Derivation of Utility Values of Project Procurement Systems Against Selection Criteria for Major Highway Construction Projects

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Abstract
In the project management process for the realization of major highway projects, the choice of Project Procurement System (PPS) is central to success as the relevant social environments are numerous and with interdependent interfaces. An extensive literature review showed significant research into PPS selections models for building projects. The PPSs investigated are Traditional, Traditional Fast Track, Design and Build (D&B), Private Public Partnership (PPP), Construction Management (CM), Management Contracts and Partnering. Based on this literature review, the most common Selection Criteria (SC) considered when choosing a PPS were derived. A questionnaire was developed and distributed to experts in highway authorities in Europe and abroad to rate each PPS against these SC in order to determine their Utility Values (UV) to be employed in the Multi-Attribute Utility Analysis (MAUA) decision making methodology. The UV's are in effect a relative measurement of the suitability of a certain CT for a given criterion.

The purpose of this paper is to present the resulting UV of each PPS against each SC from the analysis of the collected data using SPSS 18 PASW software. The selected techniques employed include: estimation of the sample population mean, mode and standard deviation. In addition Pearson chi-square and Analysis of Variance (ANOVA) tests were carried out for inferential analysis between respondent's characteristics and their ratings in order to determine any significant tendency towards specific responses. The results of these analyses are presented and discussed.

Keywords
Procurement, highway projects, questionaire survey,

1. Introduction

The procurement process of any major infrastructure project includes the design phase, tender phase and construction phase. The major participants in the above procedure are the Owner, also known as the Client, the Design Consultant, Contractor and Construction Manager (CM). The project procurement system (PPS) chosen defines the number and types of contracts drawn up between the major participants.

The number and quality of contractual relationships between the major participants are crucial in terms of time, cost and quality achievement of the resulting project.

This paper is part of an ongoing research project aiming at recording, evaluating and utilizing the experience of awarding bodies in the procurement of major road projects from the 2nd and 3rd Community Support Framework by grasping the managerial and technical experience of high level experts that have been involved in the procurement of major motorway projects around the world via questionnaires and personal interviews. As a result, it is expected that the research results will contribute to the upgrading of local technical services by directly contributing to reduction of procurement time as the ultimate model to be developed has the potential to be implemented by local, regional and national Awarding Authorities (AA).

Following an extensive literature review the possible PPS as well as the required selection criteria (SC) that should be considered when making the choice where determined. The most common PPS that have been employed in the construction industry are Traditional, Traditional Fast Track, D&B, PPP contract (BOT, turnkey etc,), CM, Management Contracts and Partnering. The choice of the 17 SC (Complexity, Flexibility, Integration, Project funding, Design completion at tender, Size, Certainty of cost, Price competition, Quality standards, Point of responsibility, Risk allocation/avoidance, Speed, Certainty of time, Minimization of disputes, Client's involvement, Availability of competent contractors and design firms and Familiarity of procurement system) was made by taking into consideration the view point of the AA. Those criteria that were most frequently used in similar studies relating mostly to building projects were chosen to be included in this survey for road projects (Author's prior publication, 2009).

This paper attempts to draw conclusions from the ratings of each of the 7 examined PPS against the 17 SC, obtained from a survey between 91 highway procurement experts from Greece and abroad as a first step towards the development of a model that can be employed by highway agencies in Greece when faced with the choice of project procurement system most compatible with the specific project characteristics, the AA needs and the market situation.

2. Questionaire survey

The collection of opinions took place via a questionnaire survey carried out either in person or by email. The survey was conducted from 2010-2012 due to the very slow response rate, something very common because of the workload of experts in the project management field (Palaneeswaran & Kumaraswamy, 2003).

The first part of the questionnaire was dedicated to the experts who responded to a series of personal questions about their professional experience related with their current (at the time of completion) position, their years of experience in design, supervision and project management, their years of service in the public and private sectors, and to which of the considered PPS they have had direct personal experience. The questionnaire presented and described the various PPS with the SC and the rating scale. The second part, called on the experts to rate on a scale of 1 to 10 each PPS against each SC giving a grade 10 if the PPS fully achieves the criterion, a grade 5 if it satisfactorily achieves the criterion, and 1 if PPS fails the criterion.

2.1 Sample description

The survey collected 91 answers from engineers with various roles and involvement in project realization, from Greece and abroad during 2010-2012. As a result, the experts involved represent all stakeholders in the highway procurement process. Greek participants were selected based on the degree of involvement in highway project contracting. The largest highway project in Greece, during the last decade is Egnatia

Motorway and most of the participants were actively involved. Foreign participants were chosen according to their experience with the research topic, through a relevant conference workshop of the World Road Association. From the total of 91 responses, Greek participants were 65 and foreign participants were 26. Foreign participants' nationalities are presented in the following table 1. From the total of 26 foreign participants only 2 of them have worked both in Greece and abroad.

Table 1. Origin of Foreign Participants

ITALY	AUSTRALIA	USA	BELGIUM	UK	HUNGARY	ROMANIA	SPAIN	NEWZEALAND	AUSTRIA	FRANCE	MALAYSIA	JAPAN	IRELAND
1	1	4	1	7	2	1	1	1	1	1	1	2	2

Regarding current occupational status, 14 respondents specialize in highway design, 26 in construction supervision, 31 respondents in project management and finally 20 in construction. Participants with public sector experience represent the 78% of the sample, while participants with some private sector experience represent 70 % of the pool of respondents In addition, 80% of the respondents had some experience in Project Management, 76% in construction supervision and 57% in highway design. As far as the quality of the sample is concerned, the result of the Cronbach's Alpha computation (= 0,919) reveals that the measure has high internal consistency. (Field 2009). The size of the research sample is considered adequate as in similar studies regarding the choice of PPS, responses were obtained from 50 or less experts (Cheung et al. 2001a; 2001b; 2001c; Chan et al., 2006).

2.2 Statistical Analysis of Results

The results are processed through statistical techniques such as the calculation of descriptive statistical measures of variables (mean, mode and frequencies). In addition Pearson chi-square and Analysis of Variance (ANOVA) tests were carried out for inferential analysis between respondent's characteristics and their ratings in order to determine if the variables related to the expert profiles are also related to their scores and examine if significantly different views appear among the various sub - sample groups compared to the total results and among the results of each sub-group. The experts' ratings were converted into variables in order to be analyzed by the IBM SPSS Statistics software v.19. In total 133 variables were introduced in the program, where 119 variables were the scores of each PPS against each SC (7X17 = 119) taking values from 1-10 (which were then converted into a scale of 1-5) and 14 variables relating to respondent profile characteristics.

2.2.1 Descriptive Statistical Measures

While analyzing the results of the expert ratings, these were converted into a 5-point Likert scale (from a 10 point scale) to allow a more comprehensive analysis and to facilitate the evaluation of the results. Tables 3 and 4 show the mean, standard deviation, mode and the frequency of the mode values of the scores of each PPS against each SC. Only four variables had more than one mode value. By utilizing the data on the original scale, the frequency percentages of the ratings between 1-3, 4-7 and 8-10 were added, giving the total frequency of the low, medium, and high categories respectively and a matrix table was developed between CTs and the SC ratings (table 5) where it can easily be seen whether a CT was given an overall high, medium or low frequency rating against any given selection criterion. The results showed in summary that:

I. The Traditional PPS guarantees the lowest cost because it is based on price competition (SC 8) and ensures a high level of quality through strict monitoring (SC 9). It also requires significant involvement of the project owner while it is familiar to designers, contractors and AA (SC 16, 17).
II. The Fast Track Traditional PPS had similar ratings to the Traditional PPS but in addition it doesn't require complete final designs at tender (SC5).

Table 3. Mean, standard deviation, mode and frequency of mode of the scores of the Traditional, Traditional Fast Track, Design - Build and PPP PPS's against each SC

	Selection Criterion	Traditional				Traditional Fast Track				D&B				PPP			
		(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
SC1	Complexity	1,76	,71	2	43,68	1,80	,59	2	62,12	2,23	,59	2	60,27	2,36	,61	2	50,00
SC2	Flexibility	2,24	1,33	1	44,94	3,24	1,20	4	31,82	3,32	1,17	4	32,39	3,78	1,04	4	44,93
SC3	Integration	1,89	1,18	1	55,68	2,82	1,09	3	37,88	4,25	,85	5	46,58	4,25	,92	5	50,70
SC4	Project Funding	1,46	,94	1	75,00	1,42	,91	1	76,56	2,03	1,26	1	50,72	4,68	,60	5	74,65
SC5	Design Completion at Tender	1,66	1,24	1	71,95	3,44	1,51	5	37,50	4,07	1,25	5	54,17	3,99	1,28	5	53,62
SC6	Size	3,28	1,04	3	36,78	3,28	,98	4	40,63	3,83	1,13	5	39,44	3,52	1,08	4	37,93
SC7	Certainty of Cost	3,21	1,19	4	32,56	2,86	1,08	3	43,75	3,58	1,18	4	35,21	3,90	1,14	5	36,23
SC8	Price Competition	4,01	1,20	5	47,19	3,71	1,26	5	36,36	3,52	1,35	5	30,99	3,17	1,27	3	33,33
SC9	Quality Standards	3,79	1,00	4	35,63	3,75	1,01	4	37,50	3,61	1,01	4	34,29	3,59	1,14	3	30,88
SC10	Point of responsibility	2,27	1,17	1	38,37	2,06	1,03	1	42,86	3,22	1,28	3	28,99	2,68	1,00	3	43,86
SC11	Risk Allocation / Avoidance	2,53	1,26	1[a]	28,74	2,50	1,21	3	39,06	3,61	1,16	4	39,44	4,43	,84	5	60,00
SC12	Speed	2,03	1,14	1	45,98	2,85	1,08	3	43,08	3,75	1,08	4	32,39	3,82	1,16	5	39,71
SC13	Certainty of time	3,07	1,18	3	34,48	3,07	1,18	3	39,06	3,56	,97	4	40,85	3,05	,82	3	60,71
SC14	Minimization of	2,56	1,16	3	35,23	2,34	,96	3	35,94	3,30	1,19	4	35,21	3,77	,97	4	39,13
SC15	Client's involvement	4,15	1,02	5	48,86	4,25	,92	5	49,23	3,68	,95	4	36,62	2,29	1,13	1[a]	30,00
SC16	Availability of competent contractors and design firms	4,18	1,03	5	54,02	4,06	,97	5	43,75	3,92	1,00	5	35,21	3,32	1,16	3	23,19
SC17	Familiarity of procurement system	4,60	,75	5	72,41	4,03	1,10	5	43,75	3,93	1,03	5	36,62	3,31	1,18	3	27,94
(1) Mean Score (2) Standard Deviation (3) Mode Value (4) Frequency of Mode Value (%)																	

Table 4 Mean, standard deviation, mode and frequency of mode of the scores of the CM, Management Contract and Partnering PPS's against each SC.

Selection Criterion		CM				Project Management				Partnering			
		(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
SC1	Complexity	2,14	0,63	2	59,32	1,90	0,42	2	81,63	2,33	0,66	2	46,9
SC2	Flexibility	3,22	1,04	3	39,66	3,38	1,02	4	41,67	3,81	0,94	4	41,7
SC3	Integration	2,98	1,03	2[a]	31,03	2,96	0,99	3	35,42	4,13	0,71	4	61,7
SC4	Project Funding	1,74	1,04	1	59,65	1,88	1,21	1	54,17	2,26	1,34	1	46,8
SC5	Design Completion at Tender	2,53	1,38	1	34,48	2,50	1,34	1	33,33	3,33	1,24	3	31,3
SC6	Size	3,52	1,08	4	37,93	3,10	1,02	4	35,42	3,24	1,15	2[a]	26,5
SC7	Certainty of Cost	3,12	0,95	3	47,37	2,87	0,90	3	44,68	2,91	0,97	3	44,7
SC8	Price Competition	3,48	1,29	5	29,31	2,83	1,15	3	31,91	2,67	1,31	3	33,3
SC9	Quality Standards	4,20	0,88	5	42,86	3,72	1,16	4	38,30	3,52	1,01	3	39,1
SC10	Point of responsibility	2,68	1,00	3	43,86	3,13	0,88	3	48,94	3,21	1,03	3	41,7
SC11	Risk Allocation / Avoidance	3,32	1,00	3	36,17	3,32	1,00	3	36,17	3,00	1,18	3	40,4
SC12	Speed	2,82	0,87	3	49,12	3,13	0,88	3	48,94	3,17	1,01	3	36,2
SC13	Certainty of time	3,05	0,82	3	60,71	3,09	0,89	3	47,83	2,80	0,96	3	39,1
SC14	Minimization of disputes	2,68	0,83	3	48,21	3,17	1,10	2	32,61	4,07	1,22	5	54,3
SC15	Client's involvement	3,24	1,03	3	41,38	2,81	1,04	3	42,55	3,32	1,24	4	25,5
SC16	Availability of competent contractors and design firms	3,51	0,98	4	36,84	2,70	1,15	3	39,13	2,53	1,27	3	36,2
SC17	Familiarity of procurement system	3,23	1,19	3	35,71	2,13	1,12	2	37,78	2,17	1,17	1	36,2
(1) Mean Score (2) Standard Deviation (3) Mode Value (4) Frequency of mode value (%)													

III. The D&B PPS, received high scores against 8 SC. In particular it rated highly against the SC Integration (SC3), Design completion at tender (SC5), Size (SC 6), Risk allocation/avoidance (SC11), Speed (SC12), Client's involvement (SC 15), Availability of competent contractors and design firms (SC16) and Familiarity of procurement system (SC17).

IV. The PPP PPS received high scores in most SC (11 of 17).

V. The CM PPS scored highly against SC 6 size as it is considered ideal for large highway construction and against the SC 9 Quality Standards, because the role of the Construction Manager, is to ensure the quality of the work through a strict process of quality assurance.

VI. The Management Contract PPS received similar scores as the CM PPS though relatively unknown.

VII The Partnering PPS received high scores against the SC 1, 2 and 3 as it is able to implement special construction methods, flexible to design changes or structural adjustments after the commencement of work and enables collaboration between designers and contractors during construction. Also, it is considered by the experts that it has the potential to reduce the number of claims by contractors.

Table 5. Most frequent scores of PPS against SC

Selection Criterion	Traditional	Traditional Fast Track	D&B	PPP Contracts	CM	Management contracts	Partnering
1. Complexity	moderate	moderate	moderate	high	moderate	moderate	high
2.Flexibility	low	moderate	moderate	high	moderate	moderate	high
3.Integration	low	moderate	high	high	moderate	moderate	high
4.Project funding	low	low	low	high	low	low	low
5.Design completion at tender	low	high	high	high	low	low	moderate
6.Size	moderate	moderate	high	high	high/ moderate	moderate	moderate
7.Certainty of cost	moderate	moderate	moderate	high	moderate	moderate	moderate
8.Price competition	high	moderate	moderate	moderate	moderate	moderate	moderate
9.Quality standards	high	high	moderate	moderate	high	high	moderate
10.Point of responsibility	low	moderate	moderate	high	moderate	moderate	moderate
11.Risk allocation/avoidance	moderate / low	moderate	high	high	moderate	moderate	moderate
12.Speed	low	moderate	high/ moderate	high	moderate	moderate	moderate
13.Certainty of time	moderate	moderate	moderate	high	moderate	moderate	moderate
14.Minimization of disputes	moderate	moderate	moderate	high	moderate	moderate	high
15.Client's involvement	high	high	high/ moderate	moderate	moderate	moderate	moderate
16.Availability of competent contractors and design firms	high	high	high	moderate	moderate	moderate	moderate
17.Familiarity of procurement system	high	high	high	moderate	moderate	moderate	moderate

2.2.2 Pearson Chi – Square Tests

In order to determine if the variables related to the expert profiles are related to their scores, Pearson's chi-square test was used. This is an inductive process that tests the hypothesis that two variables are independent of each other, and thus do not affect one another (Gnardellis, 2006). This is achieved by comparing the observed frequencies in some categories with the expected frequencies that would be anticipated by chance. If the significance value is quite small (<0.05), then the null hypothesis that the variables are independent is rejected and there is confidence on the assumption that somehow the variables are related (Field 2009). In SPSS this can be done by the process «Crosstabs».

For each dependent variable, out of 119 ratings of each PPS against each SC (7x17=119) that took values from 1-5 and for each of the 14 independent variables relating to the experts' profiles and taking values in accordance with table 2, 1666 contingency tables (14x119 = 1666) were created using SPSS. The resulting contingency tables for which it was found that the Asymptotic Significance (2 sided) was less than 0.05 and thus the specific variables were independent, were examined in order to determine which values deviated from the assumption of independence and what scores and categories they represented.

The most associations were found in relation to the origin of the experts and that's the reason for the focused discussion. Specifically Table 6 presents trends in scores where associations were found between the expert's origin and the scores. The most significant results per PPS are as follows:

I. Traditional PPS - Experts from abroad rated this PPS with the lowest score in relation to the SC 2 Flexibility and the SC 10 Point of Responsibility, while the Greeks experts tend to rate it with 4. Namely, there are opposing views based on origin as to whether this PPS is flexible regarding design changes after construction work starts and if it reduces the bureaucracy of the AA due to few points of responsibility.
II. Traditional Fast Track PPS- Again there is significant disagreement between Greek and foreign experts. Specifically, the Greeks, unlike foreigners, tend to believe that this PPS does not attract private capital (SC4) and does not reduce the number of requests and claims.
III. D&B PPS - The major trends observed here in relation to the origin of the experts is that the Greeks believe that it requires significant involvement of the AA and is more familiar in the Greek construction market while foreign experts provide lower scores.

IV. PPP PPS - The Greeks consider this PPS as the ideal for large road projects in contrast to foreign colleagues.
V. CM PPS- Here experts tend to agree that the PPS guarantees the lowest cost because it is based on price competition and that it ensures a high level of quality through strict supervision of works.
VI. Management Contract PPS- The only association found, with respect to the origin and the scores of this PPS, is that foreign participants tend to rate the SC 8 highly indicating that they believe that it guarantees the lowest cost because it is based on price competition.
VII. Partnering PPS - Foreigner participants consider this PPS as familiar in the construction sector of their home country unlike their Greeks colleagues.

Table 6: Major trends in the scores based on the origin of experts

		Traditional		Traditional Fast Track		D&B		PPP contract		CM		Management contracts		Partnering	
	Selection Criterion	**Greece**	**Abroad**	**Greece**	**Abroad**	**Greece**	**Abroad**	**Greece**	**Abroad**	**Greece**	**Abroad**	**Greece**	**Abroad**	**Greece**	**Abroad**
1	Complexity		3						1						
2	Flexibility	1	4	5	4	3	2		2						
3	Integration					5	4	5	4						
4	Project funding		3	1	3										
5	Design completion at tender					5	2/4							3	1
6	Size						3	5	2						
7	Certainty of cost														
8	Price competition		4	5						5	4		4		
9	Quality standards	3	4	5	4					5	4				
10	Point of responsibility	1	4	1	2/4				4						
11	Risk allocation/avoidance														
12	Speed														
13	Certainty of time	5					4								
14	Minimization of disputes	1		1	4										
15	Client's involvement		4	5	3/4	5	3	1	2						
16	Availability of competent contractors and design firms						2		1						
17	Familiarity of procurement system		2			5	2							1	5

2.2.3 One Way Analysis of Variance (ANOVA)

Specifically, one-way analysis of variance (ANOVA) will be performed to test the perceptions of experts from the various sub groups of respondents, i.e. according to origin, years of experience in the public or private sector, years of experience in design, construction supervision or project management and according to their current position. The one-way ANOVA will be used to test the hypothesis that several means between the above mentioned sub groups are equal and hence are in agreement.

One way ANOVA analyses were carried out for each of the 119 dependent variables against 7 independent variables to determine in which cases significant differences were found between the mean values between subgroups.

Initially, Levene's tests, which are tests designed to test the null hypothesis that the variances of the groups are the same, were carried out. If Levene's test is significant (i.e. Sig. <0,05) then the variances are significantly different and a basic assumption of ANOVA procedure has been violated.

Next for all the dependent variables and each grouping the value of ANOVA F is calculated except for those who presented significant values in the Levene test which were tested for the F values of Welch instead. If the F value is significantly large (ie Sig. <0.05) the null hypothesis of equality of the means of

groups was rejected. Finally, after identifying the variables with significant F values the ω^2 index is calculated for the clarification size of the effect as follows (Field 2009):

$$\omega^2 = \frac{SS_M - (df_M)MS_R}{SS_T + MS_R}$$

It has been suggested that values of ω^2 0.01, 0.06 and 0.14 correspond to small, medium and large effects respectively (Field 2009). The final results where significant effects between group values and resulting ratings were determined highlight the following:

I. 38 of the 119 dependent variables have different mean values per group for at least one (up to two) of the 7 different groupings.
II. Grouping by origin presented the most differences in mean scores per sub - group (29 variables) and the groupings by years of experience in design presented significant differences in 5 variables.
III. Large effects (ie $\omega^2 > 0.14$) were found in 11 dependent variables, among the three groupings that affected most the variables as follows (per PPS):
    1. There were no significant differences in the mean scores for the Traditional and the Management Contract PPSs over any SC in relation to any grouping.
    2. The scores of the Traditional Fast Track PPS against the SC "Project funding" is strongly influenced by the respondent's origin.
    3. The mean scores of the D&B PPS against the SC "Familiarity of procurement system" are strongly influenced by the respondent's origin and years of experience in the public sector. Also, mean scores against the SC "Size" are greatly influenced by the respondent's years of experience in road design.
    4. The mean scores of the PPP PPS against the SC "Availability of competent contractors and design firms" are strongly influenced by the respondents' origin. Also the mean scores against the SC "Design completion at tender" was greatly influenced by the years of experience in road design.
    5. The mean rating of the CM PPS against the SC "Complexity" is strongly influenced by years of experience in the design of road projects.
    6. The mean rating of the Partnering PPS against the SC "Quality Level" and "Familiarity of PPS" are greatly influenced by origin. Also the scores against the SC "Design Completion at tender" was greatly influenced by years of experience in road design and the scores against the SC 'Flexibility' was influenced by the years of experience in supervision.
IV. Because those usually involved in making the choice regarding which PPS to be implemented for the procurement of a major highway project are not designers it is considered that the sample of participants should not be tampered by removing these groups in order to modify the mean values of the total sample to be used as utility values in the MAUA to be employed in making the decision.
V. On the contrary, since the purpose of the research is to evaluate methodologies for choosing the most appropriate PPS for highway construction projects in Greece, research should be focused on using the means of the scores of Greek experts for application in Multi Criteria Decision Making (MCDM) methodologies.

3.0 Conclusions

This paper is part of an ongoing research work which will implement the resulting mean values of the ratings of each PPS against each SC in the MAUA methodology which was chosen for implementation as it is a methodology that can be used as a tool to measure objectivity in an otherwise subjective area of management. Love et al. (1998) state that the use of MAUA in a procurement selection system has been seen as the foremost technique for examining client needs and for weighting the preferences from experts for each procurement system in the most objective way available. The MAUA approach utilizes a score or

utility factor, which is determined by industry experts for each criterion (client need, project characteristic, risk allocation, etc.) for each procurement system. Since a PPS is defined in this paper as the overall design-tender-construction procedure employed by clients in order to obtain major motorway project, the MAUA is considered to be the foremost technique appropriate for quantifying the expected utility that each PPS can provide against each criteria according to expert opinion and determining the weights that client's would representing the importance of each criteria for a specific highway project.

The purpose of this paper was to present the results from a questionnaire survey carried out between 91 Greek and foreign highway project management experts, in order to determine the utility values of each PPS against each SC for highway projects. These values are considered to be useful to AA in Greece in order to be directly employed in any chosen MCDM method to be employed for the choice of the most appropriate PPS for any proposed project. As the Pearson X^2 tests and ANOVA test results showed significant differences in the mean results according to origin, it can be concluded the use of the overall mean values as utility values for implementation in the MAUA for choice of PPS for a given project may lead to different choice of PPS compared to the results obtained when using the mean values resulting from the 78 Greek participants.

It is the object of future research work to consider both the overall mean values and the mean values of the rating of the Greek participants for implementation in the MAUA decision making methodology for the choice of the most appropriate PPS for a given highway project by taking into consideration the predefined weights for each SC for a given pilot project as the next step towards development of a simple to implement project procurement system selection model for major highway projects in Greece.

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