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Qualitative Evaluation and Selecting the Optimum Public Private Partnership System for Transportation

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ABSTRACT

A very effective and strategic factor in the success of transportation projects is the process of selecting an execution system (delivery option). This is the reason why identifying the challenges and selecting an appropriate execution system in transportation projects are quite important; proper selecting will lead to proper progress in the execution of the projects of this sector which is somehow the basis for the country's development. In this paper, using extensive field studies, the most important affecting factors of the existing main execution systems in Iran, including Design-Bid-Build (DBB), Design-Build (DB) and Construction Management (CM), in road, railway, and freeway projects were determined. Then, using the Analytic Hierarchy Process (AHP) and the Expert Choice software, the appropriate execution system for each of such projects were identified and grouped.

1. Introduction

Many studies have been done regarding the causes of increase in the time and cost of projects. They have revealed that the process of selecting the execution system (delivery option) – hence selecting the factors affecting projects – is a very effective element in the failure of transportation construction projects. This has also been verified in the results of studies carried out by the Union of Big Projects (UBP) on 4000 big cases in different countries in the world. In these studies, the process of selecting the execution system (delivery option) – hence the improper choice of the two parties of the contract – has been introduced as one reason for the strategic mistake that, if made, can lead to disastrous consequences. It means that if a good consultant or a proper contractor is not chosen, the project cannot achieve its goals even if the employer tries his best to manage the execution [1]. An unsuitable choice of the contract system, lack of comprehensive studies and quantitative evaluations, and a bad choice of the optimum execution system (delivery option) are among the main reasons for the inappropriate choice of the consultant or the contractor. These defects and weaknesses will not only lead to selecting an improper contract party, but they can also confuse the employer in precise understanding and correct use of the chosen contract system and, sometimes, incorrect interpretations of the contract terms [2]. Due to the

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challenges existing in Iran's execution (delivery) and contracting systems, their study and optimum choice have much importance in the success of projects which, if considered properly and taken use of sufficiently, will lead to good progress in the execution (delivery) of transportation projects which are, somehow, a basis for the country's development, and will have considerable profit for the economy.

2. Determination of delivery options

Delivery option is a comprehensive process for reaching a successful design and construction of a project that consists of the explanation of the procedures and proceedings, limits of responsibilities, and undertakings of the project's main parties. The execution method of a project plays a basic role in the distribution of the execution risks among different organizations involved in the project. Therefore, determination of delivery options consists of the following 4 main key decision makings:

1 – Delivery method: One work-package for all the projects or multiple packages?

2 – Selecting the arrangement of the work areas: Either Design-Bid-Build (DBB), Construction Management (CM), Design-Build (DB), or single party (trusteeship).

3 – Rating method and payments: Either Cost plus Fee (C+F), Guaranteed Maximum Price (GMP), Lump Sum (LS), or Fixed Price (FP).

4 – Method of selecting the main elements of the project execution: Negotiation or tender; tender itself may be limited, public, or without eligibility checking (based on the lowest price-quality).

Considering the above 4 factors and their sub-divisions, a variety of combinations is possible and, therefore, many options are available for the project execution [3].

Work areas include the services necessary for the project, outsourced by the employer to other agents (mainly consultants or contractors), or carried out by the employer's internal organization itself.

Usually, the "combination of the work areas centered on construction" is the factor used as an index for the classification of different delivery options and the name of these options is also originated from this same factor.

Different combinations and the degree of integrity of the work areas (except for the preliminary and feasibility studies) will lead to the creation of different types of delivery options [4]. Delivery options (civil contracts) are divided into the following 3 main groups each of which has many sub-groups. These include DB (2 – party), DBB (3 – party), and CM (4 – party) contracts [5].

3. History

Gordon's method, introduced in 1994, has always been considered as a reference in the subject of selecting an optimum delivery option. Nevertheless, there are some such defects as the negligence of each project's outstanding specifications including the project size, 3_{rd} party agreement, and laws [3]. In 2001, Cheung et al. made use of the AHP to select the delivery option. Through defining 6 possible options, they chose and explained 8 factors for their

weighting system. Any option that can acquire more scores with the AHP and the weighting system through a questionnaire will be chosen as the optimum choice [6]. In 2002, Al-Khalil [7], proposed a model, based on the AHP, for selecting the optimum delivery option that can make the final choice from among the 3 possible options (DBB, DB and CM) considering 3 main factors and detailing them. He believes that the AHP is a capable method of decision making regarding project delivery options and says it is owing to AHP's capability of considering known and unknown factors and the possibility of the formation of failure (fracture) structure in AHP's hierarchical analyses. Mafakheri et al [8], consider AHP as the best method of decision making regarding project delivery options. They suggest, for the employer, a list of affecting factors that, if used with the AHP, will select the best possible delivery option for a project. In 2009, Wang et al. [9], made use of a combination of the Topsis Fuzzy method and the AHP to select the supplier and concluded that they could not model uncertainties in a project. K. Ghavamifar [10], believes that the AHP is an effective method in helping the decision maker regarding the breaking up of the complicated problems into simpler parts. In his proposed model, he asks 2 main questions from the employer. First, "Is it possible to use the PPP?" Second, if not, "What is the best choice from among the 3 possible options?" He, then, suggests that the best option from among DBB, DB, and CM should be chosen using the AHP and experts' opinions and considering the scores acquired most in the questionnaire. In chapter 5 of its publication titled "Guidelines for the Evaluation of Different Project Delivery Options" published in 2009, Transit Cooperative Research Institute (TCRI) introduced the AHP as the best method for selecting a project delivery option. In 2011, Zavadskas et al. [11], using SWOT and the AHP, proposed a method for project management that is able to do the choosing considering the present and possible future options. After the factors have been weighted, the options are listed with priority using the permutation method.

4. Methodology

4.1. Determination of the important factors that highly affect the selecting of the optimum delivery option for transportation projects through interviews with the experts

In this research, road transportation projects have been divided into 3 main groups – road, railway, and freeway – so that the best option can be determined for each group. To achieve this, the most affecting factors were determined through interviews with the experts, and the amount each factor affected each option (in all 3 groups) were also specified. Then, using AHP's multi-criteria decision making procedure, the optimum option was chosen for each group.

In this research, 2 main questionnaires were used. In the first, the factors affecting road, railway, and freeway projects were determined and, in the second, the amount each factor affected a delivery option was specified. Then, using the AHP, the results were analyzed. The effective factors and their quantitative rate of effect were determined according to the numerical scaling in Table 1.

Table 1. Preferences (oral judgment)	
Highly preferred, important, or desired	9
Very strongly preferred, important, or desired	7
Strongly preferred, important, or desired	5
Weakly preferred, important, or desired	3
Similarly preferred, important, or desired	1
In between preferences	2,4,6,8

4.1.1. Sample volume and how it was evaluated

In this research, use was made of Levy & Lemeshow's formula for the No. of interviewees or, more precisely, to calculate the No. of the (statistical) population. It is, of course, worth mentioning that the populations found through other formulas make not much difference from the one used. Using Levy & Lemeshow's sampling formula, a sample of 30 interviewees were selected (the procedure follows) from a population of 166 people [12].

$$n \geq \frac{Z^2 N V_x^2}{(N-1)\varepsilon^2 + Z^2 V_x^2} \qquad (1)$$

where,

$V_X = \frac{S_X}{\overline{X}}$

V_X: Coefficient of variations

Sx: Standard deviation

n: Average sample volume

Z: No. showing safety level

N: Population

$\mathcal{E}$: Error coefficient (= 0.08 in this research)

Sx = 0.66,X = 2.77, *Vx* = 0.24, *Z = 1.96, N* = 166, n ≥ 28.69.

Therefore, the population has been found to be 166 out of which 42 were selected as the sample considering the factor of safety for collecting the questionnaires.

4.1.2. Reliability of the research instruments

In the present research, the reliability of the whole questionnaire was calculated, through Alphacronbach, to be 0.92 using the SPSS software which, in fact, verifies the reliability of this questionnaire [13], [14], [15].

Studying the first questionnaire (experts' opinions about the identified factors) resulted in specifying 15 factors (shown in Table 2) important in road transportation projects.

4.2.Delivery options

The options considered in this research for selecting the optimum execution system in road, railway and freeway projects are as follows:

- Design-Bid-Build (DBB)
- Design-Build (DB)
- Construction Management (CM)

Table 2. Results obtained through studying the first questionnaire

No.	Freeway projects	Railway projects	Road projects
1	Reduced costs	Reduced costs	Reduced costs
2	Reduced delivery time	Reduced delivery time	Enhanced quality
3	Enhanced quality	Enhanced quality	Reduced employer's risks
4	Reduced employer's risks	Reduced employer's risks	(DB) office responsibility
5	(DB) office responsibility	(DB) office responsibility	Minimizing contract claims
6	Efficient & defined mechanisms for the receipt and analysis of the project information	Efficient & defined mechanisms for the receipt and analysis of the project information	Project flexibility against variations during construction
7	Minimizing contract claims	Project output	Risks of geotechnical studies
8	Project size	Project size	Reduced delivery time
9	Inflation	Country's economic situation	Administrative bureaucracy
10	Confirmed project funding	Legal observations & limitations and the related regulations	Inflation
11	Environmental observations & limitations	Error in the estimation of final cost	Error in the estimation of final cost
12	Project output	Administrative bureaucracy	Confirmed project funding
13	Not considering contractor's capability & eligibility	Project flexibility against variations during construction	Country's economic situation
14	Risks of geotechnical studies	Minimizing contract claims	Project size
15	Administrative bureaucracy	Confirmed project funding	Legal observations & limitations and the related regulations
16	Legal observations & limitations and the related regulations		

4.3.Selecting the optimum option for road transportation projects with the AHP

Now, after collecting questionnaire No. 2, the scores related to every option were determined and sorted in a decreasing order.

4.3.1. Analytic Hierarchy Process (AHP)

AHP, invented in 1970 by T. L. Saati, is a very famous technique of multi-criteria decision making and is used when decision making faces some rival options and different criteria. It makes possible the simultaneous combining of the qualitative and quantitative criteria and is based on paired or dual comparisons of the options and decision making criteria. We need, for such comparisons, to gather information from the decision makers. This makes it possible for the latter to concentrate only on the comparison of 2 options or 2 criteria without any foreign interference. Apart from these dual comparisons, since the interviewees compare only 2 items, they provide valuable information for the case in question and make the process of decision making rather logical. After the information in the questionnaire has been studied, it has to be checked for correctness; this is done by finding the coefficient of irreconcilability which has to be less than 0.1 [16]. The AHP can be said to be a very comprehensive system designed for multi-criteria decision making. It is capable of formulating problems considering qualitative and quantitative criteria and shows the amount of reconcilability and

irreconcilability of the decision made; this is, in fact, a very important advantage of this technique in multi-criteria decision making and is based on obvious principles [17].

4.3.2. Data investigation

Out of 42 questionnaires, 40 were completed and then investigated. An example of a completed questionnaire is shown in Table 3 where 15 criteria for selecting the optimum delivery option in road transportation projects have been compared. In the table, the quality enhancement criterion, for example, is a little more important than that of the cost reduction; therefore, digit 3 has been entered into the matrix. Finally, the coefficient of irreconcilability for the questionnaire has come out to be 0.06 which is less than 0.1; the information in the questionnaire is, therefore, reliable.

4.3.3. Sensitivity analysis related to the criteria

By drawing 1D sensitivity analyses diagrams like the one shown in Figure 4, we can make the understandability of the results of the work more possible and the concluding much easier [18]. This diagram shows the amount each factor affects each option and, using it, we can see the changes in the chosen option, by changing a factor, from 0 to 100 %. For example, in Figures 1, 2, and 3, with a little increase in the numerical value of the criterion “Legal observations & limitations and the related regulations”, the DBB will be chosen instead of the DB option.

We will reach the outputs of Figures 1, 2, and 3 after exercising the distributive synthesis. In this case, the weights of the criteria are divided with respect to those of the options. Therefore, the sum of the relative weights of the options under each criterion will be equal to that of the related criterion which is an indication of the weights of the DBB, DB, and CM options considering the criteria found in every group of road, railway, and freeway projects. In these Figures, the numbers on the diagram show the ranks of the options.

5. Conclusions

Since there is no single best delivery option that can be definitely introduced and suggested, it is necessary that the best option be determined for every project based on the conditions of the same project. In other words, the employer has to select an option that yields the best output through specifying the requirements and specific conditions of the project. It is obvious that every option has its own peculiar advantages and disadvantages. Therefore, the employer should be after an option that yields the best value for the cost he incurs.

To achieve this, the employer should first identify different options and their characteristics precisely, and then determine the available capabilities and specific conditions of the project in question. On this basis, effort was made in this research to first identify important factors that affect decision making for selecting the optimum delivery option for road transportation projects through questionnaires. Then, using the SPSS software and Cronbach's alpha, the reliability of the questionnaire was calculated to be 0.92. Next, use was made of the AHP and the Expert Choice software to determine the best delivery option for road transportation

projects in Iran. In this study, considering all the identified factors, the most suitable options for the delivery of road transportation projects in Iran, including road, railway, and freeway projects, were specified as follows:

- Design-build (DB) with a score of 552 is the best option for freeway projects; Construction Management (CM) and Design-Bid-Build (DBB) stand respectively second and third.
- CM with a score of 334 is best for railway projects; DB and DBB are second and third respectively.
- The most suitable option for road projects, based on this research, is DB with a score of 340; DBB and CM are respectively second and third.

The existing governing system in road transportation projects in Iran is the DBB (3-party) option, but the results of this research show that it would best if it was changed to DB. It can be stated, on this basis, that CM may not be suggested for road transportation projects in Iran except for railway construction projects. Also, using sensitivity analyses, the importance of every factor in the process of decision making, and in changing the chosen option based on the change in the importance of every decision making factor, has been shown through sensitivity analysis diagram. The importance of every factor could change in a range of 0 – 100% (meaning ineffective – the only effective factor). An example of the sensitivity analysis diagram for road transportation projects in Iran is shown in Figure 4.

Table 3. An example of a completed questionnaire

	Reduced costs	Enhanced quality	Reduced employer's risks	(DB) office responsibility	Minimizing contract claims	Project flexibility against variations during construction	Risks of geotechnical studies	Reduced delivery time	Administrative bureaucracy	Inflation	Error in the estimation of final cost	Confirmed project funding	Country's economic situation	Project size	Legal observations & limitations and the related regulations
Reduced costs	1	3	1	1	2	3	3	1	5	1	3	1	3	5	5
Enhanced quality		1	3	3	5	5	3	2	7	3	3	4	5	7	7
Reduced employer's risks			1	1	1	3	3	1	3	1	3	3	5	5	3
(DB) office responsibility				1	1	1	2	5	2	3	3	2	3	3	3
Minimizing contract claims					1	3	1	5	3	3	1	2	4	5	1
Project flexibility against variations during construction						1	3	5	2	3	3	2	3	3	1

Table 3. Continued															
Risks of geotechnical studies							1	1	3	2	2	3	5	5	3
Reduced delivery time								1	5	3	2	5	5	6	5
Administrative bureaucracy									1	3	3	4	3	2	1
Inflation										1	1	1	3	4	4
Error in the estimation of final cost											1	3	4	4	2
Confirmed project funding												1	5	4	3
Country's economic situation													1	1	3
Project size														1	3
Legal observations & limitations and the related regulations															1

Figure 1. Results obtained from the distributive synthesis for freeway projects

Figure 2. Results obtained from the distributive synthesis for railway projects

Figure 3. Results obtained from the distributive synthesis for road projects

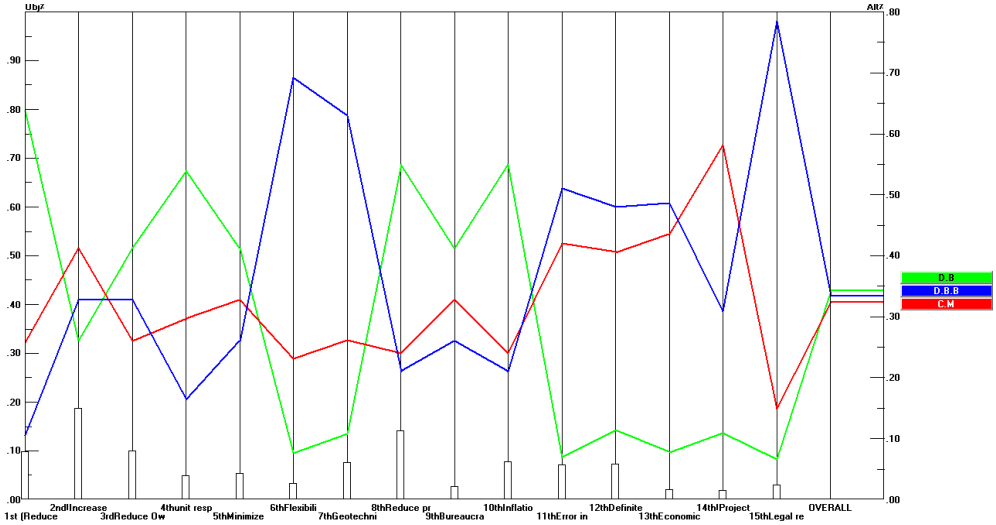

Figure 4. 1D Sensitivity analysis diagrams

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