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Developing Decision Support System to Optimize the Delivery System, Tendering Method, and Type of Contract

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Abstract
In the last ten years, Decision Support System has been used for many applications such as evaluation, prediction, selection, and optimization purpose. The main objective of this study is to design and develop a Decision Support System (DSS) to assist project owners in selecting the most appropriate project delivery system, tendering method and type of contract as they start a new project, having considered the appropriate factors necessary for taking such decisions. Project owners are keen to choose an appropriate selection because of their positive effect on project success. A Decision Support System developed in this paper is simple to use and allows the owner to consider all decision-relevant factors. Its practical application will benefit the owner's decision making in the selection of proper project delivery system, tendering method, and type of contract.

Key Words: *Decision* Support System; Project Delivery Systems; tendering methods; contract types, sensitivity analysis.

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I. INTRODUCTION

Project owners are faced with an important question at the start of any construction project. This is related to organization of the project team that will manage the design and construction process or the project delivery method (Touran et al., 2009). This decision is important as it affects achieving project objectives such as cost, time, and others. There are five options of project delivery in use aboard during the past twenty years. These options are the traditional project delivery design-bid-build, construction manager at risk, design-build, integrated project delivery, and public-private partnership. The choice of the appropriate project delivery method (PDM) greatly influences the project outcome and is one of the most important factors that determine a project's success (Al Khalil, 2002). Also, one of the important decisions is choosing the proper tendering method. Most contracts in construction are made by tender. Thus, the contract price formation occurs through a competitive tendering framework that clients often use to obtain the lowest price from the winning contractor (Laryea, 2017). There are three options of tendering methods in use aboard during the past 25 years. These options are the traditional open tendering, selected tendering, and negotiated tendering. The successful execution of a construction project is heavily impacted by making the right decision choosing the proper tendering method. Other one of the important decisions is choosing the proper contract type. The contract is defined as "the most important contractual relationship in terms of cost is that between the owner and the contractor". For this reason, the contractor selection method employed and the chosen contract type (CT) which defines the method of payment , play a significant role in ensuring construction costs are within the approved funding limits (Antoniou et al. , 2012). There are four options of contract types in use aboard during the past 25 years. These options are the traditional unit price, lump sum, cost plus and guaranteed maximum price contract. The choice of the most appropriate CT regarding the method of contractor compensation is one of the most essential and complex decisions. This choice is based on the decision maker's knowledge, experience and intuition (Antoniou et al., 2013). The choice of the appropriate delivery system, tendering method, and type of

contract was a key decision that has to be made by owners early in the project lifecycle. This decision had a great impact on project success. To assist the owner in choosing the appropriate option, a number of factors should be considered and a DSS is designed and developed in this research.

II. DECISION SUPPORT SYSTEM

Decision support system (DSS), as a kind of interactive computer-based information systems, help decision makers utilizes data and models to solve mostly semi-structured or un-structured decision problems in practice (Kaklauskas, 2015).

2.1 Categories (Types) of Decision Support Systems

There are five key approaches of DSS defined based on the input they can handle and type of decision processes they can support including data-driven DSS, model-driven DSS, knowledge-driven DSS, document-driven DSS, and communications-driven DSS. Power (2004) briefly discussed these categories as follows:

2.1.1 Data-driven DSS

This system focuses on large database access and manipulation. The large database contains time-series and structured data either from internal or from external source.

2.1.2 Model-driven DSS

Model-driven DSSs use limited data and parameters provided by decision makers to aid decision makers in analyzing a situation, but in general large data bases are not needed for model-driven DSSs.

2.1.3 Knowledge-driven DSS

Knowledge-driven DSS can suggest or recommend actions to decision makers. These DSSs are software applications with specialized problem-solving expertise. The "expertise" consists of knowledge about a particular domain, understanding of problems within that domain, and "skill" at solving some of these problems. Knowledge-driven DSS use special heuristic models called inference engines for processing rules.

2.1.4 Document-driven DSS

A document-driven DSS uses computer storage and processing technologies to provide document retrieval and analysis. Large document databases may include scanned documents, hypertext documents, images, sounds, and video. Examples of documents that might be accessed by a document-driven DSS are policies and procedures, product specifications, catalogs, and corporate historical documents, including minutes of meetings and correspondence. A search engine is a primary decision-aiding tool associated with a document-driven DSS.

2.1.5 Communications-driven DSS

Communications-driven DSSs use network and communications technologies to facilitate decision-relevant collaboration and communication. In these systems, communication technologies are the dominant architectural component. Tools used include groupware, video conferencing and computer-based bulletin boards.

III. TYPICAL PROJECT DELIVERY METHODS

The choice of the most appropriate delivery method for a particular project is dependent upon a number of factors; however, the number of delivery methods and variations thereof has expanded so that public agencies can deliver more projects (Mahdi & Alreshaid, 2005). Examples of the most common methods used are as follows:

3.1 Design-Bid-Build (DBB)

Design-Bid-Build (DBB), or design then bid then build, is the traditional project delivery method. In this method, an owner retains a designer to furnish complete design services (prepare fully completed plans and specifications) and then advertises and awards a separate construction contract that is based on the designer's completed construction documents. The owner is responsible for the details of design and warrants the quality of the construction design documents to the construction contractor (Touran et al., 2009). This is a familiar delivery method to most owners and requires a defined scope prior to bidding. The main disadvantages are the lack of involvement of construction professional during the design phase, longer delivery time (sequential), less flexible for changes and it often results in adversarial relationships among the parties involved (El-Sayegh, 2007). DBB is the most common delivery method applied for a public project in Egypt. This method traditionally is a unit priced contract. Design-Bid-Build Structure is shown in figure (I).

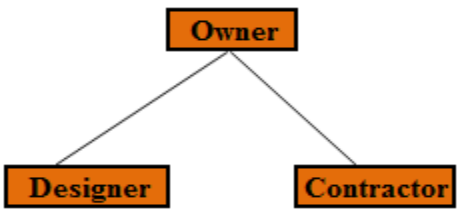

Figure (I): Design-Bid-Build Structure (Source: Maharjan, 2013)

3.2 Construction Manager at Risk (CMAR)

Construction Manager at Risk (CM@R, CMAR) is an alternative project delivery method and also known as Construction Manager/General Contractor (CM/GC) or construction manager as constructor (Haugen et al., 2017). It is a delivery method in which the applicant retains a design engineer and a CMAR firm under separate and discrete design and construction contracts. The CMAR firm provides construction-related advice during design development, and if the applicant and CMAR firm agree on a price to construct the project, the CMAR firm acts as the general contractor during construction. The CMAR firm may either subcontract all construction work or self-perform portions of it. The CMAR firm often has two contracts during a CMAR project: the first is a design services contract that is completed during the design phase for services such as design reviews, constructability reviews, cost estimation, value engineering, and scheduling; and the second contract for the construction of the project (Francom, 2015). As an alternate to DBB, many projects use a CM@R approach where the construction manager is engaged by the owner to be directly and completely responsible for the construction of the project. The timing of the CM@R's engagement, which occurs ideally relatively early in the design process, has a large impact on his influence in the project. Under this arrangement, the CM@R, not the owner, holds the contracts for the construction subcontractors, and so the CM@R is not only responsible for management of the construction, but also is at risk for the construction cost (Nassim and Mahmoud, 2009). CMAR projects are usually those involving multiple contracts, fast-tracking, or are of such a complex nature that intense professional management is necessary. The construction manager will control the design and later implement the project (Haugen et al., 2017). In this method, the Criteria for final selection do not include total construction cost.

3.3 Design-Build (DB)

The fastest growing method of construction delivery is design-build. Under this system, the owner contracts with a single entity which assumes responsibility for both the design and construction of the project. The form and organization of the entity varies. It may be a construction firm which hires a design firm as a subcontractor. In fewer cases, it is a design firm which hires a construction firm as a subcontractor (Woods and LLP, 2005). Design and Built shall be suitable for the fast track project allowing construction to begin before the design is 100% complete (Gaikwad and Sarode, 2017). The DB project delivery system is perceived as a suitable approach for complex projects in all construction types as well as small project such as road widening or new construction, road rehabilitation or reconstruction, and for bridges (Dewi et al., 2011). DB is traditionally a lump sum contract based on schematic design to build the specified facility. Design-Build Structure is shown in figure (II).

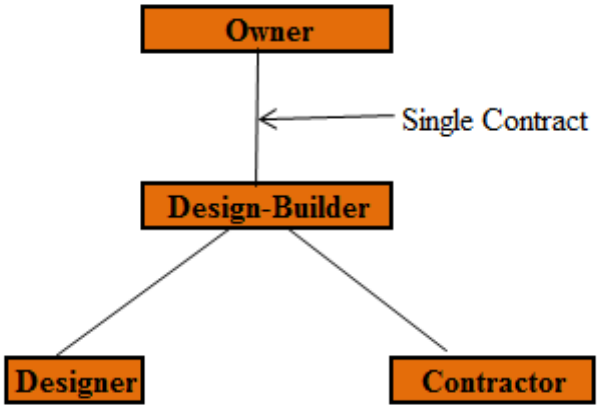

Figure (II): Design-Build Structure (Source: Maharjan, 2013)

3.4 Integrated Project Delivery (IPD)

Integrated Project Delivery (IPD) is a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication, and construction. IPD principles can be applied to a variety of contractual arrangements. In all cases, integrated projects are uniquely distinguished by highly effective collaboration among the owner, the prime designer, and the prime constructor, commencing at early design and continuing through to project handover. In this method, project participants come together as an integrated team, with the common overriding goal of designing and constructing a successful project. In contrast, IPD demands that participants work together when trouble arises on a traditional project (American Institute of Architects

AIA, 2007). In this method, the designer, the builder and the owner (and possibly other key members of the project team) all sign one multi party contract.

3.5 Public-Private Partnership (PPP)

In addition to conventional delivery methods (DBB, DB, IPD and CMR), another PDM, namely Public-Private Partnership (PPP) will be considered as an option for the owners who seek private financing for their projects. It should be noted that PPP is essentially a kind of DB with the addition of financial and operation agreement during the concession period (Ghavamifar, 2009). A public–private partnership (PPP, 3P or P3) is a cooperative arrangement between two or more public and private sectors. Through this agreement, the skills and assets of each sector (public and private) are shared in delivering a service or facility for the use of the general public. In addition to sharing the resources, each party shares the potential risks and rewards in the delivery of the public service and/or facility. Sectors where PPPs have been used successfully are transportation, water/ wastewater management, urban planning, infrastructure and utility development, financial management and education (Pirvu and Voice-Olteanu, 2009).

According to Weimer and Vining (2010), "A P3 typically involves a private entity financing, constructing, or managing a project in return for a promised stream of payments directly from government or indirectly from users over the projected life of the project or some other specified period of time".

PPP projects are long-term partnerships (typical projects have the duration between 20 and 40 years). Another distinctive feature of the PPP projects is the fact that the private partner carries the risk for the invested capital, not the public sector, as it is the case of projects based on outsourcing (Pirvu and Voice-Olteanu, 2009).

IV. TYPICAL TENDERING METHODS

In construction industry, there are different methods of tendering. Examples of the most common methods used are as follows:

4.1 Open Tendering

All interested contractors are invited through an announcement in public media to submit tenders in competition for carrying out the work. This method opens the opportunity for new or unfamiliar contractor to compete for the contract (Hansen, 2012). It is true that the employer can check the resources and experience of the lowest bidder and reject his tender if the enquiry proves unsatisfactory; but several bids may be below the estimated cost of the job and, if such tender appear satisfactory and their bids are not far apart in value, it is difficult for the employer to choose other than the lowest. In many countries, public agencies are forced to use open tendering (Twort and Rees, 2004).

4.2 Restricted / Selected Tendering

Under this system, a short list is drawn up of contractors who are considered to be suitable to carry out the proposed project. Experienced employers and consultants will normally have a list of contractors who undertake different types of contracts and their records. Contractors are invited to tender on their proven record in relation to the type and size of contract and their reliability (Hansen, 2012). Only selected contractors are allowed to bid the tender. This approach makes competition among contractors lesser. Normally, it is applied when construction contract needs special expertise and high technology. Those contractors who filled these requirements are invited. Sometimes some organizations in Egypt adopt this method.

4.3 Negotiated Tendering

Client consults the chosen contractors and negotiates the term of contract with them. Normally, it is applied under special circumstances (Mohemad et al., 2010) such as:

- When the construction contract is too complex or unique to identify technical and financial properties.
- When there is an emergency situation that requires the project to be completed in a short time.
- When there is only one contractor that fulfils the contract requirement in terms of expertise and technology.
- When involves security project of national importance.

This system is usually used to employ contractors of a specialist nature, or to extend an existing contract, i.e. where a new tower is added to a building after the construction has been started (Hansen, 2012). However, negotiated tenders for public works are rare because the standing rules of public authorities do not normally permit them. But a private employer or company can always negotiate a contract (Twort and Rees, 2004). This method also called direct negotiation.

V. CONSTRUCTION CONTRACTS

The contract is a written agreement between a client and a contractor where liabilities and responsibilities of each party assigned. Construction contracts form the behavior of different actors in a project and have a major impact on the successful completion of the project (Osipova and Apleberger, 2007).

5.1 The Main Functions of a Contract

The main functions of a contract are (Gaikwad and Sarode, 2017):
1) To specify the work to be done,
2) The amount to be paid,
3) To assign responsibility to the concerned parties to finish the work and
4) Decide who takes charge for the unexpected events if they occur.

5.2 Typical Contract Types

The four primary or common types of contracts used in the construction industry are:

5.2.1 Unit Price Contract (UP)

The most common contract type (CT) applied for public works projects in Egypt is the Unit Price (UP) contract. It is the most common payment strategy for roadway projects in United States that establishes a set monetary price for construction items in which the owner pays the unit price multiplied by the quantity installed. This is useful for projects where quantities are difficult to determine before the work begins. The contractor determines the quantities, the owner verifies the quantities, and then utilizes the unit price to find the total cost (Molenaar and Harper, 2014).

5.2.2 Firm Fixed Price or lump Sum Contract (FFP or LS)

A firm fixed price or lump sum contract is an arrangement where the builder agrees to construct the defined scope of work for a set price. In this type of contract, the owner's risk of cost overrun is minimal. The builder has incentive to be efficient and lower cost because it can both be more cost competitive at bid time, and also can increase its own profit during construction. The owner does not share in the construction cost savings (Nassim and Mahmoud, 2009). In this contract type, the contractor takes all the cost risk. Firm Fixed Price or lump Sum contract is used for projects procured with the design and build project procurement system.

5.2.3 Reimbursable or Cost Plus Contract (CP)

A reimbursable or cost plus contract is where a schedule or list of fees, unit prices, rates and markups are established under which the builder performs the work as requested and defined by the owner during the course of the project (Nassim and Mahmoud, 2009). It is a type of contract where the contractor is paid on the basis of actual costs of "time and materials" plus agreed amount to cover profits and overheads. This method is different from all other cost based terms of payment. In the simplest form of a Cost-reimbursable contract the employer reimburses the contractor's costs of work on a project, plus usually a fixed sum or percentage for financing, overheads and profit. This type of contract is used for design studies, development, some repair, demolition and emergency work. The advantage of this method is that the work is started as the changes are defined and the contractor won't incur any prices avoiding the disputes (Gaikwad and Sarode, 2017). Reimbursable contracts are suitable for projects that need to start construction early. These types of contracts are suitable for projects with variability in the scope of work (Molenaar and Harper, 2014).

5.2.4 Guaranteed Maximum Price Contract (GMP)

Between the firm fixed and reimbursable contract types is the guaranteed maximum price contract where the builder and owner agree on a target or maximum price for the construction (Nassim and Mahmoud, 2009). The GMP sets a not to exceed price. If the accumulation of actual costs goes over the GMP the contractor pays. If it goes under the contractor may share in savings based on the contract. Guaranteed maximum price contracts are suitable for projects with limited time or funding. These types of contracts are suitable to use also for Fast-track projects (Molenaar and Harper, 2014).

VI. FACTORS AFFECTING THE SELECTION PROCESS

A review was carried out to identify the different factors that may affect the selection of proper project delivery method. Twenty-two factors were identified and categorized into eight groups as shown in Table (I).

Table I: Factors Affecting the Selection of Proper Project Delivery Method

No.	Factor	Group
F1	Project cost	Owner's requirements for project characteristics
F2	Project time (Fast track)	
F3	Project (cost + time)	
F4	Owner's share level of risk involvement	Share level of risk involvement
F5	Contractor's share level of risk involvement	
F6	Public owner	Owner's conditions
F7	Private owner	
F8	Management policy by consultant	Management policy
F9	Management policy by construction manager	
F10	Management policy by BIM	
F11	Owner's participation in project management	Participation in project management
F12	Lump sum contract	Contract Type
F13	Unit price contract	
F14	Cost plus contract	
F15	Project type (residential)	Project Conditions
F16	Project type (commercial and non residential)	
F17	Project type (Heavy construction)	
F18	Project type (Industrial)	
F19	Project complexity	
F20	Project scope maturity	
F21	Contractor's experience in implementation similar works	Contractor's Capabilities
F22	Contractor's willingness to finance certain parts of the Project	

The identification of the relative importance of these factors was carried out via structured interviews with selected experts. The questionnaire created to collect opinions for random answers from expert's consultant engineers about the degree of importance for each one of 22 factors on project delivery method selection so it has been distributed directly through a meeting with the experts. An important step in the methodology is to calculate the sample size. As, the number of answers needed for the questionnaire should be known to have a sufficient analysis for the questionnaire answers, accommodate the size of experts knowing about project delivery methods and achieve the needed percentage of confidence for the result of the questionnaire and later for study scope. The questionnaire was sent to a sample of 55 specialized consultants who had at least 10 years experience in contracting systems in different public and private sectors. A total 50 of consultants replied as the response rate approximately 91%. Interviews and questionnaire were used together to collect information from consultants specialists. The data collected during these interviews was analyzed to determine their relative importance.

VII. RESULTS OF SURVEYING

After determination of factors affecting the selection of optimal PDS, questionnaires were designed in order to collect information to compare the performance of project delivery systems. The results of the analyzed collected data in this stage have been shown in table (II).

Table II: The percentage of Factor's Impact on PDM selection

No.	Factor	Impact %				
		DBB	CMAR	DB	IPD	PPP
F1	Project cost	68.0	54.4	89.6	80.0	35.2
F2	Project time (Fast track)	33.2	75.2	95.2	93.6	34.4
F3	Project (cost + time)	50.8	60.4	92.4	83.2	34.8
F4	Owner's share level of risk involvement	86.8	33.2	41.2	66.0	56.8
F5	Contractor's share level of risk involvement	36.0	75.6	93.2	66.8	82.4
F6	Public owner	96.8	24.0	40.0	30.8	68.0

F7	Private owner	62.0	88.4	80.8	92.4	20.4
F8	Management policy by consultants	98.8	24.4	78.4	90.0	90.4
F9	Management policy by Construction Manager	21.2	96.8	50.0	34.4	25.2
F10	Management policy by BIM System	20.8	30.4	21.6	88.4	24.0
F11	Owner's willingness to management participation	62.8	27.6	35.2	90.4	44.8
F12	Lump sum contract	20.4	96.4	97.2	25.2	67.2
F13	Unit price contract	99.2	23.6	22.0	28.0	67.2
F14	Cost plus contract	20.4	21.6	21.6	96.0	20.8
F15	Project type (residential)	97.6	39.6	48.8	44.4	51.6
F16	Project type (Commercial and non residential)	82.8	55.2	68.0	55.6	76.8
F17	Project type (Heavy construction)	33.6	82.4	93.2	77.2	91.2
F18	Project type (Industrial)	26.8	86.0	93.2	65.6	86.0
F19	Project complexity	27.6	91.2	90.8	80.8	94.8
F20	Project scope maturity	99.6	43.6	46.4	42.0	40.4
F21	Contractor's Experience in Implementation Similar Works	69.2	90.4	95.2	94.4	95.2
F22	Contractor's willingness to finance certain parts of the Project	22.0	29.6	49.2	28.4	99.6

VIII. The VALIDITY AND Reliability OF THE STATISTICAL DATA

The following criteria were considered in order to increase validity and reliability of data in results of questionnaires and interviews:

- Studying questions of questionnaire by university experts and gave them the chance to edit these questions or add any new question if it was necessary.
- Accurate defining in terms existing at questionnaires.
- Filling out questionnaires in person.

Also, results of questionnaires were developed in likert scale using SPSS Software system in order to calculate validity of data of questionnaires. The Cronbach's Alpha coefficient calculated by the SPSS software was 0.87 which shows that the collected data by questionnaires and through interviews have high level of validity.

IX. SENSITIVITY ANALYSIS OF THE RESULTS

In this study, a local sensitivity analysis was carried out to study the impact of one factor on deciding the proper project delivery option, keeping the other factors fixed. Local sensitivity analysis is the assessment of the local impact of input factors' variation on model response by concentrating on the sensitivity in vicinity of a set of factor values. Such sensitivity is often evaluated through gradients or partial derivatives of the output functions at these factor values, i.e., the values of other input factors are kept constant when studying the local sensitivity of an input factor.

This analysis has three folds. In first fold, the relative importance of all factors was the same (4.55%). In second fold, the relative importance of one factor is changed from the value recorded as the basis of survey to represent 20% and all the other factors areas represent 80% with equal values. In the third fold, the relative importance of one factor is changed from the value recorded as the basis of survey to represent 30% and all the other factors represent 70% with equal values. The sensitivity analysis conducted in this study also gave a better understanding of the robustness of the results to changes.

The sensitivity analysis reveals that the Integrated Project Delivery (IPD) is the most appropriate project delivery option when relative importance of all factors was the same (4.55%).

Also, the analysis reveals that the Design Build (DB) is the most appropriate option when relative importance of project cost = 20% and relative importance of other 21 factors = 80% with equal weight for each = 3.81%

Also, the analysis reveals that the Public-Private Partnership (PPP) is the most appropriate option when relative importance of contractor's willingness to finance certain parts of the project = 30% and relative importance of other 21 factors = 70% with equal weight for each = 3.33%.

Other results were recorded in this anaylsis and helped project owners in choosing the most appropriate project delivery option.

X. The DEVELOPED DECISION SUPPORT SYSTEM (DSS)

Decision Support System (DSS) is chosen as one of the most comprehensive and multiple decision-making models. The DSS developed in this study is multi-objective and knowledge-driven. It will "suggest and recommend actions to owners" and should be applied by people with expertise and knowledge of the particular domain. The results of questionnaire were inserted and saved in Decision Support System software package, so that weight value of options was obtained in comparison with the factors.

10.1 Design the Proposed Decision Support System

The characteristics of the DSS design were as follows:

- Programming Language Used: C #.net (C SHARP.NET)

C # is an easy to use as programming language with enhanced human-computer interface. This interface is similar to that provided by window application and thus any user already familiar with windows can easily handle C# applications. Database manipulation is another powerful feature of C# that makes it suitable for this research. C# also allows for scalability, a feature which supports incremental delivery.

- Database Engine Used: Structure Query Language (SQL) Server 2008.

SQL server was chosen to be the database engine to be employed. SQL server is a database program that allows the user to store and manage large collections of information. It is provided with all tools the user might need to create an efficient and effective database. It is an excellent database that could be suitable for use in this research. The program provides a wide range of options to choose. It is also trying to be very friendly to the user by displaying a lot of help menus and windows for constructing the database very quickly. It is required by the business for several reasons:

– It is easy and very simple to use,
– It can store and manage large collections of information,
– The user can efficiently and accurately add, update, view and organize the information stored in a database,
– The user can instantly locate information of interest in any database,
– The user can also perform more advanced searches, and
– The user can also perform calculations on the information in a database to help you make quick, accurate and informed decisions.

- Interface Design: Photo Shop C55.
- Programming Design: The system is implemented on the plat form of Visual Studio (Version 2012).

10.2 Characteristics for the proposed Decision Support System

The characteristics for the proposed decision support systems are as follows:
1- Facilitate decision processes,
2- Support rather than automate decision making,
3- Able to respond quickly to the changing needs of decision makers,
4- Incorporate both data and models,
5- Improve the effectiveness of the decisions,
6- Interact directly with the decision maker in such a way that the user has a flexible choice and a sequence of knowledge management activities, and
7- Provide support for decision makers by bringing together human judgment and computerized information".

10.3 Case Studies and Validity of the system

Finally, the validity of the proposed DSS was tested by practical application via three actual case studies as follows:
Case study No. (1):
In this case, All factors with equal importance to the project owner i.e. factor's importance equal to 4.55%.
By applying the Decision Support System software to the project by inputting the percentage of each factor's importance for owner, the output report showed that:
The most appropriate Project Delivery Method is "Integrated Project Delivery".
The most appropriate Tendering Method is "Selected Tendering – Technical only".
The most appropriate Contract Type is "Cost plus".
Case study No. (2):
In this case, the owner requirements were as follows, Importance of Time (Fast Track) was 50% and the total importance of other factors was 50% with equal importance for each one of them.
By applying the Decision Support System software to the project by inputting the percentage of each factor's importance for owner, the output report showed that:
The most appropriate Project Delivery Method is "Design Build".

The most appropriate Tendering Method is "Selected Tendering".
The most appropriate Contract Type is "Lump sum".
Case study No. (3):
In this case, the owner requirements were as follows, Importance of contractor's willingness to finance certain parts of the project was 60% and the importance of all other factors was 40% with equal importance for each factor.
By applying the Decision Support System software to the project by inputting the percentage of each factor's importance for owner, the output report showed that:
The most appropriate Project Delivery Method is "Public Private Partnership".
The most appropriate Tendering Method is "Selected Tendering".
The most appropriate Contract Type is "Lump sum or Unit Price or Both".
Finally, all of these results matched with the results of typical calculations of sensitivity analysis on this project and the same proposed by managers of project with several years of successful work in construction projects.

XI. CONCLUSIONS AND DISCUSSIONS

While no project delivery option is perfect, one option may be better suited than another based on the unique requirements of a particular project. The requirements for each project should be evaluated to determine which of the various options would mostly likely produce the best outcome for the public or private owners. Each project delivery method comes up with its own advantages and disadvantages with the best choice being governed by the requirements of the specific project.

In this study, with comprehensive and all-out study of different types of construction projects, a number of 22 effective factors were identified and selected in decision making and selection of the proper project delivery method. This selection helps directly in selection of the proper tendering method and contract type. In the same direction, relative significance of each one of these factors was obtained using questionnaires distributed among experts from consulting engineers who have though knowledge in related field. In continuation, an analytical approach was used for optimal construction of projects and the impact of each factor on project delivery method selection was calculated. Then, results of questionnaire were inserted and saved in Decision Support System software package, so that weight value of options was obtained in comparison with the factors. It should be noted that this software is used for the optimal construction of several types of projects. The answers obtained from software were the same obtained from sensitivity analysis and the same proposed by managers of project with several years of successful work in construction projects. Also, significance of each of factors studied in decision-making and change process in the selected methods based on change in significance of each of decision-making factors using sensitivity analysis. It can be mentioned that the proposed software can be adapted easily to changes, so that an option or factor can be removed or added easily and/or adopt some corrections in data of input questionnaire to software. It should be noted that this software can be completed more comprehensively in future studies. Moreover, this software can be used by employers of different types of construction projects as contractual management software in line with selecting the optimal delivery system, tendering method, and type of contract.

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