Implementing Multi-Dimensional CAD Models to Reduce the Project Cost Estimations Gap between the Financial Ministry and Other Government Ministries in Saudi Arabia

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***Abstract*—Saudi government ministries have depended on transparent outsourcing regulations, to contract independent competent companies to estimate costs during the conceptualization phases of construction projects. Aforementioned companies often face the errors in their estimations. Unprofessionalism, inflation, lack of standardised industry cost estimation methods and uncertainty play vital role to failure the project estimations. To attain more accurate project cost estimations, the Saudi ministries must regulate their cost estimation methods and should incorporate recent technological solutions into their cost estimation processes. This paper qualitatively analyses project cost estimation processes adopted by Saudi government ministries, identifies their shortcomings and examined the effects of adopting multi-dimensional computer aided design (MDCAD). The information used for this analysis has been collected from ministries, contract companies and academic literature.**

***Index Terms*—MDCAD, construction, cost estimation, Saudi Arabia.**

I. Introduction

Construction project cost estimation includes predicting construction costs and quantities based on resource prices and construction project costs, but must also address risks and uncertainties associated with the particular construction project [1]-[2]. Saudi government ministries have depended on cost estimates as inputs for budgeting, cost and value analysis, decision making, asset and project planning, and cost and schedule control processes [3]. However, their efforts have largely been inefficient and are best explained by the Friedman curve (Fig. 1). These cost estimation tools have commonly been inaccurate and call into question the annual multi-billion Saudi Riyal (SAR) construction projects undertaken by government ministries. The result has been huge differentials between a project's proposed and completion costs [4]-[5] reported that as of 2011, Saudi government ministries had a total of 687 on-going construction projects valued at SAR 2.6 trillion, 22% being in the execution phase. This figure is against a backdrop of SAR 240 billion awarded in 2010 and the then projected SAR 322 billion for 2011, all part of the SAR 188 billion in total Saudi government expenditure in construction projects [5].

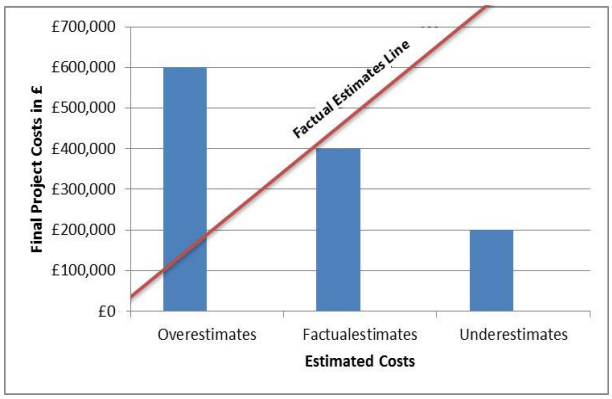

Figure 1: The project estimations graph

While the Saudi government ministries have attached much importance to project cost estimations, they have generally agreed that these have failed; resulting in budget overruns [6]. The failures include arithmetic errors when calculating figures, erroneous plans and specification measurements, incorrect labour wage rates, improper pricing of supplies and materials, incorrect measurement units, failure to review local government construct inspections, codes and permits, overlooking construction items, and not making allowances for realistic contingencies. Inefficient cost estimations ultimately lead to ministries' staff burnout, lower quality work, credibility loss, missing deadlines, and inefficient efforts that take longer than projected [6]. In contrast, accurate construction project cost estimates help in avoiding false precision, relate contingency to experiences with uncertainty, and increase transparency and continuous quality control of the construction process [7].

Consequently, this paper examines cost estimation techniques adopted by Saudi government ministries and their efficiency in accurately estimating construction project costs. Consideration of MDCAD is also argued as

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of major importance, since there is a need to adopt technology that saves time and increase accuracy in construction project cost estimation. MDCAD is expected to improve programmability and measurability of the cost estimation effort, and thereby shift this merely from an input-oriented control to a combination of behaviour and output control. In so doing the research will answer questions regarding how Saudi ministries estimate construction project costs; what the shortfalls are of their construction project cost estimation methods; and how priority adoption of MDCAD by Saudi government ministries in estimating construction project costs would ensure that the identified shortfalls are rectified.

II. Aims and Objectives

This research sought to evaluate the efficiency of construction project estimation tools adopted by Saudi government ministries and how MDCAD could aid in overcoming the identified shortcomings regarding estimation of costs. In so doing the researcher hopes to:

- Conducted library searches, which included online and database searches of peer reviewed materials that discuss Saudi government ministries' estimations of construction project costs and the adoption of MDCAD. Online searches were conducted in public accessible websites with the phrases being; Saudi government ministries, traditional construction project cost estimation tools; efficiency in cost estimation; and MDCAD within the Kingdom of Saudi Arabia.
- Identify and examine the relationship between Saudi government ministries' traditional construction project cost estimation tools, efficiency in cost estimation and MDCAD within the Kingdom of Saudi Arabia.

Therefore, as the research study evaluated the efficiency of construction project estimation tools adopted by Saudi government ministries and how MDCAD could aid in overcoming the identified shortcomings as concerns estimation of construction project costs, it addresses the following objectives:

- To examine the concept of construction project cost estimation as adopted by Saudi government ministries.
- To apply the qualitative approach to research by making use of library searches to generate qualitative results.
- To generate implications and conclusions regarding the impact of Saudi government ministries using traditional construction cost estimation tools, and MDCAD use to estimate construction project costs within the Kingdom of Saudi Arabia.
- To provide a base for decision making as concerns Saudi Arabia construction project cost estimation and further research on the research study topic.

III. Study Area/Background

Saudi construction project estimation has traditionally applied a five step cost estimation approach that involves step one - project magnitude conceptualization and order of magnitude estimation; step two - feasibility and conceptualization estimation; step three - preliminary budget planning and estimation; step four - definitive engineering estimation; and step five - final construction project cost estimation [8]. Traditional construction cost estimation methods take a deterministic and conservative approach to construction projects' cost estimation with a contingency factor added that varies depending on the stage of the project's definition, experience, and other factors [9]-[4].

The first step, project magnitude conceptualization and order of magnitude estimation, involves conducting a preliminary feasibility study for the construction project. This step has 50 per cent accuracy in estimating the accurate project cost, 25 per cent contingency developed by risk analysis, and the costs for this step being approximately between 0.1 and 0.2 per cent of the total project cost. The information required for conducting this step include; project raw material specifications, design, location, storage and logistics requirements, engineering expenditure and a historical project database for cost references. By analysing the historical project database, the cost estimating company can establish the expected project cost estimate by adjusting prior costs for differences due to inflation, size, and site specific costs that include labour rates. Typical construction cost indices, which include database figures, new project specifications, completed projects estimates and cost factors dependent on the project magnitude, are used. The accuracy of this step is largely dependent on the similarity between the new project and a similar one that was completed recently and is found in the database. The cost ratio, a time factor between new and old projects, increases with increase in construction magnitude [10].

The second step, feasibility and conceptual estimation, involves conducting a project feasibility to include the availability of resources and possibility of carrying the completion the construction project. This step has 70 per cent accuracy in estimating the accurate project cost, 15 per cent contingency developed by risk analysis, and the costs for this step being approximately between 0.2 and 0.5 per cent of the total project cost. The purpose of this step is to conduct project economic, material and technological comparison select materials that match project quality needs to acceptable cost levels. The information required for this step include; project design, description and schedule, design criteria and labour cost estimates. This step is carried out when the preliminary project scope is being developed and includes design basis and material list. It borrows heavily form the Lang Factor Method (LFM) that bases construction project costs estimation on the Lang factor and materials costs estimates. The LFM uses historical factors and material pricing to estimate the proposed project capital costs. Market quotations are factored in for material costs and adjusted for the specific construction project's needs. Materials and labour ratios are adjusted for site conditions and location,

while labour costs are factored as a percentage of the total estimated project cost, based on historical information from the company construction database [11].

The third step, preliminary budget planning and estimation, involves preparation of a preliminary construction budget that takes into account all labour and material needs of the project based on the project time schedule. This step has 80 per cent accuracy in estimating the accurate project cost, 15 per cent contingency developed by risk analysis, and the cost for this step being approximately 1.5 per cent of the total project cost. The purpose of this step is to improve step four estimates by taking 'time' into account as a constraint. The information required for this step include construction project; material and equipment specifications, location, labour costs, and limited material and equipment take off for major materials and equipment. The project cost estimates come from the in-house database that contains quotations of materials, equipment and labour costs. The estimated construction project cost in this step, therefore, includes direct and indirect costs, commissioning allowance, infrastructure, overhead, labour productivity and escalation. Material and equipment costs, for this step, are based on recent purchases and budget quotes contained in the company database. Preliminary material and equipment take off are developed with historical rates applied to the take offs for major accounts that include; steel, concrete and electrical wires. Man-hours are factored by similar past construction projects and considered as a percentage of the total project cost based on historical information contained in the company database [12].

The fourth step, definitive engineering estimation, involves determining construction project owner capital appropriation and construction project budget. This step has 90 per cent accuracy in estimating the accurate project cost, 12.5 per cent contingency developed by risk analysis, and the cost for this step being approximately 3 per cent of the total project cost. The information required for this step include; proposed project related graphical designs and drawings, specific information on contractual terms, specific trade labour rates, and take off materials and equipment cost estimates. It includes equipment and material quotations, labour and material ratios, and detailed man hour estimates based on construction project specific deliverables and individual discipline schedules [13].

The fifth step, final construction project cost estimation, involves developing higher accuracy construction project cost estimates for construction project planning. This step has higher than 94 per cent accuracy in estimating accurate project costs, 7.5 per cent contingency developed by risk analysis, and the cost for this step being approximately 3 per cent of the total project costs. The purpose of this step is to develop higher accuracy final cost estimates for the construction project planning. The information needed for this step include; construction project related graphical designs and drawings, specific information on contractual terms, specific trade labour rates, take off materials and equipment cost estimates, materials and equipment specified for purchase and vendors selected, and pricing on actual labour productivity [14].

IV. Methodology and Materials

Methodology comprises data collection, incorporating technical data and finally data analysis with updated versions of diverse software (Vico). This paper also uses mixed methods research (both Qualitative and Quantities) to obtain accurate results. Consequently, this study based on the collected data form government reports, surveys, government officials and other related persons as well as organisations (with their permission). Accordingly, this research took the 20 interviews, conducted 3 surveys and analysed more than 200 government and other reports.). Then offered the new findings based on aforementioned issues.

V. Results and Discussion

This study crucially evaluated the collected data and found following novel findings;

A. Evaluation of Computer Integrated Manufacturing (CIM) Technologies in Saudi Industries using the Analytical Hierarchy Process (AHP)

A survey of Saudi government ministries construction estimation tools shows that 52 per cent use traditional cost estimation tools while the remaining 48 per cent have adopted the use of CAD as a construction project cost estimation tool. While all the ministries felt that CAD was better than traditional tools, they reiterated that their adoption of the technology was hindered by high investment costs associated with the technology; high costs of development programs aimed at increasing industry efficiency and output; high costs associated with upgrading and merging new and older technologies; high maintenance costs of technology associated with CAD; absence of adequate numbers of well trained and skilled personnel to carry out changes within the industry; and low digestion of advanced CAD technologies that require investments in acquiring and digesting the technology.

B. Towards Computer Aided Life-Cycle Costing

The Saudi government is an institution that is slowly but surely taking advantage of the cost estimation accuracy and efficiency aspects of CAD technology in controlling and tracking construction project costs. Previously, the government engaged in construction activities with short-term economics in mind, and without considering project life-cycles. This shortcoming was attributed to the lack of structured coherent cost input integration by tradition cost estimation techniques. This problem was further confounded by limited capital availability that was stretched over many capital development programs. There were many considerably worthy construction projects vying for the limited available funding that the government had to resort to the equation of picking the projects requiring the least capital cost while procuring the most construction activity.

Between 1995 and 1998, the Saudi government contracted the Symonds Group to develop a computer

aided management (CAM) system, which is a variation of CAD they dubbed Maximo®. The system is a project component based system that assigns unique project codes to all components in a construction project, based on a hierarchy that includes cost modelling. It allowed for cost interrogation in relation to horizontal and vertical construction project component groups. Apart from initial data input, it also had a help section where cost requests are made. The requests identified the unique project component code and approximate costing based on pre-agreed cost schedule rates. As the construction components and system are specified, an asset register emerges that is integrated into a common database. Not only does this inform the stakeholders of current activities but also kept accurate records of past activities and schedules.

The register and database also introduced the concepts of performance benchmarking and continuous improvement. Performance benchmarking is the managerial technique that establishes an average performance across a range to estimate optimal and realistic costs. Continuous improvement is the managerial technique that involves adopting corrective action in a trial and error mode to estimate optimal and realistic costs.

When the system was used in calculating project life-cycle costs, it was discovered that the system had a serious drawback that included the assumption that all cost requiring activities were carried out when required and not differed within the construction project profile.

C. *A Review of Object-Oriented CAD Potential for Building Information Modelling (BIM) and Life Cycle Management*

TABLE I. TRADITIONAL CONSTRUCTION PROJECT COST ESTIMATION STEPS

Cost Estimation Stage	Name	Purpose	Contingency (%)	Accuracy (%)
Step1	Project magnitude and order of magnitude estimation	Conduct a Preliminary feasibility study	25	50
Step2	Feasibility and conceptual estimation	Conduct a project feasibility of resources	15	70
Step3	Preliminary budget planning and estimation	Preparation of preliminary construction budget that takes into account all time, labour and material needs	15	80
Step4	Definitive engineering estimation	Determine owner capital appropriation and project budget	12.5	90
Step5	Final project estimation	Develop higher accuracy cost estimates	7.5	94

Saudi government construction activities are plagued by persistent cost overruns and project delays that seriously undermine efforts to streamline cost estimates. This is further confounded by poor performance, inoperable design solutions, delays and late deliveries. The largest contributor to these problems is the traditional approach to construction design and information handling that has been adopted by a considerable percentage of the Saudi government ministries. The traditional approach to construction design and information handling involves a process that does not encourage examining relationships, information flows and the integration of activities, particularly between design, construction and operational phases (Table I). The process generates information that is complex, fragmented, and has to be mediated and interpreted before being acted upon. The disjointed nature of such a design process also means that alterations and changes are frequent, requiring close communication and coordination, which do not always arise.

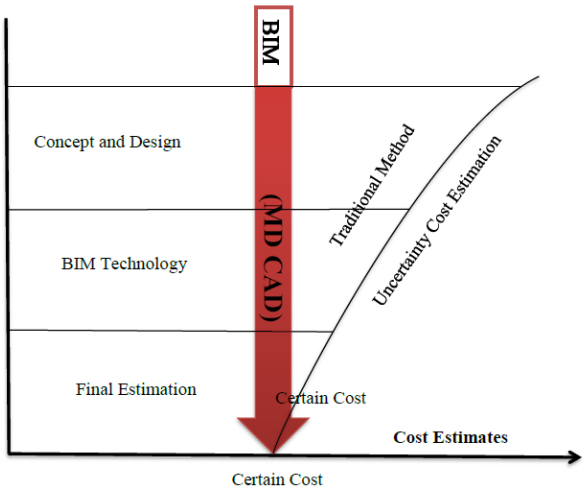

Figure 2. The traditional approach of construction design

The result is that conflicts, inconsistencies and mismatches are realized on a regular basis and this translates into higher construction costs and late construction deliveries. Predictably, the consequences become more evident during the construction process, resulting in variation orders and contractual disputes that lead to cost overruns and general dissatisfaction. This in turn escalates the complexity of the construction process and imposes constraints on design time and costs. Despite these problems being common knowledge among construction industry players, manual methods of recording and communication still prevail in the Saudi construction industry, resulting in poorly coordinated documentation MDCAD technology is an evolving product that has the potential to facilitate solutions to these problems. By streamlining project variables into a single register and database, MDCAD has the potential to unify the focus of construction project activities, thereby enabling improvements in the overall process of cost estimation (Al- Ahmari, 2007. Active coordination between the design team and other parties in the construction process facilitates the cost estimation process. This leads to a significant reduction in costs. Overall, integration of MDCAD technology into the Saudi government construction activities should result in

increased accuracy and efficiency of construction project cost estimation processes. Moreover, BIM process (Fig. 2 and Fig. 3) BIM concept has begun with a three dimensional computer design (3D CAD) processes and technologies in the architecture, engineering and construction (A/E/C) industry. Nowadays, BIM is integrating 3D CAD modelling with construction data like schedule, cost data and etc. to be fourth, fifth and multi-dimensional CAD.

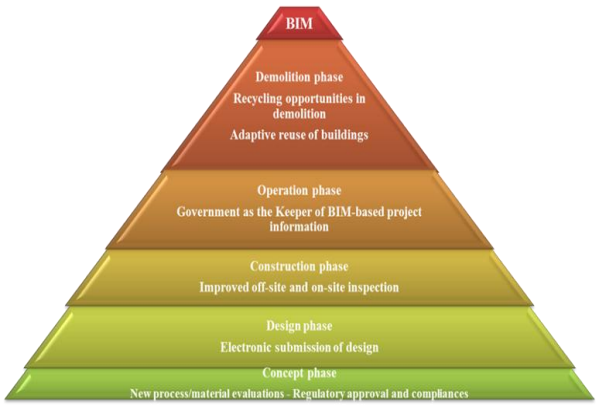

Figure 3. Proposed BIM implementation steps and BIM uses at various project phases

VI. Discussion

Despite acknowledgement of the perceived benefits of acquiring and using MDCAD technology, Saudi government ministries have faced difficulty in applying the technology. The costs associated with installing, maintaining and upgrading this, and the trained personnel needed for running it have been cited as the most prohibitive and prevalent reasons.

It is clear that the ministries construction projects are plagued by cost overruns. The major similarity as concerns the adoption of MDCAD technology is their acknowledgement that this technology allows for faster and more efficient interfacing between different teams engaged in a construction activity. While it has been agreed that the technology is the way to go forward for the ministries, it must be noted that the ideal is not the case. Three key factors hinder the adoption of the technology: the fragmented nature of the industry; construction project variations; and construction projects' technological factors as relating to the amount of data, technological familiarity, data standards and interoperability.

Overall, it is clear that the database creation opportunities associated with MDCAD technology provide a unique opportunity for ministries to accurately and efficiently predict and track project costs and time schedules. In an economically pressured environment where capital is precious, technology savvy environment where embracing technology is projected to increase efficiency, and time sensitive environment where delays can mean the difference between failure and success, the ministries face the choice of either embracing the technology and increasing their activity efficiency or sticking to traditional cost estimation where they experience low efficiency and accuracy.

From the research results, MDCAD has been identified as an accurate and integral tool for construction cost estimation by the Saudi government ministries. The shift by the ministries from the traditional tools to a design structure oriented around MDCAD technology and process, however, represents an attitude challenge rather than achieving any scientific and technological breakthrough. It requires adherence to the discipline and the tenet that no single unit of construction activity is the product of one individual discipline, but that the construction activity instructions represent the collective talents of diverse disciplines. It is here that the horizontal and vertical introduction of tooling, levels of skills and methods, in the form of multidimensional CAD, come into play to ask 'how is project cost accurately and efficiently estimated?' rather than 'what is the project cost estimation?'

Detailed databases of construction requirements and processes are required if full benefits of MDCAD planning and execution are to be realized. But creation of the databases will not be easy and quick to achieve. At the onset, the transformation of the Saudi government ministries from a traditional tools oriented industry to one that embraces later technological advances requires a strategic plan that is closely coupled to modern methods. The interconnectivity between construction projects' conceptualization, design, execution, use and ultimate demolition must form the central fabric of this overall plan. Just the step of exploiting the stated linkage and eliminating many of the redundant and duplicative construction efforts, common in the tradition tools, will result in significant cost savings. But this integrated strategy transcends the simple cost savings, for the ultimate objective of MDCAD technology is to accurately predict construction project costs.

VII. Conclusion

Accurate cost estimation for construction project has proven to be a dominant variable in the Saudi government ministries. Consequentially, this study shows that, the ministries are increasingly implementing the use of MDCAD to obtain precise estimation costs for construction projects with in allocated time. Therefore, this research results should be useful to ministries to improve project cost estimations enormously.

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