Quality Management System for Design Consultants: Development and Application on Projects in the Middle East

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Abstract: In this paper, the development and implementation processes of a quality management system (QMS) for design consultants in the Middle East are presented. The current design practices are first reviewed through the conduct of multiple interviews. The development of the QMS for designing residential and commercial buildings is also based on quality standards from the literature. The practical implementation of the model is conducted using actual design projects in a real design environment. The model implementation consists of three stages, the first stage is awareness; the second stage is benchmarking of existing practice, which is carried out on 20 projects; and finally, the validation of the model is verified using data from 11 projects. The benchmarking of existing performance and the validation of the model are carried out utilizing statistical approaches. The implementation of the QMS model improves the efficiency of the designs and the production process distributions.

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Introduction

Total quality management (TQM) is a management approach that made its debut in the 1950’s and has steadily grown to a popular approach in the early 1980’s. TQM is a technique by which management and employees can establish a continuous quality implementation in order to improve services or products. The implementation and hierarchy of typical quality management systems have been introduced in the publications of the International Organization for Standardization (ISO 2000).

Design is an integrated part of the construction industry. The quality in a design office is a major tool that helps in managing the work effectively. The effectiveness of this type of management focuses on effective employment of people and their ideas, expertise and enthusiasm to produce drawings, specifications, and other information that define a project. It also includes the production of this information to the agreed standard of quality and safety on time and within budget (Burati et al. 1992; Rutter 1992).

The writers performed an extensive literature review on international standard requirements along with quality definitions with an emphasis on design consultants’ quality aspects and organizational structures. They also reviewed the current practices of design consultants in the region through the conduct of interviews with members from various design consultant offices. It was evident from the information gathered that there are deficiencies in adhering to quality requirements with respect to international recognitions and standard compliances (Abu-Ghazala 2001; Ezeldin and Abu-Ghazala 2002). To address this problem, a quality management system (QMS) model for consultants designing residential and commercial buildings was proposed (Ezeldin and Abu-Ghazala 2003). In this paper, the emphasis is on the sources used to develop the QMS model and on the implementation phase adopted to validate the model.

QMS Applications by Design Consultants

The application of a QMS by design consultants was investigated. Various sources were utilized to explore the extent of this application. Information was obtained on design consultants from the United States, the United Kingdom, Saudi Arabia, Jordan, and Egypt. Valuable information was gathered and is summarized in the following section. Detailed information is available in Abu-Ghazala (2001).

1. United States and United Kingdom consultants express sincere commitment to quality objectives through very clear mission statements. Companies’ objectives were focused towards the achievement of quality through customers’ satisfaction as well as other parties’ satisfaction including people stakeholders and the society. The detailed QMS models ap-
plied were not specifically identified within the reviewed documents (ADC 2001; Bechtel 2001; MMG 2001; Parsons 2001; SOM 2001).

2. At least two Saudi consultants have successfully adopted quality management systems in conformance with the ISO 9001 quality standard. The consultants were proud of this achievement and have publicized it as part of their marketing strategy. This was further supported with a clear mission statement that was focused toward customer satisfaction and society interest in particular (SaudConsult 2001; ZFP 2001).

3. Researches that were carried out on design consultants in Egypt clarified that at least one Egyptian consultant among 24 consultants surveyed and interviewed achieved international recognition on the applied QMS through the achievement of ISO standard compliance certification (Mustafa 2001). The market investigation has revealed that at least three other design consultants are either working on their ISO standard compliance certification or have already achieved it. In addition, branches of Saudi Arabian consultants operating in Egypt have exhibited implementation of quality management systems aligned with the mother company applied system.

The typical quality management system documentation hierarchy is suggested in the publications of the International Organization for Standardization (ISO 2000). This structure can be adapted to design consultant activities as well. The documentation is typically presented in three levels.

- Level A: Quality manual. This describes the quality management system in compliance with the stated quality policy and objectives in accordance with standards.
- Level B: Documented quality management system procedures. This level of documentation describes the activities of individual functional units needed to implement system requirements. These documents must clearly identify responsibilities, authorities, in addition to the details of the operations to satisfy quality policies and objectives.
- Level C: Other quality documents. This level includes detailed work documents and instructions. Forms constitute part of this level of documentation and are usually useful tools to ensure that quality has been conducted in the required manner. Reports may be considered part of this level of documentation.

**Interviews Results**

The writers first tried to use questionnaires submitted to design consultants to get feedback from practicing designers. However, because of the weak response, the writers opted to use the approach of formal interviews using a common checklist based on quality measurement references (Burati et al. 1992; Kirby et al. 1988; ISO 2000). This approach was adopted to obtain better feedback on design consultants’ practices in the region. Interviews were conducted with members from design consultant offices dealing with design of residential and commercial buildings (Abu-Ghazala 2001). The checklist was prepared and used to establish a consistent dialogue with interviewees, and accordingly, consistent feedback. The interviewed members were 32 designers from 12 different design offices working in Egypt, Saudi Arabia, and Jordan. At least four offices have either achieved their international ISO standard compliance certification or currently are working on it. The interviewees were selected to have 7–10 years of experience in the field. Managerial positions with certain levels of authority and responsibility were preferred. The purpose of the interviews was to establish a clear understanding of the practices and systems of operation used by design consultants. They also allowed for the identification of the practice regarding quality requirements, project stages, flow, objectives, and common organizational structure. The details of the outcomes of these interviews are included in Abu-Ghazala (2001). It must be emphasized that these findings are based on input from 32 expert engineers. A summary and a brief discussion on the interview outcomes are presented below. The numbers in parentheses represent the percentage of the interviewees agreeing on the various statements.

**Quality System Existence, Documentation, and Awareness**

- A quality system was in existence within the firm (70%).
- The quality system was not in compliance with internationally recognized standard (80%).
- Staff members were not aware of quality systems (50%).
- Design quality is project dependent (80%).

There was a mix between quality and grade. Usually, grade is related to the extent of information included in drawings and not its quality. The management’s review covered business results and market shares with little focus on the review of quality objectives, policy, and quality systems.

**Project Design Stages**

Ninety percent stated that they were often in accordance with the internationally known stages such as conceptual, preliminary, and detailed design stages.

**Organizational Structure**

- The design firm was using departmental (administrative) organizational structures (70%).
- The design firm was using studio (functional) organizational structure (30%).

Generally, team leaders in the organization were not always functionally effective.

**Document Control System**

- The official documentations were properly controlled in project files (90%).
- The drawings, calculations, bills of quantities, and specification soft and hard copies were not properly identified (50%).
- Document changes were not properly controlled (50%).

**Resources Management**

- Manpower assignments for each project were usually carried out but not necessarily in writing (70%).
- Manpower forecast was not a common activity in many design offices (50%).
- Manpower evaluation was usually carried out but not necessarily documented (70%).
- The training was either not planned or not regularly evaluated (70%).
Design Control

- Design was usually controlled by department heads (80%).
- Rigorous design reviews took place for large projects (70%).
- Design changes were main sources of quality failure and profit leak (70%).
- The internal design changes were often not recorded and their impact not evaluated (70%).
- There was some design checklists in existence and were used as design control tools (50%).

Identification of Customer Requirements

The ongoing system was not very effective and was not regularly conducted (60%).

Technical Purchasing

There were little documented procedures in existence for it (80%).

Process Control

The firm applied control procedures on man hour recording and project follow-up meetings (70%).

Measurements

The measurement in terms of conducting internal audits was carried out to satisfy quality certifications, yet it was not used for measurement of performance or improvement techniques (60%).

Statistical Technique Applications

The statistical techniques were seldom used as a tool for the analysis of performance and improvement measures. Some averaging mechanisms were being used as requested by top management but were not routinely carried out (80%).

The overall results of the interviews pointed out that the quality management systems can be customized to suit the practices of design consultants because the typical design stages are compatible with the international references on quality. The results also indicated that the applications of the quality management systems by the design consultants in the region are not as formalized as they were in other international counterparts.

Development of the QMS Model

Requirements for a QMS

A quality management system for consultants practicing residential and commercial building designs has to follow certain requirements to ensure its effective operation and implementation (Burati et al. 1992; Kirby 1988; Stukhart 1987). These requirements extend to cover four major parts.

- General management responsibilities including management review and document and data control;
- Resources management that covers manpower and training;
- Product realization related activities that include quality planning, design and development, customer requirements, purchasing, and project control;
- Measurement aspects including the measurement of customer satisfaction and comments handling. It also covers audit and improvement requirements.

Incorporation of Requirements and Interviews’ Results

These requirements are aligned with the international quality standards. These requirements along with the results of the interviews were carefully analyzed and customized to suit design consultants practicing residential and commercial building designs as shown below.

Management Responsibility

The management shall be responsible and committed to the QMS. This should be reflected by emphasizing the need for quality requirements, by providing necessary resources to achieve the required tasks, by endorsing a quality policy that is appropriate for design, and by reviewing the quality system at regular intervals.

Resources Management

Management is expected to carry out resource planning for both human and nonhuman resources. In addition, training has been considered as one of the effective tools in achieving staff competency.

Quality Planning

Each project would have specific quality objectives that need to be fulfilled. The design firm and customer needs should both be considered.

Design and Developments

Design consultants carry out design and development throughout the project stages according to certain requirements for each stage to achieve the desired quality of the design.

Customer Requirements

Customers or clients for design consultants are very unique and specific about their requirements. The misinterpretation of their requirements usually leads to major rework and eventually a major cost impact. Accordingly, it is very important to precisely identify their requirements.

Purchasing

Proper control should be exercised to ensure that purchased product or service conforms to the requirement. The extent of the control depends on the impact of purchased product or the subsequent validation process on final product.

Measurement of Customer Satisfaction

The organization must monitor information on customer satisfaction and dissatisfaction as one measure of system performance.

Audits

Internal audit must be part of the verification of the implementation and effectiveness of the quality system. It can also determine whether the quality management system conforms to the requirements of the international standards.

Improvement

The organization shall plan and manage processes necessary for the improvement of the quality management system.
Overview of the QMS Model

The quality management system model was designed by the writers in a quality manual format and contained in 104 pages. The manual was designed with specific document control formats where every document has its own reference number, issue date, and release status. An index is provided at the beginning of each of the set of documents, i.e., job descriptions, procedures, and forms for easy reference. A complete listing of the proposed QMS and its user guide is included in other references (Abu-Ghazala 2001; Ezeldin and Abu-Ghazala 2002, 2003). The composition of the model includes seven sections:

- Section 1.0 of the model is considered an introductory part of the model that includes the scope of this manual, which is limited to design consultants practicing residential and commercial building designs.
- Section 1.1 includes the activities of various departments within the organization including architectural, landscapes, civil, structural, HVAC, plumbing, and electrical departments. The primary activities and function of each department is included in this part. General requirements that are applicable to all departments are also included at the end of this section.
- Section 1.2 illustrates the project flow and project stages. Details of typical design stages, which include conceptual design 0–15%, preliminary design 15–30%, intermediate design 30–60%, and final detailed design stage 60–90% and the project close out stage 90–100%, are provided with detailed descriptions in each subsection.
- Section 1.3 illustrates the matrix organizational structure. Descriptive briefing is included in this section that clarifies the various elements of the organization and their functional relationships.
- Section 1.4 includes an index, which is followed by the details of the job descriptions included in the organizational charts. The job descriptions include: technical management, department head, team leader, project architect, project engineer, architect, engineer, and CAD technician.
- Section 1.5 includes an index, which is followed by the details of the procedures. The procedures were categorized as: management review, document control, manpower, training, quality planning, design and development, customer requirements, technical purchasing, project control, measurements, comments handling, audits, and improvement. At the end of each procedure a list of the related forms to the specific procedures are listed for easy reference.
- Section 1.6 includes an index, which is followed by the details of each form. The forms are very much related to the procedures and should be carefully read in parallel. The procedures describe the appropriate timing of using the form, the responsibility of completing the form, and any further associated actions. Many of the forms are provided with explanatory notes that describe the mechanism for completing the forms.

Implementation of the QMS Model

Arrangements were made to pursue the implementation of the quality management system model in a real design environment. The model implementation and validation were carried out on projects through design teams working in a controlled environment within a consulting office. The writers believed that this technique of QMS implementation would provide a realistic judgment of the model’s effectiveness.

The model implementation and validation were carried out in three stages. Stage 1 included the training and awareness part of the quality concept and model elements to all participants. Stage 2 included the benchmarking of the existing production rate. The benchmarking includes the establishment of the production rate with regard to man hour consumption per drawing and per square meter of area. Stages 1 and 2 went parallel and continued for about 8 weeks.

Stage 3 included the validation stage and extended for six months to allow for proper adherence to the new system and to ensure accurate data collection. The validation included the measurement of project profitability represented as net savings on each project budget hour. It also measured the production rate for all departments and the project total with regard to man hours per drawing and man hours per square meter of area. This production rate was compared with the benchmarking of production rate results.

Stages 1 and 3 were conducted in association with staff members from the consultant office. The number of teams and the number of participants were selected based on the following criteria:

1. The number of engineers and staff members in each team should adequately cover the various design specialties in accordance with the project’s scope.
2. Each design team should be working independently and separately from the other teams.
3. All teams should be working on different projects but within the same validation period of six months.
4. The training of team members during the awareness stage and the follow up during the validation stage should be compatible with the availability of the writers.

As such, the participants were divided into three teams. Each design team ranged from 25 to 30 technical staff. The teams were multidisciplined under one technical management. The departments included were: architectural (AR), structural (SE), heating, ventilating, and air conditions (HVAC) (ME), plumbing (PG), electrical (EE), civil (CE), and landscape (LS) departments.

This study has considered two project categories, namely, residential and commercial projects. No public work projects were included in the study. The residential projects included typical private residences and mansions where the basic space units are similar in function (i.e., living areas, bedrooms, and services including toilets and kitchens). Private residences are usually less than 5,000 m² in area. The mansions are similar with an extended area over 15,000 m². The commercial projects were not privately owned but rather owned by organizations or government agencies. These buildings were usually large in size, above 10,000 m², except for some public building (just above 4,000 m²). Buildings in this category include multistory, office buildings, shopping, complexes, government buildings, and public buildings.

Stage 1: Awareness and Training

The first stage in model implementation was awareness and training. The quality concept and standard requirements were explained to the teams. Training sessions were conducted for the members of the three teams to identify the changes in the existing operating system that were addressed and included in the new quality system. The training extended to a total of 15 h. The model was carefully studied and communicated throughout the project’s team. Job descriptions, operational procedures, and common forms were explained in depth with the staff.
Table 1. Projects Data Benchmarking Stage

<table>
<thead>
<tr>
<th>Project name</th>
<th>Project number</th>
<th>Building area (m²)</th>
<th>Site area (m²)</th>
<th>Total drawing units</th>
<th>Consumed man hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private residence</td>
<td>001</td>
<td>3,147</td>
<td>10,364</td>
<td>51</td>
<td>3,308</td>
</tr>
<tr>
<td>Private residence</td>
<td>002</td>
<td>1,590</td>
<td>1,795</td>
<td>44</td>
<td>1,920</td>
</tr>
<tr>
<td>Private residence</td>
<td>003</td>
<td>2,445</td>
<td>4,800</td>
<td>41</td>
<td>1,705</td>
</tr>
<tr>
<td>Private residence</td>
<td>004</td>
<td>1,975</td>
<td>2,991</td>
<td>44</td>
<td>1,844</td>
</tr>
<tr>
<td>Private residence</td>
<td>005</td>
<td>1,600</td>
<td>2,790</td>
<td>35</td>
<td>2,676</td>
</tr>
<tr>
<td>Private residence</td>
<td>006</td>
<td>3,767</td>
<td>8,057</td>
<td>62</td>
<td>4,238</td>
</tr>
<tr>
<td>Governmental facility</td>
<td>007</td>
<td>22,665</td>
<td>25,000</td>
<td>276</td>
<td>15,704</td>
</tr>
<tr>
<td>Multitower</td>
<td>008</td>
<td>88,788</td>
<td>25,347</td>
<td>894</td>
<td>41,052</td>
</tr>
<tr>
<td>Palace</td>
<td>009</td>
<td>17,689</td>
<td>183,500</td>
<td>392</td>
<td>22,949</td>
</tr>
<tr>
<td>Mixed facilities</td>
<td>010</td>
<td>21,181</td>
<td>154,250</td>
<td>433</td>
<td>23,999</td>
</tr>
<tr>
<td>Tower building</td>
<td>011</td>
<td>21,900</td>
<td>13,600</td>
<td>113</td>
<td>5,350</td>
</tr>
<tr>
<td>Residential complex</td>
<td>012</td>
<td>21,973</td>
<td>10,812</td>
<td>69</td>
<td>4,345</td>
</tr>
<tr>
<td>Shopping center</td>
<td>013</td>
<td>21,973</td>
<td>10,812</td>
<td>39</td>
<td>2,665</td>
</tr>
<tr>
<td>Office building</td>
<td>014</td>
<td>25,500</td>
<td>7,500</td>
<td>172</td>
<td>7,709</td>
</tr>
<tr>
<td>Private residence</td>
<td>015</td>
<td>2,000</td>
<td>4,200</td>
<td>47</td>
<td>2,310</td>
</tr>
<tr>
<td>Private residence</td>
<td>016</td>
<td>1,544</td>
<td>1,260</td>
<td>19</td>
<td>1,095</td>
</tr>
<tr>
<td>Private residence</td>
<td>017</td>
<td>2,415</td>
<td>2,401</td>
<td>39</td>
<td>2,665</td>
</tr>
<tr>
<td>Private residence</td>
<td>018</td>
<td>4,387</td>
<td>3,338</td>
<td>30</td>
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<tr>
<td>Private residence</td>
<td>019</td>
<td>1,158</td>
<td>960</td>
<td>22</td>
<td>1,250</td>
</tr>
<tr>
<td>Public service office building</td>
<td>020</td>
<td>4,122</td>
<td>41,224</td>
<td>106</td>
<td>3,660</td>
</tr>
</tbody>
</table>

Table 2. Statistical Analysis for the Consumption of Man Hours per Drawings–Benchmarking Stage

<table>
<thead>
<tr>
<th>Department</th>
<th>Mean</th>
<th>Lower limit</th>
<th>Upper limit</th>
<th>Standard deviation</th>
<th>Standard deviation/mean (%)</th>
<th>Total samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Civil</td>
<td>50.80</td>
<td>36.75</td>
<td>64.85</td>
<td>16.25</td>
<td>32</td>
<td>19</td>
</tr>
<tr>
<td>Landscape</td>
<td>57.31</td>
<td>44.83</td>
<td>69.79</td>
<td>14.35</td>
<td>25</td>
<td>17</td>
</tr>
<tr>
<td>Architectural</td>
<td>61.73</td>
<td>52.07</td>
<td>71.39</td>
<td>11.14</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>Structural</td>
<td>62.30</td>
<td>49.71</td>
<td>74.89</td>
<td>14.42</td>
<td>23</td>
<td>16</td>
</tr>
<tr>
<td>HVAC</td>
<td>53.79</td>
<td>42.55</td>
<td>65.02</td>
<td>13.02</td>
<td>24</td>
<td>20</td>
</tr>
<tr>
<td>Plumbing</td>
<td>45.28</td>
<td>32.75</td>
<td>57.81</td>
<td>14.53</td>
<td>32</td>
<td>20</td>
</tr>
<tr>
<td>Electrical</td>
<td>47.60</td>
<td>36.76</td>
<td>58.45</td>
<td>12.54</td>
<td>26</td>
<td>19</td>
</tr>
<tr>
<td>Overall</td>
<td>55.29</td>
<td>45.08</td>
<td>64.85</td>
<td>11.83</td>
<td>21</td>
<td>20</td>
</tr>
</tbody>
</table>

Table 3. Statistical Analysis for the Consumption of Man Hours per Square Meter of Area–Benchmarking Stage

<table>
<thead>
<tr>
<th>Department</th>
<th>Mean</th>
<th>Lower limit</th>
<th>Upper limit</th>
<th>Standard deviation</th>
<th>Standard deviation/mean (%)</th>
<th>Total samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Civil</td>
<td>0.0151</td>
<td>0.0045</td>
<td>0.0257</td>
<td>0.0122</td>
<td>81</td>
<td>18</td>
</tr>
<tr>
<td>Landscape</td>
<td>0.0251</td>
<td>0.0092</td>
<td>0.0411</td>
<td>0.0184</td>
<td>73</td>
<td>18</td>
</tr>
<tr>
<td>Architectural</td>
<td>0.2134</td>
<td>0.1283</td>
<td>0.2986</td>
<td>0.0987</td>
<td>46</td>
<td>20</td>
</tr>
<tr>
<td>Structural</td>
<td>0.1656</td>
<td>0.0867</td>
<td>0.2445</td>
<td>0.0915</td>
<td>55</td>
<td>20</td>
</tr>
<tr>
<td>HVAC</td>
<td>0.1159</td>
<td>0.0681</td>
<td>0.1636</td>
<td>0.0554</td>
<td>48</td>
<td>20</td>
</tr>
<tr>
<td>Plumbing</td>
<td>0.1240</td>
<td>0.0702</td>
<td>0.1777</td>
<td>0.0623</td>
<td>50</td>
<td>20</td>
</tr>
<tr>
<td>Electrical</td>
<td>0.1433</td>
<td>0.0864</td>
<td>0.2001</td>
<td>0.0658</td>
<td>46</td>
<td>19</td>
</tr>
<tr>
<td>Overall</td>
<td>0.8438</td>
<td>1.1883</td>
<td>0.4994</td>
<td>0.3994</td>
<td>47</td>
<td>20</td>
</tr>
</tbody>
</table>
Stage Two: Benchmarking of Production Rates

The performance of design teams during design production stages can be measured by a few parameters, among which man-hour consumption per drawing produced and man hours per square meter of built-up area or site area. In order to establish a benchmark for the performance in the particular consulting office at hand, an analysis of the productivity rates must be performed before applying the QMS model. The writers opted to use quantitative data for benchmarking in order to document the effectiveness of the QMS within a reasonable period of time.

Statistical techniques were utilized for the analysis and evaluation of production rates with regard to hours per drawing and per square meter of built-up or site area as applicable. This analysis evaluated the existing production process as represented by the mean values and upper and lower limit ranges and standard deviations.

Data from 20 projects were collected and analyzed. The total man-hour budgets for these projects were about 155,000 man hours. These man hours represented the data of the previous two years of the design teams. T-distribution was adopted with 90% confidence level. The $t(a/2)$ associated with related degree of freedom (v) was determined and the upper and lower limits and the standard deviation were accordingly calculated for the specified variables. The data were checked for consistency based on the Chauvenet ratio and all inconsistent data were removed and the results were adjusted accordingly [Lipson 1973]. This stage was performed concurrently with Stage 1 but the team members were not involved in it.

### Data Collection

The man-hour consumption for the projects was obtained. A master list was prepared that contained the 20 projects. The man-hour consumption per drawing was calculated for every department. This analysis evaluated the existing production process as represented by the mean values and upper and lower limit ranges and standard deviations.

### Table 4. Summary of Model Validation Data

<table>
<thead>
<tr>
<th>Data</th>
<th>Project number</th>
<th>101</th>
<th>102</th>
<th>103</th>
<th>104</th>
<th>105</th>
<th>106</th>
<th>107</th>
<th>108</th>
<th>109</th>
<th>110</th>
<th>111</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building area</td>
<td></td>
<td>6,300</td>
<td>15,125</td>
<td>2,510</td>
<td>3,332</td>
<td>17,274</td>
<td>981</td>
<td>2,436</td>
<td>3,601</td>
<td>7,165</td>
<td>7,815</td>
<td>9,900</td>
<td>76,439</td>
</tr>
<tr>
<td>Site area</td>
<td></td>
<td>19,190</td>
<td>25,442</td>
<td>8,200</td>
<td>2,502</td>
<td>77,841</td>
<td>1,200</td>
<td>9,504</td>
<td>9,856</td>
<td>11,488</td>
<td>10,870</td>
<td>12,524</td>
<td>188,617</td>
</tr>
<tr>
<td>Total</td>
<td>Drawings</td>
<td>110</td>
<td>156</td>
<td>44</td>
<td>70</td>
<td>497</td>
<td>26</td>
<td>97</td>
<td>96</td>
<td>90</td>
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Note: NC = not conducted.
projects general data, such as project site area, built-up area, total number of drawings, and total consumed man hours including projects title are presented in Table 1.

Data Analysis
The mean values of the man-hour consumption per drawing and per square meter of built-up area for the different departments were established. The mean of the man-hour consumption per drawing and the mean per square meter of site area were also established for all departments. These results are summarized in Tables 2 and 3, respectively. It is noted that the standard deviation/mean in the case of man-hour consumption per square meter of area at the benchmarking stage is relatively high when compare to that for the man-hour consumption per drawing. This can be attributed to the variation in the extent of the required work. This is evident in the case of site-related work (landscape and civil). However, the difference was smaller in the case of other disciplines (architectural, structural, HVAC, plumbing, and electrical).

Stage Three: Model Validation
The validation stage extended for about six months and covered 11 new projects. These projects were designed by the three design teams during this period while working at the consulting office within the same environment. The implementation of the quality management system model was the main new parameter added to the existing operating system. As such, it would be acceptable to use the performance of the selected teams as a representation of the effectiveness of the QMS.

The follow up during the validation stage on fulfilling the quality standards was implemented by the writers and the team leaders. Projects adopted the matrix organization with specific assignments of team leaders. The department heads’ authorities and responsibilities were maintained as part of the effective organization’s structure. More details on these quality assurances are included in Abu-Ghazala (2001).

The total built-up area of 76,439 m² was considered for validation while it was 260,898 m² for the benchmarking stage at a ratio of 0.293. The details of the data obtained during the validation stage are included in Table 4.

The data collection methodology during the validation stage was consistent with the one used during the benchmarking stage.

The model validation included a quantitative evaluation of the projects profitability in terms of net saving in the department budget and the overall project budget. The project profitability was limited to the comparison of man hours consumed versus the estimated or the allocated budgets. The validation stage included another quantitative evaluation of the departmental production rate efficiencies as the ratio of the production rate results from the benchmarking to that on new projects for both the man-hour consumption per drawing and man-hour consumption per square meter of area. An efficiency factor equal to 1 indicates that the performance was unchanged after the adoption of the new quality management system. An efficiency factor that is greater than 1 would indicate an improvement. Confidentiality of production rate was assured by scaling the data for the benchmarking and model validation stage.

Results Analysis
Three quantitative aspects of improvement were covered, namely, project design profitability, efficiency levels, and improvement in production.
Project’s Profitability. The analysis of project profitability reflected the actual project financial status as represented in man hours. It was obtained by comparing the estimated design hours allocated to the project to the actual hours consumed for completing the designs. The allocation of budget hours had been carried out by upper management based on market and contract circumstances. Therefore, the project’s profitability was not based on the benchmarking results as they were not available at the time.

Table 5 includes the allocated and actual hours for the 11 projects included in the validation stages. Comparisons are included for the overall design process as well as for each specialized department.

Although it could be claimed that upper management may intentionally increase the number of drawings to reduce risk, the management strategy on this regard was unchanged during benchmarking and the validation phase. Accordingly, it can be stated that the relative measurement and evaluation of profitability and departmental efficiency is relevant in terms of the introduction of the TQM to the processes. Moreover, the man hours/drawing as a benchmarking indicator is not used as an absolute value but rather as a relative and comparative tool. Hence, the possible intentional inflation of the number of drawings was a common factor during both benchmarking and validation processes while the relative indicators were utilized for the purpose of validating the introduction of the quality management system to the design sequence.

Another concern could be that the projects are not similar in size but range from 88,788 to 981 m². However, a closer analysis of the project characteristics indicates that the analysis conducted at the benchmarking stage considers projects ranging from 1158 to 88,788 m². In the same manner the validation stage considers projects ranging from 981 to 17,274 m². Moreover, the data were analyzed for consistency based on the Chauvenet ratio in both the benchmarking and the validation stages.

The comparisons include the project balance (PB) and profit ratio (PR)

\[ PB = \text{allocated hours} - \text{actual hours} \]  \hspace{1cm} (1)

\[ PR = \text{allocated hours/actual hours} \]  \hspace{1cm} (2)

The data collected from the 11 projects that adopted the QMS indicate a consistent improvement in profitability, Fig. 1. The average PR varied from 1.22 to 2.52 for the different departments with an average overall value of 1.34.

Efficiency Levels. The analysis of the departmental efficiency levels reflected the improvements achieved in production rate for both the man hours per drawing and per square meter of area. This measure of the quality system effectiveness would give another angle to evaluate the QMS. This measure compared an on-going practice to a proposed one. Again, for this evaluation, comparison was made between the estimated values by upper management before the start of the design process against the actual values at the end of the design. Table 6 includes the allocated and actual values for both the hours/drawing and hours/m² for different departments and for the overall design. The performance is evaluated with two efficiency ratios (ER)

\[ ER_{\text{hours/drawing}} = \frac{\text{estimated hours/drawing}}{\text{actual hours/drawing}} \]  \hspace{1cm} (3)

\[ ER_{\text{hours/m²}} = \frac{\text{estimated hours/m²}}{\text{actual hours/m²}} \]  \hspace{1cm} (4)

Fig. 2 indicates that the overall average project efficiency level for man hours per drawing is 2.6. The rate on the departmental levels ranges from above 5.43 for the civil department to 1.75 for the HVAC department. On the other hand, the efficiency rate with regard to man hours per square meter indicates more modest levels. The efficiency level results indicate that the overall average project efficiency levels for the man hours per square meter is 2.02. The rate on the departmental levels ranges from above 9.24 for the civil department to 1.67 for the HVAC department. Overall, these results reflect a positive influence of the quality management system on the departments’ performance and the production rate.

The varying ranges of the efficiency improvement for the man-hour consumption per drawing to that of the man-hour consumption per square meter could be attributed to the possible unnecessary inflation of the drawings numbers. The inflation of drawing numbers could be due to many reasons among which include contractual obligations.

Production Process Improvement. The evaluation of the new production process identified the overall improvements in team performance. This evaluation included the mean, standard deviation, and the lower and upper limits of the production process. The production process during the validation stage was compared against the production process of the benchmarking stage.
A reduction of the values of the mean and the standard deviation, and the upper and lower limits would indicate an improvement in the process distribution.

The statistical analysis applied to the data of the validation stage was identical to that applied to the benchmarking stage. The same statistical distribution curves and confidence levels were maintained throughout the analysis. Data were verified for fitness for use and all inconsistent data were rejected and removed based on the Chauvenet ratio.

Figs. 3–6 illustrate in graphical format both the benchmarking and the current performance rates including the mean, standard deviation, lower limit, and upper limit for the man hours/drawing. Figs. 7–10 illustrate in graphical format both the benchmarking and the current performance rates including the mean, standard deviation, lower limit, and upper limits for the man hours per square meter of area.

This analysis discloses that there is an improvement in the general performance rate. The mean values are reduced in varying ranges. The lower and upper limits are also reduced and accordingly the standard deviation is reduced. The reduction in the mean value can directly affect the pricing strategy and accordingly result in a potential increase of market share and business opportunities.

The reduction in the standard deviation is a positive sign of improvement through the reduction of the variances. The pricing strategy can be much more precise and the contingencies can accordingly be reduced to achieve more competitive rates.

The results obtained can be further utilized to carry out correlation analysis and apply regression techniques, which will assist in the estimation of the number of drawings per project and the number of hours required for each project. This is expected to be a very useful tool in the estimation of project budget hours based on project programs and areas.

**Conclusions**

The study is concluded with a proposed QMS for design consultants in an operation manual. The model was based on information gathered from 32 expert designers working in the region and on international quality requirements. The model’s benchmarks were established with 20 real design projects and the validation was executed using 11 additional design projects.

Based on the work undertaken during this study and the collected data, the following specific findings can be listed:

- The review of current practices of design consultants in the Middle East reveals that the applications of the quality management system by design consultants are not yet formalized, that the project design stages are compatible with the internationally references and that a quality management system can be customized to suit design consultants’ practices.
- The main components of the QMS model are based on recognized QMS elements in the literature.
- The implementation of the quality management system is conducted in a real design environment through three stages, namely, awareness, benchmarking, and validation.
- The design profitability for projects when comparing the allocated design hours to the actual design hours shows an improvement with an overall value of 1.34.
- The efficiency’s results for the consumption of man hours per drawing indicate an overall improvement with a ratio of 2.6. At departmental levels, the improvement ranged from 1.75 to 5.43.

### Table 6. Overall Data for Projects’ Efficiencies

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**Note:** NC = not conducted; SD = standard deviation; and efficiency = production rate at validation/estimated production rate.
Fig. 2. Summary of departmental efficiencies ratio

Fig. 3. Performance rate for man hours per drawings (mean)

Fig. 4. Performance rate for man hours per drawings (standard deviation)
**Fig. 5.** Performance rate for man hours per drawings (lower limit)

**Fig. 6.** Performance rate for man hours per drawings (upper limit)

**Fig. 7.** Performance rate for man hours per square meter (mean)
Fig. 8. Performance rate for man hours per square meter (standard deviation)

Fig. 9. Performance rate for man hours per square meter (lower limit)

Fig. 10. Performance rate for man hours per square meter (upper limit)
The efficiency results for the consumption of man hours per square meter of area indicate an overall improvement with a ratio of 2.02. At departmental levels, the improvement ranged from 1.67 to 9.24.

The results of the statistical analysis indicate that the introduction of the QMS resulted in a more consistent design production process. The values of the mean, standard deviation, and limits for the process are lowered showing a more homogeneous design production.

References


