Implementation of Six Sigma Tools in Building Construction

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Abstract

Since the building's problems in construction projects have increased, there is serious need to focus on the quality of building constructions industry. Even though Six Sigma has been employed in the manufacturing and other industries, it is quite a fairly new impression in the construction project. Therefore, a case study of how Six Sigma has been established in the building industry to identify problems of building projects in Amman. The main objectives of this case study to investigate the implementation of Six Sigma tools to investigate the main building's problems and the root causes of these problems. Also, the study intends to implement these tools to improve the performance and the efficiency of construction projects. To achieve this objective, the data is collected from government institutions to identify the main building problems and then the survey-based approach is used in order to identify the root causes of these problems. The main results of six sigma tools showed the main problems in building projects in Amman are excavation collapse, defective water proofing system at roof and bad drainage system of rainwater and lack of ventilation which represent 52.2% of total problems in building projects. Although the concept of using Pareto analysis and cause and effect diagrams have been around for a considerable period of time, the paper has successfully shown how can make use of these simple Six Sigma tools to find out the root causes of the problem and allocate resources to eliminate such problems. This study may trigger an important debate over the research and implementation of Six Sigma in the construction industry of developing countries that may greatly benefit by improving the quality of their projects.

Key words: Six Sigma tools, excavation collapse, building construction.

1. Introduction

There are numerous problems associated with quality in projects constructed by international firms. The construction problems refer to inaccurate design, faulty execution, and bad concrete mixtures. A lot of construction problems

necessitated making studies and researches in quality of building constructions sector. Jha (2006) concluded that the factors having positive contributions to achieve the desired quality level includes project manager's competence, top management support and their competence, interaction between project participants, owner's competence, and monitoring and feedback by project participants. Jalote (2005) discussed the role of problem analysis, as a feedback mechanism, to improve the quality of the project. The author also showed how analysis of problems found in one iteration can provide feedback for problem prevention in later iterations, leading to quality and productivity improvement. Many researches had taken place on quality in construction projects that discussed their problems, causes structural problems in buildings. Seng Kian (2001) examined the causes of problems in building construction in Singaporean isolated the following as most frequent building problems in commercial buildings, leaky roof and walls; floor problem; and and improper outlet pipe. Ismail et al (2012). demonstrated that, based on analysis of concrete problems factors in Malaysia, there are seven types of problems seven types of problems. Shah (2009) in his research found that the most structural problems are: inaccurate design, faulty execution, bad concrete mixture, building insulation problems, changing the function of buildings, and inadequate drawings and specifications. According to above mentioned studies there are five main categories of concrete structure problems namely: design errors, building materials, geotechnical problems, construction errors and unpredicted errors. Mansor (2012) Showed that there are numerous problems and problems which are common to historical buildings parts such as roofs, walls, floors, ceilings, toilets, doors and windows.

Therefore, the contractor can improve performance of quality in his construction by analyzed the causes of buildings problems using Six Sigma tools like check lists, Pareto diagram, cause and effect diagrams and control charts to determine the main problems that occurred in projects. A Six Sigma became a useful method as a performance indicator and process improver for the companies from different industry. Bechtel Corporation reported substantial savings by using Six Sigma program to identify and prevent rework and defects from design to construction (Kwak and Anbari, 2006). Schonberger (2008) and Chakravorty (2009) have pointed out that the target of Six Sigma is to create a higher supposed value of the services of company in the eyes of customer. Six Sigma is a disciplined method of using extremely rigorous data gathering and statistical analysis to pinpoint sources of errors and ways of eliminating them" (Aboelmaged 2010). It helps to decrease costs, increase quality by improving process and reduce the production time (Aboelmaged 2010, Han 2008, Hahn 2005, Antony 2002).

The main objective of this study, therefore, is s to investigate the level of implementation of Six Sigma as a process improvement method. In addition to identify importance of the causes defect influencing in Jordan's construction industry, so that the findings can be used by local and international contractors, in addition to consultants, to develop a wider perspective of the significant causes impacting on the problems and provide guidance to construction project managers for effective planning; and thus, assist in achieving a reasonable level of competitiveness and a cost-effective operation. The paper provides a discussion of the results obtained, and concludes, based on the findings of the study, geared toward improving the quality level of constructer to overcome main building problems in the Jordan.

2. Research Methodology

The research methodology was divided into the following steps:

Step 1: This step consists of collecting real data about problems that happened in Amman buildings constructions from the government institutions to determine the problems.
Step 2: In this step Six sigma tools including check lists, histogram, Pareto diagram, cause and effect diagrams have been used to figure out the vital Amman building problems.
Step 3: The scope of this step is to the find out the causes of vital problems by using questionnaire form which was distributed to a select sample of grad (A) contractors and consultant engineers.

3. Results and Discussion Approach

3.1 Identify the main building problems

As mentioned before a real data of problems has been collected from real existing building projects. The Six sigma tools applied to these problems to determine their types, frequencies, and causes of vital problems. The following Six sigma tools were used in analysis of collected data:

1. Check list sheet

As illustrated in Table 1. The check list sheet is a measurement and collection of Amman building problems data forms. The check list is the basis for any analysis and the data collection needs to be planned in such a way to ensure that information is relevant and comprehensive.

Table 1. Check list sheet of buildings problems in Amman

Buildings Problems	Frequency	Total
Bad sanitation system	卌卌卌卌卌卌卌卌	40
Collapse of retaining walls	卌卌卌|	16
Use of brick instead of concrete for retaining walls	卌卌卌卌卌卌卌卌	40
Slab settlement or excessive slab deflection	卌卌卌卌卌卌||	32
Slabs collapse	||	2
Problems in foundations	卌卌卌卌||||	24
Excavations collapse	卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌	120
Cracks in the ground slab	卌卌卌卌卌卌卌卌卌|||	48
Cracks in the plaster	卌卌卌卌||||	24
Cracks in the brick walls	卌卌卌|	16
Cracks in the retaining walls	卌卌卌卌||||	24
Lack of ventilation in buildings	卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌|	186
Water leak under foundations	卌卌卌卌||||	24
Water leakage inside buildings	卌卌卌卌卌卌卌卌卌|||	48
Unsafe construction for stone walls	卌卌卌卌卌卌||	32
Problem in water proofing system at roof and bad drainage system of rainwater	卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌卌|||	168
Problems in the installation of elevators	卌卌卌卌卌卌||	32
Unprotected electricity wires and problems in power rooms	卌卌卌卌卌卌||	32

2. Histogram

Histograms or Frequency distribution diagrams are bar charts showing the distribution pattern of the Amman building problems grouped in convenient class intervals and arranged in rank of magnitude (See Figure 1).

3. Pareto diagram

From the data gathered through different sources Pareto chart was developed and important causes of the problems related to quality were analyzed. Pareto chart has benefit in economic term; it breaks a big problem down into smaller items, identifies the most significant factors, shows where to focus efforts, and allows better use of limited resources. Pareto principle (Vital Few, Useful Many) tells that the most effects come from relatively few causes; that is, 80% of the effects come from 20% of the possible causes. Pareto chart (See Figure 2) illustrates that the vital problems are: lack of ventilation in buildings, the percentage of its repetition in Amman buildings is 20.5%, water proofing system at roof and bad drainage system of rainwater with percentage 18.5% and excavations collapse with percentage 13.2%. Solving the above mentioned vital problems means that 52.2% of buildings problems in Amman are solved.

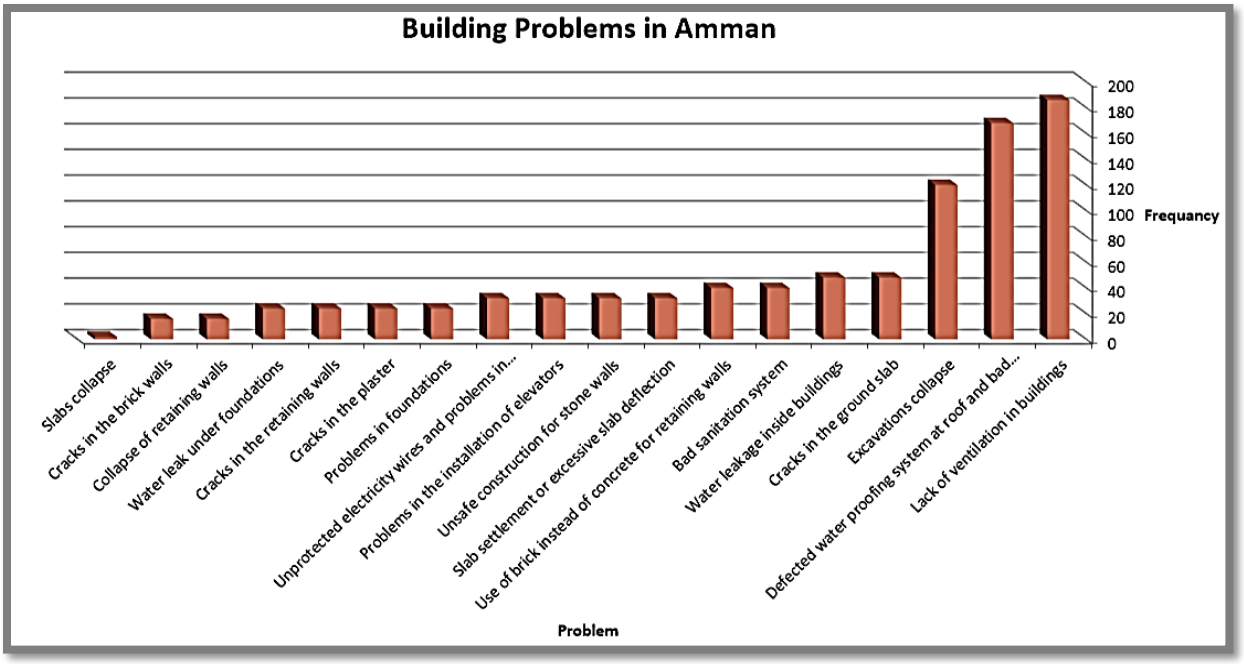

Figure 1. Histogram of Building Problems in Amman

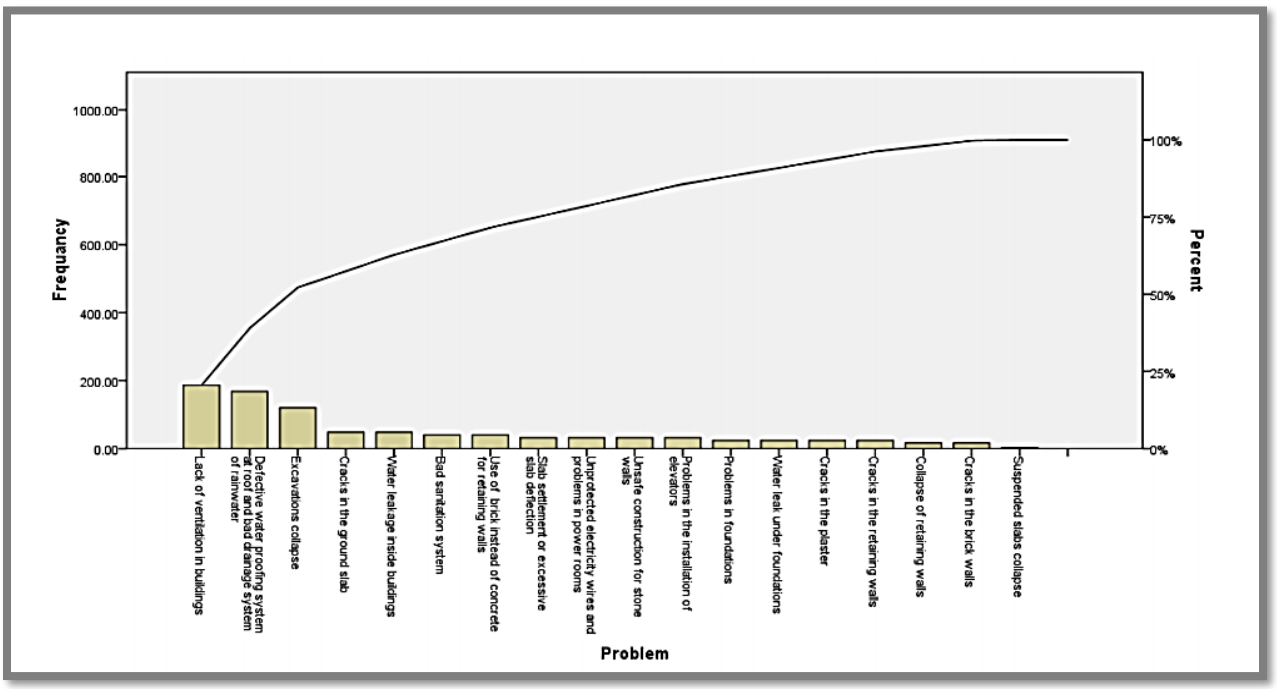

Figure 2. Pareto diagram of buildings problems in Amman

4. Cause and effect diagram

Cause-and Effect Diagram it is a Six sigma tool that shows systematic relationship between a result or an effect and its possible causes. It is an effective tool to systematically generate ideas about causes for problems and to present these in a structured form. From Cause-and Effect diagram it is easily to identify the reasons that are causing an

undesired effect or to identify the factors needed to bring about a desired result. Figure 3 shows causes of building problems that led to poor quality in building constructions.

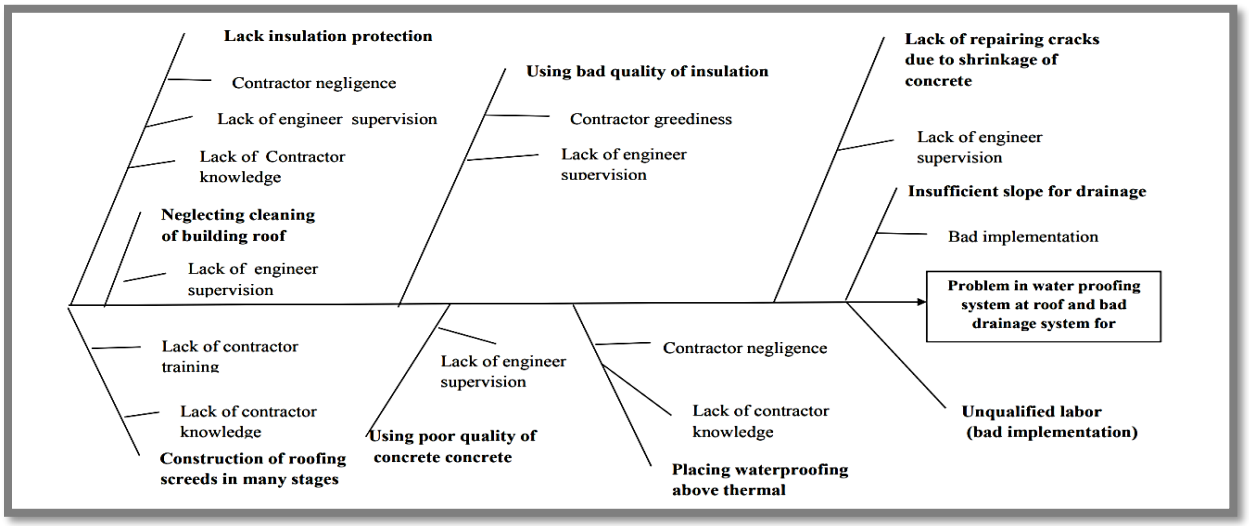

Figure 3. Cause and effect of buildings problems in Amman

3.2 Identify the root causes of the main building problems

A field survey performed to identify the causes of problems that occurring in building projects in Amman. A total of 100 questionnaires were completed by, contractors, consultants, managers, and experienced engineers. The overall response to the survey comprised a total of 49 completed questionnaires, representing approximately 49% response rate. The response from the contractors represents 55% while the responses from consultant represents 45%. The data collected were analyzed using the Relative Importance Index technique.

The overall problems are classified under three major categories as follows: six under the Buildings excavation collapse category; nine under the Defective Water Proofing System at Roof and Bad Drainage System of Rainwater category; and six under Lack of Ventilation category. Furthermore, the category importance indices are quantified, and a comparison is conducted to determine their relevant importance. After the questionnaire responses were collected the next step was analyzing the tabulated answers statistically. Weighted arithmetic mean, standard deviations and t test were calculated and used to evaluate the responses.

1. Buildings excavation collapse

Figure 4 shows the mean, standard deviation and t test of reasons that lead to buildings excavation collapse. It can be seen that reason which states, "improper shoring or sloping for excavation sides" was indicated as the most important reason with mean equal to 4.8, while reason which states "Increased soil density due to the presence of wastewater sum pits" was indicated the less critical reason with mean equal to 1.59.

As shown in table 2, T test illustrates the causes lead to excavation problems different significantly from a given critical mean. The results indicate that improper shoring or sloping for excavation sides, Materials and machinery resting dangerously close to excavation, poor dewatering and drainage of ground and rain water during excavation and Increased soil density due to the presence of wastewater sum pits have a significant level < 0.05, these result lead to conclude that these reasons have main effect on excavation problem more than other causes.

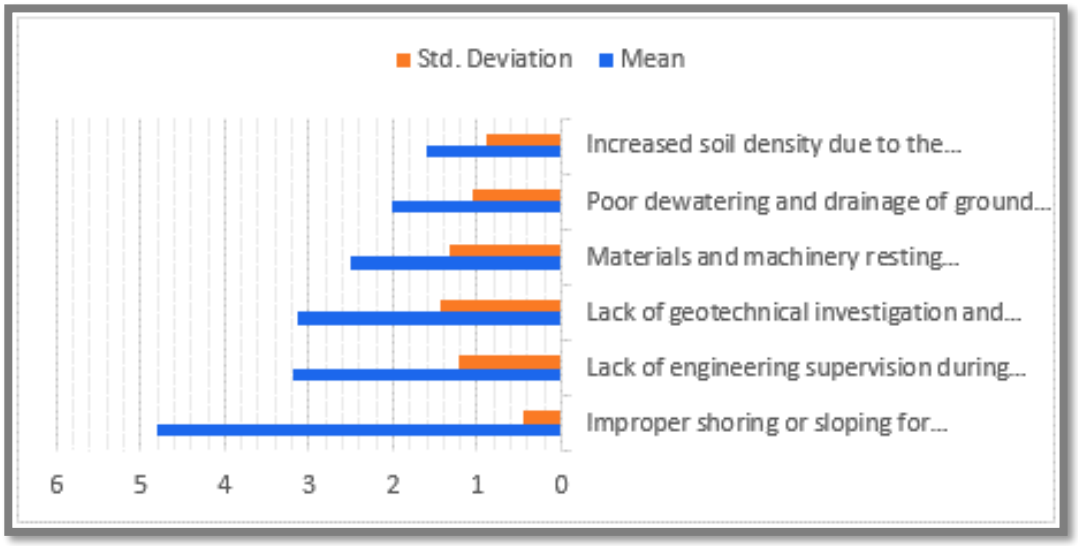

Figure 4. Mean and Standard Division of the Buildings Excavation Collapse Reasons Addressed

Table 2. T Test Value of the Reasons That Lead to of Buildings excavation collapse in Amman

Causes		
	t-test	p-value
Improper shoring or sloping for excavation sides.	27.599	*0.00
Lack of engineering supervision during excavation.	1.183	0.243
Lack of geotechnical investigation and tests.	0.7	0.487
Materials and machinery resting dangerously close to excavation.	-2.558	0.014
Poor drainage of ground and rain water during excavation.	-06.52	*0.00
Increased soil density due to the presence of wastewater sum pits.	-11.12	*0.00

2. Defective Water Proofing System at Roof and Bad Drainage System of Rainwater

Figure 5 indicates the values of mean, standard deviation and t test of each reason that causes defects in water proofing systems at roofs and bad drainage of rainwater as addressed by consultants and contractors in building projects. It can be seen that reason which states, " Unqualified labor (bad implementation)." was the most indicated reason with mean of 3.88 and, while reason which states "Placing waterproofing above thermal insulation" was the less indicted reason and its mean was 1.92. As shown in Table 3, T test illustrates the causes lead to problems in water proofing system at roof and bad drainage of rainwater different significantly from a given critical mean. The results indicate that neglecting cleaning of building roof, using bad quality of insulation materials, placing waterproofing above thermal insulation, using poor quality of concrete and unqualified labor (bad implementation) have a significant level < 0.05, these result lead to conclude that these reasons have main effect for problem in water proofing system at roof and bad drainage.

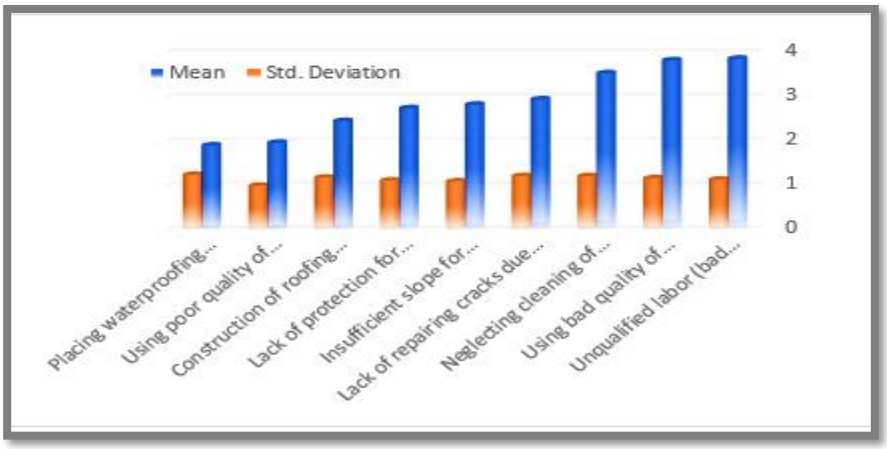

Figure 5. Mean and Standard Division of Defective Water Proofing System at Roof

Table 3. T Test Value of the Reasons That Cause Defects in Water Proofing Systems at Roofs and Bad Drainage of Rain Water Addressed

Causes		
	t-test	p-value
Unqualified labor (bad implementation).	5.35	*0.00
Using bad quality of insulation materials.	4.969	*0.00
Neglecting cleaning of building roof.	63.147	*0.003
Lack of repairing cracks due to shrinkage of concrete.	-0.233	0.816
Insufficient slope for drainage.	-1.034	0.307
Lack of protection for insulation materials.	-1.52	0.135
Construction of roofing screeds in many stages.	-3.116	*0.003
Using poor quality of concrete.	-7.071	*0.00
Placing waterproofing above thermal insulation.	-6.03	*0.00

3. Lack of Ventilation

Figure 7 indicates the values of mean and standard deviation and t test of the ventilation problems as addressed by consultants and contractors in building projects. Problem which states, "Lack of adequate ventilation systems to drive out water vapor from wet areas such as kitchens, bathrooms and swimming pools" was the most indicated reason with mean equal to 3.96, while problem which states "Non-respecting the ventilation distances around the building" was the less indicated problem with mean equal to 2.94.

As shown in Table 3, t test illustrates the causes lead to ventilation problems different significantly from a given critical mean. The results indicate that Lack of adequate ventilation systems to drive out water vapor from wet areas such as kitchens, bathrooms and swimming pools, violation of spaces dedicated for ventilation purposes, inadequate location and insufficient sizing of doors and windows during the design stage, bad internal design which prevents entrance of fresh air have a significant level < 0.05, these result lead to conclude that these reasons have main effect on ventilation problems from other causes.

Figure 7. Mean and Standard Division of Lack of Ventilation Reasons Addressed

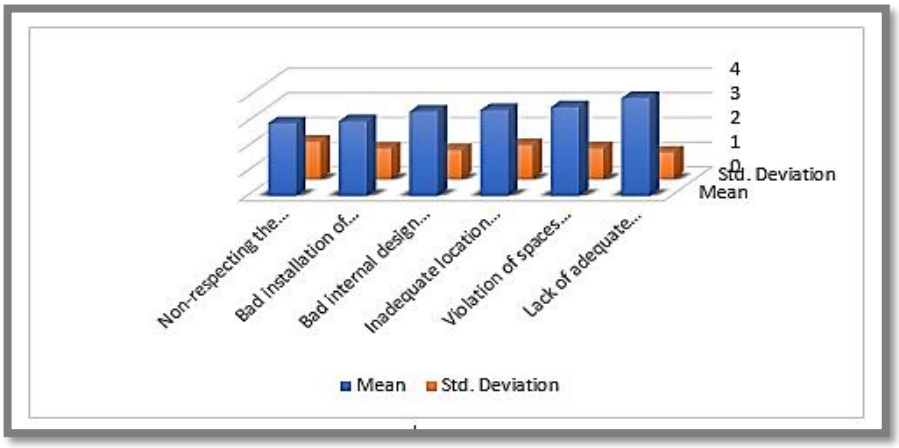

Table 4: Mean, standard deviation and t test of the ventilation problems

Causes		
	t-test	p-value
Lack of adequate ventilation systems to drive out water vapor from wet areas such as kitchens, bathrooms and swimming pools.	5.35	*0.00
Violation of spaces dedicated for ventilation purposes	4.969	*0.001
Inadequate location and insufficient sizing of doors and windows during the design stage.	63.147	*0.019
Bad internal design which prevents entrance of fresh air.	-0.233	*0.017
Bad installation of ventilation systems.	-1.034	0.907
Non-respecting the ventilation distances around the building.	-1.52	0.775

4. Conclusion

Six Sigma as a quality management practice is gaining importance in Building Construction. This study has attempted to contribute to the understanding of performance and implementation aspects of Six Sigma in building construction. This study has identified the relative importance of the causes defect influencing in Amman's construction industry by applying Six Sigma. These causes of problems must be identified as early as possible so that quality can be improved. Six sigma tools and techniques that have been applied in this research includes Pareto, cause and effect diagram, check list sheet, histogram, scatter diagram. From previous analysis it can be concluded that the cause of excavation collapse are: improper shoring or sloping for excavation sides, materials and machinery resting dangerously close to excavation, poor dewatering and drainage of ground and rain water during excavation and Increased soil density due to the presence of wastewater sum pits .Also, it illustrates the causes lead to problems in water proofing system at roof and bad drainage of rainwater are neglecting cleaning of building roof, using bad quality of insulation materials, placing waterproofing above thermal insulation, using poor quality of concrete, and unqualified labor .Regarding to ventilation problems, the causes of it are Lack of adequate ventilation systems to drive out water vapor from wet areas such as kitchens, bathrooms and swimming pools, violation of spaces dedicated for ventilation purposes, inadequate location and insufficient sizing of doors and windows during the design stage, and bad internal design which prevents entrance of fresh air .The implementation of Six Sigma in construction project has resulted on fill a gap in knowledge of common problems in the construction industry, which can serve as a guide for contractors and construction managers for helping to achieve a competitive level of quality and a cost-effective project. Barriers and critical success factors for six sigma implementations in the construction industry in the Amman could be potential future research direction.

References

Aboelmaged, M. G. 2010. Six Sigma quality: a structured review and implications for future research. *International Journal of Quality & Reliability Management,* 27**,** 268-317.

Antony, J. & Banuelas, R. 2002. Key ingredients for the effective implementation of Six Sigma program. *Measuring Business Excellence,* 6**,** 20-27.

Chakravorty, S.S. (2009a), "Six Sigma failures: an escalation model", Operations Management Research, Vol. 2 Nos 1-4, pp. 44-5

Hahn, G. 2005. Six Sigma: 20 key lessons learned. *Quality and Reliability Engineering International,* 21**,** 225-233.

Han, S. H., Chae, M. J., Keon Soon Im, P. & Ryu, H. D. 2008. Six sigma-based approach to improve performance in construction operations. *Journal of Management in Engineering,* 24**,** 21.

Ismail, I., Che-Ani, A.I., Tawil, N.M., Yahaya, H. and Abd-Razak, M.Z. (2012), Housing Problem of Newly Completed House: An Analysis Using Condition Survey Protocol (CSP) 1 Matrix, *World Academy of Science, Engineering and Technology,* 66 (2012): 960-963.

Jalote, Pankaj and Agrawal, Naresh (2005), Using Problem Analysis Feedback for I Quality and Productivity in iterative Software Development, *3rd International Conference on Information and Communications Technology*, 703-7013.

Jha, K. N. And Iyer, K. C. (2006), Critical Factors Affecting Quality Performance in Construction Projects, *the Total Quality Management (TQM) Journal*, 17 (9): 1155-1170.

Kian, Po Seng (2001), A review of Factors Affecting Building Problems in Singapore, Dimensi Teknik Sipil, 3 (2): 64-68.

Kwak, Y.H. and Anbari, F.T. (2006), "Benefits, obstacles, and future of Six Sigma approach", Technovation, Vol. 26 No. 5, pp. 708-715.

Mansor, Rozliani, Mydin, Md Azree Othman, Ismail, Mazran and Wan Harun, Wan Mariah (2012), Categorization of General Problems and Problems in Historical Building, *Analele Universitaui "Eftimie Murgu" Resila*, XIX (1): 127-136.

Schonberger, R.J. (2008), Best Practices in Lean Six Sigma Process Improvement, John Wiley & Sons, Hoboken, NJ.

Shah Ali, Azlan (2009), Cost Decision Making in Building Maintenance Practice in Malaysia, *Journal of Facilities Management*, 7 (4): 298 – 306.