of C0)			Payment basis	Responsibilities of Contractor
				Price	Cost	Margin	Price	Cost	Margin		
				(P0)	(C0)	(M0)	(P1)	(C1)	(M1)		
1	2001	Infrastructure - water	Public sector - local government agency	100%	100%	0%	101%	91%	10%	Lump Sum	Build only
2	2001	Other	Public sector - state government agency	110%	100%	10%	110%	106%	4%	Lump Sum	Build only
3	2001	Building - commercial	Own organization / internal project	91%	100%	-9%	112%	100%	12%	Lump Sum	Design + Build
4	2001	Building - industrial	Private sector - other	130%	100%	30%	221%	221%	0%	Lump Sum	Build only
5	2002	Building - industrial	Private sector - other	120%	100%	20%	120%	79%	41%	Lump Sum	Design + Build
6	2002	Building - industrial	Private sector - other	109%	100%	9%	120%	107%	13%	Lump Sum	Design + Build
7	2002	Building - industrial	Private sector - other	121%	100%	21%	111%	103%	8%	Lump Sum	Design + Build
8	2002	Building - Institutional	Private sector - other	103%	100%	3%	103%	96%	7%	Lump Sum	Design + Build
9	2002	Building - industrial	Private sector - other	115%	100%	15%	115%	92%	23%	Lump Sum	Design + Build
10	2002	Building - commercial	Private sector - other	100%	100%	0%	100%	102%	-2%	Lump Sum	Build only
11	2002	Building - industrial	Private sector - other	103%	100%	3%	105%	99%	6%	Lump Sum	Build only
12	2002	Infrastructure - ports	Private sector - other	114%	100%	14%	134%	126%	8%	Lump Sum	Design + Build
13	2002	Building - industrial	Private sector - other	102%	100%	2%	113%	107%	6%	Lump Sum	Design + Build
14	2002	Building - Institutional	Public sector - local government agency	106%	100%	6%	115%	104%	10%	Lump Sum	Build only
15	2002	Infrastructure - highways	Public sector - local government agency	102%	100%	2%	122%	120%	2%	Lump Sum	Build only
16	2002	Infrastructure - ports	Private sector - other	100%	100%	0%	99%	90%	10%	Lump Sum	Design + Build
17	2002	Building - commercial	Public sector - publicly owned company	104%	100%	4%	111%	103%	8%	Lump Sum	Design + Build
18	2002	Building - industrial	Private sector - other	98%	100%	-2%	100%	99%	1%	Lump Sum	Design + Build
19	2003	Building - industrial	Private sector - other	138%	100%	38%	138%	117%	20%	Lump Sum	Build only
20	2003	Building - residential	Own organization / internal project	103%	100%	3%	98%	97%	1%		

Appendix 1 – Project Data (continued)

Project #	Start Year	Project Type	Client Organization Type	Initial Estimate (As a ratio of C0)			Actual Out-turn (As a ratio of C0)			Payment basis	Responsibilities of Contractor
				Price	Cost	Margin	Price	Cost	Margin		
				(P0)	(C0)	(M0)	(P1)	(C1)	(M1)		
21	2003	Infrastructure - ports	Public sector - publicly owned company	107%	100%	7%	107%	100%	7%	Lump Sum	Design + Build
22	2003	Building - commercial	Private sector - other	100%	100%	0%	100%	94%	6%	Lump Sum	Build only
23	2003	Infrastructure - ports	Public sector - publicly owned company	117%	100%	17%	119%	91%	28%	Lump Sum	Build only
24	2003	Other	Private sector - other	100%	100%	0%	140%	121%	19%	Lump Sum	Design + Build
25	2003	Other	Public sector - state government agency	100%	100%	0%	100%	97%	4%	Lump Sum	Build only
26	2003	Building - commercial	Private sector - other	105%	100%	5%	107%	93%	14%	Lump Sum	Build only
27	2003	Building - residential	Own organization / internal project	103%	100%	3%	119%	105%	14%		
28	2003	Building - residential	Own organization / internal project	111%	100%	11%	114%	107%	8%	Other	Design + Build
29	2003	Building - industrial	Public sector - publicly owned company	100%	100%	0%	107%	92%	14%	Lump Sum	Design + Build
30	2003	Building - residential	Own organization / internal project	115%	100%	15%	132%	110%	21%	Cost plus % fee	Build only
31	2003	Building - residential	Own organization / internal project	111%	100%	11%	94%	83%	11%	Target Cost	Design + Build + Finance + Operate
32	2003	Building - Institutional	Public sector - other	114%	100%	14%	136%	120%	16%	Lump Sum	Build only
33	2003	Infrastructure - ports	Public sector - publicly owned company	108%	100%	8%	108%	103%	5%	Lump Sum	Design + Build
34	2003	Infrastructure - ports	Private sector - other	108%	100%	8%	107%	95%	13%	Lump Sum	Design + Build
35	2003	Infrastructure - water	Private sector - utility	106%	100%	6%	106%	103%	3%	Lump Sum	Build only
36	2003	Building - Institutional	Private sector - other	110%	100%	10%	122%	100%	22%	Lump Sum	Build only
37	2004	Building - commercial	Private sector - other	100%	100%	0%	112%	109%	3%	Lump Sum	Build only
38	2004	Other	Private sector - other	93%	100%	-7%	111%	98%	13%	Lump Sum	Design + Build
39	2004	Other	Private sector - other	102%	100%	2%	128%	88%	41%	Lump Sum	Build only
40	2004	Other	Private sector - other	104%	100%	4%	107%	105%	2%	Lump Sum	Design + Build
41	2004	Infrastructure - highways	Public sector - state government agency	100%	100%	0%	100%	100%	0%	Lump Sum	Build only

Appendix 1 – Project Data (continued)

Project #	Start Year	Project Type	Client Organization Type	Initial Estimate (As a ratio of C0)			Actual Out-turn (As a ratio of C0)			Payment basis	Responsibilities of Contractor
				Price	Cost	Margin	Price	Cost	Margin		
				(P0)	(C0)	(M0)	(P1)	(C1)	(M1)		
42	2004	Building - Institutional	Public sector - publicly owned company	101%	100%	1%	103%	84%	19%	Lump Sum	Build only
43	2004	Building - industrial	Private sector - other	101%	100%	1%	110%	106%	3%	Lump Sum	Build only
44	2004	Building - commercial	Private sector - other	101%	100%	1%	105%	103%	2%	Lump Sum	Build only
45	2004	Infrastructure - railways	Public sector - other	111%	100%	11%	407%	310%	97%	Lump Sum	Build only
46	2004	Building - Institutional	Public sector - state government agency	95%	100%	-5%	102%	102%	0%	Lump Sum	Build only
47	2004	Building - Institutional	Public sector - state government agency	100%	100%	0%	105%	114%	-8%	Lump Sum	Build only
48	2004	Infrastructure - water	Private sector - other	102%	100%	2%	133%	130%	4%	Lump Sum	Design + Build
49	2005	Building - industrial	Private sector - other	126%	100%	26%	134%	103%	30%	Lump Sum	Design + Build
50	2005	Building - industrial	Private sector - other	133%	100%	33%	138%	97%	41%	Lump Sum	Design + Build
51	2005	Infrastructure - ports	Private sector - other	106%	100%	6%	607%	507%	100%	Lump Sum	Design + Build
52	2005	Building - residential	Private sector - other	106%	100%	6%	90%	78%	12%	Lump Sum	Build only
53	2005	Building - industrial	Private sector - utility	109%	100%	9%	92%	84%	8%	Lump Sum	Build only
54	2005	Building - residential	Own organization / internal project	109%	100%	9%	92%	83%	9%	Target Cost	Design + Build
55	2005	Building - Institutional	Private sector - utility	109%	100%	9%	92%	79%	13%	Lump Sum	Design + Build
56	2005	Building - Institutional	Public sector - local government agency	109%	100%	9%	92%	77%	15%	Lump Sum	Design + Build
57	2005	Building - industrial	Private sector - other	107%	100%	7%	113%	104%	9%	Lump Sum	Build only
58	2005	Infrastructure - power / energy	Private sector - other	106%	100%	6%	92%	83%	9%	Lump Sum	Build only
59	2005	Building - residential	Private sector - property development	114%	100%	14%	121%	117%	3%	Lump Sum	Build only
60	2005	Infrastructure - highways	Private sector - other	102%	100%	2%	105%	116%	-11%	Lump Sum	Design + Build
61	2005	Building - residential	Private sector - property development	106%	100%	6%	90%	88%	3%	Lump Sum	Build only
62	2005	Building - industrial	Private sector - other	107%	100%	7%	124%	117%	7%	Lump Sum	Build only

Appendix 1 – Project Data (continued)

Project #	Start Year	Project Type	Client Organization Type	Initial Estimate (As a ratio of C0)			Actual Out-turn (As a ratio of C0)			Payment basis	Responsibilities of Contractor
				Price	Cost	Margin	Price	Cost	Margin		
				(P0)	(C0)	(M0)	(P1)	(C1)	(M1)		
63	2005	Building - Institutional	Public sector - state government agency	92%	100%	-8%	102%	104%	-2%	Lump Sum	Design + Build
64	2005	Building - industrial	Private sector - utility	109%	100%	9%	93%	68%	25%	Lump Sum	Design + Build
65	2005	Building - residential	Own organization / internal project	109%	100%	9%	124%	104%	20%	Target Cost	Design + Build
66	2005	Infrastructure - water	Public sector - publicly owned company	100%	100%	0%	105%	93%	13%	Lump Sum	Design + Build
67	2005	Building - Institutional	Public sector - local government agency	100%	100%	0%	100%	100%	0%	Lump Sum	Build only
68	2005	Building - commercial	Private sector - property development	100%	100%	0%	125%	113%	12%	Cost plus % fee	Build only
69	2005	Building - Institutional	Own organization / internal project	109%	100%	9%	92%	95%	-3%	Lump Sum	Design + Build
70	2005	Building - industrial	Private sector - other	115%	100%	15%	190%	151%	38%	Lump Sum	Build only
71	2005	Building - Institutional	Public sector - publicly owned company	106%	100%	6%	109%	90%	18%	Lump Sum	Design + Build
72	2006	Building - commercial	Private sector - other	501%	100%	401%	574%	170%	404%	Unit Price	Build only
73	2006	Building - residential	Private sector - property development	110%	100%	10%	5%	5%	1%	Cost plus fixed fee	Build only
74	2006	Infrastructure - highways	Public sector - publicly owned company	124%	100%	24%	124%	79%	45%	Lump Sum	Design + Build
75	2006	Infrastructure - highways	Public sector - publicly owned company	141%	100%	41%	141%	75%	66%	Lump Sum	Design + Build
76	2006	Infrastructure - power / energy	Public sector - publicly owned company	104%	100%	4%	89%	83%	6%	Lump Sum	Build only
77	2006	Building - residential	Private sector - other	100%	100%	0%	204%	198%	6%	Lump Sum	Design + Build
78	2006	Infrastructure - highways	Public sector - state government agency	100%	100%	0%	108%	108%	0%	Lump Sum	Design + Build
79	2006	Other	Private sector - other	107%	100%	7%	409%	358%	51%	Lump Sum	Design + Build
80	2006	Other	Public sector - local government agency	106%	100%	6%	91%	80%	12%	Lump Sum	Build only
81	2006	Building - industrial	Private sector - other	106%	100%	6%	117%	112%	4%	Lump Sum	Build only
82	2006	Building - Institutional	Public sector - state government agency	132%	100%	32%	132%	75%	57%	Lump Sum	Design + Build
83	2006	Building - Institutional	Public sector - other	111%	100%	11%	94%	66%	28%	Lump Sum	Design + Build

Appendix 1 – Project Data (continued)

Project #	Start Year	Project Type	Client Organization Type	Initial Estimate (As a ratio of C0)			Actual Out-turn (As a ratio of C0)			Payment basis	Responsibilities of Contractor
				Price	Cost	Margin	Price	Cost	Margin		
				(P0)	(C0)	(M0)	(P1)	(C1)	(M1)		
84	2006	Building - Institutional	Public sector - state government agency	109%	100%	9%	109%	97%	12%	Lump Sum	Build only
85	2006	Building - Institutional	Public sector - local government agency	109%	100%	9%	92%	82%	10%	Target Cost	Design + Build
86	2006	Building - residential	Own organization / internal project	111%	100%	11%	113%	102%	11%	Cost plus % fee	Build only
87	2006	Building - industrial	Private sector - other	147%	100%	47%	147%	134%	13%	Lump Sum	Build only
88	2006	Building - residential	Private sector - property development	105%	100%	5%	78%	106%	-28%	Lump Sum	Build only
89	2006	Building - residential	Own organization / internal project	109%	100%	9%	104%	90%	13%	Target Cost	Design + Build + Finance + Operate
90	2006	Building - Institutional	Public sector - state government agency	109%	100%	9%	109%	99%	10%	Lump Sum	Build only
91	2006	Building - Institutional	Public sector - publicly owned company	106%	100%	6%	108%	104%	5%	Lump Sum	Design + Build
92	2006	Building - residential	Private sector - property development	112%	100%	12%	115%	99%	15%	Cost plus fixed fee	Build only
93	2006	Infrastructure - highways	Public sector - publicly owned company	123%	100%	23%	121%	100%	21%	Unit Price	Design + Build
94	2006	Infrastructure - water	Public sector - publicly owned company	114%	100%	14%	115%	88%	27%	Lump Sum	Design + Build
95	2006	Building - industrial	Own organization / internal project	105%	100%	5%	124%	118%	6%	Cost plus % fee	Design + Build
96	2006	Building - commercial	Private sector - property development	110%	100%	10%	111%	97%	14%	Cost plus fixed fee	Build only
97	2006	Infrastructure - water	Private sector - utility	104%	100%	4%	89%	97%	-8%	Lump Sum	Build only
98	2006	Infrastructure - water	Private sector - other	114%	100%	14%	116%	86%	30%	Lump Sum	Design + Build
99	2007	Other	Private sector - unspecified	109%	100%	9%	109%	85%	24%		
100	2007	Other	Own organization / internal project	117%	100%	17%	148%	72%	76%		
101	2007	Other	Own organization / internal project	113%	100%	13%	188%	108%	80%		
102	2007	Infrastructure - unspec transport	Own organization / internal project	114%	100%	14%	93%	58%	35%		
103	2007	Infrastructure - unspec transport	Private sector - unspecified	116%	100%	16%	116%	88%	28%		
104	2007	Infrastructure - unspec transport	Private sector - unspecified	105%	100%	5%	105%	100%	5%		

Appendix 1 – Project Data (continued)

Project #	Start Year	Project Type	Client Organization Type	Initial Estimate (As a ratio of C0)			Actual Out-turn (As a ratio of C0)			Payment basis	Responsibilities of Contractor
				Price	Cost	Margin	Price	Cost	Margin		
				(P0)	(C0)	(M0)	(P1)	(C1)	(M1)		
105	2007	Building - residential	Private sector - unspecified	115%	100%	15%	115%	91%	24%		
106	2007	Building - residential	Own organization / internal project	116%	100%	16%	213%	93%	120%		
107	2007	Building - residential	Private sector - unspecified	115%	100%	15%	115%	81%	34%		
108	2007	Infrastructure - unspec transport	Private sector - unspecified	105%	100%	5%	112%	106%	6%		
109	2007	Building - commercial	Private sector - unspecified	117%	100%	17%	117%	79%	38%		
110	2007	Building - industrial	Private sector - unspecified	116%	100%	16%	116%	87%	29%		
111	2007	Infrastructure - unspec transport	Own organization / internal project	106%	100%	6%	134%	122%	12%		
112	2007	Infrastructure - unspec transport	Private sector - unspecified	106%	100%	6%	110%	77%	32%		
113	2007	Infrastructure - unspec transport	Private sector - unspecified	107%	100%	7%	137%	123%	13%		
114	2007	Building - industrial	Private sector - unspecified	116%	100%	16%	116%	97%	19%		
115	2007	Building - Institutional	Private sector - unspecified	114%	100%	14%	118%	118%	0%		
116	2007	Building - commercial	Private sector - unspecified	109%	100%	9%	109%	98%	11%		
117	2007	Other	Own organization / internal project	106%	100%	6%	106%	96%	10%		
118	2007	Infrastructure - unspec transport	Public sector - local government agency	103%	100%	3%	95%	101%	-6%		
119	2007	Building - commercial	Private sector - unspecified	116%	100%	16%	116%	91%	26%		
120	2007	Other	Private sector - unspecified	106%	100%	6%	89%	126%	-37%		
121	2007	Building - commercial	Private sector - unspecified	116%	100%	16%	122%	98%	24%		
122	2007	Building - industrial	Private sector - unspecified	115%	100%	15%	115%	75%	41%		
123	2007	Building - residential	Own organization / internal project	117%	100%	17%	130%	82%	48%		
124	2007	Building - commercial	Private sector - unspecified	116%	100%	16%	116%	75%	41%		
125	2007	Building - residential	Own organization / internal project	116%	100%	16%	143%	97%	45%		

Appendix 1 – Project Data (continued)

Project #	Start Year	Project Type	Client Organization Type	Initial Estimate (As a ratio of C0)			Actual Out-turn (As a ratio of C0)			Payment basis	Responsibilities of Contractor
				Price	Cost	Margin	Price	Cost	Margin		
				(P0)	(C0)	(M0)	(P1)	(C1)	(M1)		
126	2007	Building - residential	Own organization / internal project	117%	100%	17%	139%	91%	49%		
127	2007	Building - commercial	Private sector - unspecified	117%	100%	17%	117%	86%	30%		
128	2007	Infrastructure - unspec transport	Public sector - local government agency	101%	100%	1%	107%	117%	-9%		
129	2007	Building - commercial	Own organization / internal project	116%	100%	16%	113%	86%	27%		
130	2007	Building - residential	Own organization / internal project	117%	100%	17%	111%	82%	29%		
131	2007	Building - Institutional	Public sector - local government agency	109%	100%	9%	113%	102%	10%		
132	2007	Building - commercial	Private sector - unspecified	115%	100%	15%	115%	82%	33%		
133	2007	Infrastructure - unspec transport	Public sector - state government agency	106%	100%	6%	106%	96%	11%		
134	2007	Building - commercial	Private sector - unspecified	114%	100%	14%	114%	87%	27%		
135	2007	Building - unspecified	Private sector - unspecified	115%	100%	15%	115%	82%	33%		
136	2007	Infrastructure - unspec transport	Public sector - state government agency	105%	100%	5%	105%	90%	15%		
137	2007	Other	Private sector - unspecified	105%	100%	5%	117%	115%	2%		
138	2007	Infrastructure - unspec transport	Public sector - state government agency	106%	100%	6%	113%	105%	8%		
139	2007	Building - commercial	Private sector - unspecified	106%	100%	6%	39%	37%	3%		
140	2007	Infrastructure - unspec transport	Public sector - local government agency	106%	100%	6%	118%	106%	13%		
141	2007	Building - residential	Own organization / internal project	116%	100%	16%	109%	72%	37%		
142	2007	Infrastructure - unspec transport	Public sector - state government agency	106%	100%	6%	115%	100%	15%		
143	2007	Building - residential	Own organization / internal project	116%	100%	16%	246%	166%	80%		
144	2007	Building - commercial	Private sector - unspecified	116%	100%	16%	116%	92%	24%		
145	2007	Building - industrial	Private sector - unspecified	116%	100%	16%	144%	115%	28%		
146	2007	Building - commercial	Private sector - unspecified	116%	100%	16%	116%	80%	36%		

Appendix 1 – Project Data (continued)

Project #	Start Year	Project Type	Client Organization Type	Initial Estimate (As a ratio of C0)			Actual Out-turn (As a ratio of C0)			Payment basis	Responsibilities of Contractor
				Price	Cost	Margin	Price	Cost	Margin		
				(P0)	(C0)	(M0)	(P1)	(C1)	(M1)		
147	2007	Building - residential	Own organization / internal project	116%	100%	16%	167%	105%	62%		
148	2007	Building - residential	Own organization / internal project	118%	100%	18%	161%	119%	42%		
149	2007	Building - commercial	Private sector - unspecified	114%	100%	14%	81%	65%	15%		
150	2007	Building - industrial	Private sector - unspecified	116%	100%	16%	126%	103%	23%		
151	2007	Building - residential	Own organization / internal project	117%	100%	17%	172%	96%	76%		
152	2007	Building - commercial	Private sector - unspecified	117%	100%	17%	117%	87%	29%		
153	2007	Building - industrial	Private sector - unspecified	106%	100%	6%	106%	101%	5%		
154	2007	Infrastructure - unspec transport	Public sector - state government agency	106%	100%	6%	108%	109%	-2%		
155	2007	Infrastructure - unspec transport	Public sector - state government agency	106%	100%	6%	119%	105%	14%		
156	2007	Infrastructure - unspec transport	Public sector - local government agency	105%	100%	5%	108%	102%	5%		
157	2007	Building - commercial	Own organization / internal project	118%	100%	18%	157%	122%	35%		
158	2007	Infrastructure - unspec transport	Private sector - unspecified	115%	100%	15%	59%	37%	23%		
159	2007	Infrastructure - unspec transport	Public sector - state government agency	105%	100%	5%	118%	110%	8%		
160	2007	Building - commercial	Private sector - unspecified	116%	100%	16%	116%	98%	18%		
161	2007	Building - residential	Private sector - unspecified	114%	100%	14%	373%	299%	74%		
162	2007	Building - unspecified	Own organization / internal project	119%	100%	19%	117%	85%	32%		
163	2007	Infrastructure - unspec transport	Public sector - local government agency	105%	100%	5%	119%	114%	5%		
164	2007	Building - residential	Private sector - unspecified	116%	100%	16%	106%	80%	26%		
165	2007	Infrastructure - highways	Public sector - local government agency	104%	100%	4%	70%	54%	16%	Lump Sum	Build only
166	2007	Infrastructure - unspec transport	Public sector - state government agency	106%	100%	6%	121%	101%	20%		
167	2007	Infrastructure - unspec transport	Public sector - local government agency	106%	100%	6%	102%	92%	10%		

Appendix 1 – Project Data (continued)

Project #	Start Year	Project Type	Client Organization Type	Initial Estimate (As a ratio of C0)			Actual Out-turn (As a ratio of C0)			Payment basis	Responsibilities of Contractor
				Price	Cost	Margin	Price	Cost	Margin		
				(P0)	(C0)	(M0)	(P1)	(C1)	(M1)		
168	2007	Building - industrial	Private sector - utility	109%	100%	9%	92%	77%	15%	Lump Sum	Build only
169	2007	Infrastructure - unspec transport	Public sector - local government agency	105%	100%	5%	102%	100%	2%		
170	2007	Building - unspecified	Private sector - unspecified	115%	100%	15%	101%	83%	18%		
171	2007	Building - residential	Private sector - unspecified	107%	100%	7%	107%	92%	15%		
172	2007	Infrastructure - unspec transport	Private sector - unspecified	116%	100%	16%	116%	95%	22%		
173	2007	Infrastructure - water	Public sector - publicly owned company	108%	100%	8%	92%	89%	3%	Lump Sum	Build only
174	2007	Building - commercial	Own organization / internal project	116%	100%	16%	113%	97%	16%		
175	2007	Infrastructure - unspec transport	Public sector - local government agency	106%	100%	6%	103%	96%	7%		
176	2007	Building - residential	Own organization / internal project	109%	100%	9%	240%	197%	43%	Target Cost	Design + Build + Finance + Operate
177	2007	Other	Private sector - unspecified	107%	100%	7%	107%	97%	10%		
178	2007	Building - Institutional	Public sector - publicly owned company	106%	100%	6%	111%	99%	12%	Lump Sum	Build only
179	2007	Building - residential	Own organization / internal project	109%	100%	9%	89%	76%	13%	Target Cost	Design + Build + Finance + Operate
180	2007	Building - residential	Private sector - property development	106%	100%	6%	90%	94%	-3%	Lump Sum	Build only
181	2007	Building - residential	Private sector - property development	122%	100%	22%	176%	148%	29%	Lump Sum	Design + Build
182	2007	Building - residential	Private sector - unspecified	107%	100%	7%	107%	94%	13%		
183	2007	Building - residential	Private sector - unspecified	107%	100%	7%	107%	83%	24%		
184	2007	Building - commercial	Private sector - unspecified	108%	100%	8%	102%	97%	5%		
185	2007	Building - commercial	Private sector - unspecified	111%	100%	11%	111%	98%	12%		
186	2007	Building - commercial	Private sector - unspecified	109%	100%	9%	82%	74%	8%		
187	2008	Building - residential	Own organization / internal project	116%	100%	16%	248%	125%	124%		
188	2008	Other	Private sector - unspecified	111%	100%	11%	175%	148%	26%		

Appendix 1 – Project Data (continued)

Project #	Start Year	Project Type	Client Organization Type	Initial Estimate (As a ratio of C0)			Actual Out-turn (As a ratio of C0)			Payment basis	Responsibilities of Contractor
				Price	Cost	Margin	Price	Cost	Margin		
				(P0)	(C0)	(M0)	(P1)	(C1)	(M1)		
189	2008	Building - commercial	Private sector - unspecified	114%	100%	14%	114%	90%	24%		
190	2008	Infrastructure - unspec transport	Public sector - local government agency	105%	100%	5%	105%	100%	6%		
191	2008	Building - commercial	Private sector - unspecified	109%	100%	9%	109%	72%	37%		
192	2008	Infrastructure - unspec transport	Private sector - unspecified	114%	100%	14%	114%	93%	21%		
193	2008	Building - commercial	Private sector - unspecified	111%	100%	11%	111%	85%	26%		
194	2008	Building - unspecified	Private sector - unspecified	109%	100%	9%	109%	89%	19%		
195	2008	Infrastructure - unspec transport	Own organization / internal project	106%	100%	6%	76%	71%	4%		
196	2008	Other	Public sector - local government agency	109%	100%	9%	109%	99%	10%		
197	2008	Other	Public sector - state government agency	114%	100%	14%	114%	92%	22%		
198	2008	Building - Institutional	Private sector - unspecified	116%	100%	16%	116%	93%	24%		
199	2008	Building - commercial	Private sector - unspecified	116%	100%	16%	116%	89%	27%		
200	2008	Building - commercial	Own organization / internal project	117%	100%	17%	97%	74%	23%		
201	2008	Infrastructure - unspec transport	Public sector - local government agency	105%	100%	5%	147%	146%	1%		
202	2008	Building - commercial	Private sector - unspecified	114%	100%	14%	114%	88%	26%		
203	2008	Building - Institutional	Private sector - unspecified	109%	100%	9%	286%	242%	44%		
204	2008	Building - Institutional	Private sector - unspecified	114%	100%	14%	114%	93%	20%		
205	2008	Building - commercial	Own organization / internal project	116%	100%	16%	105%	81%	24%		
206	2008	Infrastructure - unspec transport	Public sector - state government agency	105%	100%	5%	115%	110%	6%		
207	2008	Building - industrial	Private sector - unspecified	109%	100%	9%	103%	90%	14%		
208	2008	Infrastructure - unspec transport	Public sector - state government agency	100%	100%	0%	102%	99%	3%		
209	2008	Building - commercial	Private sector - unspecified	116%	100%	16%	116%	81%	36%		

Appendix 1 – Project Data (continued)

Project #	Start Year	Project Type	Client Organization Type	Initial Estimate (As a ratio of C0)			Actual Out-turn (As a ratio of C0)			Payment basis	Responsibilities of Contractor
				Price	Cost	Margin	Price	Cost	Margin		
				(P0)	(C0)	(M0)	(P1)	(C1)	(M1)		
210	2008	Infrastructure - unspec transport	Public sector - state government agency	106%	100%	6%	117%	108%	9%		
211	2008	Infrastructure - unspec transport	Public sector - state government agency	103%	100%	3%	108%	103%	6%		
212	2008	Other	Public sector - local government agency	106%	100%	6%	112%	105%	6%		
213	2008	Infrastructure - unspec transport	Public sector - state government agency	100%	100%	0%	105%	104%	1%		
214	2008	Infrastructure - unspec transport	Private sector - unspecified	105%	100%	5%	113%	114%	-1%		
215	2008	Infrastructure - unspec transport	Public sector - state government agency	105%	100%	5%	110%	101%	9%		
216	2008	Building - residential	Own organization / internal project	114%	100%	14%	128%	104%	24%		
217	2008	Infrastructure - unspec transport	Public sector - state government agency	106%	100%	6%	116%	113%	3%		
218	2008	Infrastructure - unspec transport	Public sector - local government agency	105%	100%	5%	129%	150%	-21%		
219	2008	Other	Public sector - local government agency	106%	100%	6%	106%	102%	3%		
220	2008	Infrastructure - unspec transport	Public sector - state government agency	105%	100%	5%	110%	105%	6%		
221	2008	Infrastructure - unspec transport	Public sector - local government agency	105%	100%	5%	109%	106%	3%		
222	2008	Other	Public sector - local government agency	106%	100%	6%	112%	106%	6%		
223	2008	Infrastructure - unspec transport	Private sector - unspecified	106%	100%	6%	121%	101%	20%		
224	2008	Other	Public sector - local government agency	105%	100%	5%	125%	124%	1%		
225	2008	Other	Public sector - local government agency	103%	100%	3%	103%	101%	2%		
226	2008	Other	Public sector - local government agency	106%	100%	6%	106%	104%	2%		
227	2008	Infrastructure - unspec transport	Public sector - state government agency	105%	100%	5%	110%	139%	-28%		
228	2008	Other	Public sector - local government agency	108%	100%	8%	110%	103%	7%		
229	2008	Infrastructure - unspec transport	Public sector - state government agency	104%	100%	4%	115%	119%	-4%		
230	2008	Other	Public sector - local government agency	106%	100%	6%	110%	106%	4%		

Appendix 1 – Project Data (continued)

Project #	Start Year	Project Type	Client Organization Type	Initial Estimate (As a ratio of C0)			Actual Out-turn (As a ratio of C0)			Payment basis	Responsibilities of Contractor
				Price	Cost	Margin	Price	Cost	Margin		
				(P0)	(C0)	(M0)	(P1)	(C1)	(M1)		
231	2008	Infrastructure - unspec transport	Public sector - state government agency	104%	100%	4%	112%	129%	-17%		
232	2008	Infrastructure - unspec transport	Public sector - state government agency	105%	100%	5%	111%	114%	-3%		
233	2008	Infrastructure - ports	Public sector - publicly owned company	102%	100%	2%	94%	90%	5%	Lump Sum	Build only
234	2008	Infrastructure - unspec transport	Public sector - local government agency	104%	100%	4%	109%	97%	12%		
235	2008	Infrastructure - unspec transport	Public sector - state government agency	104%	100%	4%	109%	120%	-11%		
236	2008	Infrastructure - ports	Public sector - publicly owned company	101%	100%	1%	115%	105%	10%	Lump Sum	Build only
237	2008	Building - Institutional	Private sector - unspecified	108%	100%	8%	139%	134%	5%		
238	2008	Building - Institutional	Public sector - local government agency	109%	100%	9%	113%	103%	10%	Target Cost	Build only
239	2008	Building - Institutional	Public sector - local government agency	102%	100%	2%	102%	75%	27%	Lump Sum	Design + Build
240	2009	Building - commercial	Private sector - unspecified	108%	100%	8%	108%	87%	20%		
241	2009	Building - industrial	Private sector - unspecified	106%	100%	6%	106%	83%	23%		
242	2009	Other	Own organization / internal project	105%	100%	5%	102%	97%	5%		
243	2009	Building - unspecified	Private sector - unspecified	106%	100%	6%	106%	89%	17%		
244	2009	Infrastructure - unspec transport	Private sector - unspecified	111%	100%	11%	111%	80%	31%		
245	2009	Building - industrial	Private sector - unspecified	105%	100%	5%	105%	98%	7%		
246	2009	Infrastructure - unspec transport	Private sector - unspecified	106%	100%	6%	160%	140%	21%		
247	2009	Other	Own organization / internal project	109%	100%	9%	109%	106%	3%		
248	2009	Building - commercial	Private sector - unspecified	106%	100%	6%	106%	90%	16%		
249	2009	Infrastructure - unspec transport	Public sector - local government agency	105%	100%	5%	78%	74%	4%		
250	2009	Other	Own organization / internal project	107%	100%	7%	111%	102%	9%		
251	2009	Infrastructure - unspec transport	Public sector - state government agency	105%	100%	5%	108%	91%	17%		

Appendix 1 – Project Data (continued)

Project #	Start Year	Project Type	Client Organization Type	Initial Estimate (As a ratio of C0)			Actual Out-turn (As a ratio of C0)			Payment basis	Responsibilities of Contractor
				Price	Cost	Margin	Price	Cost	Margin		
				(P0)	(C0)	(M0)	(P1)	(C1)	(M1)		
252	2009	Infrastructure - unspec transport	Own organization / internal project	109%	100%	9%	98%	90%	8%		
253	2009	Building - commercial	Private sector - unspecified	106%	100%	6%	116%	104%	13%		
254	2009	Infrastructure - unspec transport	Public sector - state government agency	106%	100%	6%	113%	106%	7%		
255	2009	Infrastructure - unspec transport	Private sector - unspecified	107%	100%	7%	107%	84%	23%		
256	2009	Other	Public sector - local government agency	106%	100%	6%	106%	96%	11%		
257	2009	Infrastructure - unspec transport	Public sector - state government agency	106%	100%	6%	117%	110%	7%		
258	2009	Infrastructure - unspec transport	Public sector - state government agency	105%	100%	5%	110%	100%	11%		
259	2009	Building - Institutional	Private sector - unspecified	106%	100%	6%	106%	100%	7%		
260	2009	Infrastructure - unspec transport	Public sector - state government agency	103%	100%	3%	122%	112%	11%		
261	2009	Other	Own organization / internal project	105%	100%	5%	89%	84%	6%		
262	2009	Infrastructure - unspec transport	Public sector - local government agency	105%	100%	5%	99%	84%	16%		
263	2009	Infrastructure - unspec transport	Public sector - state government agency	105%	100%	5%	116%	102%	13%		
264	2009	Building - residential	Own organization / internal project	109%	100%	9%	120%	115%	5%		
265	2009	Building - commercial	Public sector - publicly owned company	105%	100%	5%	110%	105%	6%		
266	2009	Building - commercial	Own organization / internal project	111%	100%	11%	127%	156%	-29%		
267	2009	Other	Public sector - publicly owned company	105%	100%	5%	106%	93%	13%		
268	2009	Other	Public sector - publicly owned company	105%	100%	5%	106%	98%	8%		
269	2009	Building - commercial	Private sector - unspecified	109%	100%	9%	135%	132%	2%		
270	2009	Infrastructure - unspec transport	Public sector - state government agency	105%	100%	5%	116%	104%	11%		
271	2009	Building - commercial	Private sector - unspecified	110%	100%	10%	114%	99%	15%		
272	2009	Building - Institutional	Own organization / internal project	111%	100%	11%	130%	100%	30%		

Appendix 1 – Project Data (continued)

Project #	Start Year	Project Type	Client Organization Type	Initial Estimate (As a ratio of C0)			Actual Out-turn (As a ratio of C0)			Payment basis	Responsibilities of Contractor
				Price	Cost	Margin	Price	Cost	Margin		
				(P0)	(C0)	(M0)	(P1)	(C1)	(M1)		
273	2009	Building - commercial	Own organization / internal project	111%	100%	11%	135%	174%	-39%		
274	2009	Building - commercial	Private sector - property development	101%	100%	1%	105%	103%	2%	Lump Sum	Build only
275	2009	Other	Public sector - publicly owned company	105%	100%	5%	106%	99%	7%		
276	2009	Infrastructure - ports	Public sector - publicly owned company	104%	100%	4%	114%	111%	3%	Lump Sum	Build only
277	2009	Building - Institutional	Public sector - local government agency	120%	100%	20%	120%	104%	17%	Guaranteed Maximum Price	Design + Build + Operate
278	2009	Infrastructure - power / energy	Public sector - state government agency	100%	100%	0%	116%	116%	0%	Lump Sum	Build only
279	2010	Building - industrial	Private sector - unspecified	109%	100%	9%	109%	95%	14%		
280	2010	Building - residential	Private sector - unspecified	111%	100%	11%	111%	96%	15%		
281	2010	Other	Private sector - unspecified	111%	100%	11%	117%	103%	14%		
282	2010	Other	Public sector - publicly owned company	109%	100%	9%	105%	92%	13%		
283	2010	Building - residential	Private sector - unspecified	110%	100%	10%	91%	75%	16%		
284	2010	Building - commercial	Own organization / internal project	109%	100%	9%	118%	127%	-9%		
285	2010	Building - commercial	Own organization / internal project	109%	100%	9%	113%	91%	22%		
286	2010	Infrastructure - highways	Public sector - state government agency	108%	100%	8%	107%	99%	8%		
287	2010	Building - Institutional	Public sector - state government agency	122%	100%	22%	159%	113%	45%	Unit Price	Design + Build
288	2010	Building - industrial	Private sector - unspecified	111%	100%	11%	111%	93%	18%		
289	2010	Infrastructure - highways	Public sector - state government agency	108%	100%	8%	106%	98%	7%		
290	2010	Building - Institutional	Public sector - other	105%	100%	5%	105%	101%	5%	Lump Sum	Build only
291	2010	Infrastructure - unspec transport	Public sector - state government agency	108%	100%	8%	108%	101%	7%		
292	2010	Infrastructure - highways	Public sector - state government agency	108%	100%	8%	113%	105%	8%		
293	2010	Building - unspecified	Private sector - unspecified	108%	100%	8%	113%	113%	0%		

Appendix 1 – Project Data (continued)

Project #	Start Year	Project Type	Client Organization Type	Initial Estimate (As a ratio of C0)			Actual Out-turn (As a ratio of C0)			Payment basis	Responsibilities of Contractor
				Price	Cost	Margin	Price	Cost	Margin		
				(P0)	(C0)	(M0)	(P1)	(C1)	(M1)		
294	2010	Infrastructure - unspec transport	Private sector - unspecified	111%	100%	11%	138%	121%	17%		
295	2010	Infrastructure - highways	Public sector - state government agency	106%	100%	6%	114%	104%	10%		
296	2010	Infrastructure - ports	Public sector - other	91%	100%	-9%	98%	97%	1%	Lump Sum	Build only

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ABSTRACT

A principle contention in the argument for the employment of public private partnerships (PPPs) is that they enable a more appropriate allocation of risk than other procurement arrangements. This is considered to provide greater alignment of incentives for the private sector contractor to perform efficiently in the pursuit of the public sector client's objectives. The resulting efficiency gains must be of sufficient magnitude to offset the higher arrangement costs and private sector borrowing costs that PPPs entail. The research problem is: *how can this be verified on the basis of empirical evidence from the construction industry and what is the order of magnitude of the resulting efficiency gain (if any)?*

This research investigates the concept of risk and the notion of its allocation and transfer in the context of construction projects. It explores the relationship between procurement arrangements, risk transfers and project delivery efficiencies. PPPs are compared to other procurement arrangements in terms of risk transfer intentions. An eventuated risk model is developed to measure and compare the extent to which risk transfer actually takes place in construction projects.

Applying the eventuated risk model to historical data from the Estonian construction industry enables the comparison of project delivery efficiencies under different procurement arrangements. Considerable divergence between risk transfer intentions and actually realised risk transfers is revealed and the magnitude of the efficiency gains associated with greater risk transfers is shown to be insufficient to offset the higher arrangement and financing costs of PPPs.

Keywords: Risk; Risk Allocation; Risk Transfer; Public Private Partnerships (PPPs); Construction; Estonia

KOKKUVÕTE

Riskijuhtimise delegeerimise mõju avaliku ja erasektori ühiste ehitusprojektide tõhusale juhtimisele

Doktoritöö

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Sissejuhatus

Väitekirjas uuritakse avaliku ja erasektori partnerlust (*public private partnership* – PPP) kui infrastruktuuri riigihangete üht võimalust. Käsitluses keskendutakse avaliku ja erasektori koostööle ehituse kapitalimahutuse valdkonnas ning vaadeldakse eriti põhjalikult riskijuhtimise delegeerimise ja ehituse projektijuhtimise efektiivsuse seost. Uuringu käigus tuletatakse ehitusprojektide riski üldkontseptsioon, töötatakse välja riskijuhtimise delegeerimise ja tõhusa projektijuhtimise kvantitatiivsed näitajad, modelleeritakse nendevaheline seos ning kontrollitakse seda empiiriliselt.

Avaliku ja erasektori partnerlus (PPP)

Avaliku ja erasektori partnerlussuhted tekkisid 1990. aastatel ühelt poolt laenuvahendite abil rahastatavate infrastruktuuri riigihangete ja teiselt poolt erastamise vahel. Riigihanke vormina käsitletakse seda kui väljasttellimist või erastamist ning erasektorile/turule suunatud reformidega nn uut haldusjuhtimist (*new public managemen*t – NPM).

Mõistet PPP kasutatakse mitmesuguste avaliku ja erasektori partnerite lepingujärgsete kokkulepete kohta, mille raames arendatakse ja kasutatakse avalike teenuste tarnimise infrastruktuuri. Avaliku sektori partneri rollis esineb tavaliselt erinevate teenuste osutaja ja põhiostja. Erasektor on põhitegijaks: enamasti see rahastab, projekteerib, ehitab ja käitab infrastruktuuri, et müüa avalikule sektorile vajalikke infrastruktuuriteenuseid.

Avaliku ja erasektori koostöö kontseptsiooni kasutuselevõtu peamiseks õigustuseks on väide, et riskijuhtimise optimaalse delegeerimise kaudu luuakse stiimulid, mis tõhustavad erasektori tegevust ning tänu millele saavutatakse parem hinna ja kvaliteedi suhe. Selliselt on riskijuhtimise delegeerimisel kesksel kohal avaliku ja erasektori koostöö.

Euroopa Liit on edendanud avaliku ja erasektori koostöökontseptsiooni kui infrastruktuurihanke üht võimalust. Vaatamata avaliku ja erasektori partnerlust tabanud kriitikale (eriti puudutab see avaliku sektori tulevaste kohustuste käsitlemist raamatupidamises ning hinna ja kvaliteedi suhte arvutusi) ning 2007.

a järgsete finantskriiside mõjule on avaliku ja erasektori partnerlussuhted kogu Euroopa avaliku sektori klientide jaoks jätkuvalt atraktiivsed. Suurem osa Euroopa PPP kogemusest on omandatud Ühendkuningriigis. Vastupidiselt sellele on PPP kogemus Eestis väike ning siin näib puuduvat selgelt määratletud avaliku ja erasektori koostöö poliitika. Ehkki PPP kontseptsioon hakkab üsna ilmselt kaotama Ühendkuningriigi valitsuse poolehoidu, paistab Eesti soovivat seda mudelit laialdasemalt kasutusele võtta.

Suure osa avaliku ja erasektori koostööd käsitlevast kirjandusest on loonud avaliku sektori institutsioonid ja erasektori üksused, kes on otseselt huvitatud avaliku ja erasektori partnerettevõtluse edust ning pooldavad üldiselt ja mitte sugugi üllatuslikult seda koostööd. Akadeemiline (eriti raamatupidamisalane) kirjandus kaldub olema kriitilisem, kuid ka see ei ole veenev: raskusi tekitab mõistete „avaliku ja erasektori partnerlus" ja „traditsiooniline" ebamäärasus, ühise nimetaja andmine kõigile riigihankevormidele, kus avaliku ja erasektori koostööd ei rakendata (ja millega tavaliselt võrreldakse avaliku ja erasektori koostööhankeid) ning vajadus suurema hulga empiiriliste tõendite järele.

Avaliku ja erasektori partnerlust käsitlevas ehituskirjanduses leidub mõningaid ehituskulude analüüsi andmeid, kuid tulemuse parandamiseks keskendutakse seal kõige sagedamini PPP-spetsiifilistele üksikasjadele, eeldades samas, et hankekorralduse meetod on välja valitud.

Kuna väitekirjas käsitletakse riskijuhtimise delegeerimise ja tõhusa projektijuhtimise vahelist seost Eesti ehitusprojektide empiiriliste andmete alusel, võib uurimistöös esitatud avaliku ja erasektori partnerluse hinna ja kvaliteedi suhte käsitlust pidada algupäraseks ja asjakohaseks ehitusprojektide riskijuhtimise mõistmise panuseks.

Ehitushangete insenerisüsteemide disainiteadusliku teooria poole

Avaliku ja erasektori koostööd käsitlev kirjandus õigustab keskendumist infrastruktuurihanke ehituskomponendile, sest avaliku ja erasektori partnerluse kapitalikulud (enamjaolt ehituskulud) moodustavad märkimisväärse osa PPP kogukuludest. Ehitamisega seotud riske peetakse ühtedeks avaliku ja erasektori partnerlust kõige olulisemalt mõjutavateks riskideks ning PPP koostöölepingus kavatsetakse nende juhtimine tavaliselt täies ulatuses delegeerida erasektori partnerile. Niisugune ehitamisele keskendumine võimaldab lihtsustada riskijuhtimise delegeerimise määra väljaselgitamist, samuti vaadelda PPP hankeid ehitushangete üldises kontekstis. See loob võimaluse uurimistööks, mis annab teavet avaliku ja erasektori partnerluse suhtelist efektiivsust puudutava debati tarbeks ja täiendab ehitushanke probleemide lahendamiseks vajalikke alusteadmisi.

Põhiliselt uuritakse seost, kus (ehitus-)riskide juhtimise ulatuslikum delegeerimine kliendilt töövõtjale tingib (ehitus-)projekti parema juhtimise (kui kõik muud tegurid jäävad samaks). Ehitusega seotud uurimistöö vastab hästi insenerisüsteemide disainiteaduse paradigmale ja tuvastatud seos sarnaneb

insenerisüsteemide disainiteooriaga. Selliselt lähenedes muutub selgemaks uurimistöö teooria arengupotentsiaal ja ilmneb töö vajalikkus ehituse juhtimiseks vajalike teadmiste seisukohalt.

Insenerisüsteemide disainiteadusliku kontseptsiooni kasutamisel on metodoloogiline tähendus selles mõttes, et teooria väljatöötamiseks pakub see põhjendatud teadusliku lähenemisena järgmist iteratsiooni:

insenerisüsteemide disainiteooria -> disainiprotsess -> disainitud tehisesemete hindamine -> disainiteooria õigsuse kontrollimine / muutmine.

Kui on määratletud kontrollimist vajav insenerisüsteemide disainiteooria, võib arvestada, et kaasnevat disainiprotsessi kehastavad kõik aja jooksul hanke läbinud ehitusprojektid, nii et need on tehisesemeteks, mida tuleks hinnata insenerisüsteemide disainiteooria kehtivuse üle otsustamisel. Enne kui koguda ja analüüsida projektiandmeid teooria õigsuse kontrollimiseks ja/või teooria edasiarendamiseks vajalike tõendite saamiseks, tuleb seega kindlaks määrata asjakohane hindamisalus (s.t riskijuhtimise delegeerimise ja projektijuhtimise efektiivsuse näitaja).

Riskikontseptsioon on aga ebamäärane ja soovides mõõta riskijuhtimise delegeerimist, kujuneb sellest paikapidavuse proovikivi.

Riskikontseptsioon

Riskide määratlusi on palju ja mitmesuguseid. Erinevates teadusvaldkondades kasutatakse erinevaid ja vastuolulisi riskikontseptsioone.

Ehitusega seotud teadusaladel tehtava uurimistöö puhul tavatsetakse mõistete kontseptsioone üle võtta mitmetest n-ö täpsematest valdkondadest, kuid riski mõiste puhul kaasatakse ka vastuolud. Segadust süvendavad veelgi katsed viidata riskile kui üldmõistele, mis peaks hõlmama paljusid täpselt määratletud valdkondade (nt kindlustus, majandus, rahandus, tervishoid) (erinevaid) kontseptsioone.

Ei ole üllatav, et ehituskirjandus sisaldab palju ühildumatute riskidefinitsioonide näiteid ja autorid ei ole järginud valitud definitsioone nii pikema aja jooksul kui mõnel juhul ka sama artikli piires.

Selle väitekirja uurimisprobleem on seotud tellija ja töövõtja organisatsioonide vahelise riskijuhtimise delegeerimisega ehitusprojektide kontekstis. Riskijuhtimise delegeerimise uurimiseks on vajalik selline riskikontseptsioon, mis võimaldaks riskijuhtimise delegeerimist mingil kujul mõõta. Seetõttu on vaadeldud riskikontseptsiooni ajaloolisi põhiideid ja nii tõenäosusteooria, kindlustuse, majanduse ja rahanduse kui ka ehituskirjanduse ühiseid mõisteid ning ühendatud need projekti kontekstis üldistatud riskikontseptsiooniks. Selle üldistatud riskikontseptsiooni alusel saab mõõta n-ö lõppriski kui projekti oodatava tulemuse ja tegelikult realiseerunud tulemuse erinevust. See annab sobiva aluse, mis võimaldab mõõta kogu riskijuhtimise delegeerimist. Ulatus, milles mõlemad ehituslepingu osalised (tellija ja töövõtja) maksavad lõppriski eest (tellija puhul lepingujärgse hinna muutumise kaudu,

töövõtja puhul lepingu kogukasumi muutumise kaudu), määrab konkreetse lepingu puhul otseselt kindlaks, mil määral riskijuhtimist tellijalt töövõtjale delegeerida.

Lõppriskide juhtimise delegeerimise mudel

(Lõpp)riskide juhtimise delegeerimise tase koos projektijuhtimise efektiivsuse näitajaga, mis on vaadeldav kui määr, mille ulatuses täidetakse nii tellija kui ka töövõtja esialgseid ootusi, loovad aluse (lõpp)riskide juhtimise delegeerimise ja tõhusa projektijuhtimise vahelise seose mugavaks geomeetriliseks esitamiseks. Selline esitus teeb võimalikuks idealiseeritud seose *mida suuremal määral delegeeritakse (ehitus-)riskijuhtimine tellijalt töövõtjale, seda efektiivsem on (ehitus-)projekti juhtimine (kui kõik muud tingimused on muutumatud)*, mis on kesksel kohal nii avaliku ja erasektori partnerluse kontseptsiooni õigustamisel kui ka modelleeritava ehitushanke puhul üldiselt.

Loodud mudel näitab, et kui antud projektide hulga kohta kehtib idealiseeritud seos, on projektiandmete jaotus ootuspärane ja annab seetõttu aluse seose paikapidavuse kontrollimiseks.

Andmete kogumine, analüüs ja järeldused

Analüüsiti aastatel 2001–2010 lõpuleviidud 296 ehitusprojekti andmeid Eestis, mis vastasid ligikaudu 2% kogu riigi sama perioodi ehitustegevusest. Tehtud analüüs näitas, et ehkki riskijuhtimise delegeerimise määra ja ebatõhusa projektijuhtimise väärtuste vahel on negatiivne korrelatsioon, on riskijuhtimise delegeerimise ja tõhusa projektijuhtimise vaheline seos nõrk ning on ebatõenäone, et riskijuhtimise ulatuslikum delegeerimine töövõtjale tõhustaks märgatavalt projektijuhtimist.

Selle asemel, et kajastada riskijuhtimise delegeerimise eesmärke, näiteks neid, mida näitab projekteerimise, ehitamise, rahastamise, kasutamise jms komponentide ühte lepingupakki koondamise tase, ja määra, milles töövõtja tasustamise mehhanism tugineb pigem projekti väljunditel kui sisenditel, leiti, et riskijuhtimise delegeerimine mõjutab rohkem kulude vähenemist ja vähem kulude suurenemist. Sama tulemus saadi siis, kui riskijuhtimise kavandatud delegeerimine oli ulatuslik nii „koondamise" kui ka väljundipõhise tasustamise puhul. See võimaldab järeldada, et riskijuhtimise delegeerimine ei ole ette kindlaks määratud, vaid see muutub või seda juhitakse või mõjutatakse teataval määral projekti käigus. Andmed näitavad, et niisugune mõjutamine on kasulik pigem töövõtjatele kui tellijale.

Järeldused

Püüe delegeerida riskijuhtimist töövõtjale projekti alguses toob tellijale vähe tulu:

- praktikas ei ole riskijuhtimise tellijalt töövõtjale delegeerimise eelnev kindlaksmääramine tõhus
- riskijuhtimise ulatuslikum delegeerimine töövõtjale ei suurenda oluliselt efektiivsust
- projekti käigus võidakse riskijuhtimise delegeerimist oluliselt mõjutada.

Eestiga seotud tõendusmaterjal ei õigusta PPP kontseptsiooni kasutamist: ulatuslik integreeritus ja väljundipõhine tasustamismehhanism tähendavad pigem seda, et riskijuhtimist töövõtjale suuremal määral ei delegeerita, ka ei tõhusta riskijuhtimise ulatuslikum delegeerimine piisavalt projektijuhtimist, et korvata PPP-ga seotud suuremaid rahastamis- ja korralduskulusid. Pealegi osutusid avaliku sektori tellijad ehitusprojektide juhtimisel tõhusamaks ja järjekindlamaks.

Seega osutus, et insenerisüsteemide disainiteooriana ei ole seos *mida suuremal määral delegeeritakse (ehitus-)riskjuhtimine tellijalt töövõtjale, seda efektiivsem on (ehitus-)projekti juhtimine (kui kõik muud tingimused on muutumatud)* eriti kasulik. Samuti ei toeta (uue haldusjuhtimisega seotud) andmed tõhusama erasektori põhiteooriat.

Tundub, et projekti alguses tehtavaid riskijaotamise otsuseid iseloomustab suhteline võhiklikkus. Ehkki ei ole selge, millises ulatuses kajastab see olukord praegu teadmiste kättesaadavust, ja võttes arvesse ka ehitusriski mõiste ebajärjekindlat kasutamist, võib see osutuda tõhusa projektijuhtimise riskipõhiste kontseptsioonide proovikiviks.

Uurimistöö põhilised takistused olid seotud andmete kogumisega mitmest projektist (et saada üle projektide suurest erinevusest) ja suhteliselt väikesest valimist. Ehkki mitme projekti tasandil tehtud järeldused on asjakohased uurimistööks, mille eesmärk on riigihankepõhimõtete õigustuste empiiriline kontrollimine, ei saa neid üksikprojektide puhul vahetult rakendada. Samuti piirab väike valim – kõik andmed pärinesid neljast Eesti ehitusettevõttest – Eesti kohta tehtavaid järeldusi.

Edaspidi oleks soovitatav teha üksikasjalikke pikaajalisi uuringuid, et jälgida projektipõhiste lõppriskideni jõudmist ja mõista sel teel paremini riskijuhtimise delegeerimise praktilisi valikuid ning mehhanismi. Samuti tuleks süvitsi uurida muudel kontseptsioonidel põhinevaid projektijuhtimise tõhustamise võimalusi. Peale selle pakuks huvi selles uurimistöös Eesti kohta väljaselgitatud (lõpp)riskide juhtimise delegeerimise ja tõhusa projektijuhtimise näitajate võrdlemine teiste riikide tulemustega, et tuvastada rahvusvahelise turu erinevusi.

Väitekirja eesmärk oli kontrollida empiiriliselt PPP kontseptsiooni kehtivust Eesti infrastruktuuri riigihangete puhul ja anda sel teel panus ehitusteaduse arengusse. Avaliku ja erasektori partnerluse kontseptsiooni õigustusena tuvastati kõigi ehitusprojektide puhul kehtiv riskijuhtimise delegeerimise ja tõhusa projektijuhtimise vaheline seos. Seose kontrollimiseks töötati välja üldkohaldatav ehitusprojektide riskikontseptsioon ja ehitushanke lõppriski mudel, mis seostasid riskijuhtimise delegeerimise otseselt tõhusa

projektijuhtimisega. Sellele tuginedes koguti Eesti ehitusprojektide valimi andmed ja analüüsiti neid. Analüüs näitas, et Eestis ei ole riskijuhtimise delegeerimine ette kindlaks määratud ning riskijuhtimise ulatuslikuma delegeerimise kaudu saavutatavast efektiivsuse kasvust ei piisa selleks, et korvata PPP hangetega tavaliselt kaasnevaid suuremaid rahastamis- ja korralduskulusid. Peale selle leiti, et Eestis juhivad avaliku sektori ehitustellijad järjekindlalt projekte tõhusamalt kui erasektori tellijad. Seega saavutati uurimistöö otsene eesmärk selles mõttes, et leiti, et PPP kontseptsiooni põhiõigustus Eesti oludes ei kehti.

Pannes proovile insenerisüsteemide disainiteooria ehitusprojektide hanke kohta ja seda toetavad põhiteooriad nii erasektori suhtelise efektiivsuse kui ka riskijuhtimise delegeerimise eelneva kindlaksmääramise kohta projektide alguses, selgus, et insenerisüsteemide disainiteaduse seisukohalt ei ole riskijuhtimise delegeerimise ja tõhusa projektijuhtimise vaheline seos kasulik.

Tehtud uurimistöö on andnud kahekordse panuse teadusteadmiste suurendamiseks. Esiteks on selle töö raames ehituse ja laiema valdkonna kirjanduse hindamine (eriti seoses riski ning PPP-d käsitleva kirjandusega) nõudnud suuri pingutusi ning teiseks on formuleeritud algupärased väited riskikontseptsiooni, riskijuhtimise delegeerimise ja tõhusa projektijuhtimise mõõtmiseks, modelleeritud nendevaheline seos ja tõlgendatud PPP kontseptsiooni suhtelist efektiivsust puudutavaid empiirilisi andmeid. Esitatud väited ootavad teaduskogukonna kriitilist hinnangut.

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