Journal of Ecological Engineering

Journal of Ecological Engineering 2024, 25(2),
ISSN 2299–8993, License CC-BY 4.0

Received: 2023.08.24
Accepted: 2023.09.24
Published:2024.01.01

The Integration between Six Sigma and (QFD) in the Iraqi Residential Project

Sabreen Murtadha Baqer [1*], Mervit R. Altaie [2],

[1] Civil Engineering Department, University of Baghdad, Baghdad, Iraq.
[2] Civil Engineering Department, University of Baghdad, Baghdad, Iraq.
* Corresponding author's e-mail: sabreen9013@gmail.com

ABSTRACT

In this paper, integrated quality system will be developed based on the integration process of Six Sigma (DAMIC approach) and the House of Quality (QFD) technique, the House of Quality is an effective tool to link the Voice of Customer (VOC) with the Voice of Engineer (VOE), will be applied to improve the project Quality to achieve the customer and Stakeholders requirements. The process of quality improvement by utilizing the integrated system applied the case study, practically in the planning and design, construction, and handover phase. For the competitive evaluation, the requirements of this case study were compared with the other eight case studies in terms of customer requirements and technical resolutions.

Keywords: Six Sigma, QFD, Quality Auditing, Quality, DMAIC.

Introduction

The construction sector is considered one of the most vital sectors in Iraq, where many parties participate in, including owner, investor, designer, and consultant, in view of the increase in population growth and the expansion taking place in the growth of urban projects, especially vertical residential ones at the present time, and in light of the incompetence of contractors and contracting companies to implement these residential complexes with the required quality. The current study explains the methods of its solutions in a way that suits the other side in achieving customer satisfaction and fulfilling his desires. In this thesis, audit also plays a very vital role in maintaining the quality of residential projects through conformity with standard specifications and customer satisfaction. The quality audit system is a complex system for dealing with several parties and variables in the project. Therefore, this system must be documented in all contracts, where the cost of quality control is less than the cost of repairing defects. The presence of a quality control engineer has become essential in every construction project for monitoring, checking and controlling daily with contract requirements and standard specifications. The main objective of the study is to develop an effective quality audit system in Iraq in terms of achieving quality and all stakeholder requirements. A Six Sigma with QFD integration-based method is created to identify the problems, analyze the causes of problems, and provide solutions to the problems, taking into account the satisfaction of the customer's needs and expectations and serving the goal of verifying the quality audit capability in Iraqi residential projects.

Background of Quality Function Deployment (QFD):

The quality function deployment method first originated in Japan and is used to select the design features of a product to satisfy the expressed needs and preferences of the customer as well as to prioritize those features and select the most important for special attention further down the design process **(Fischer, and Schutta, 2003), (Maritan, and Panizzolo, 2009)** proposed that when used in the strategic planning process, QFD maintains the integrity of the VOC and generates innovative strategies to achieve an organization’s vision. (**Fischer, and Schutta, 2003), (Maritan, and Panizzolo, 2009)** also argue that it leads directly to policy deployment for implementation and performance management. Overall, QFD is a service planning and development tool, that facilitates service providers with an organized way to assure quality and customer satisfaction while maintaining a sustainable competitive advantage **(Akao, 1990)**. QFD aims at enhanced customer satisfaction, organizational integration of expressed customer wants and needs, and higher profit levels **(Griffin, and Hauser,1992)**. QFD differs from traditional quality systems that aim to minimize negative quality such as poor service **(Mazur, 1994)**. QFD provides an organized, systematic approach to bringing customer requirements into product and service design **(Helper and Mazur, 2006)**. QFD focuses on delivering “value” by seeking out both spoken and unspoken customer requirements, translating them into actionable service features, and communicating them throughout an organization **(Pun, Chin, and Lau, 2000)**. It is driven by the voice of the customer and because of that, it helps service providers to address gaps between specific and holistic components of customer expectations and actual service experience. In addition, it helps managers adopt a more customer-driven perspective, pointing out the differences between what managers visualize as customer expectations and the actual customer expectations. It provides a way to more objectively address subjective needs yet demonstrates the belief in customer focus and employee involvement for every party involved in the supply chain. QFD focuses on designing in quality rather than inspecting in quality which reduces development times, lowers startup costs, and promotes the use of teams **(Fisher, and Schutta, 2003),(Cudney, and Elrod, 2011).**

Six Sigma Background

Six Sigma is a quality improvement technique based on statistics that was used firstly by Motorola in the 1980s by Bill Smith of Motorola to gain a competitive advantage against Japanese products and companies and to decrease cost, increase quality by improving processes, and reduce production time **(Linderman, et al., 2003)**. It received little publicity until the late 1990s. As a result of implementing the Six Sigma method, Motorola gained important benefits, and competitive advantage as well. Therefore, other companies also recognized the success of Motorola, and they started applying the Six Sigma method **(Bircan, and Said, 2012)**. American Express, Boeing, Citibank, Ford, General Electric DAF Trucks, Nokia, and Philips are some of the examples of these firms **(Van den Heuvel, Does, and Vermaat, 2004)**. Subsequently, other giant companies like Ford and Dow Chemicals, Bombaridier, ABB, and Sony adopted the Six Sigma program **(Motwani, Kumar, and Antony, 2004), (Kumar, Antony, and Douglas, 2009) (Sathe, and Allampallewar, 2017)** Prioritize it for the later five years, after the introduction of Six Sigma, GE saw rapid stock growth even before the results came out. This led to other organizations paying close attention to the strategy. GE also played a crucial role in Six Sigma's growth. GE decided to add the "Define" phase before MAIC after some projects saw hindrances due to a lack of problem understanding. Thus, the now-established DMAIC methodology was developed **(Antony, Snee, and Hoerl, 2017), (Kumar, et al., 2020).** The adoption of Six Sigma by these giant companies is one of the reasons for the fast dissemination of Six Sigma principles across the world **(Thirunavukkarasu et al., 2008).** Today, most organizations constantly seek new ways of increasing and maintaining their competitive advantage, and the Six Sigma approach has been cited as an important method for this aim **(Tlapa et al., 2016).** Today, Six Sigma has become one of the most popular and successful ways of worsening defects **(Kumar, et al.,2020).**

DMAIC Process

The DMAIC steps are commonly applied to solve a problem that is related to “process-enhancement”. For example, **(Hakimi et al., 2018)** applied DMAIC steps to improve the quality of plain yogurt production processes. The design of the experiment (DOE) was used to identify the significant process parameters that contributed to product defects, and thus, the optimum setting required of key process parameters to solve the problem of product quality was determined.

More recent examples of the application of DMAIC steps were presented by **(Khan et al., 2020) (Khan, Badar, and Alzaabi, 2010) (Patyal et al., 2021) (Patyal, 2019) (Kumar, Singh, and Bhamu, 2021) (Hardy et al., 2021) and (Productivity, 2021).**

DMAIC is commonly used by Six Sigma firms to improve the current capabilities of an existing process **(Shrikant and Kanade 2019)**. The Six Sigma is administered by the DMAIC process loop in every organization to measure, analyze improve, and control. It is easier to derive from PDCA since it is detailed in the substantial PDCA Plan process. It has now come to be recognized as DMAIC. The literature defines Six Sigma DMAIC as a sequence of steps that seek to establish the source or origin of variation in the process. This methodology is composed of five phases and these are: 1) Define, 2) Measure, 3) Analyze, 4) Improve, and 5) Control **(Gupta et al., 2018) (Herrera et al. 2019)**. The DMAIC is often described as an approach to problem-solving **(Deniz 2018).** DMAIC process is used to perform certain improvements in the process. The purpose of the define phase is to identify the process. In this stage, problems related to the product or service, and critical quality characteristics, which are important for customers, are identified. In the measurement phase, both desired and unacceptable performance indicators related to the product and process are identified, and then the current performance is evaluated by collecting data. In the analysis phase, the root causes of the problems are identified and analyzed. In the improvement phase, defects are aimed to be decreased, and certain improvements are aimed to be introduced by using statistical methods. Finally, in the control phase, the

main aim is to monitor and maintain the solutions and improvements developed
A brief definition of each one is shown in Figure1
.

(Antony and Banuelas, 2002) (Deniz, 2018).

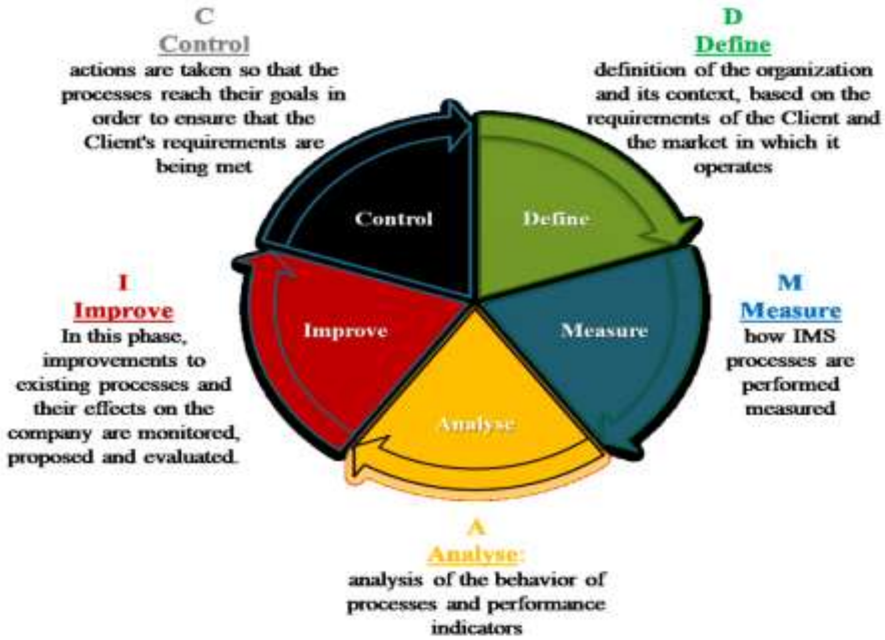


Figure 1: DMAIC circle (Bravo et al. 2020).

Define Step

The first step of the Six Sigma identification stage is to identify the problem. The problem is the gap between the actual and the desired state of the process. The construction organizations must identify the root cause of the problem and determine its impact on the customer. The goal of this step is to develop a clear and concise problem statement that defines the scope and boundaries of the project. The results of the step are explained below as:

Table 1: The identified defects in case study

Phase	No.	Defects (problems)
Design Phase	1	The spaces are small for the rooms in the department
	2	Insufficient number of elevators
	3	Lack of green spaces and therefore no resting points for the residents
	4	Insufficient parking space
	5	There are no public services (Health Centers, Schools, Public Services, Water and Electricity Stations, Malls)
	6	Lack of entrances to the complex
	7	A defect in the sewage pipe space
	8	Defective joint connection of sewage pipes
	9	The walls are not heat and sound-insulated
Cons tructi	1	Segregation the concrete mix during casting
	2	Occupational safety measures are not applied to workers

Phase	No.	Defects (problems)
	3	The raw materials are not tested in government laboratories which helps in the presence of salts in much numbers in the construction units
	4	The use of fast-rusting rebar, quality outside of specifications
	5	The quality of the water used in the concrete mixes unfit for construction use
	6	The equipment and machine used are worn out and cause breakdowns and work stoppages
	7	Not fully adhering to the construction work schedule for the specific time delivering
	8	Intersection in doing activities works between secondary contactors
	9	The machines used un fit with the volume of work
	10	Difficulty in reaching used materials to the site
Handover and Occupancy	1	Sewage pipe perfusion
	2	Electrical connection problems
	3	The elevators are old-fashioned and there is no UPS service
	4	Lack of national electric power (although it is in the hiring contract)
	5	No internet system (although it is in the hiring contract)
	6	There is no system for cleaning (although it is in the hiring contract)
	7	The main gate has not yet been implemented or opened, and the entrance to the complex is through a dirt service road, which causes dust to rise in summer and mud to appear in winter.
	8	The verticality of the walls
	9	The appearance of salts on the surfaces of the concrete walls
	10	Unevenness of wall finishes (albedo)
	11	Cracks in the final coat of the walls
	12	There are gaps between windows and the surrounding walls
	13	The edges of the walls in the corners and the perimeter of doors and windows are not vertical

After conducting the equation of “Defects Per Million Opportunities (DPMO)’’, the process resulted in identifying the most critical defects in the residential projects and determining the sigma level of the process, “Defects Per Million Opportunities (DPMO)’’ **(Shrikant and Kanade 2019)**, So, Sigma level is calculated using DPMO, the formula of DPMO is as follows:

DPMO = No. of defects x 1 million / no. of units X no. of opportunities per unit (6-1)

1. DPMO of planning and Design phase in case study C1
   - No. of defects = 22 observed in each unit
   - Total No. of Defects = 29,040
   - No. of units = 1320 checked
   - No. of opportunities per unit = 33
   - Total opportunities =43560
   - DPMO = 29040 *1000000/1320*33= 666666,667
   - Yield = 33.333%
   - Defect %= 66.6667

So, based on the Sigma level Table (3-3) Sigma level = **1.0677**

2. DPMO of Execution phase in case study C1
   - No. of defects = 53 observed in each unit
   - Total No. of Defects = 69,690
   - No. of units = 1320 checked
   - No. of opportunities per unit = 74
   - Total opportunities =97680

- DPMO = 69,690 *1000000/1320*74= 713452,088
- Yield = 28.6548%
- Defect %= 71.345%

So, based on the sigma level Table (3-3)
Sigma level = **0.94**

3. DPMO of Handover and Occupation phase in case study C1
   - No. of defects = 11 observed in each unit
   - Total No. of Defects = 14,520
   - No. of units = 1320 checked
   - No. of opportunities per unit = 15
   - Total opportunities =19800
   - DPMO = 14,520 *1000000/1320*15= 733333,333
   - Yield = 26.6667%
   - Defect %= 73.333%

So, based on the sigma level Table (3-3)
Sigma level = **0.877**
To increase the sigma level, the DMAIC of Six Sigma methodology for eliminating defects is applied.

Measure Phase

Once the defined phase is completed, the project team can move on to the next phase, measurement. This stage involves measuring performance and creating a baseline for the process based on the most important factors affecting the quality of residential construction projects, to determine the current performance of the process and identify areas for improvement. The performance measurement stage is crucial for the success of the project because it provides the basis for the stages of analysis of the problem and improvement. Measuring the process performance accurately according to all the influencing factors then enables the team to identify the root causes of the problem and develop effective solutions to improve the process. An actual performance measurement plan provides a structured approach to collecting data that can be used to measure and evaluate process performance. Construction organizations should also consider developing a performance measurement procedure to make it easier to understand and follow. Based on the most important factors affecting the quality of construction projects, the weight for each factor and actual performance was measured in case study by distributing performance measurement form to seven engineers on the site, the mean of the seven responses used in calculation the factors weights and performance in this case study and calculate the performance level, Effect and the variance between actual and standard performance based on equations (1), (2) and (3) **(Ahmed, 2019)** a in thought project stages and the real performance will be shown as percentages and clarify the extent of deviation of the actual performance from the standard performance

Performance level = Actual performance / Standard performance ***(1)***

Result = Actual performance - Standard performance ***(2)***

Effect = Weight / Actual performance ***(3)***

Contract

Table 2 explains the measurement of the actual and standard performance and the difference between them in the contract phase.

Table 2: Performance level measurement (contract)

No.	Factors	weight	Actual performance	Standard performance	Performance level	Result	Effect
1	The commitment of the investor to achieve ISO 14001 and its requirements during the selection of the project site	6.76%	19	60	32%	-41	-2.7716

No.	Factors	weight	Actual performance	Standard performance	Performance level	Result	Effect
2	The extent of the company implementing ISO 18001 and its requirements during implementation	6.08%	8	60	13%	-52	-3.1616
3	The commitment of the investor and the executing company to ISO 14001 and its requirements during design and implementation	6.42%	14	60	23%	-46	-2.9532
4	The commitment of the investor and the executing company to the plans and designs approved and signed by the Investment Authority and all clauses of the contract	7.43%	21.4	60	36%	-38.6	-2.86798
5	The commitment of the investor and the executing company to ISO 9001 and its requirements during the structural design and implementation	7.09%	30	50	60%	-20	-1.418
6	Methods of contracting between the owner and the contractor	7.09%	25	50	50%	-25	-1.7725
7	Selection of contractors	6.76%	19	50	38%	-31	-2.0956
8	Good selection of subcontractors and their level of performance (similar work)	7.43%	15	50	30%	-35	-2.6005
9	Project cost and clear financing plan	7.09%	20	50	40%	-30	-2.127
10	The accuracy of the initial estimate of the project	7.43%	22	50	44%	-28	-2.0804
11	Project requirements (availability of resources, international approvals, union approvals, government regulations, financing, environmental impacts	6.42%	16	50	32%	-34	-2.1828
12	The level of the project owners' knowledge of the importance of applying quality systems	17.91%	19	60	32%	-41	-7.3431
13	Applying quality systems by the contracting companies	6.08%	24	75	32%	-51	-3.1008

Planning and Design

Table 3 explains the measurement of the actual and standard performance and the difference between them in the planning and design phase

Table 3: Performance level measurement (Planning and design phase).

No.	Factors	The Weight	Actual Performance	Standard Performance	Performance Level	Result	Effect
1	The degree of complexity of the project in design and implementation	5.54%	9	60	15%	-51	-2.8254
2	The quality of the design and the comprehensiveness of the plans for all the details	6.41%	18.4	60	31%	-41.6	-2.66656
3	The nature of the project is new, development, or addition	5.83%	18	60	30%	-42	-2.4486
4	Project scope	6.41%	2.6	80	3%	-77.4	-4.96134

No.	Factors	The Weight	Actual Performance	Standard Performance	Performance Level	Result	Effect
5	High quality, clarity, and accuracy for the required specifications (materials, implementation method, equipment)	6.12%	12	80	15%	-68	-4.1616
6	Emphasis on pursuing continuous improvement in projects	4.96%	17	70	24%	-53	-2.6288
7	How to organize the work in the project	6.12%	8	70	11%	-62	-3.7944
8	Top management needs to create a culture of quality to ensure project success	5.25%	17	50	34%	-33	-1.7325
9	Activities include quality management practices through evaluation and project plan preparation	4.96%	23	70	33%	-47	-2.3312
10	Decision-making process	4.66%	36	70	51%	-34	-1.5844
11	Efficient project management and cost control	5.25%	6	70	9%	-64	-3.36
12	Periodically document data collection reviews and forecast resource requirements	4.96%	15	70	21%	-55	-2.728
13	There is planning and control of project resources that includes the amount and timing of obtaining resources and how to allocate them	4.37%	9	70	13%	-61	-2.6657
14	The causes of deficit and excess in resources are identified and documented for continuous improvement	5.83%	22.4	70	32%	-47.6	-2.77508
15	The company seeks to meet the current and potential needs and requirements of customers and beneficiaries	6.12%	6	80	8%	-74	-4.5288
16	Focusing on customer requirements requires balancing time, cost, and quality in a project	5.54%	6	80	8%	-74	-4.0996
17	Good experience with the requirements of the quality system	5.83%	4	50	8%	-46	-2.6818
18	Established training and planning courses and high qualifications	5.83%	6	50	12%	-44	-2.5652

Construction Phase

Table 4 explains the measurement of the actual and standard performance and the difference between them in the construction phase

Table 4: Performance level measurement (Construction phase).

No.	Factors	The weight	Actual performance	Standard performance	Performance Level	Result	Effect
1	Connecting the service networks of the residential complex with the public networks close to it (electricity, water, sewage, communications)	4.97%	16	70	23%	-54	-2.6838
2	Cooperation and coordination between the parties involved in the project	4.32%	7	70	10%	-63	-2.7216

No.	Factors	The weight	Actual performance	Standard performance	Performance Level	Result	Effect
3	Check the project schedule and monitor it to evaluate performance	5.18%	8.4	70	12%	-61.6	-3.19088
4	Checking materials on site	4.75%	8	80	10%	-72	-3.42
5	Material brand	4.10%	11	70	16%	-59	-2.419
6	Material quality	4.54%	0	70	0%	-70	-3.178
7	Operational efficiency of the equipment	4.32%	25	70	36%	-45	-1.944
8	Equipment lifespan	4.54%	32	70	46%	-38	-1.7252
9	Equipment reuse	3.89%	28	70	40%	-42	-1.6338
10	The cost of implementation techniques	4.75%	29	70	41%	-41	-1.9475
11	Cost of equipment and materials	4.75%	14	70	20%	-56	-2.66
12	The cost of monitoring and ensuring the quality of outputs and repairing defects	4.32%	20	70	29%	-50	-2.16
13	Review of monitoring and evaluation standards	4.75%	17	50	34%	-33	-1.5675
14	Evaluate progress according to a set schedule	3.89%	13	50	26%	-37	-1.4393
15	Evaluate the implementation and overlap of project operations	4.32%	3.4	50	7%	-46.6	-2.01312
16	Top management reviews changes in external and internal issues that are relevant to the quality management system	3.46%	9	50	18%	-41	-1.4186
17	Top management reviews the effectiveness and actions taken to address risks	3.89%	8.2	50	16%	-41.8	-1.62602
18	Effective project management	4.54%	6	50	12%	-44	-1.9976
19	Good coordination and communication between project parties	4.54%	5.4	50	11%	-44.6	-2.02484
20	Efficiency and integrity of the oversight bodies	3.67%	10	50	20%	-40	-1.468
21	Good follow-up of compliance with the laws and general conditions for the implementation of buildings	4.54%	19	50	38%	-31	-1.4074
22	Quality legislation Appling	4.10%	5	50	10%	-45	-1.845
23	Obligation of professional ethics	3.89%	3	50	6%	-47	-1.8283

Handover and Occupation

Table 5 explains the measurement of the actual and standard performance and the difference between them in the construction phase

Table 5: Performance level measurement (Handover and occupation).

No.	Factors	The weight	Actual performance	Standard performance	Performance Level	Result	Effect
1	Carry out continuous improvement in light of the available time and resources	8.21%	12	50	24%	-38	-3.1198
2	Collecting and analyzing data during the project period to use it for continuous improvement	10.14%	12	50	24%	-38	-3.8532
3	The organization maintains documented data as evidence of program implementation and audit results	10.63%	23	50	46%	-27	-2.8701
4	Take appropriate action without undue delay	4.75%	50	50	100%	0	0
5	Ensure that documentation processes are submitted to the administration	9.66%	11	50	22%	-39	-3.7674
6	Plan, implement and maintain an audit program including frequency, methods, responsibilities, and planning and reporting requirements	9.66%	19	50	38%	-31	-2.9946
7	The organization selects auditors and manages the audit to ensure the objectivity and integrity of the audit process	10.63%	12	50	24%	-38	-4.0394
8	Top management reviews any need for changes in the quality management system	10.14%	7	50	14%	-43	-4.3602
9	Top management reviews information on the performance and effectiveness of the quality management system	11.11%	18	50	36%	-32	-3.5552
10	Providing service aspects to suit the occupants	9.66%	15	50	30%	-35	-3.381

Analysis Phase

The analysis phase is the third phase in the Six Sigma approach. Its primary goal is to identify the root causes of defects identified at the identification stage in the residential complex. The analysis stage involves data collection, data analysis using various statistical tools and techniques, and identification of significant causes of defects. The analysis phase is crucial because it allows the team to better understand the process, identify critical factors that affect the performance of the process, and focus their efforts on addressing the root causes of defects in the next step. There are many statistical tools and techniques used during the analysis phase. This project will be used two tools to analyze the problems to the root cause of defects.

Tree Diagrams

A tree diagram is a visual tool used to depict hierarchical relationships between various elements of a system or process. It provides a clear and concise representation of the flow of information in a complex system, making it an essential tool for problem-solving, decision-making, and analysis. The analysis phase has objectives that aim to identify the root cause of problems within a process in all stages of the project (Design, construction, and handover and occupation) by tree diagram as shown in Figures 2, 3 and 4.

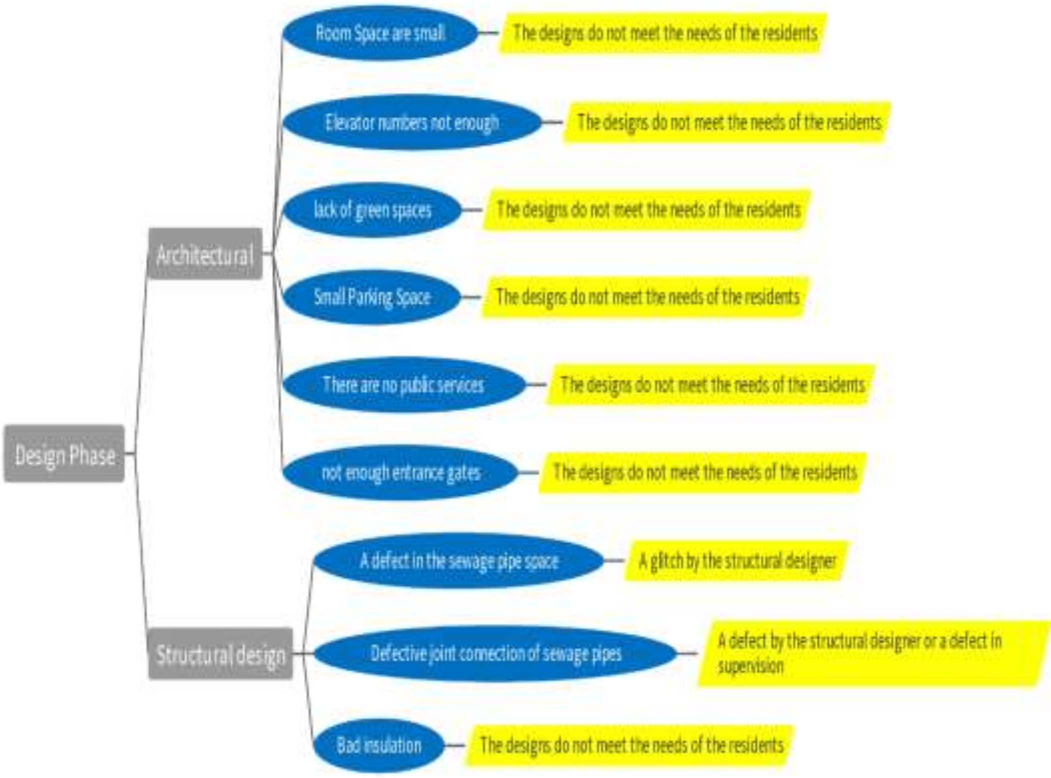


Figure 2: Tree diagram of the design phase.

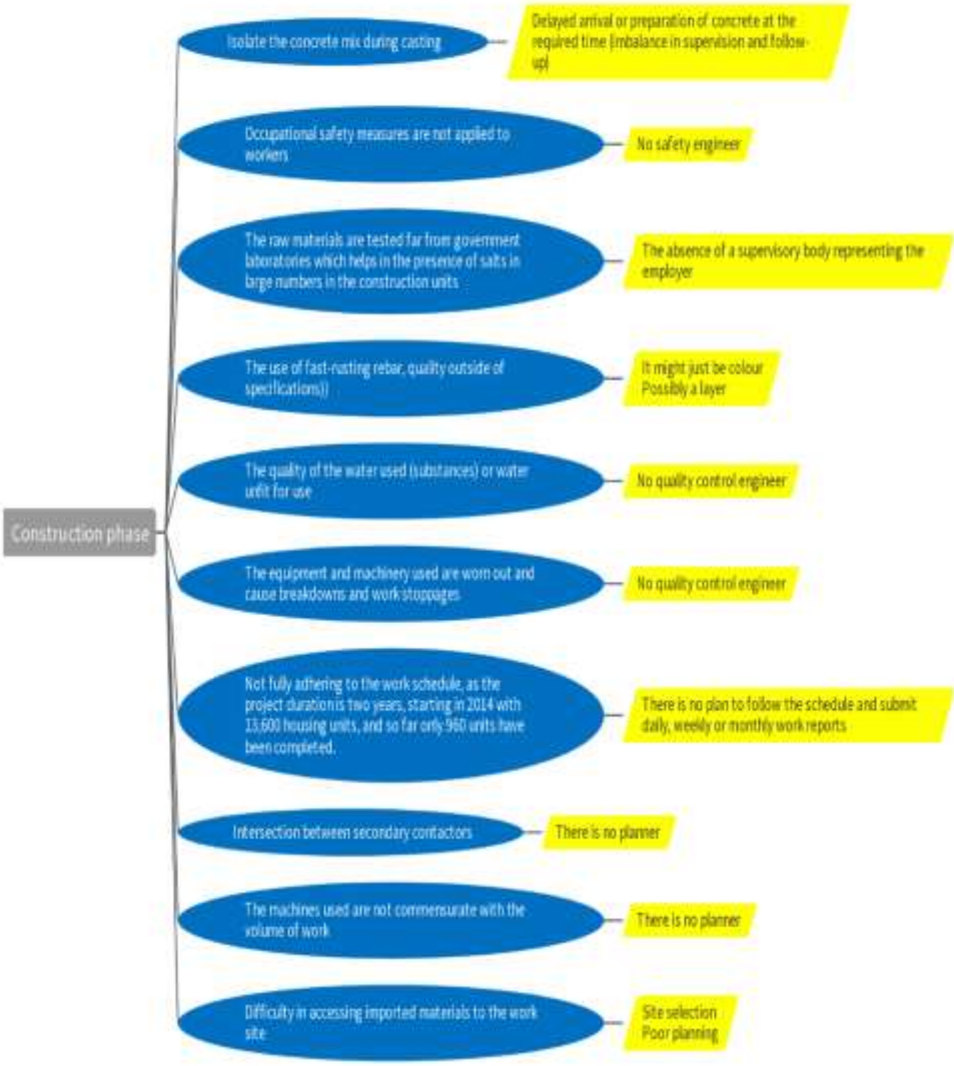


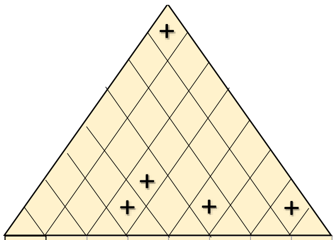
Figure 3: Tree diagram of construction phase.

Figure 4: Tree diagram of handover phase.

Improve Phase

The improvement phase is a critical stage in the Six Sigma methodology, as it involves the actual implementation of the solutions identified in the analysis phase. This phase requires a collaborative effort between the project team and the stakeholders to ensure that the proposed solutions are feasible and effective. It is important to note that the success of the improvement phase depends on the accuracy of the data collected in the previous phases. Therefore, it is crucial to have a reliable data collection process in place to ensure that the solutions implemented will have a positive impact on the organization and its customers. The Improve phase consists of several essential steps that ensure the proposed solutions work as intended. One of the first steps is to prioritize the list of solutions generated in the analysis phase. These solutions should be evaluated based on a list of criteria such as feasibility, impact, and resources required to implement them. By doing this, organizations can select the most efficient solutions.

Construction of the House of Quality in Design Phase

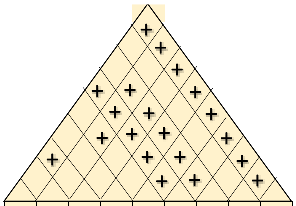


House of Quality for Design Phase			Technical Specifications (How)								Customer Competitive projects Assesment			
	Customer Requirements (What)	Importance	Redesign interiors	Use faster elevators	Redesign landscape	Redesign parking area	adding service to the complex	opening additional entrenance to the complex	Redesign sewage pipes	Make 3 different design for each unit	Case study C2	Case study C4	Case study C5	Case Study C 6
											Evaluaion			
1	The spaces are small for the rooms in the department	11.66	6	0	0	0	0	0	0	8	3	2	3	3
2	Insufficient number of elevators	11.04	0	9	0	0	0	0	0	0	3	1	5	5
3	Lack of green spaces and therefore no resting points for the residents	12.27	0	0	5	1	0	0	0	3	2	3	4	5
4	Insufficient parking space	10.43	0	0	1	4	0	0	0	1	2	5	3	4
5	There are no public services (Health Centers, Schools, Public Services, Water and Electricity Stations, Malls)	10.43	0	0	0	0	6	0	0	0	2	4	4	5
6	Lack of entrances to the complex	11.96	0	0	0	0	0	5	0	0		3	4	2
7	A defect in the sewage pipe space	10.12	0	0	0	0	0	0	7	5	2	2	4	4
8	Defective joint connection of sewage pipes	9.51	0	0	0	0	0	0	8	0	4	3	3	2
9	The walls are not heat and sound-insulated	12.58	1	0	0	0	0	0	0	9	1	1	3	4
IW			82.5	99.4	71.8	54	62.6	59.8	147	304				
RW%			9.4	11.2	8.2	6.1	7.1	6.8	16.7	34.5				
max Relashionship			9	9	9	9	9	9	9	9				
Priorities Rank			4	3	5	8	6	7	2	1				
Decision				✓					✓	✓				
	Technical Cometitive Assesment		Evaluaion											
	Case Study C2		5	5	4	5	5	4	4	4				
	Case Study C4		4	4	4	5	4	4	4	5				
	Case Studty C5		4	4	5	4	5	5	5	5				
	Case Study C6		5	5	4	5	5	5	4	5				
	Targets		5	5	5	5	5	5	5	5				

Figure 5: House of quality for the design phase.

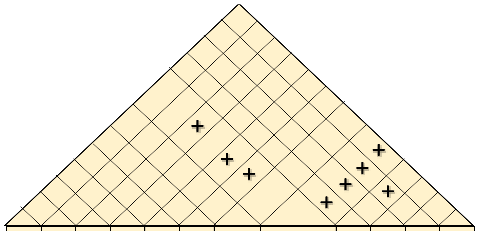
Construction of the House of Quality in Construction (Execution) Phase

In the construction (execution) phase, the customer's requirements will be considered as the stakeholder's requirements. Figure (6): House of quality for the construction phase.



House of Quality for construction Phase			Technical Specifications (How)									Customer Competitive projects Assesment						
			increase the workability of concrete	Appoint a trained safety team	Sober government laboratory provide mandated and approved by the owner	it is exposed to sand cannons is replaced	the quality of the water used is imposed (specification water)	Appoint a quality engineer	Direct supervision by the owner of work	Having a planner with prioritizing work	Appointing a planner	Case study C2	Case study C3	Case study C4	Case study C5	Case study 6	Case study 7	Case study 8
	Stakeholder Requirements (What)	Importance										Evaluaion						
1	Segregation the concrete mix during casting	11.67	5	0	0	0	0	5	5	0	0	3	3	3	5	3	4	1
2	Occupational safety measures are not applied to workers	9.44	0	5	0	0	0	4	6	0	2	1	1	2	3	1	2	1
3	The raw materials are not tested in government laboratories which helps in the presence of salts in much numbers in the construction units	11.67	1	0	8	0	1	6	6	1	1	2	2	3	4	4	4	1
4	The use of fast-rusting rebar, quality outside of specifications	11.11	0	0	3	6	0	5	3	0	0	2	2	3	5	5	4	2
5	The quality of the water used in the concrete mixes unfit for construction use	9.72	1	0	7	0	5	3	5	0	0	3	3	4	4	5	4	1
6	The equipment and machine used are worn out and cause breakdowns and work stoppages	9.72	0	0	0	0	0	8	4	0	7	3	3	2	4	5	5	2
7	Not fully adhering to the construction work schedule for the specific time delivering	9.44	0	0	0	0	0	1	9	3	8	2	3	2	4	5	5	1
8	Intersection in doing activities works between secondary contactors	10	0	0	0	0	0	0	6	0	5	3	3	5	4	5	4	3
9	The machines used un fit with the volume of work	10.56	0	0	0	0	0	1	6	0	6	3	3	4	5	4	4	2
10	Difficulty in reaching used materials to the site	9.33	0	0	0	0	0	0	5	0	4	5	4	3	5	4	5	1
	IW		80	47	195	67	60	349	561	40	325							
	RW%		4.6	2.7	11	3.9	3.5	20	33	2.3	19							
	Max Relationship		9	9	9	9	9	9	9	9	9							
	Priorities Rank		5	7	4	6	6	2	1	9	3							
	Decision				✓			✓	✓		✓							
	Technical Cometitive Assesment		Evaluaion															
	Case Study C2		4	4	4	3	4	5	5	5	5							
	Case study C3		4	5	4	4	3	5	5	5	5							
	Case Study C4		5	5	5	5	4	5	5	5	5							
	Case study C5		3	5	5	4	5	4	5	4	4							
	Case Study C6		4	5	3	3	2	2	3	3	3							
	Case Study C7		3	5	3	2	2	2	3	3	2							
	Case study C8		5	5	4	5	5	5	5	5	5							
	Targets		5	5	5	5	5	5	5	5	5							

Construction of the House of Quality in Handover Phase



House of Quality for Handover Phase			Technical Specifications (How)												Customer Competitive projects Assesment			
			Replacing external tubes	Use laying wires	Contracting with a modern elevat	Construction of governmental power stations	Internet system installation	Contracting with a cleaning comp	speed up the implementation of the portal	Identify three alternativies for the finishing materials with different qualities and cost	Treatment with chemicals	Use chicken wire	Rework on wall finish	use of iron structures before the construction phase	Case study C2	Case study C4	Case study C5	Case Study C 6
	Customer Requirements (What)	Importance													Evaluaion			
1	Sewage pipe perfusion	8.14	9	0	0	0	0	0	0	0	0	0	0	0	4	3	3	4
2	Electrical connection problems	7.92	0	7	0	7	0	0	0	5	0	0	0	0	3	3	5	5
3	The elevators are old-fashioned and there is no UPS service	7.92	0	0	6	6	0	0	0	4	0	0	0	0	3	1	5	5
4	Lack of national electric power (although it is in the hiring contract)	8.99	0	0	0	9	0	0	0	0	0	0	0	0	3	3	4	2
5	No internet system (although it is in the hiring contract)	7.49	0	0	0	0	8	0	0	2	0	0	0	0	2	4	5	5
6	There is no system for cleaning (although it is in the hiring contract)	7.28	0	0	0	0	0	7	0	0	0	0	0	0	3	2	5	5
7	The main gate has not yet been implemented or opened, and the entrance to the complex is through a dirt service road, which causes dust to rise in summer and mud to appear in winter.	7.07	0	0	0	0	0	0	6	0	0	0	0	0	4	2	5	5
8	The verticality of the walls	7.23	0	0	0	0	0	0	0	0	0	0	0	0	1	4	4	5
9	The appearance of salts on the surfaces of the concrete walls	7.71	0	0	0	0	0	0	0	8	0	0	0	0	4	3	5	5
10	Unevenness of wall finishes (albedo)	7.49	0	0	0	0	0	0	0	5	4	6	0	0	2	3	5	4
11	Cracks in the final coat of the walls	7.92	0	0	0	0	0	0	0	6	3	1	7	0	2	4	5	5
12	There are gaps between windows and the surrounding walls	6.64	0	0	0	0	0	0	0	4	0	0	0	7	3	5	5	5
13	The edges of the walls in the corners and the perimeter of doors and windows are not vertical	8.14	0	0	0	0	0	0	0	3	0	0	0	8	1	4	4	5
	IW		73	55	48	184	60	51	42.4	283.89	54	53	55	112				
	RW%		6.8	5.1	4.5	17	5.6	4.8	4	26.5	5	4.9	5.1	11				
	Max Relationship		9	9	9	9	9	9	9	9	9	9	9	9				
	Priorities Rank		4	6	9	2	5	8	9	1	7	8	6	3				
	Decision		✓			✓				✓				✓				
Technical Cometitive	Case study C2		3	4	5	4	4	4	4	5	4	3	5	4				
	Case study C4		5	4	5	5	4	5	2	5	4	5	5	4				
	Case study C5		4	2	3	2	2	2	2	3	2	2	2	2				
	Case study C6		2	2	2	3	2	2	2	5	2	2	3	2				
	Targets		5	5	5	5	5	5	5	5	5	5	5	5				

Figure 7: House of quality for handover phase.

Control Phase:

The control phase focuses on two key objectives: verifying that the process improvements implemented in the measure, analyze, improve (MAI) phase have been successful and ensuring that the improvements are sustained over time. This is done by implementing processes, procedures, and controls to monitor the process and maintain it at a high level of performance. The project team must also develop a feedback mechanism to allow for continuous improvement over time. As the solution is being implemented, continuous monitoring and data collection is necessary to identify opportunities for further improvements. The organization should continue to measure the effectiveness of the new process and ensure there is no deviation from the targeted goals.

Auditing Report

One of the primary tools used in the control phase is Statistical Process Control (SPC). This involves monitoring key process metrics to detect any trends or patterns that may indicate an issue with the process. SPC uses statistical techniques to determine whether any variation in the process output is within acceptable limits. If the process output falls outside of these limits, corrective action is taken to get the process back on track.

Risk management is another key element of the control phase. The project team should conduct a risk analysis to identify any risks to the process and consider potential mitigation strategies. Once the risks have been identified and mitigation strategies have been developed, it is important to monitor the process closely to ensure that the control plan is effective. This may involve regular check-ins with stakeholders, data analysis, and adjustments to the plan as needed. By proactively managing risks and implementing a solid control plan, the project team can increase the likelihood of success and minimize the impact of any issues that may arise. These risks can include issues related to people, processes, infrastructure, or technology.

The implementation of the control plan is the final step of the control phase. During the control phase, it is important to monitor the progress of the project and make adjustments as necessary. This may involve revising the control plan or implementing additional measures to address any new risks that arise. By staying vigilant and proactive, the project team can ensure that the project stays on track and achieves its goals. This involves distributing the control plan to all relevant stakeholders and ensuring that everyone understands their roles and responsibilities. The team should also conduct regular reviews of the control plan to ensure that it remains effective over time.

Conclusion

This paper explains the integrating between Six Sigma and QFD (house of Quality) It is one of the most effective tools in controlling the audit plan and statistical process control, to assure Sustainability for the Improvement solutions. to work on achieving the quality requirements in the three phases with the fulfillment of customers' requirements. the verification work identifies by measuring the performance on the factors after using the solutions and make a report to check the most important risks and matters that should be taken concern. The proposed quality audit system targets summary as:

1. The project has been finished in the fastest time.
2. The project has been finished in the highest quality.
3. The project has been finished at a minimum cost.
4. The project has been finished in maximum value.
5. The project has been finished with the easiest technique.
6. The project has been used the maximum available technology.
7. Foster a safe and healthy work environment.
8. The forecasting and evaluation of all risks together with the identification of procedures to avoid or minimize their impact.
9. Effective communication matrix between all parties to exchange knowledge and improve coordination.
10. Easy maintenance for a long period.

Reference

- Fischer, C. M., and Schutta, J. T. (2003). "*Developing New Services: Incorporating the Voice of the Customer into Strategic Service Development*". Quality Press.
- Maritan, D. and Panizzolo, R. (2009), "Identifying Business Priorities Through Quality Function Deployment". Marketing Intelligence and planning, 27(5), pp. 714- 728.
- Akao, Y. (1990). "*History of Quality Function Deployment in Japan. The Best on Quality: Targets, Improvement, Systems*". (3), 183-96.
- Griffin, A., and Hauser, J. R. (1992). "Patterns of Communication Among

Marketing, Engineering and Manufacturing—A Comparison Between Two New Product Teams". Management Science, 38(3), 360-373.

- Mazur, G. (1994). "QFD Outside North America–Current practices in Europe, the Pacific Rim, South America, and beyond". In 6. Symposium on Quality Function Deployment.
- Helper, C., and Mazur, G. (2006). "Finding Customer Delights Using QFD". Transactions of the Eighteenth Symposium on QFD, QFD Institute.
- Pun, K. F., Chin, K. S., and Lau, H. (2000). "A QFD/Hoshin Approach for Service Quality Deployment: A Case Study". Managing Service Quality: An International Journal, 10(3), 156-170.
- Cudney, E. A., and Elrod, C. C. (2011). "Quality Function Deployment in Continuous Improvement, Six Sigma Projects and Personal Experiences", 45-77.
- Deniz, S., and Çimen, M. (2018). "Barriers of Six Sigma in Healthcare Organizations". Management Science Letters, 8(9), 885-890.
- Bircan, H., and Said, K. Ö. S. E. (2012). "Six Sigma and Companies' Attitude Towards Six Sigma: A Study in Kayseri-Sivas Region". The International Journal of Economic and Social Research, 8(8), 107-129.
- Linderman, K., Schroeder, R., Zaheer, S. and Choo, A. (2003). "Six Sigma: A Goal-Theoretic Perspective". Journal of Operations Management, 21, 193–203.
- Van den Heuvel, J., Does, R. J., and Vermaat, M. B. (2004). "Six Sigma in A Dutch Hospital: Does It Work in The Nursing Department". Quality and Reliability Engineering International, 20(5), 419-426.
- Motwani, J., Kumar, A., and Antony, J. (2004). "A Business Process Change Framework for Examining the Implementation of Six Sigma: A Case Study of Dow Chemicals". The TQM magazine, 16(4), 273-283.
- Kumar, P., Raju, N. V. S., and Kumar, M. V. (2016). "Quality of Quality Definitions an Analysis". International Journal of Scientific Engineering and Technology, 5(3), 142-148.
- Sathe, S., and Allampallewar, D. S. B. (2017). "Application of Six Sigma in Construction". International Journal of Innovative Research in Science, Engineering and Technology, 6(11).
- Antony, J. and Banuelas, R. (2002). "Key Ingredients for The Effective Implementation of Six Sigma Program". Measuring Business Excellence, 6(4), 20-27.
- Kumar, P., Khan, M. A., Mughal, U. K., and Kumar, S. (2020). "Exploring the Potential of Six Sigma (DMAIC) in Minimizing the Production Defects". In Proceedings of the 3rd International Conference on Industrial and Mechanical Engineering and Operations Management Dhaka, Bangladesh, 26-27. 36–46.
- Thirunavukkarasu, V., Devadasan, S. R., Prabhushankar, G. V., Murugesh, R., and Senthilkumar, K. M. (2008). "Conceptualization of Total Six Sigma Function Deployment Through Literature Snapshots". International Journal of Applied Management Science, 1(1), 97-122.
- Tlapa, D., Limon, J., García-Alcaraz, J.L., Baez, Y. & Sánchez, C. (2016). "Six Sigma Enablers in Mexican

Manufacturing Companies: A Proposed Model". Industrial Management and Data Systems, 116(5), 926- 959.

- Hakimi, S., Zahraee, S. M., and Rohani, J. M. (2018). "Application of Six Sigma DMAIC Methodology in Plain Yogurt Production Process". International Journal of Lean Six Sigma, 9(4), 562-578.
- Hardy, D. L., Kundu, S., and Latif, M. (2021). Productivity and Process Performance in A Manual Trimming Cell Exploiting Lean Six Sigma (LSS) DMAIC–A Case Study in Laminated Panel Production. International Journal of Quality & Reliability Management, 38(9), 1861-1879.
- Khan, S. A., Badar, M. A., and Alzaabi, M. (2020). Productivity Improvement Using DMAIC in A Caravan Manufacturing Company. International Journal of Productivity and Quality Management, 30(2), 234-251.
- Khan, M. H. A. K., Deng, S., Rashid, A., Khan, J. A., and Zulfiqar, F. (2017). "An Integration of Kano Model, QFD and Six Sigma to Present A New Description Of DFSS". European Journal of Business and Management, 9(6), 1-17.
- Patyal, V. S., Modgil, S., and Koilakuntla, M. (2021). "Application of Six Sigma Methodology in an Indian Chemical Company". International Journal of Productivity and Performance Management, 70(2), 350-375.
- Patel, A. R. P. A. N., and Deshpande, V. I. V. E. K. (2016). "A Review: Quality Improvement Through the Integration of Six Sigma, QFD and TRIZ in Manufacturing Industries". Industrial Engineering Journal, 9(10), 34-39.
- Herrera, A. R. C., Benavides, E. P., Aguirre, J. D. P. U., and Leyva, L. L. L. (2019). "Improvement Production Capacity of Recycled Plastic Wood Through Six Sigma DMAIC". In Proceedings of the International Conference on Industrial Engineering and Operations Management, 1212-1223.
- Gupta, V., Jain, R., Meena, M. L., and Dangayach, G. S. (2018). Six-Sigma Application in Tire-Manufacturing Company: A Case Study. Journal of Industrial Engineering International, 14, 511-520.
- Antony, J. and Banuelas, R. (2002). "Key Ingredients for The Effective Implementation of Six Sigma Program". Measuring Business Excellence, 6(4), 20-27.
- Bravo, M., Euphrosino, C. A., and Fontanini, P. S. P. (2020). "DMAIC Manual for an Integrated Management System: Application in A Construction Company". In Proc. 28th Annual.
- Ahmed Fathi Abdelrazek , "Sustainability Balanced Scorecard: A Comprehensive tool to measure Sustainability Performance'' On February,2019, https://www.researchgate.net/publication/331688857.
- Shrikant, Pandit Prachee, and Prof G N Kanade. 2019. "Quality Audit of Public Building Project by Using Six Sigma Techniques," 483–96.
- Productivity, Muhammad. 2021. "Productivity and Process Performance in a Manual Trimming Cell Exploiting Lean Six Sigma (LSS) DMAIC – a Case Study in Laminated Panel Production" 38