Traditional or Public Private Partnerships for Procurement of Light Rail Transit?

Céline Clements and Margaret O'Mahony, Centre for Transportation Research, Department of Civil, Structural & Environmental Engineering, Trinity College Dublin, Dublin 2, Ireland, Tel: 353 1 6082084, Fax: 353 1 6773072 Email: margaret.omahony@tcd.ie

ABSTRACT

Over the past number of years infrastructural development has been a major concern in Ireland. The economic upturn of the country has required significant developments in this area in order to maintain the financial position the country now finds itself in. The Irish Government has acknowledged that the lack of infrastructure, particularly public transport, is creating a serious congestion problem. At an urban level, two lines of a Light Rail Transit (LRT) System have been introduced into Dublin this year. They were funded from the European Union (EU) and government funds. An extension of one of the LRT lines is currently at procurement stage and the paper uses the Tsamboulos method to assess if it is likely to be attractive to private finance. It was found that investors are likely to be very averse to planning risk but are less worried about financial and construction risks.

PUBLIC PRIVATE PARTNERSHIPS

The proposals for public transport investment in the Greater Dublin area aim to address the projected growth in traffic by a series of demand management measures along with increased investment in transport infrastructure. Proposals have been made to improve the quality and quantity of public transport services through an extension of the bus

network, improvements to urban rail services, an extension of the Light Rail Transit (LRT) called Luas in Dublin, development of a Metro system and to improve integration of public transport through park and ride facilities and integrated ticketing systems.

The introduction of private financing for the development of infrastructural projects can be advantageous and this is the basis of Public Private Partnerships (PPP). In these arrangements, the traditional roles of the public sector are transferred from owner and provider to enabler and purchaser, but more importantly they become guardians of the interests of the general public (Fox et Al., 1999). There are a number of different types of PPP / Private Finance Initiative (PFI) projects. The main types are: services may be sold to the public sector; projects may be financially free-standing (concessions); or they may be joint ventures. A more general use of the term includes leasing and privatisation under the heading of PFI. Concessions are the most frequently used of the above mentioned types of PPP project and pre-date the use of PFI. They include toll-bridges etc. and are often built on the DBFO (design, build, finance, operate) principle. This is basically the handing over of a project to the private sector for the contractual period, typically 25-30 years, to design, construct and operate for this time. After the contract period is complete the asset is handed back to the public sector. The major benefit of this approach is the construction of infrastructure at a time when it is required but the public purse cannot provide finance. Joint ventures are also often used in infrastructure. A joint venture is a partnership in which the public and private sector partners pool their assets, finance and expertise under joint management, so as to deliver long-term growth in value for both partners. Through this partnership the public and private sectors assume co-responsibility and co-ownership for delivery of the services *1.*

A very important feature of all PPP projects is that the public sector retains the responsibility for providing the services and in deciding what level of services to provide retains control of quality and performance standards. Should the project fail however, the authorities must step in and continue to provide the services in whatever way is appropriate.

It has been suggested that the major problem of the public sector in infrastructural projects lies in 'appraisal optimism' *2*. In reality things do not always go according to plan resulting in projects running substantially over time and budget *3*. A study by Aalborg University, Denmark (1995) *3* considering 258 large scale projects concluded that cost overrun was a global phenomenon which has not reduced over the last 70 years but cannot be explained by error, only by systematic misrepresentation. It was noted that over a period extending from 1927 – 1998 over 5 continents 9/10^{ths} of all transport infrastructure projects resulted in cost overruns with rail projects costing on average 45% more than estimated.

Coupled with this is the problem of optimism bias. This is the tendency to leave unquantifiable risks out of the account altogether *4*. This may not be down to delusion or simple oversight and can have seriously detrimental effects to the project as cost and time overruns are inevitable if all risks are not considered. Conversely, the private sector can provide more cost effective and efficient solutions to problems due to its ambition to achieve maximum profit and its ability to not over-engineer as the public sector very often does. The private sector designs for all that is required of them to satisfy their contractual obligations but does not attempt to cater for every eventuality, as the public sector does.

It is argued that the borrowing costs of the private sector are significantly higher than corresponding public sector borrowing. Chantry Vellacott DFK, estimate that a typical PFI contract has an inherent cost of some 5% per year higher than if the Treasury borrowed the money directly *5*. The Government can raise finance cheaper than any private sector business as it has the monopolistic powers to tax and is thus regarded as a very good debtor from the perspective of financial markets. It is possible that this difference may be more than offset by the correct handling of the risk transfer process.

RISK AND CONTROL

The essence of PPP's is the transfer of risk and the key to the success of these projects is optimal risk allocation. The risk should be borne by the party best able to manage it, i.e. the party with most control over the relevant risks. The level of risk and control transfer achieved for a project depends on the type of procurement option chosen. Conventional procurement methods do not transfer control or risk but at the other end of the spectrum full privatisation totally removes risk and control from the public sector *6*. The objective of a public private partnership is to secure value for money to the public sector in procurement of services by optimally apportioning risk between the public and private sectors *2*.

The transfer of risk is usually achieved by formally categorizing the risks. A suggestion of such categories is; systematic risks (non-specific risks which result in broad economic conditions, affecting all equities to some extent), non-systematic risks (associated with only a particular asset or section of the market and therefore avoidable), credit risks, counterparty risks, operational risks and legal risks *1*. There are many

different risk categorizations but management of these risks, however they be assigned, is essential if the project is to be a success.

For a project to be considered as a PPP / PFI scheme it is essential that there is a genuine transfer of risk and that the project may prove to be value for money. The most common way of testing for this criterion is through the use of a public sector comparator (PSC), sometimes referred to as public sector benchmarking. Projects which may be defined as financially free-standing do not require comparison with a similar public sector project. A PSC represents a systematic approach to comparing the whole life value for money of a project as a PPP compared to a reference project. The reference project should be the most likely and efficient form of public sector delivery of a project by way of traditional procurement methods. It should be noted that PSC's are not always worthwhile as it can be easy to neglect certain risk elements in the pricing and with the public sector's appraisal optimism problem some projects may be disregarded while some PSC's are specifically engineered to make projects look good value for money because the public sector simply cannot afford to undertake them.

The Policy Framework for Public Private Partnerships developed for the Department of Environment and Local Government by PricewaterhouseCoopers states that a PPP assessment must be prepared for each individual project identified as having the potential to be undertaken as a PPP and the result of this assessment will determine whether or not a Contracting Authority is allowed to proceed with PPP procurement. The assessment should include the initial output specifications, an assessment of value for money potential, a preliminary risk assessment, a detailed legal viability assessment, an initial bank ability assessment and an indicative implementation plan *7*.

The project costs should remain off balance sheet for the public sector although the argument for any activity that public authorities control should count as public spending *8* may be equally valid. In the United Kingdom (UK) it is necessary that the 'contract structure test' be passed for PPP schemes. This requires that 20% of all payments for the project depend on availability, performance and usage of the service *4*.

The adoption of the PPP approach for projects is determined according to the above criteria of value for money, affordability etc. but the willingness of private sector parties to participate and the balance between economic and social benefits must also be accounted for. As value for money is a key aspect of PPP, every effort should be made when it comes to improving this feature. This can be achieved through better allocation of risk, providing greater incentives to perform, by promoting maximum efficiency over the long term, by placing clearer focus on responsibilities, by using economies of scale and by enhancing the resale value of the infrastructure. As a result of these savings on the PPP scheme, further resources are released for use on additional developments *2*.

LUAS LINE UNDER CONSIDERATION

An extension to the existing Luas network, a 1.5 km section from Connolly Station to the Point Depot, is currently in the design stages. In developing a procurement strategy for this extension a number of technical difficulties arising from existing levels in the Docklands and its construction on reclaimed land almost certainly means the ground will be contaminated. As with all projects of this nature utilities diversion is a serious issue, this line having the added complication of intersecting with private fibre optics networks.

As this line is an extension to an existing project, a number of lessons can be learnt from the previous project which was developed on a more traditional basis. It is generally accepted that this contractual framework was reasonably robust with well managed statutory processes, good relationships with utility companies and a high quality finished product.

A major concern, however, was the management of the contracts, with some confusion arising over the roles and responsibilities involved. It was noted that risk transfer had not been maximised in the main infrastructure contract, leaving room for improvement in this extension.

The objectives and constraints of this project were considered in depth at a workshop session at which a diverse range of staff were charged with the duty of selecting the most appropriate method of procurement for the LRT line. This team of experts included professionals in the disciplines of engineering, project management, programme management, procurement and commercial management. In order that all options could be considered fairly a number of assumptions were made. These include that the responsibility for securing the Railway Order and acquiring land would remain with the RPA, sufficient rolling stock was already available on the LRT network so there would be no rolling stock considered in this contract, existing LRT maintenance and operations contracts would be extended to include the new line.

The options considered for procurement for the LRT extension are presented in Table 1. These options range between the extremes of transferring all risk to the private sector as a DBFO contract and the traditional approach of the Railway Procurement Agency (RPA) retaining all risk and taking responsibility for the design. The inclusion of

PPP schemes in these options comes as a result of the National Developments Plan 2000 – 2006 requirements for rail sector projects to be partially financed under PPP schemes *9*.

After much consideration and the establishment of the pros and cons of each option under the categories of lessons learnt, innovation, competitive tension, whole life, risk transfer, good management, procurement time, roll out and market appetite, the procurement decision was made. With options C and F performing almost equally on lessons learnt, good management, risk balance, process and technical compliance and competitive tension they both seemed to be viable options. Option C allows succession from the original LRT project, incorporating the lessons learnt and provides a flexible approach to risk. It may provide a marginal saving in procurement time but it scored poorly on private sector innovation and guaranteed delivery in respect of time and budget. Option F provides greater time and cost certainty and is likely to offer a better vehicle for the transfer of risk. The major drawback of Option F comes with the scale of the project. The residual value of the PPP element may be too small to attract major investors and the bid costs may outweigh the potential benefits.

Procurement of projects as PPP schemes incurs significant costs for legal and technical advisors. These costs do not tend to be in proportion to the size of the project and this makes PPP prohibitive for small scale projects. In light of this predicted lack of attractiveness to private sector investors it was recommended that option C be pursued as the procurement strategy for the LRT extension i.e. a government funded contract.

This completes the description of how the procurement decision for the LRT extension has been made in practice. However, the authors of this paper wish to explore another method of reaching the decision on the procurement method to be used. This

exploration is hypothetical and although data was obtained from the Railway Procurement Agency to enable the authors to do this exercise, the results and interpretation of the results are theirs alone. The method used is one developed by Tsamboulas *10* and the primary objective of the method is to gauge the attractiveness of transport infrastructure projects to private finance. The results from this exercise are of interest because whether more use should be made of private finance in developing transport infrastructure across Europe is currently the subject of considerable debate, not least of all for the funding of LRT.

METHOD

Tsamboulas et al *10* developed a method to assess the attractiveness of transportation infrastructure projects to private financing. In addition to assessing the attractiveness, the method also aims to highlight factors that tend to reduce such attractiveness. It also attempts to provide the means to examine the viability of alternative risk-allocation scenarios consisting of different combinations of risk to be undertaken by the public sector.

The method attempts to simulate the private sector's response to suggested risk sharing. The idea behind the approach is that the public sector, in preparing tender documents, does not fully consider the risk allocation from the perspective of the private sector. This often results in the public sector suggesting projects that are unattractive to the private sector. Based on the Analytic Hierarchy Process, developed by Saaty *11* the method reduces complex decisions to a series of one-to-one comparisons enabling both

qualitative and quantitative aspects of a decision to be considered. The innovation of the method *10* lies in the structuring of the process and the one-to-one comparisons.

Risk and the expected outcome of taking a risk requires an estimate of the maximum possible losses and the certainty of reaching maximum profit. The estimates rely on five alternative risk scenarios; very high, high, medium, low and very low each representing different capital ranges. Each investor will have a different perception of the risks involved and the method allows for these ranges to be created according to the investor's preferences.

The method *10* provides a procedure that organises the various components and develops priorities in each hierarchy according to the Analytical Hierarchy Process (AHP) *11*. The method is broken down into a four-step procedure; decomposition, comparative judgements, synthesis of priorities and assessment of private financing attractiveness. Decomposition structures the hierarchy in such a way that it can be worked through either from the top down or from the bottom u. The hierarchy of risks for the assessment of the attractiveness of the extension of LRT in Dublin to private finance is shown in Figure 1. As required by Tsamboulas *10* the types of risks considered important were selected on an ad hoc basis and were organised using the following rules: (i) the hierarchy should contain risks considered important from the perspective of the private sector irrespective of whether the public sector shares the same opinion (ii) the hierarchy should be able to cope with different modes, countries and types of investment (iii) the level of aggregation at which the private sector is typically required to work should be taken into account (iv) double-counting should be avoided.

In step 2 of the method, the principle of comparative judgements requires the introduction of a matrix a_{ij} having as elements a_{ij} which represent the importance of alternative i over alternative j. Pairwise comparisons of the relative importance of the elements in the second level (see Figure 1) with respect to the overall objective at the first level (see Figure 1) are made. Comparisons are made judgementally using a scale drawn up by Tsamboulas (*10*) based on qualitative values provided by interviewed private investors. The scale is presented in Table 2.

In the synthesis of priorities step, the priorities from the second level down are found by multiplying local priorities by the priority of their corresponding 'cluster' component at the level above and adding them for each element at that level, according to the elements it affects *10* (an example is presented later). This provides the global priority of that element which is then used to weight the local priorities of elements in the level below. The global priority (Ψ) of each alternative risk scenario, i, is computed as follows: $\psi_i = \sum_j \left(w_j \Omega_{ij} \right)$ where w_j is the weight of the j^{th} criterion and Ω_{ij} is the performance of alternative i with respect to criterion j.

After the computation of weights for each risk scenario, the next step is the final one, the assessment of private financing attractiveness. The range of possible losses must be translated into 'very high', 'high' and other verbal descriptors. This is done by identifying the range of money losses (c_i - c_j) that correspond to each verbal variable. They are then combined together to determine the most likely amount, x_p, that a potential investor would be expected to risk for the specific project *10*. This is calculated as follows:

$$x_p = \frac{w_1(c_o - c_1) + w_2(c_1 - c_2) + ... + w_5(c_4 - c_5)}{\sum_{i=1}^{5} w_i}$$ where w_i represent the priorities (weights) of the five alternative risk scenarios and c_i the alternative proportions of the invested capital or a measure of performance such as return on equity (ROE).

When the largest possibility of loss, x_p, and the associated risk, w_5, have been calculated, the potential private investor is required to determine the indifference curve that characterises his/her risk attitude. The certainty, y_p, required by the investor to participate in a PPP scheme can be obtained for an amount of capital equal to x_p. The public sector can then deduce whether the private investor participation is attractive i.e. if $w_p > y_p$.

THE TSAMBOULOS METHOD APPLIED TO LRT INVESTMENT IN DUBLIN – HYPOTHETICAL EXAMPLE

The first task, as mentioned earlier, was to produce a hierarchy of risks. This was done by the project director LRT system in Dublin and is presented in Figure 1. The top level is private sector investment risk and this is sub-divided into five major risk categories (see second level in Figure 1). Each is further sub-divided according to levels 3 and 4, as presented in Figure 1. The comparative judgements phase was done by means of a workshop with three individuals, two from the public sector involved in the LRT project and one from the private financing sector.

In making their decisions for the matrix, a number of assumptions were made. Irish conditions were taken into account in relation to planning regulations and the attitudes of the private sector. It was noted during the workshop, that should the same

exercise be conducted for a PPP project in the UK, the results would be different. The second assumption made was the type of PPP selected. It was decided to select a Design, Build, Finance, Operate and Maintain (DBFOM) contract because this would be the most likely option if the LRT extension was developed as a PPP.

The comparison matrices were drawn up for each level of risk. For level 2 (second level in Figure 1) the comparison matrix is presented in Table 3. The number 1 is assigned to each of the diagonals because, in each diagonal cell, like is compared with like and 1 represents equal importance. When planning risk is compared with design and construction risks, a score of 7 (see Table 2 to see what a score of 7 means) is assigned indicating very strong or demonstrated importance. In this case, planning risk is considered to be a much higher risk than design and construction risks. The matrix is completed in this way throughout, with reciprocals assigned so that the product of two mirror cells always results in 1. Similar matrices are produced for Level 3 and Level 4 risks, the results of which are presented in Figures 2 and 3.

The consistency of each matrix was then required to be checked using the consistency index (mathematical test but used any further in the calculations) defined as:

$$CI = \frac{(\lambda_{\max} - n)}{(n-1)}$$

where $\lambda_{\max}$ represents the maximum eigenvalue while n represents the order of the matrix in question. $\lambda_{\max}$ and CI for each level are presented in Table 4. For consistency, the CI should be less than 0.1 *11*. In Table 4, it can be seen that all except one, i.e. Level 2, comply with this requirement with Level 2 showing a value of CI at 0.12. Given that the

difference is nominal, it was decided to accept these risk levels rather than completing the entire exercise again.

The weights of the risk elements at the third and fourth levels were calculated by determining both the local and global priorities of each as laid down in the Tsamboulas Method. This involved calculating the local priority of each element of the third level from the comparative judgement matrices. The global priority was calculated by multiplying the local priority by the corresponding local priority of the level above. A priority vector was created, the elements of which correspond to the weights of risks that lie at the second level (i.e. planning risk 0.457, financial risk 0.039 and operating & maintenance risk 0.146). An example as to how to calculate one of these values, 0.457, is now presented. The entries presented in each cell of the planning risk row of Table 3 are multiplied by each other and the total is raised to the power of 1/(the number of entries i.e. 5 in this case). This gives a value of 3.022 and this is further divided by 3.022 plus all similar values calculated for the other rows in Table 3 for design, legal, financial and operating risks, resulting in a value of 0.457. Similar calculations are made for the remainder and the results are the priorities for all levels and are presented in Table 5.

The next step of the process involved assessing the relative importance of the five alternative risk scenarios. These represent the investor's belief that one of them might turn into reality. The scenario with the highest relative importance or weighting value is deemed the most likely to occur. The investor's belief is quantified by the use of an indifference curve, the coefficients of which were those used by Tsamboulos *10*. Ideally, an indifference curve would have been determined specific to the Irish LRT example but this was not possible because of the difficulties in identifying suitable private investors to

discuss this issue with and the fact that the exercise was hypothetical. The values from the indifference curve were designated as percentage values and translated to the relative weightings which can be seen in Table 6. The sum of each of the columns in this table corresponds to their respective entries in the priority vector as detailed above (e.g. the total of the first column of Table 6 is 0.457 which was calculated earlier).

From Table 6, it can be seen that the private sector investors for the LRT project are less averse to taking large amounts of design & construction or financial risks than they are to taking planning risk. The reason behind this is that although there may be substantial design & construction risk in this project it is nothing unusual. These risks must be accepted by contractors or they would never take on any project but with their experience in this field they are in a strong position to mitigate most of the risks involved. If the contractor is confident that they can ensure that the design & construction of a project will be carried out to the prescribed standards then this risk does not pose a large problem.

It is understandable that private investors in the LRT project are most averse to taking on planning risk. This is because they cannot exercise the same control over planning risks. The key to a successful PPP agreement lies in allocating the risks to the party best able to manage them. Planning risks are controlled by the appropriate public sector bodies and hence cannot be effectively managed by the private sector. Planning risk poses a serious threat to projects from the outset. Planning permission may be denied resulting in project failure or land acquisition may be held up for long periods with compulsory purchase orders contested in the courts.

This examination of the LRT extension is an analysis exercise as the decision not

to use PPP has already been arrived at using another decision making method. For the purposes of the exercise, the assumed requested investment contribution of the project owner for the LRT project is €50 million. An average return on equity of 15% is assumed for the project. The various possible losses are calculated below relative to the equity and the required return on equity. These values form a major component of the calculation to establish the most likely amount (x_p) that the potential private sector investor is expected to risk for the project.

Requested investment contribution of the project owner	€50 million
Equity	Equity ranges between €40 and €10 million examined
Requested average Return on Equity (ROE)	€15%

A number of risk levels were included in the calculations.

Very High Risk	Possible losses exceeding 50% of contractor's equity
High Risk	Possible losses fluctuating between 50% of equity and 50% of required ROE
Medium Risk	Possible losses fluctuating between 50% and 30% of required ROE
Low Risk	Possible losses fluctuating between 30% and 5% of required ROE
Very Low Risk	Possible losses not exceeding 5% of required ROE

The most likely amount that the potential private sector investor is expected to risk for the project is calculated as follows:

$$x_p = \frac{w_1(c_o - c_1) + w_2(c_1 - c_2) + ... + w_5(c_4 - c_5)}{\sum_{i=1}^{5} w_i}$$

using the following weights as calculated in Table 6.

$w_1 = 0.158$

$w_2 = 0.317$

$w_3 = 0.198$

$w_4 = 0.193$

$w_5 = 0.134$

c values represent the range of possible losses as detailed above.

$$\sum_{i=1}^{5} w_i = 1$$

According to the Tsamboulas Methodology, the attractiveness of a project to private financing is assessed with respect to the certainty (y_p) required by the private investor to participate in a PPP scheme. This certainty is gauged from an indifference curve (mentioned earlier) of the form $y_p = a(1-e^{(-bx)})$.

$y_p = a(1-e^{(-bx)})$ (a = 1.052, b = 0.019)

$y_p = 1.052 (1-e^{(-0.019\ x)})$

The coefficients used by Tsamboulas are used here because it was not possible to calibrate them for the Luas case. A range of equity levels were examined and the corresponding y_p values are presented in Table 7.

w_5 represents the priority (weight) of the very low risk scenario and in this case it was calculated as 0.134, as shown above. The comparison between w_5 and y_p is the deciding factor to ascertain if private finance may be attracted to the project. The criteria for attractiveness to the private sector requires that $w_5 > y_p$. From Table 7 it can be seen that below a level of risk of approximately €7million which the contractor is prepared to take that the LUAS extension would be attractive to private financing. Above this level, the project is unattractive.

CONCLUDING REMARKS

The paper uses the Tsamboulas method of assessing the attractiveness of transport infrastructure projects to private finance for an extension to an LRT line in Dublin. The analysis is done as an analysis exercise rather than as contributing to the decision making process for this project because it has already been decided that the project will not be constructed by means of a PPP. However, it is interesting to note that should it have been, it is likely that private financing would have been attracted to it. This is a different result to the actual choice of procurement strategy chosen for the project, which was along more traditional lines. It is clear therefore that the method used in making such a decision and the weights given to particular risk types have a significant impact on whether private finance can be attracted to transport infrastructure projects.

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Figure 1. Risk Hierarchy for Private Sector Involvement in LRT in Dublin

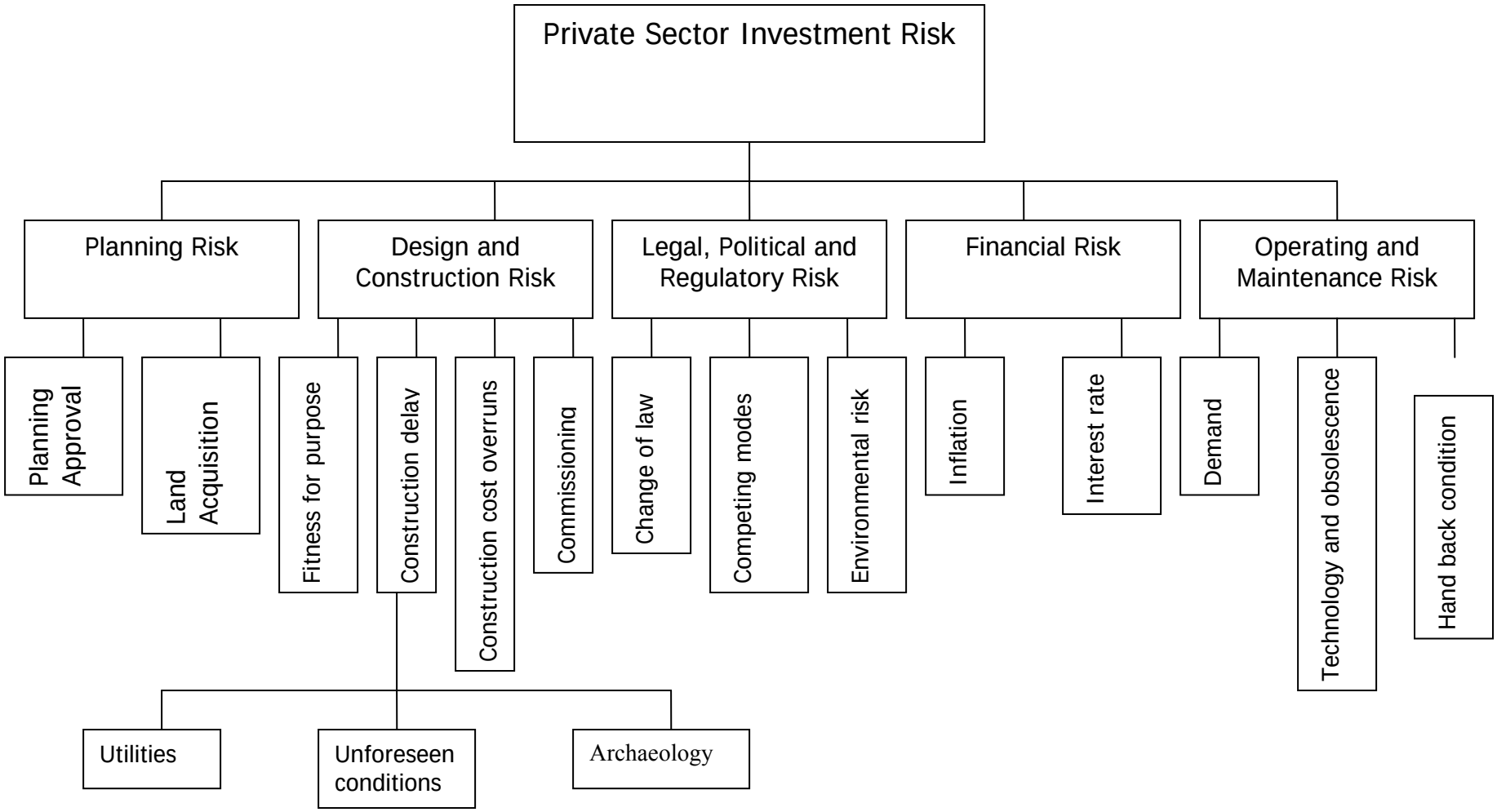

Figure 2 Comparison Matrices for Level 3 Risks

Level 3.1

	Planning Approval	Land Acquisition
Planning Approval	1	7
Land Acquistion	1/7	1

Level 3.2

	Fitness for Purpose	Const'n Delay	Const'n Cost Overruns	Commissioning
Fitness for Purpose	1	1/4	1/4	1
Construction Delay	4	1	1	1/4
Const'n Cost Overruns	4	1	1	1/4
Commiss-ioning	1	4	4	1

Level 3.3

	Change of Law	Competing Modes	Environmental Risk
Change of Law	1	6	8
Competing Modes	1/6	1	1
Environmental Risk	1/8	1	1

Level 3.4

	Inflation	Interest Rate Risk
Inflation	1	1
Interest rate	1	1

Level 3.5

	Demand	Technology & Obsolence	Hand Back Condition
Demand	1	8	7
Technology & obsolecence	1/8	1	1/4
Hand Back Condition	1/7	4	1

Figure 3. Comparison Matrix for Level 4 Risks

Level 4

	Utilities	Unforeseen Conditions	Archaeology
Utilities	1	2	1/7
Unforeseen Conditions	1/2	1	1/8
Archaeology	7	8	1

Table 1. Procurement Options for LUAS Extension

OPTION	BRIEF DESCRIPTION
A	Turnkey Design, Build, Finance and Maintain (DBFM) contract let to a single consortium including all enabling works, wholly financed by the private sector.
B	Turnkey Design and Build contract let to a single consortium including all enabling works, 100% exchequer funded.
C	Initial contract(s) for enabling works including utility diversions and key structures. Luas style D&B for civils, trackwork, E&M and signalling, 100% exchequer funded. This is similar to the Luas procurement model with Systems integration being the responsibility of the main Joint Venture.
D	RPA carry out 100% design and let a series of separate contracts covering; (1) enabling works, including utility diversions and key structures; (2) Civils and trackwork and (3) E&M/Signalling. Responsibility for Systems integration remains with RPA. 100% exchequer funded.
E	Early Contractor involvement using Luas to benchmark the cost plan. Select a primary contractor, agree a series of cost and programme benchmarks and transfer responsibility for sub-letting all packages and systems integration. 100% exchequer funded.
F	Initial contract(s) for enabling works including utility diversions and key structures. 100% exchequer funded. Privately financed single DBFM contract for all civils, trackwork, E&M and signalling. This is a privately financed option similar to option C with Systems integration being the responsibility of the DBFM concessionaire.

E&M – Electrical and Mechanical
D&B – Design and Build

Table 2. Comparative Judgements Scale (*10*)

Intensity of Importance	**Definition**	**Explanation**
1	Equal importance	Two risk elements contributed equally to the objective
2 3	Weak Moderate importance	Experience and judgement slightly favour one element over another
4 5	Moderate plus Strong importance	Experience and judgement strongly favour one element over another
6 7	Strong plus Very strong or demonstrated importance	An element is favoured very strongly over another; its dominance demonstrated in practice
8 9	Very, very strong Extreme importance	The evidence favouring one element over another is of the highest order of affirmation
Reciprocals of above	If risk element I has one of the above nonzero numbers assigned to it when compared with element j, then j has the reciprocal value when compared with i	A reasonable assumption
Rational	Ratios arising from the scale	If consistency were to be forced by obtaining n numerical values to span the matrix

Table 3 Comparison Matrix for Level 2

	Planning Risk	Design & Construction Risk	Legal, Political & Regulatory Risk	Financial Risk	Operating and Maintenance Risk
Planning Risk	1	7	3	6	2
Design & Construction Risk	1/7	1	1/3	4	3
Legal, Political & Regulatory Risk	1/3	3	1	7	1
Financial Risk	1/6	1/4	1/7	1	
Operating and Maintenance Risk	½	1/3	1	5	1

Table 4 Maximum Eigenvalues and Consistency Index Values

Risk Level	λ_{max}	CI
2.0	5.48	0.12
3.1	2.00	0
3.2	3.88	-0.04
3.3	3.01	4.5E-3
3.4	2.00	0
3.5	3.18	0.09
4.0	3.04	0.02

Table 5. Weights of Risk Elements

SECOND LEVEL

	Local
Planning Risk	0.457
Design & Construction Risk	0.135
Legal, Political & Regulatory Risk	0.223
Financial Risk	0.04
Operating & Maintenance Risk	0.146

THIRD LEVEL

	Local	Global
Planning Approval	0.875	0.400
Land Acquisition	0.125	0.057
		0.457

	Local	Global
Fitness for Purpose	0.111	0.015
Construction Delay	0.222	0.030
Construction Cost Overruns	0.222	0.030
Commissioning	0.444	0.060
		0.135

	Local	Global
Change of Law	0.776	0.173
Competing Modes	0.117	0.026
Environmental Risks	0.107	0.024
		0.223

	Local	Global
Inflation	0.500	0.020
Interest Rate	0.500	0.020
		0.04

	Local	Global
Demand	0.770	0.112
Technology & Obsolescence	0.063	0.009
Handback Condition	0.167	0.024
		0.146

FOURTH LEVEL

	Local	Global
Utilities	0.135	0.004
Unforeseen Conditions	0.081	0.0024
Archaeology	0.784	0.023
		0.0094

Table 6. Relative Importance of Alternative Risk Scenarios

Risk Scenarios	Planning Risk	Design & Construction Risk	Legal, Political & Regulatory Risk	Financial Risk	Operating & Maintenance Risk	Overall Ranking
Very high	0.114	0.027	0.002	0.000	0.015	0.158
High	0.228	0.054	0.011	0.002	0.022	0.317
Medium	0.069	0.034	0.033	0.004	0.058	0.198
Low	0.032	0.014	0.100	0.018	0.029	0.193
Very low	0.014	0.007	0.076	0.016	0.022	0.134
Total	0.457	0.135	0.223	0.039	0.146	1.000

Table 7. y_p Values for Different Equity Levels

Million Euro							
Equity	50	40	30	28	25	20	10
50% of Equity	25	20	15	14	12.5	10	5
Risk the contractor is most likely to take	12.60	10.08	7.56	7.05	6.30	5.04	2.52
y_p	0.22	0.18	0.14	0.13	0.12	0.10	0.05

LIST OF FIGURES

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