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The Graph Decision Model for Risk Allocation in Design-Build Contracts; Game Theory approach

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ABSTRACT: Risk allocation, the definition and division of responsibility associated with a possible future loss or gain, seeks to assign responsibility for a variety of hypothetical circumstances should a project not proceed as planned. The result of improper risk allocation is increased costs, project delays and services, which cause loss of value-for-money for the public interest. This paper introduced a decision support system based on the graph model for systematically resolving construction risk allocation. In this model mainly assumed success of a contract needs to agreement on how risks are allocated by parties. The graph analysis process considers the decision-makers, their decision options, and their relative preferences when modeling risk allocation negotiation as a game theory problem. Owners could also use the model to perform an in-depth stability analysis in order to ascertain the possible compromise resolutions or equilibrium. The model predicts the sequence of decisions that took place in the dispute and furnishes an array of useful strategic insights about the risk allocation renegotiation. Moreover, the model to determine how changes in preferences can affect the equilibrium results executes a sensitivity analysis. This risk allocation procedure is useful for both researchers and practitioners to better deal with the dispute-prone nature of construction contracts.

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1- Introduction

As construction projects are always suffered from uncertainties and conflict interests of participants, the achievement of any construction project's goals depends on the efficiency of project risk allocation [1]. Risk can be defined as any kind of unpredictable situation that can hinder a project's success in achieving its time, cost, or quality goals [2], the risk allocation is the definition and division of responsibilities and benefits arising from possible conditions based on Planning should not happen [3]. Risk allocation in the contract can have a great impact on the cost, time and quality of the project [4]. However, owners should consider that unilateral and unbalanced risk allocation causes the contractor to adopt defensive strategies [5] and finally lead to time delays, cost overrun and financial losses of the owner. In order to know the appropriate risk allocation in a project, two main criteria are selected [6]: a) the factor that accepts the risk must have the necessary ability to control and manage the consequences of risk occurrence. B) Risk should be managed by the factor that imposes the least cost on the project. Prior to this research, conventional multi-criteria decision-making models have already been used to select the optimal allocation in construction projects, including the use of HP [7], the use of TOPSIS [8], and the theory of systems dynamics [9]. However, conventional decision-making models are suitable for situations where comparisons and decisions between options are made by only one decision-maker based on multiple identifiable criteria [7]; while risk allocation negotiations are between at least two different decision-makers with unpredictable decisions. Where decision-making requires attention to the behavior of the other party and mutual understanding. In such complex processes and with several different decision-makers, game theory approaches are well applied [10].

2- Methodology

To select the allocation of risks, the risk allocation negotiation process is modeled on a dispute resolution issue; then with the help of graph logic and game theory, a decision support system (DSS) is developed that has the ability to provide the most appropriate allocation of risks to the decision-maker (owner or contractor). In the proposed model, there are two decision-makers: a decision-maker is the owner who wants to transfer the project risks to the other party as much as possible and the second decision-maker is the contractor who wants to make more profit from accepting the project risks [11]. The owner has a risk-averse behavior that tends to bear as few risks as possible, and the contractor has a risk-taking behavior that is willing to accept a higher level of risk [11].

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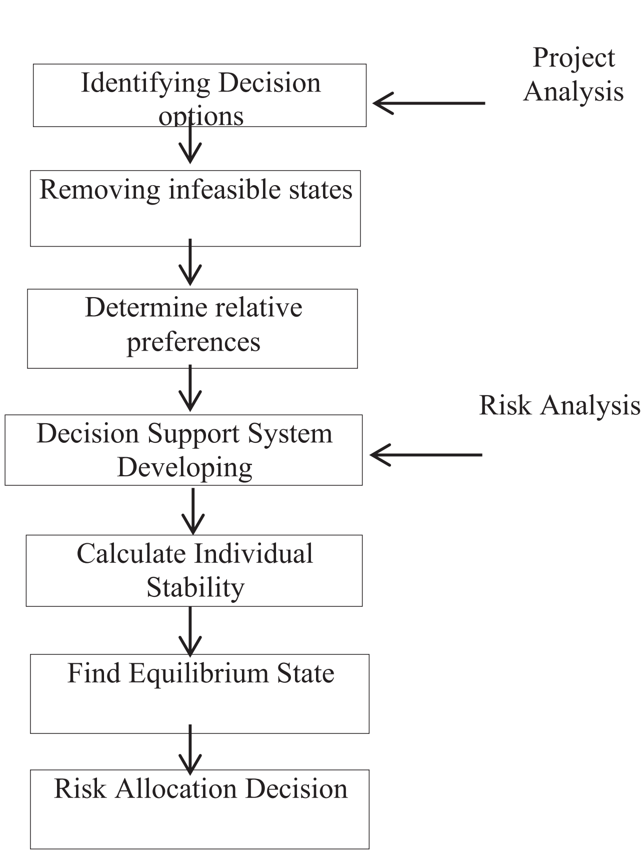

Fig.1. Problem-solving process and graph decision model development process

Finally, a decision support system for selecting risk allocation has been developed using the graph model and coded in the form of a software program in Matlab. The results of the proposed decision system are applied and validated by a case study.

The development steps of the proposed graph model to identify the balanced allocation of risks are described in seven steps:

1. Identify decision situations
2. Determine possible decision situations
3. Graph design of transitions between positions
4. Determining decision priorities
5. Stability analysis and determination of equilibrium points
6. Evaluate negotiation strategies and
7. Select risk allocation

The identified equilibrium points indicate situations that which both decision-makers are reluctant to change and can therefore be chosen as the final risk allocation decision. But since the model may offer more than one equilibrium point, any decision based on risk management strategies and the reliability of predicting the other party's behavior prioritizes the choice of some of these equilibrium points.

3- Validation of the Model in a case study

To control the performance of the proposed model, this model has been implemented in a case study and the results have been compared with similar studies. The selected project is a Wastewater Treatment Plant, which was tendered by an Iranian Industrial Free Trade Zone in August 2017 for implementation by design and construction. The purpose of the project is the treatment of the wastewater of the industrial zone and warehouses of the Free Zone with the technology of polyethylene packages and includes three modules with a capacity of 2650 cubic meters of treated wastewater. This project will be awarded in the form of a design and construction contract with the Design Build Finance (DBF) method. The contractor is negotiating with the commitment to provide financing on how to transfer and conclude the contract.

A comparison of the results of the proposed model with the results presented in the study of Lam et al. [7] shows seven differences. It seems that in Lam's proposed model, risk allocation is done in one-sided cases, while if the costs of unilateral imposition of the owner's views were taken into account, a more appropriate model could be proposed. For example, in the study of Lam et al. [7],

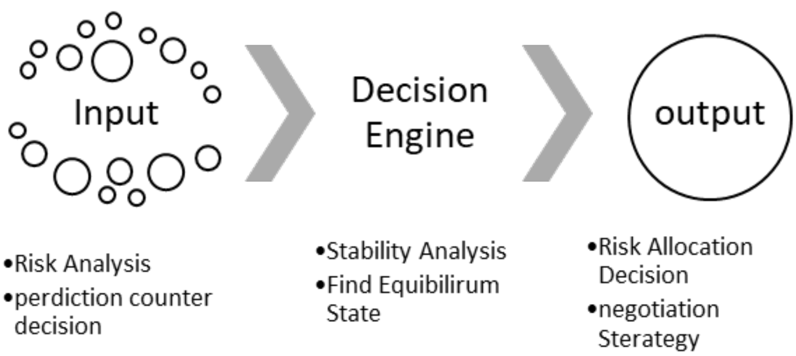

Fig. 2. Graph decision support system structure

the risk of "delay in licenses" is assigned to the contractor, while the employer will have a better ability and access to provide and renew licenses and a more appropriate option to allocate this risk.

The results of stability analysis by the model proposed in this paper show that in case of allocating the risk of "delay in licenses" to the contractor, in front of the contractor by choosing the strategy of increasing time or plan to cover his claim and the consequences of unilateral allocation returns the risk to the owner. Just as the owner's acceptance of responsibility for the risk of subsurface soil condition (as suggested by Lam et al. [14]) cannot lead to equilibrium. Because despite the employer's responsibility for the initial studies, it causes the employer to pay twice for the same responsibility and contractual relations become bilateral. Therefore, the proposed model in this article recommends that this risk be shared between the two parties.

It can also be seen that the proposed model has the critical advantage that, unlike similar studies, it not only determines the factor responsible for risk management but also states the measures needed to achieve balanced risk allocation and clarifies the consequences of the decision for the decision-maker. For example, this model shows that if the risk of "changing volume" is assigned to the contractor (as the software suggests), the owner must accept the consequences of the decision to project cost overrun due to an increase in the contractor's profit.

Finally, the results of this research were communicated to the owner and the contractor in comparison with the results of similar studies. The two sides confirmed the accuracy of the results of the proposed model after holding two negotiations and discussing how to adjust the provisions of the contract. By agreeing between the two parties and accepting the proposed risk allocation model for inclusion in the final agreement, the performance of the proposed model was confirmed.

4- Results and Discussion:

The result shows that the employer can choose different equilibrium points as risk allocation based on the degree of predictability of the interests and behavior of the other party (contractor). Balanced risk allocation is a situation that has been identified as equilibrium points in most strategies.

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