ARTICLE
The Effect of Critical Success Factors in the Application of Six Sigma Methodology on the Quality of Construction Projects’ Output

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ARTICLE INFO

Article history
Received: 2 December 2020
Accepted: 18 December 2020
Published Online: 30 December 2020

Keywords:
Critical success factors
Six sigma approach
Management in quality assurance in construction projects

ABSTRACT

Determining and understanding the critical success factors in order to apply the six sigma methodology in construction organizations to ensure reaching a higher level of construction organizations’ output. The main purpose is divided into the following secondary objectives: Determining the effect of each of the critical success factors (management support, project selection and execution of six-sigma) in the success of the This study aims at application of six-sigma methodology in construction organizations. Determining the effect of critical success factors altogether (support management, project selection and execution of six-sigma) on the quality of construction organizations’ output. This study used the quantitative (descriptive analytical) method through using practical method for the purpose of collecting and analyzing information, and testing hypotheses. This study helps in finding out the factors of success in the application of six-sigma methodology, and how much they affect the quality of construction organizations’ output. This will help find out the level of quality of construction project’s output in terms of speed, cost and precision in results, which will help the improvement mechanism. This in turn will help the construction organization produce high-quality output, which will help the construction organization achieve competitive advantage, and lead to its continuity to work, thus the continuity of organizations, which have vertical association with the construction organization in work too, and this will lead to turning the wheels of the national economy. Results of Statistical Analysis indicate that the relative importance of critical success factors in applying the approach of six sigma in a middle level of importance. Whereas, the arithmetic averages have ranged between (2.77-3.58). Moreover, Results of Statistical Analysis of this study indicate a positive impact on the outcomes of construction organizations for combined critical success factors which are; Senior Management support Factor, Project Selection, Implementation factor of six sigma. Furthermore, Results of Statistical Analysis indicate a positive impact of applying six sigma approach on the quality of the outcomes of construction organizations.

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1. Introduction

In light of globalization, fierce competition, and rapid changes in the external environment, construction organizations are seeking to cope with these changes. Consequently, construction organizations become bound to look for ways that guarantee its continuity and quality, and to focus on the most important aspects that are considered as decisive and critical in construction organizations, and through which objectives can be reached efficiently and effectively. In addition, construction organizations focus on the workers inside the construction organization, the type of predominant organizational culture, how much supportive they are of development, and coping up with change and improvement systems. Therefore, it is necessary to adopt and support quality management systems. Many construction work organizations widened the scope of initiatives to follow and apply the philosophy of total quality management, and methodologies listed within this philosophy. One of the most important methodologies of total quality management is six-sigma methodology.

The six-sigma methodology involves measuring the improvement of the ability of organizational processes in order to get faultless products through integrating a wide range of tools and methods in the organization to improve the performance and organizational profit. Construction organizations have realized the importance of critical success factors in the application of six-sigma methodology to reach the objectives that they are seeking to achieve taking into account opportunities and costs, and controlling them.

Critical success factors for six-sigma methodology are a number of strategies, and methodologies which symbolizes basic success indicators to ensure the organizational quality and competitiveness.

The study aims to answer the following research questions:

(1) Are critical success factors (senior management support, project selection, the execution of six-sigma) effective in the application of six-sigma in construction organizations?

(2) What is the effect of critical success factors for six-sigma methodology on the quality of construction organizations’ output?

(3) What is the effect of applying six-sigma methodology on the quality of construction organizations’ output?

To answer these questions, the study first presents literature review to check the validity of concepts of critical success factors, six-sigma methodology, and total quality management in construction organizations and to form hypotheses. After that statistical analysis is given and statistical results are presented including presenting a discussion on these results, and giving recommendations to construction organizations, and suggestions for future research.

2. Literature Review

2.1 Critical success factors for six-sigma methodology

has defined critical success factors (CSF) as a specified number of things that guarantee a successful and competitive performance of the organization depending on the notions mentioned in the studies. This is the most frequent definition of critical success factors. Similarly, defined it as those characteristics, conditions, or variables, which could have a significant effect on the success of the competitiveness of an organization in a certain field when they are managed properly. has mentioned many ways, such as practical search, case study, Delphi method, group interview, literature review, multi-skill analysis, scenarios analysis, and methodological interviews to determine critical success factors. emphasize that the most used ways to determine critical success factors are questionnaires, whereas states that the most used ways are a case study, surveys in which a list of questions related to critical success factors for each factor, or the relation of individual success factor is checked using a significance measure, which indicates that there is a low, medium or high significance.

As to the types of critical success factors for six-sigma methodology, they were based on the study. The researcher classifies it into critical factors and crucial factors. However, he did not explain the bases that he relied on to classify those factors. He has not shown clearly the difference between a critical factor and a crucial factor, whereas conducted a study in which he discussed the reality of applying six-sigma methodology in British organizations. He analyzed critical success factors as soft factors and hard factors as he considers soft factors to be the ones that are related to non-financial and not measurable things, and they are connected to leadership and the involvement of workers, while hard factors are related to financial resources. also carried out a study on the application of six-sigma methodology using an app to make cosmetic products in a Brazilian company. Based on the results of the study, critical success factors in the application of six-sigma methodology have been identified as supportive factors and discouraging ones.

For ease of presenting the previous studies, which included critical success factors, they will be presented in chronological sequence in the following table.
Table 1. Chronological sequence of previous referential studies related to identifying critical success factors in the application of six-sigma methodology

| Sequence | Study                                      |
|----------|--------------------------------------------|
| 1        | (Goldstein, 2001)                          |
| 2        | (Bhaiji & Antony, 2001)                    |
| 3        | (Urdhwareshe, 2004)                        |
| 4        | (Hakeem Khan, 2005)                        |
| 5        | (Kwak & Anbari, 2006)                      |
| 6        | (Martins et al., 2006)                     |
| 7        | (Buch & Tolentins, 2006)                   |
| 8        | (Johnson & Catetwohill, 2008)              |
| 9        | (Coronet et al., 2009)                     |
| 10       | (Gosnik & Vujica Her Zog, 2010)            |
| 11       | (Brun, 2010)                               |
| 12       | (Shahin, 2010)                             |
| 13       | (Zailani & Sashtriga, 2011)                |
| 14       | (Kanjapanykom & Kungvol, 2011)             |

The number of critical success factors for the application of six-sigma methodology, which has been included in previous studies, is 39. The researcher has classified them into 3 basic categories:

(1) Factors for senior management support.
(2) Factors for project selection.
(3) Factors for the execution of six-sigma.

Table 2. Critical success factors in six sigma methodology, which have been mentioned in previous referential studies

| Classification                | Critical success factor                                                                 | Frequency |
|-------------------------------|----------------------------------------------------------------------------------------|-----------|
| Senior management support    | Firm leadership, senior management’s commitment, participation and support.             | 15        |
|                               | Reward and incentive system.                                                            | 5         |
|                               | Technical support, guidance, and direction by the main black belt holder.                | 2         |
|                               | Organizational structure of the organization                                          | 10        |
|                               | The number of people holding black or green belts.                                     | 2         |
|                               | Infrastructure of information technology.                                               | 2         |
|                               | Providing supportive organizational resources.                                         | 2         |
|                               | Dividing six sigma team to work full-time, or saving sufficient time for application   | 3         |
|                               | The presence of total quality management system                                         | 1         |
|                               | Supportive organizational culture                                                      | 8         |
|                               | Training and education                                                                 | 12        |
|                               | Internal marketing of six sigma methodology                                            | 1         |
|                               | Common organizational environment                                                      | 1         |

| Project selection             | Critical success factor                                                                 | Frequency |
|-------------------------------|----------------------------------------------------------------------------------------|-----------|
|                               | Arranging and selecting the project in order of importance                              | 12        |
|                               | The association of six sigma with customers                                            | 7         |
|                               | The association of six sigma with suppliers                                            | 6         |
|                               | The association of six sigma with human resources                                      | 6         |
|                               | The association of six sigma with a strategy for expansion and distribution             | 1         |
|                               | The association of six sigma with accurate and measurable performance standards         | 1         |
|                               | Linking with critical characteristics as to research and cost                           | 1         |
|                               | The objective of the project is to have a significant effect in the organization        | 1         |
|                               | Effective use of six sigma methodology                                                 | 1         |
|                               | Skills of project leadership                                                           | 7         |
|                               | Review and follow-up of the project                                                    | 3         |
|                               | Accountability of project leaders                                                     | 1         |
|                               | Returning the project’s charter properly, in addition to its documentation and evaluation| 1         |

| Execution of six sigma        | Critical success factor                                                                 | Frequency |
|-------------------------------|----------------------------------------------------------------------------------------|-----------|
|                               | Selecting appropriate workers and supervising them                                      | 1         |
|                               | A work team with multiple specializations/jobs                                           | 1         |
|                               | Understanding of the processes related to work                                          | 2         |
|                               | Analyzing reliable and easy-to-collect data                                            | 2         |
|                               | Referring to counselors                                                                 | 2         |
|                               | Participation of the process owner                                                     | 1         |
|                               | Communication, cooperation and exchanging experiences                                   | 6         |
|                               | Realizing and distinguishing six sigma results                                          | 1         |
|                               | Knowledge and statistics                                                                | 1         |
|                               | Understanding of six sigma, its tools, methods and measures.                           | 9         |

Based on [41] study, the benefits of determining critical success factors for six sigma methodology is summarized by the following:

(1) Organization management helps in determining what has to be focused on, and ensures that it will undergo a precise and continuous examination.

(2) Organization management helps to develop performance indicators, and good measures for these factors, and control them.

(3) It allows a clear definition of the amount of information that has to be collected by the organization, and restricts the collection of unnecessary data.

(4) Attracting the attention of organization management to rely on general data to prepare their reports, and infor-
2.2 Six Sigma Methodology

Many researchers \cite{17,29} tried to describe six sigma in a single or two definitions. Despite that, it turns out that there are at least three definitions so as six sigma can be looked at as a metric tool, a mindset and methodology \cite{16,36}. According to researchers \cite{20,23,32,37,44}, the first logical and most common definition of six sigma is a mathematical expression (a measuring tool) as this is a basic statistical definition, which refers to standard deviation in statistical population, and measures the difference and deviation from the value of arithmetic mean. Others like \cite{25} defined six sigma as a statistical term to perform a process which causes only a 3.4 fault in every one million chance for the faults to happen (DPMO), i.e. with a precision that equals to 99.99966%, which is considered to be a value, that is close to perfection \cite{1,5}. According to \cite{4,10,19}, a second definition of six sigma is that it is considered as a mindset which emphasizes the focus on customers and intended improvement to organizational process as six sigma philosophy considers that there is a direct relation between the number of faults in the product, wasting operating costs, and the level of customer satisfaction. In such a mindset, individuals are ready to work in teams in order to accomplish six sigma and its final objective of reducing variability in production process to a level that does not exceed 3.4 flaw in every million chance for faults to happen \cite{5,30}.

\cite{29} explained that the reason behind relying on six-sigma rather than five-sigma or seven-sigma is that five-sigma will not meet the customers’ demands, and seven-sigma will not add a great value. He considers six sigma as very close to perfection, and this has made six sigma a more realistic and attainable goal \cite{23}.

A third definition of six-sigma is that it is seen as an improvement methodology, which is called DMAIC as it has been expressed by the researchers \cite{1,25,27,22,35}, and it represents five phases: identification, measure, analysis, improvement and control. \cite{22} defined it as a comprehensive and flexible system for achieving the organization’s success, maintaining this success, and improving it to the maximum through accurate understanding of customers’ needs, relying on facts, data and statistical analysis, and paying attention to process management, improvement and identification \cite{14}. According to \cite{39}, six sigma is a strategy for improving the organization, and is used to increase profit, minimize loss, reduce the low quality costs, and improve the effectiveness and efficiency of all processes to meet customers’ needs and expectations \cite{3}. Measure indicators, in any six sigma project, aims at determining the performance of production processes in a quantitative manner, which make it easy to study the causes for this level of performance. There are many indicators that can be used as referred to by \cite{14,15,31}. (1) Number of faults in every million chance of happening (DPMO). (2) Cost of low quality (COPQ).

In general, quality cost is divided into four categories:

\begin{enumerate}
\item Prevention costs.
\item Appraisal costs.
\item Internal failure costs.
\item External failure costs.
\end{enumerate}

\begin{enumerate}
\item Rolled through put yield.
\item Return rate.
\item Number of problem reports.
\item On-time delivery.
\end{enumerate}

Figure 1 illustrates the structure (members) of six sigma, that give advice to construction organizations so that they carry out their projects successfully knowing that the number of those members depend on the organization’s size, and the complexity level of executed projects. There are also graded levels of skills that the members of six sigma teams are required to have according to the importance of this skill in performing the roles assumed by them.

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{six_sigma_structure.png}
\caption{Six sigma structure of construction organizations}
\end{figure}

Source: Guion, C. The Impact Of TQM and Six Sigma Improvement Methodologies On Organizational Performance, Doctoral Dissertation, Capella university, United State.

Not all construction projects are appropriate to be six sigma projects. For instance, construction projects whose solutions are already known (causes, problems, and ways to solve them) are not appropriate to be six sigma proj-
The importance of selecting appropriate construction projects lies in that identification and poor selection of construction project lead to late results, which in turn lead to great frustration\textsuperscript{18}. There are many indicators that can be relied on to select the construction project so that they would be within six sigma projects according to\textsuperscript{17,26,27}.

(1) The association of the project with the organization’s strategic objectives.

(2) The effect that the project has on increasing the satisfaction of internal and external customers.

(3) Probable proceeds from carrying out the project, which are considered to be the main standard for selecting projects in many organizations.

(4) The availability of measures (measurement indicators). In the event that they are not available, there is a possibility for identifying them in a period of time which matches with the period of project execution.

(5) The easiness of collecting data about input and output of the process necessary for carrying out the project, and the clarity of how information are gathered during each of the production process phases.

(6) The period of time necessary to accomplish the project. It is preferred that this period ranges from 4 to 6 months.

(7) The possibility of completion and success of the project within the time limit and the available resources.

(8) The recurrence of problems in the process. It should be noted that priorities are not to be sorted out depending on their recurrence only because it could increase the failure cost of partial faults.

(9) The necessary resources to accomplish the project including human and financial resources.

(10) The urgent need to carry out the project.

(11) Focus on the critical characteristics of quality, as a project is considered to be good when it has a full effect. Internal and external customers should be able to perceive a notable difference.

(12) The level of project complexity.

(13) Organizational effect in terms of benefits that are accrued (acquiring new knowledge) of organization works.

Six-sigma project has to be supervised regularly to determine how much it is compatible with the timetable, the need for any modifications in work plan, and what has been reached. Regular reports are submitted to the project sponsor. Supervision process is done in several ways, such as carrying out the final reviews of phases at the end of project execution and before the project. The review is done in the presence of publication manager, project sponsor, main black belt holder, and black or green belt holder. A short presentation on the work that has been done till the meeting date is given by black or green belt holder and all questions are answered put by the present members (ISO 13053-1:2011).

2.3 Total Quality Management in Construction Projects

According to\textsuperscript{22,7,12}, the definition and concept of quality is rather vague, and is mostly related to the special opinion of the customer or user according to their need and objective of the product. However, in essence quality is meeting the basic requirements of quality by the product or service. The quality of building and construction work\textsuperscript{51,38} necessarily means that such works should include mainly safety factors, durability, and the possibility for use so that it serves their purpose during its investment, and it should gain the trust of its users as well as their satisfaction. From the viewpoint of\textsuperscript{43,49}, the concept of quality in construction could be mainly related to the following main aspects and concepts:

(1) Job: Does the construction serve its stated purpose?

(2) Economics: Does the construction represent the value of money?

(3) Age: Is the construction durable and capable of withstanding with time?

(4) Aesthetics: Is the construction satisfactory in appearance and does the construction match with the constructions around it?

(5) Consumption and economic power: Is the construction considered to be a good investment?

This means that quality management and quality itself in construction is related to a number of factors and expectations surrounding construction process, most notably perfection, durability, and reliability\textsuperscript{9,43}.

In order to achieve quality in construction industry, the construction project has to be viewed as as a number of activities that start with the user’s need and end with the user’s feeling of satisfaction and happiness\textsuperscript{9,23}. According to\textsuperscript{7,40}, the concept of quality in construction projects depends on two basic principles. The first principle is the customer’s satisfaction and the second one is constant improvement. Customers are of two types: external customer and internal one. The external customer is not a part of the productive organization, but they are affected by it through using the product or service. Internal customers are people or groups within the productive organization, that receive information from other people and groups within the productive body, and satisfying them is a basic part of supplying external customers with a quality product.

Each party in the production process has three roles: a supplier, a process executor, and a customer. This three-role concept is present at all levels of construction process.
and its phases, architects and engineers are customers for the owners and executors of the process of study and design. At the same time, they supply plans and specifications to the contractor, who in turn attracts a customer for plans and specifications laid down by architects and engineers. The contractor is an executor of the construction process. The contractor also supplies the construction or the service to the owner. The success of this entire process relies heavily on the design efficiency produced by architects and engineers as the possibility for controlling the quality level of the finished product decreases with the advancement of the project, and this emphasizes the importance of focusing on the customer’s requirements\textsuperscript{[12,13]}.

The second principle is constant improvement. The gap between the customer’s needs and the ones that have been met can be bridged by applying quality track analysis through the Deming cycle, which is illustrated by the following figure 2:

![Deming cycle diagram](image1)

**Figure 2.** Constant improvement

Source: \textsuperscript{[7]}

![Steps of TQM in construction organizations](image2)

**Figure 3.** Steps of TQM in construction organizations
3. Methodology of the Study

The researcher used the quantitative (descriptive analytical) method through using practical method for the purpose of collecting and analyzing information, and testing hypotheses. The descriptive analytical approach is considered to be a way the researchers rely on to obtain adequate and accurate information, which reflect social reality, and help analyze its phenomena to gain thorough and detailed knowledge about its problems, and acquire a better and more thorough understanding of the phenomena related to it since it is one of the most used approaches to study social and human phenomena and is suitable for them and the topic of research [13].

3.1 Data Collection Methods

For the purpose of obtaining secondary and primary data to achieve the study’s objectives, the researcher used two main data sources:

(1) Secondary sources: To address the theoretical framework, the researcher referred to secondary sources, which are represented by books, related Arabic and foreign references, periodicals, articles, reports, research, and previous studies, which dealt with the study’s topic, and looked up in different databases (proquest, psychlnfo, Elsevier, social science Abstracts.

(2) Primary sources: To deal with the analytical aspects of the study’s topic, questionnaire has been used as a main tool. The questionnaire included a number of expressions, which reflect the study’s objectives and questions so that these questions are answered by individuals of the study sample. 5-point Likert scale has been used so that every answer is assumed a relative significance. For the purposes of analysis, the statistical program SPSS will be used.

3.2 Validity of the Study Instrument

validity: To check face validity of the measure, the questionnaire has been presented to a number of arbiters, who are members of teaching staff majored in management sciences, statistics, project engineering in Jordanian public and private universities. The researcher has responded to the arbiters’ opinions, and made the necessary modifications in light of their suggestions. The total response accounts for 100%, which gives reassurance about the validity of study results.

3.3 Reliability of the Study Instrument

In order to prove that the questionnaire measures the intended variables, and check its validity, internal consistency of measure’s paragraphs has been tested, as the consistency of a measure has been evaluated by calculating Cronbach’s Alpha.

From a practical aspect, the value (Alpha ≥ 0.60) is considered to be acceptable in scientific research. Look at the table 3.

Table 3. Internal consistency reliability coefficient of questionnaire dimensions (Cronbach’s Alpha)

| Variable                  | Dimension                          | Number of paragraphs | Reliability coefficient |
|---------------------------|------------------------------------|----------------------|-------------------------|
| Critical success factors  | Senior management support          | 7                    | 81.2                    |
|                           | Project selection                  | 6                    | 83.4                    |
|                           | Six sigma execution                | 6                    | 81.6                    |
| Six sigma methodology     | -                                  | 6                    | 85.6                    |
| The quality of construction organizations’ output | - | 6 | 87.1 |
| Questionnaire as a whole  | -                                  | 6                    | 87.8                    |

Cronbach’s Alpha inditors show that the study’s instrument enjoys generally a high reliability rate, and it is able to achieve the study’s objectives according to [45]. It is clear from table 3 that the reliability coefficient of all questionnaire dimensions is 87.8, which is undoubtedly a high rate, and this confirms that questionnaire phrases are closely related and consistent. In terms of questionnaire dimensions, it turns out that all dimensions of the questionnaire enjoy a high reliability coefficient, which increases the trust in the studied data and reliance on them to test the study’s hypotheses.

3.4 Study Sample

The study sample is comprised of Jordanian construction organizations in the capital city of Amman. The number of construction organizations contained in the study sample amounts to (61) . The sample population accounts for (220) out of 800 employees. (220) questionnaires have been distributed randomly. (214) questionnaires have been returned with a rate of (87.2%). Nine questionnaires have been excluded because they are not valid for statistical analysis. Therefore, the number of questionnaires, which are valid for statistical analysis, amount to (205), while the rate of questionnaires valid for statistical analysis accounts for 95.79% of the total of questionnaires distributed for statistical analysis.

3.5 Used Statistical Processing

The study has adopted the statistical package (SPSS) in data processing and obtaining the results used to answer
the study’s questions, and test its hypotheses, and the following statistical methods and tests were used:

(1) Descriptive statistics measures: for the purpose of ordering the variables, and studied dimensions according to their relative importance, and then answering the first study’s question.

(2) Cronbach’s Alpha test: to ensure the reliability of the used measure.

(3) Simple and multiple regression test: to test the study’s hypotheses.

3.6 Results of Statistical Processing

(1) Results of statistical processing related to the study’s first question

Are critical success factors (senior management support, project selection, the execution of six-sigma) significant for the application of six-sigma in construction organizations?

To answer this question, the researcher used arithmetic means, and standard deviations to describe the average significance level of each of the critical success factors as it is shown in the following table.

Table 4. Arithmetic means and standard deviations and significance level of critical success factors

| Variable                      | Arithmetic mean | Standard deviation | Class | Significance level | Relative significance |
|-------------------------------|-----------------|--------------------|-------|-------------------|-----------------------|
| Senior management support     | 3.22            | 0.96               | 2     | 0.000             | Medium                |
| Project selection             | 2.77            | 0.99               | 3     | 0.000             | Medium                |
| Six sigma execution           | 3.58            | 0.93               | 1     | 0.000             | Medium                |

Table 4 represents sample population’s answers to expressions related to the content of critical success factors, where arithmetic means ranged from 2.77 to 3.58. Six-sigma execution came first with an arithmetic mean accounting for 3.58, a standard deviation amounting to 0.93, and a medium significance level. Senior support management has an arithmetic mean of 3.22, a standard deviation of 0.96, and a medium significance level. Project selection has an arithmetic mean of 2.77, a standard deviation of 0.99, and a medium significance level.

(2) The results of statistical processing related to testing the study’s hypotheses

The researcher tested the primary and secondary hypotheses of the study, where this analysis focused on testing the degree to which primary and secondary hypotheses are accepted or rejected through using simple and multiple regression analysis.

First primary hypothesis

$H^1_o$: There is no statistically significant effect of critical success factors altogether (senior support management, project selection, six sigma execution) on the quality of the construction organizations’ output at significance level $(0.05 \geq \alpha)$.

Table 5. Results of regression analysis of the effect of critical success factors altogether (senior support management, project selection, and six-sigma execution) on the quality of outputs of Jordanian constructions organizations

| Correlation coefficient $R$ | Determination coefficient $R^2$ | Beta | $t$ value | Sig* |
|-----------------------------|---------------------------------|------|-----------|------|
| 0.39                        | 0.15                            | 0.39 | 8.31      | 0.00 |

It is obvious from table 5 that correlation coefficient of the effect of critical success factors altogether (senior support management, project selection, six sigma execution) on the quality of the Jordanian construction organizations’ output amounted to 0.56. The value of F-statistic accounts for 43.31, which is significant at level $(0.05)$ and less. Therefore, the first primary hypothesis, in its null formula, will be rejected and the primary hypothesis, in its alternative formula will be accepted. This hypothesis states that there is an effect of critical success factors altogether (senior support management, project selection, six sigma execution) on the quality of the Jordanian construction organizations’ output. The table also illustrates that Beta coefficient amounts to 0.80, which shows a positive effect whereas the more critical success factors are practiced and applied, the more positive the effect is on the quality of the Jordanian construction organizations’ output. Moreover, it is apparent from determination coefficient $R^2$ that critical success factors altogether explain $(31\%$ of the variation in the quality of Jordanian construction organizations’ output, and that $68\%$ of the unexplained difference is due to other factors.

First secondary hypothesis

$H^2_o$: There is no statistically significant effect of senior management support on the quality of the construction organizations’ output at significance level $(0.05 \geq \alpha)$.

Table 6. Results of regression analysis of the effect of critical success factor (senior support management) on the quality of the Jordanian construction organizations’ output

| Correlation coefficient $R$ | Determination coefficient $R^2$ | Beta | $t$ value | Sig* |
|-----------------------------|---------------------------------|------|-----------|------|
| 0.39                        | 0.15                            | 0.39 | 8.31      | 0.00 |

As can be seen from the table 6, the Correlation coefficient $R$ of the effect of critical success factor (senior
support management) on the quality of the Jordanian construction organizations’ output amounts to (0.39). The T-statistic accounts for (8.31), which is significant at level (0.05) and less. Thus, the first secondary hypothesis, in its null formula, will be rejected and the hypothesis, in its alternative formula will be accepted. The hypothesis stipulates that there is an effect of the critical success factor (senior support management) on the quality output of Jordanian construction organizations. Furthermore, the table illustrates that Beta coefficient amounts to (0.39), which shows a positive effect, i.e. the more senior management support is practiced and applied, the more positive the effect is on the quality of the construction organizations’ output. In addition, it is obvious from the value of determination coefficient R² that critical success factor explains (15%) the variation with the quality of Jordanian construction organizations’ output, and that (83%) of the unexplained variation is attributed to other factors.

**Second secondary hypothesis**

\(H_{1,2}^*:\) There is no statistically significant effect of critical success factor (project selection) on the quality of the construction organizations’ output at significance level \((0.05 ≥ α)\).

**Table 7.** Results of regression analysis of the effect of critical success factor (project selection) on the quality of the Jordanian construction organizations’ output

| Correlation coefficient R | Determination coefficient R² | Beta coefficient B | \((t)\) value | \((t)\) significance (sig) |
|---------------------------|-------------------------------|-------------------|---------------|--------------------------|
| 0.52                      | 0.27                          | 0.52              | 11.90         | 0.00                     |

As can be seen from the table 7, the Correlation coefficient R of the effect of critical success factor (project selection) on the quality of the Jordanian construction organizations’ output accounts for (0.52). The T-statistic amounts to 11.90, which is significant at level (0.05) and less. Therefore, the hypothesis, in its null formula, will be rejected and the hypothesis, in its alternative formula will be accepted. The hypothesis stipulates that there is an effect of the critical success factor (project selection) on the quality output of Jordanian construction organizations. The hypothesis states that there is an effect of the critical success factor (project selection) on the quality of the Jordanian construction organizations’ output. Moreover, the table shows that Beta coefficient accounts for (0.52), which shows a positive effect. In other words, the more critical success factor (project selection) is practiced and applied, the more positive the effect is on the quality of the construction organizations’ output. Additionally, it is apparent from the value of determination coefficient R² that critical success factor explains (27%) of the variation in the quality of Jordanian construction organizations’ output, and that (73%) of the unexplained variation is due to other factors.

**Third secondary hypothesis**

\(H_{1,2}^*:\) There is no statistically significant effect of critical success factor (six-sigma execution) on the quality of the construction organizations’ output at significance level \((0.05 ≥ α)\).

**Table 8.** Results of regression analysis of the effect of critical success factor (six-sigma execution) on the quality of the Jordanian construction organizations’ output

| Correlation coefficient R | Determination coefficient R² | Beta coefficient B | \((t)\) value | \((t)\) significance (sig) |
|---------------------------|-------------------------------|-------------------|---------------|--------------------------|
| 0.40                      | 0.16                          | 0.40              | 8.60          | 0.00                     |

As can be seen from the table 8, the Correlation coefficient R of the effect of critical success factor (six-sigma execution) on the quality of the Jordanian construction organizations’ output is (0.40). The T-statistic accounts for (8.60), which is significant at level (0.05) and less. Thus, the hypothesis, in its null formula, will be rejected and the hypothesis, in its alternative formula will be accepted. The hypothesis states that there is an effect of the critical success factor (six-sigma execution) on the Jordanian construction organizations’ output. Furthermore, the table illustrates that Beta coefficient amounts to (0.40), which shows a positive effect, i.e. the more critical success factor (six sigma execution) is practiced and applied, the more positive the effect is on the quality of the Jordanian construction organizations’ output. In addition, it is clear from the value of determination coefficient R² that (16%) of the variation is attributed to critical success factor (six sigma execution), and that (84%) of the unexplained variation is due to other factors.

**Second primary hypothesis**

\(H_{2}^*:\) There is no statistically significant effect of six-sigma methodology on the quality of the construction organizations’ output.

**Table 9.** Results of regression analysis of the effect of six-sigma methodology on the quality of the Jordanian construction organizations’ output

| Correlation coefficient R | Determination coefficient R² | Beta coefficient B | \((t)\) value | \((t)\) significance (sig) |
|---------------------------|-------------------------------|-------------------|---------------|--------------------------|
| 0.36                      | 0.17                          | 0.36              | 7.52          | 0.00                     |

As can be seen from the table 9, the Correlation coefficient R of the effect of six-sigma methodology on the quality of the Jordanian construction organizations’ output
accounts for (0.36). The T-statistic amounts to (7.52), which is significant at level (0.05) and less. Therefore, the second primary hypothesis, in its null formula, will be rejected and the hypothesis, in its alternative formula will be accepted. The hypothesis stipulates that there is an effect of six-sigma methodology on the quality of Jordanian construction organizations’ output. Moreover, the table shows that Beta coefficient accounts for (0.36), which shows a positive effect. In other words, the more six sigma methodology is practiced and applied, the more positive the effect is on the quality of the Jordanian construction organizations’ output. Additionally, it is apparent from the value of determination coefficient $R^2$ that six-sigma methodology explains (17%) of the variation in the quality of construction organizations’ output, and that (83%) of the unexplained variation is attributed to other factors.

4. Discussion and Recommendations

4.1 Discussion

Most of the reference studies, which have been investigate, have many things in common, most notably: reaching the consensus that senior management commitment and support, education and training, providing resources, understanding of six-sigma, its tools, methods and measures, leadership, dividing six sigma team, allocating adequate time. These things are the most important success factors to apply six-sigma methodology in construction organizations.

Previous studies have indicated that there are main obstacles to the application of six sigma methodology in construction organizations, which requires thinking of effective ways to remove, or minimize their severity and effect. These obstacles relate to the mindset of senior management, and its workers, their weak interest in six sigma methodology, not understanding this methodology and the used statistical methods in the field of quality in general, lacking adequate skills to lead the projects, no readiness of most instruments to provide important resources to apply and resist change activities, and adopt new practices, not allowing the possibility of proper training and experts in the field of six sigma, a weak culture of quality, the rarity of specialists in this field, unwillingness to adopt new management practices, doubt about the benefits of six sigma application, the inappropriateness of reward and incentive system, keeping away from investment by senior management in training, no interest in measurement systems, and misunderstanding of the topic of measurement instruments and equipment.

Work organization can accrue many benefits from applying six-sigma in construction organizations. These benefits include reducing the rate of fault and faulty units, identifying the problem area in the organization, measuring the performance of processes in a quantitative manner, determining the financial value of the loss of faulty pieces which might be detected, improving culture and behavior related to communication, and the ways to solve problems, raising workers’ morale, shedding light on the importance of carrying out and accurate and precise measurements. Work organization can apply six-sigma successfully by following a road map, which includes four phases: development (expansion), stability, turning to external bodies to provide training and consultation.

4.2 Recommendations

The researcher offers a set of recommendations, which can be divided into three groups:

(1) Special recommendations to construction organizations applying six-sigma methodology.

(A) Maintaining improvements achieved by six-sigma application.

(B) Qualifying a number of workers to hold all types of belts with the aim of starting to expand in applying six-sigma in different departments of the organization.

(C) Considering the establishment of a special hierarchical structure of six-sigma as a future goal, and seeking to achieve it through providing important resources, pleasant work environment, support from senior management.

(D) Training workers to use the measurement tools properly.

(E) Reconsidering the way regular meetings are managed so that it become more effective, and providing adequate training in leadership skills, problem solving, the way to act in brainstorming sessions.

(F) Laying emphasis on the importance of the customer’s voice, and measuring their satisfaction better.

(G) Modifying incentive and reward system so that it supports six-sigma application.

(2) Special recommendations to construction organizations wishing to apply six sigma:

(A) Providing the requirements for critical success factors.

(B) Turning to competent counselors to evaluate what is necessary to apply and different training needs.

(C) Turning to guideline to apply six-sigma, and following their phases and steps accurately without ignoring any of them.

(D) Developing effective systems for quality management before applying six-sigma as it provides a basis that lead to the success in applying this methodology.

(3) General recommendations to policymakers in this sector:
(A) Encouraging construction organizations to apply six-sigma by civil engineers’ unions.

(B) Studying the mechanism of preparing a cadre in universities that is capable of giving accredited training to qualify belt holders.

(C) Launching a set of training programs in six-sigma methodology by educational institutions.

(D) Developing educational plans and programs by higher education institutions.

In addition to the recommendations, the researcher suggests a number of titles for to researchers, who wish to conduct studies in the future on the same topic and these titles are represented as follows:

(1) Studying the ways to overcome difficulties of applying six-sigma in construction organizations, and identifying the requirements for providing critical success factors to succeed in its application.

(2) Analytical study of the reality of quality culture in construction organization.

(3) A case study of the success in applying six sigma in construction organizations, which has a certificate of conformity to standard specifications, and analyzing the effect of availability of a quality management system on the application process.

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