

1-1-2013

Quality Modeling And Improvement Of University Facilities Services Using Six-Sigma - A Case Study On Wayne State University Fpm Services

Mohsen F. Mohamed Isa
Wayne State University,

Follow this and additional works at: http://digitalcommons.wayne.edu/oa_dissertations

Recommended Citation

Isa, Mohsen F. Mohamed, "Quality Modeling And Improvement Of University Facilities Services Using Six-Sigma - A Case Study On Wayne State University Fpm Services" (2013). *Wayne State University Dissertations*. Paper 727.

This Open Access Dissertation is brought to you for free and open access by DigitalCommons@WayneState. It has been accepted for inclusion in Wayne State University Dissertations by an authorized administrator of DigitalCommons@WayneState.

**QUALITY MODELING AND IMPROVEMENT OF UNIVERSITY
FACILITIES SERVICES USING SIX-SIGMA – A CASE STUDY ON
WAYNE STATE UNIVERSITY FPM SERVICES**

by

MOHSEN FARAG MOHAMED ISA

DISSERTATION

Submitted to the Graduate School

of Wayne State University,

Detroit, Michigan

in partial fulfillment of the requirements

for the degree of

DOCTOR OF PHILOSOPHY

2013

**MAJOR: CIVIL AND ENVIRONMENTAL
ENGINEERING**

Approved by:

Advisor Date

DEDICATION

I dedicate my research and efforts to the soul of my Mom; my source of love and kindness, for my Dad who did all what he can for raising me, protecting me, and guiding me to be a good person in the society, for my wife, and all my family members and friends who gave me support and help to finish my dissertation.

ACKNOWLEDGEMENTS

I would like to give my sincere thanks to Dr Mumtaz Usman for his supervision, guidance and proactive contribution. I am appreciative of his advice, and the great precious time he spent to make this research comes together. I benefited greatly from his knowledge, intelligence, experience, and wisdom. Special acknowledgement goes to my PhD committee members; Dr. Ratna Babu Chinnam, Dr. Ahmed Awad, and Dr. Gerald O. Thompkins for their precious contributions and advise. I would like to express my sincere appreciation to my wife Hunida, my family and parents, and friends who gave me support and endless encouragement to go forward with my PhD career.

Special thanks especially go to the WSU FPM leadership and personnel who provided assistance in data gathering for this research, and feedback on findings along the way. Contributions of all persons who participated in interviews and responded to my reasearch survey are gratefully acknowledged.

TABLE OF CONTENTS

Dedication	ii
Acknowledgement	iii
List of Tables	viii
List of Figures.....	x
CHAPTER 1 INTRODUCTION	1
1.1. Background on Facilities Management	1
1.2. Background on Quality Management, Quality of Services, and Service Quality Modeling ..	3
1.3. Background on Six-Sigma	5
1.4. Problem Statement	7
1.5. Research Objectives	8
1.6. Research Approach and Dissertation Format	9
CHAPTER 2 STATE-OF-THE-ART LITERATURE REVIEW (SOA)	10
2.1 Facilities Services in Universities	10
2.2 Service Operations and Quality	14
2.3 Characteristics of Service Operations	16
2.3.1 <i>Relationship between Quality of Service and Organizational Performance</i>	17
2.3.2 <i>Service Industry Characteristics vs. Manufacturing</i>	18
2.3.3 <i>Differences in the Evaluation of Product Quality vs. Service Quality</i>	19
2.3.4 <i>Obstacles Facing Service Quality Improvements</i>	20
2.3.5 <i>Customer Satisfaction vs. Service Quality</i>	21

2.4	Six-Sigma and Service Quality	22
2.4.1	<i>Six-Sigma in the Service Industry</i>	24
2.4.2	<i>Tools and Techniques for Service Process Performance Improvement</i>	25
2.4.2.1	<i>Process Map</i>	26
2.4.2.2	<i>Cause and Effect Matrix (C&E) Analysis</i>	28
2.4.2.3	<i>Voice Of Customer (VOC)</i>	29
2.4.2.4	<i>Failure Mode and Effect Analysis (FMEA)</i>	30
2.4.3	<i>Critical Success Factors of Six-Sigma</i>	32
2.4.4	<i>Differences Between Six-Sigma and Other Quality Initiatives</i>	34
2.4.5	<i>Challenges for Implementation of Six-Sigma</i>	35
2.5	Dimensions and Determinants of Service Quality and Quality Models	37
2.5.1	<i>Importance of Determinants</i>	41
2.6	Justification for this Research.....	45
CHAPTER 3 RESEARCH METHODOLOGY.....		47
3.1	Construction of the Initial Quality Model.....	47
3.1.1	<i>Service Production Component</i>	49
3.1.1.1	<i>Management Commitment</i>	49
3.1.1.2	<i>Service Design</i>	50
3.1.1.3	<i>Tools and Equipment to Perform Service</i>	50
3.1.1.4	<i>IT Involvement</i>	51
3.1.2	<i>Service Delivery Component</i>	51
3.1.2.1	<i>Employee's Role</i>	51

3.1.2.2 <i>Physical Facilities</i>	52
3.2 Evaluating the Critical Factors for the Service Quality Model.....	53
3.3 Customer Service Evaluation System and Data Collection.....	60
3.3.1 <i>Rating Scale</i>	62
3.4 Analysis by using Six-Sigma.....	63
3.4.1. <i>Define Phase</i>	65
3.4.2. <i>Measure Phase</i>	65
3.4.3. <i>Analyze Phase</i>	66
3.4.4. <i>Improve Phase</i>	66
3.4.5 <i>Control Phase</i>	66
3.5 Description of the Main Six-Sigma Tools Used in GIRF Process (Process Map, Cause and Effect Matrix, and FMEA).....	67
3.5.1 <i>Process Map</i>	67
3.5.2 <i>Cause and Effect (C&E) Matrix</i>	68
3.5.3 <i>Failure Mode and Effect Analysis (FMEA)</i>	70
CHAPTER 4 RESULTS AND DISCUSSION.....	73
4.1 Quality Modeling.....	73
4.1.1 <i>Observations from the Survey Results</i>	74
4.1.1.1 <i>Service Categories Histogram</i>	75
4.1.1.1.1 <i>Mean Service Category Rating for Services</i>	75
4.1.1.1.2 <i>Histograms of each Service Quality Rating</i>	76
4.1.1.2 <i>Coefficient of Variation Histogram (CV)</i>	84

4.1.1.3 Pareto Plot for Service Rating Means	86
4.1.2 Service Model Validation and Factors Affecting Quality of Services (The Nominal Group Technique-NGT).....	87
4.2 Quality/Process Improvement.....	99
4.2.1 Process Mapping	99
4.2.1.1 New Simplified FlowCharts for the Different GIRF Sub-Processes	102
4.2.2 Cause and Effect Matrix (CE matrix)	128
4.2.3 Failure Mode and Effect Analysis FMEA.....	145
CHAPTER 5 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS.....	171
5.1 Recommendations for further research.....	176
Appendix 1: SOA survey on universities' FPM services	178
Appendix 2: Service Quality Models.....	184
Appendix 3: NGT chart for rating sub-factors composing each factor affecting the quality of service	203
Appendix 4: The measuring instrument.....	204
References	206
Abstract.....	215
Autobiographic Statement	217

LIST OF TABLES

Table 1: Common facility services in universities.....	12
Table 2: Principles, Practices, and Techniques of Total Quality	15
Table 3: Various Quality models used in the service industry	42
Table 4: Rating scale for the survey used in the research.....	63
Table 5: Statistical and Six-Sigma tools used in improving the (GIRF process)	64
Table 6: Service Rating Statistics	73
Table 7: Factors and sub-factors of the fishbone diagram.....	89
Table 8: NGT group ratings summary	90
Table 9: Input-output-responsibility matrix for JDI sub-process	105
Table 10: Input-output-responsibility matrix for a CEP sub-process	109
Table 11: Input-output-responsibility matrix for CEPD sub-process	115
Table 12: Input-output-responsibility matrix for CEPDB sub-process	122
Table 13: Cause and effect matrix for the JDI GIRF sub-process.....	129
Table 14: Cause and effect matrix for the cost estimated project, no design, no bidding (CEP) GIRF sub-process.....	132
Table 15: Cause and effect matrix for the cost estimated, schematic design and no bidding project (CEPD) GIRF sub-process	136
Table 16: Cause and effect matrix for the cost estimated, schematic design, with bidding (CEPDB) GIRF sub-process	140
Table 17: FMEA for the JDI GIRF sub-process.....	146
Table 18: FMEA for cost estimated no design no bidding (CEP) GIRF sub-process	150
Table 19: FMEA for cost estimated – schematic design (CEPD) GIRF sub-process	156

Table 20: FMEA for cost estimated, schematic designed, and bidding (CEPDB) GIRF
sub-process162

LIST OF FIGURES

Figure 1: The initial model for facilities' service quality	48
Figure 2: The Cause and Effect diagram relating service quality to factors and sub-factors affecting service quality	55
Figure 3: Schematic diagram relating Six-Sigma tools utilized in the GIRF process improvement to a particular DMAIC phase.....	65
Figure 4: The mean rating histogram for all services.	75
Figure 5: Restroom fixtures histogram	76
Figure 6: Water fountains histogram	77
Figure 7: Interior lighting histogram.....	77
Figure 8: Exterior lighting histogram	78
Figure 9: Winter comfort histogram	78
Figure 10: Summer comfort histogram.....	79
Figure 11: Elevators histogram.....	79
Figure 12: Door hardware and keys histogram.....	80
Figure 13: Ceilings histogram.....	81
Figure 14: Histogram for Floors.	81
Figure 15: Histogram for Painting	82
Figure 16: Maintenance work requests histogram	82
Figure 17: GIRF work requests histogram.....	83
Figure 18: Overall satisfaction with work performed histogram.....	84
Figure 19: All separate service histograms in one chart.	85
Figure 20: Histogram of Coefficient of Variation (CV) vs. service categories.	85

Figure 21: Pareto chart for service categories needing improvement.....	87
Figure 22: NGT Modified fish bone before prioritizing factors and sub-factors	88
Figure 23: Total weighting scores for sub-factors from NGT session.....	94
Figure 24: Further revised fishbone diagram based on a 70 percent cutoff.....	95
Figure 25: Final Fishbone diagram with the new classification of factors and sub-factors affecting FPM service quality based on 60% cutoff	97
Figure 26: The modified model for the facility services quality in higher educational institutions	98
Figure 27: Macro flowchart for major sub-processes for GIRF	100
Figure 28: Flow chart for decisions	101
Figure 29: Just Do It (JDI) sub-process flowchart.....	104
Figure 30: Cost estimate, no design and no bidding (CEP) sub-process flowchart.....	108
Figure 31: Cost estimate; schematic design, and no bidding (CEPD) sub-process flow chart.....	114
Figure 32: Cost estimate, schematic design, and bidding (CEPDB) sub-process flowchart	121
Figure 33: Pareto chart for CE matrix for the JDI GIRF sub-process	130
Figure 34: Pareto chart for CE matrix for the cost estimated project, no design, no bidding (CEP) GIRF sub-process	134
Figure 35: Pareto chart for CE matrix for the cost estimated project, schematic design, no bidding (CEPD) GIRF sub-process	138
Figure 36: Pareto chart for CE matrix for the cost estimated project, schematic design, and bidding (CEPDB) GIRF sub-process	143
Figure 37: Pareto chart prioritizing the most impact hazardous on the process output for the JDI GIRF sub-process	148
Figure 38: Pareto chart prioritizing the highest impact hazardous on the process output for the cost estimated, no design, no bidding (CEP) GIRF sub-process	154
Figure 39: Pareto chart prioritizing the most impact hazardous on the process output for the	

cost estimated, design, no bidding (CEPD) GIRF sub-process160

Figure 40: Pareto chart prioritizing the most impact hazardous on the process output for the
cost estimate, design, and bidding (CEPDB) GIRF sub-process169

CHAPTER 1 INTRODUCTION

1.1. Background on Facilities Management

Facility management (FM) is defined by (Wong 2007) as “the services related to the built environment to provide occupants with a pleasant and productive environment, under which commercial occupants can concentrate their resources on their core business and residential occupants can enjoy their living space.”

The International Facility Management Association (IFMA) defines facility management as “a profession that encompasses multiple disciplines to ensure functionality of the built environment by integrating people, place, process and technology.”

In universities, facility management service deficiencies are likely to be occurring at any time. Documents for different jobs related to service delivery could be piled on a desk; another problem could be related to electricity not resolved in some laboratories on campus for a long time; a door at a building needs repairs and may still be waiting to be fixed; there is no regular trash removal, and sometimes one will find toilets and restrooms running out of toilet paper, and do not meet cleanliness standards. These kinds of problems are potential facility services related issues at a university.

Computer and information technology resources, a stable quality service improvement business strategy, and trained staff can help universities’ facility administrators better manage their facilities and greatly eliminate the mentioned problems, making the work smoother and more efficient. Many universities suffer from these types of problems and efforts were undertaken for improvements. At Utah State University, the housing and food services department wanted to

eliminate certain steps that slow down the work-order process. Communication was found to be a big problem within the department needing improvement. At Northshore School District in Bothell, Wash., facility rental double booking occurred frequently because of the lack of adequate software, as well as some bugs in the management system. Similarly, facility management departments in universities receive criticisms for delivering services below expected quality levels. This might stem from the fact that they operate in an environment characterized by resource constraints, and growing customer expectations (Chakrabarty and Tan 2007).

Facility management efforts can be enhanced by improved communication, better collaboration within the organization, and improved employee skills. Many questions must be addressed and answered in order to improve the quality of service delivery by the Facility Management (FM) of any institution. Important questions include (Anantatmula 2004):

- What are the most important variables impacting implementation of FM services at the universities?
- What are the key success factors for implementing FM service?
- What difficulties are encountered for successful performance of FM services?
- What metrics are being used to measure service quality for FM in universities?

As noted by (Best et al. 2003), FM performance measurements should be dynamic and revised regularly, and should relate to the continuous improvement of service processes.

1.2. Background on Quality Management, Quality of Services, and Service Quality Modeling

Quality management was established as an important strategy for achieving competitive advantage through continuous improvements. Traditional quality initiatives such as zero defects, statistical quality control, and total quality management systems have acted as milestones for many years of progress through the evolution of newer quality management concepts and strategies. Recently, after the domination of total quality management concepts leading the improvements, Six-Sigma has emerged as a quality improvement initiative that has gained popularity and acceptance in many organizations around the world in both manufacturing and service industries. Even though some of the service processes are unseen, intangible, and even unmeasurable, the application of Six-Sigma in service industries has grown over time, and many service industries such as banking, healthcare, and other services have started implementing the Six-Sigma strategy through their organizations (Chakrabarty and Tan 2007).

The term “service quality” means different things to different people. Service quality should be defined in a way that has meaning for people. It may be defined with the following emphases:

- Customer focus. This approach relies on the ability of the service organization to determine the customer’s requirements and then meet these requirements. This approach is most convenient for service organizations that run a business of high and direct exposure with customers.
- Process focus. This concentrates on internal processes for producing services rather than external processes dealing with customers, and is more useful for an organization offering a service involving short exposure with customers. Facility Management at universities could be categorized under this category.

- Value focus. One of the definitions of quality is “the cost to producer and the price to customer” and “meeting the customer’s requirements in terms of quality, and price” (Ghobadian, Speller, & Jones, 1994)

Service quality was defined in terms of customer satisfaction as “the degree of alignment between customer’s expectations and their perception of the service received” (Candlin and Day 1993). Accordingly, the measure of service quality is largely based on expectations and perceptions (Samson and Parker 1994). As stated by (Lewis and Booms 1983), “Service quality is a measure of how well the service level delivered matches customer expectations.” (Parasuraman et al. 1985) define service quality as the discrepancy between customer’s expectations and perceptions. Service organizations usually face difficulties in delivering a service because of elements such as; heterogeneity, lack of visibility of quality problems, difficulties in identifying sources of quality problems, and challenges in associating any problem to a particular phase of service processes.

The growth and development of service quality modeling research can be traced back to the early eighties of the last century. Early service quality researchers such as Parasuraman, Zeithaml, Berry, Ghobadian, Speller, and Jones defined the quality model as a visualized and clear description of the actual situation for a specific service, and studied the factors affecting quality of service. It was thought that quality problems could be addressed more specifically and clearly by the existence of a conceptual quality model that will facilitate the brainstorming sessions to better identify these problems and to conduct improvement efforts toward solving these problems. In broad terms, a service quality model should involve an attempt to show the relationship between significant variables affecting the perceived service quality. Different service quality models represented different point of views (Seth et al. 2005).

Service quality models are useful for a number of reasons:

- 1- They provide an overview of factors that affect the service quality of the organization.

- 2- They facilitate understanding the service processes.
- 3- They help to clarify how quality shortfalls develop.
- 4- They can provide a framework for launching quality improvement programs.

Ghobadian et al. (1993) mentioned that service organizations usually adopt one of two basic approaches to service quality management; passive or strategic. In the passive approach, the focus is on just stop or minimizing customer annoyance, rather than achieving customer satisfaction. The strategic approach focuses on customer satisfaction and service quality is considered as the key for guiding the business and competition. Launching of a strategic service quality program requires a clear vision and understanding of the service quality features, customer requirements, and service quality determinants. This is what is missing in most service organizations, which opt essentially for a passive quality management program, such as many of the FM service departments at universities.

1.3. Background on Six-Sigma

The Six-Sigma method is becoming increasingly more popular in the quality field (Stamatis 2003). Six-Sigma is defined by (Harry and Schroeder 2006) as “the strategy that provides companies with a series of interventions and statistical tools that can lead to breakthrough profitability and quantum gains in quality, whether a company’s products are goods or services.” Harry & Schroeder; and Antony, J. (2006) mentioned that the General Electric Corporation, one of the big early implementers of Six-Sigma, emphasized that Six-Sigma is a highly disciplined process that helps us focus on developing and delivering near-perfect products and services. The word Sigma is a statistical term that measures how far a given process deviates from the mean, which represents perfection.

The Six-Sigma methodology is designed to provide a systematic way of applying statistical tools in the context of process improvements in any organization. This is done by the application of the DMAIC methodology (Define, Measure, Analyze, Improve, and Control) (Antony 2006). The DMAIC framework entails the identification and elimination of the sources of variation in a process; improving and sustaining performance with well-executed control plans; and promoting one process improvement language for all members of an organization to utilize. Six-Sigma methodology emphasizes listening to the voice of the customer in order to identify the customer's needs and requirements and converting them into specifications in the design of the service or production that can be monitored and measured (Lee 2002). Variation in processes is defined as any quantifiable difference between individual measurements; such differences can be classified as being due to common causes (random), or special causes (assignable) (Beady Fall 2005). The study described herein focuses on the application of Six-Sigma principles and tools to improve facilities services in institutions of higher learning, using the Wayne State University facilities management systems and processes as a case study.

1.4. Problem Statement

Although organizations operating with FM departments have a lot of knowledge accumulated through practice and experience over time, and a good portion of this might be internally documented, our literature survey shows that there is no published information concerning the investigation and/or evaluation (by the customer) of the services provided by universities facilities management units, and no previous research was done to measure and evaluate such services to address, identify, and model the critical factors affecting quality. Jayyousi and Usmen (2001) have worked on the evaluation and improvement of the services provided by the facility management department in public schools. Their research applied a TQM framework and focused on evaluation and ranking of facilities services, which led to general recommendations for improvements (Jayyousi 2001).

Over the past few decades, considerable effort was directed toward modeling of service quality and use of Six-Sigma methods and tools for improvement. These have not been applied to facilities services, resulting in a gap of knowledge in this area. Our research was directed toward closing this gap. Evaluating quality in various areas of service will lead to discovering the weak points for the services provided by universities' facilities departments, and help address improvements.

Through an extensive search of the literature, it was noted that even though there is a body of research on service quality modeling for different types of services, there is no work on facility services modeling linking all factors and variables affecting the service quality provided specifically for universities and higher education institutions. It is thought that these types of organizations have some unique factors to consider, such as internally provided and unpaid services. This study examines different functions of facilities services organizations at universities

and develops a performance measurement system for service categories provided, while addressing the factors affecting quality management to devise an improvement strategy using Six-Sigma methodology. A quality model is used to accomplish this objective.

1.5. Research Objectives

The purpose of this research is to devise a conceptual framework of applying Six-Sigma continuous quality improvement strategy through a model to improve quality of services provided by facilities management departments at universities. This was accomplished by applying a detailed survey to collect data from Wayne State University revealing customer evaluations of the levels of present quality of service, analyzing the data using Six-Sigma methodology, and subsequently using the Six-Sigma tool box to explore opportunities of improvements in the service delivery.

Specific objectives of the study can be summarized as follows:

1. Develop a quality model applicable to facilities services in higher learning institutions (universities); establish and document how this can be done.
2. Develop a service quality evaluation and improvement framework for facilities, and link it to the quality model.
3. Analyze and demonstrate the efficacy of the model and the approach for a specific facility department at a large university (WSU).
4. Develop an approach and an implementable plan (methodology) for process improvement; document this for a specific function.

1.6. Research Approach and Dissertation Format

This Dissertation was organized in five chapters; Introduction, Literature Review, Research Methodology, Analysis and Discussion of data, Summary and Recommendations. The “Introduction” chapter presents the problem statement, objectives and purpose of the research. The second chapter covers previous work and research in the field of quality management with a focus on service industries and with an emphasis on Six-Sigma. Chapter Three, “Research Methodology” presents the way the research was conducted, the data collection survey form, the model used in the research and the Six- Sigma tools and methodology that were used in order to improve the quality of service at universities’ facilities management units. This includes design of the survey for the data collection, and Six-Sigma tools used in the dissertation. Chapter Four, “Analysis and Discussion” presents the ways the data were analyzed, and the results. Chapter Five, “Summary and Recommendations” summarizes the research findings and the recommendations developed by the researcher on the adaption of the proposed quality model along with the methodology for the improvement of the service quality by the universities’ facility management units. References and appendices for this dissertation are included at the end.

CHAPTER 2 STATE-OF-THE-ART LITERATURE REVIEW (SOA)

A state-of-the-art review was conducted on facilities management, quality concepts and principles, quality in services, and Six-Sigma philosophy, techniques, and tools. Quality models used in different types of services, created by other researchers, were also covered. The foundation of the study was established through an extensive literature review of dozens of articles and publications relating to different aspects of the study. An analysis of relevant publications, citations, and references was carried out using multiple databases available at the Wayne State University library system databases. Information was collected on different service categories provided by many large universities facilities units, and Six-Sigma applications for services, including different definitions of Six-Sigma, and the ways and frameworks for Six-Sigma implementation as well. Comparisons were made between Six-Sigma and other quality improvement strategies such as Total Quality Management (TQM), and the benefits and limitations of the implementation of Six-Sigma strategy in service industries were researched. The information gathered from this review was helpful for efforts to construct a quality model for universities' facilities services. Different types of information sources were utilized in the preparation of this review; including scholarly papers published in different journals, theses, dissertations, and books.

2.1 Facilities Services in Universities

Service categories provided in regard to facilities management at universities, according to the literature and websites for many different large universities in the US typically consist of the service categories listed in Table 1. Certain services included under the responsibility of facilities management units at some universities are not included in similar groups at other universities, so none of the universities reviewed in this research have all of the services listed

in the table under the responsibility of its facilities unit. We have included all these services, even though some universities didn't have all the listed items, to maintain universality and inclusiveness. Therefore, any framework, model, guidelines for quality improvement resulting from this research should be applicable to any university providing such services. All the information about the services mentioned in Table 1 was taken from the different universities' official websites. More detailed description of services and universities' websites are presented in Appendix 1.

1. Construction services.
2. Facilities maintenance.
3. Facility buildings and ground services.
4. Facility administration.
5. Utilities and facilities engineering.
6. Work control services.
7. Architecture, engineering, and construction services.
8. Occupational safety & environmental health services.
9. Public safety services.
10. Parking and transportation services.

Table 1: Common facility services in universities

Services		WSU FPM	
1. Installation and repair services		Yes	No
Service Category	Description		
Plumbing	Providing all plumbing works related to building renovations	•	
Carpentry	All carpentry related works for building renovations	•	
Painting	They provide the following services: spray painting, furniture refinishing, graffiti removal, electrostatic painting, and exterior and interior painting	•	
Cabinetry	A shop produces different types of furniture	•	
Furniture repair	Wood furniture repair, reupholstery services, sports and therapy equipment, transportation materials, auditorium seating	•	
Signage	Providing signage and window films	•	
Glass works	Skylight repairs, mirrors, screen replacement, entrance systems/ doors, windows replacement	•	
2. Facilities maintenance services			
HVAC	Heating, Ventilation, Air condition	•	
Plumbing maintenance	All preventive and corrective plumbing works for buildings maintenance	•	
Roofing	Installation, maintenance, repair, and seasonal cleaning.	•	
Elevators	Maintenance and repair of elevators and escalators.	•	
Metal shops	Heating service, sheetmetal shop, machine shop, welding shop, millwright shop.	•	
Fire systems	Including all firefighting systems		•
Electrical systems	Including preventive and corrective electrical works related to building maintenance	•	
3. Facilities custodial and ground services			
Custodial services	Involves cleaning, trash removal, bulb changing, and other related works	•	
Pest control	Preventive and corrective actions regarding extermination of all pests	•	
Ground services	Street and sidewalk sweeping, snow removal, and trash removal	•	
Landscape design	Landscape renovations, develop landscape plans, provide project management during installation.	•	
4. Facilities administrative services			

Financial services	Budget administration and general accounting.	•	
Information technology services	Preparing plans for providing facilities related buildings and services with latest and proper information technology including internet systems, and sources for accessing facilities related data and information	•	
Preventive maintenances plans	Preparing plans for scheduled preventive maintenance for buildings.	•	
Quality assurance inspections	Follow up and control all facilities related activities to ensure a quality provided services to customers	•	
5. Utility and facilities engineering services			
Energy consumption awareness	Minimize energy consumption, creating awareness about energy and resource conservation, coordinating strategies for improving energy efficiency and providing an efficient electrical distribution system		•
6. Work control services			
Customer contact office	Serves as the single point of contact for facilities operations with customers.	•	
Preventive maintenance sector	Provides preventive maintenance planning and quality assurance inspections as well as coordination for estimates, shutdowns, and projects.	•	
7. Architecture, engineering, and construction services			
Capital projects	Managing and design of university's capital projects.		•
Project management	Responsible for selecting of all consultants and construction contractors through all stages of design and construction.	•	
8. Occupational safety & environmental health services			
Biological and laboratory safety	Promoting research safety and assuring sound laboratory management by providing services such as: certification services, hazardous procedures manual and safety training development, research facility planning and design		•
Environmental protection	Provide these services to all university departments in these area: storage tank management program, chemical use compliance, research activities, property redevelopment, reduce waste generation, pollution prevention and recycling activities		•
Emergency preparedness	provides resources, guidance, and training of the university community in matters related to emergency preparedness, response, and recovery		•
Fire safety services	Responsible for ensuring compliance with applicable fire safety regulations		•
Hazardous materials management	Responsible for the collection and proper disposal of chemical, radioactive, and biological waste generated during teaching, research, and clinical operations.		•
Industrial hygiene and safety	protects university staff from workplace injury and illness by assisting departments in anticipating, evaluating, and controlling potential health and safety hazards.		•

Operational safety and community health	provides community health support for food service establishments on campus, drinking water issues, pesticide usage, and swimming pool issues.		•
Radiation safety services	provides the radiological safety training, professional guidance, and technical support necessary to establish and implement an effective radiation safety program at the university.		•
Public safety	Provides information about police services as well as parking enforcement, communications center, criminal investigations, and other units.		•
Parking and transportation services	Provide maps, bus routes, schedules, parking permit and vehicle lease options; as well as brief construction updates that may affect the university community		•
9. Public safety services			
Providing information regarding safety to customers	It provides information about police services as well as Parking Enforcement, communications center, criminal investigations, and other units.		•
10. Parking and transportation services			
Providing information regarding transportation and parking to customers	Provide maps, bus routes, schedules, parking permit and vehicle lease options as well as brief construction updates that may affect the university community		•

2.2 Service Operations and Quality

Quality in a service organization is a measure of the extent to which a delivered service meets the customer's expectation. Customer perception will determine how much this service will comply with his expectations. It is, therefore, very important to determine voice of customer to determine his needs and requirements, then design the service to meet these requirements. The quality movement has spread over the service industry as it spread over manufacturing. The movement toward continuous quality improvement in service was adopted as a necessity to stay in business and be in a good competitive position (Miller 1997) .

(Sitkin et al. 1994) describe how the concepts associated with quality management can be divided into three branches: focusing on customer satisfaction, continuous improvement, and treating the organization as a total system. As proposed by (Hope and Mühlemann 1997), quality

measurement of service operations management may be expressed as asking customers about their expectations of the service and ask them about their perceptions of actual service they received. (Dean Jr and Bowen 1994) illustrate quality management in terms of three principles: customer focus, continuous improvement, and teamwork as described in Table 2

Table 2: Principles, Practices, and Techniques of Total Quality

	Customer focus	Continuous improvement	Teamwork
Principles	Paramount importance of providing products and services that fulfill customer needs; requires organizationwide focus on customers	Consistent customer satisfaction can be attained only through extreme improvement of processes that create products and services	Customers focus and continuous improvement are best achieved by collaboration throughout an organization as well as with customers and suppliers.
Practices	Direct customer contact. Collecting information about customer needs. Using information to design and deliver products and services	Process analysis. Reengineering. Problem solving. Plan/do/check/act	Search for arrangements that benefit all units involved in a process. Formation of various types of teams. Group skills training.
Techniques	Customer surveys and focus groups. Quality function deployment (translates customer information into product specifications)	Flowcharts. Pareto analysis. Statistical process control. Fishbone diagrams.	Organizational development methods such as the nominal group technique. Team-building methods (e.g., role clarification and group feedback)

(Saraph et al. 1989) classified the effective quality management sub-factors into eight categories: the role of management leadership, the role of the quality department, training,

product/service design, supplier quality management, process management, quality data and reporting, and employee relations.

2.3 Characteristics of Service Operations

(McLennan 2004) has mentioned three characteristics of service operations which have long been performed in the facility management industry and argues that facility management performance was developing within service operations management. The three characteristics are:

- FM services are often heterogeneous as no two customers are alike, each having individual requirements.
- FM services are intangible.
- Most services are inseparable. In other words, services are generally produced and consumed in the same time frame. i.e., simultaneous production and consumption.

McLennan's observations support the idea that many existing concepts, techniques, and models which were applied in service operations management may be applicable to the facility management industry. (Parasuraman et al. 1985) made the following three observations for the measurement of service quality:

- Service quality is more difficult for the customer to evaluate than manufacturing.
- The perceptions of quality result from a comparison of customer expectations with the perceived service performance.
- Not only the outcome of a service is evaluated, but also the process of service delivery.

(Al-Saggaf 1999) noted that the achievement of success in service quality requires:

- Customer focus: identify customer needs and requirements.
- Empowerment of staff in contact with customers; giving staff the flexibility to make important decisions regarding the customer's needs.

- Well trained and motivated staff; the more trained staff, the more positive results attained and more customer satisfaction level acquired
- Clear “Service Quality” standards; the absence of the clear vision of service quality will lead employees to use their own interpretation and view of good service quality. The result is a high amount of variability through the different steps of service delivery according to whom of the employees providing the service.

To provide successful service, the organization should figure out what customers need. It is not enough to simply expect that because they buy your product or use your service they will be loyal or satisfied. Customer satisfaction may not be simple for service organizations. It can be as complex as tracking customer habits and anticipating needs (Parasuraman et al. 1990).

2.3.1 Relationship between Quality of Service and Organizational Performance

(Gale 1994; Gale and Klavans 1985) found a significant positive correlation between perceived quality of service and organizational performance. The relationship between quality management practice measured in terms of conformance with Malcolm Baldrige criteria, and organizational performance measured on four categories of performance; employee relations, operating procedures, customer satisfaction, and financial performance was examined by (Usilaner 1992), and they found a positive correlation. (Hernon and Dugan 2002) suggested that quality might be viewed from two different perspectives: “technical quality” and “customer quality.” Technical quality is more about processes and procedural aspects that ensure that services function effectively and efficiently, while customer quality deals with aspects related to customer perceptions of service quality.

2.3.2 Service Industry Characteristics vs. Manufacturing

Several characteristics differentiate the service industry from the manufacturing industry (goods) in three different ways: How they are produced, consumed, and evaluated. The most common characteristics of services found in the reviewed literature are: intangibility, heterogeneity, and inseparability of production and consumption (Parasuraman et al. 1990).

Intangibility is most often considered as the most important distinction between services and goods. The fundamental difference is that most services including FM services are intangible. Services are performance, rather than objects, which cannot be sensed (seen, felt, tasted or touch) in the same manner in which goods or objects can be sensed (Ghobadian et al. 1994). Services are heterogeneous because their performance often varies by different producers, customers, times and places. It is difficult to produce services consistent and uniform as goods. Heterogeneity in service output is a particular problem for services using labor heavily, where different employees may be involved in the production of service. A significant part of FM service related problems come from the heterogeneity of service provided. This can be felt when discussing and brainstorming sources of FM service problems. The consumer's perception of quality is influenced by the behavior of service provider. It is difficult to ensure consistency and uniformity of behavior of service provider because of the heterogeneity of service. The heterogeneity and lack of standardization, results from the service provider's make it difficult to control performance or quality of a service (Berry et al. 1990). Production and consumption of many services are inseparable in many types of service industries. The provider performs the service at the same time as the full or partial consumption of the service takes place by customers. Since services are often produced in the presence of the customer, the assessment of quality is made by customers during the service delivery process (Kim 2003). In manufacturing, goods are first produced, then sold and finally consumed, while services

are first sold, then produced and consumed simultaneously. The service provider therefore needs to get the service right first time, every time. Each unique characteristic of service industry leads to the creation of unique problems for that kind of service only and not faced in the manufacturing processing of goods. Service providers need a specific kind of care in dealing with those problems (Zeithaml et al. 1993). FM services, because of their varieties and diversity as covered previously, are not affected by mentioned elements by the same manner or same way. Some FM services are more manufacturing related than service problems, especially for buildings and facilities renovation, constructing new facilities, and HVAC.

2.3.3 Differences in the Evaluation of Product Quality vs. Service Quality

Quality for manufacturing was well defined by different methodologies and methods, whereas quality in service is not as well defined. Efforts in defining quality in service industry are based on the subjective rather than the objective methods of evaluation. The ways of assessing quality of service is different from manufacturing according to the characteristics of services and goods discussed in the previous section. Customers can judge quality of goods by physical evidences such as color, style, hardness, and fit. However, when purchasing services, tangible evidences are less and assessment of quality occurs subjectively rather than by solid physical evidences (Parasuraman et al. 1985). Service quality is highly dependent on the performance of employees, and not engineered by the way goods are engineered at manufacturing plants then delivered to the consumer after final quality checking and inventorying. The quality of goods usually measured by what is called “mechanistic quality” that involves the objective aspects of features of goods, while quality of services is often measured by “humanistic quality” that involves subjective responses of people (customers) to the way that they perceive quality, which is different from one to other. Unlike the quality of goods that can be measured objectively by such countable

indicators as number of defects, most services cannot be counted, measured, inventoried, tested and verified in advance of sale to ensure quality delivery. As the evaluation of service quality is done by customers on the output of service, it also involves the process of service delivery during the contact between the customer and contact personnel of the service organization. This is very common in FM services. Service quality is more difficult for the consumer to evaluate than of the quality of goods due to the subjective effect of evaluation of quality of service (Zeithaml et al. 1988).

2.3.4 Obstacles Facing Service Quality Improvements

Difficulties unique to services include but are not limited to following complications: service cannot be stored, mass-produced, patents cannot be protected, quality of service is difficult to control; service costs are difficult to calculate; demands for services fluctuate; consumers themselves are involved during the service production process (Zeithaml et al. 1985). As seen by (Ghobadian et al. 1994), There are several issues considered to be obstacles in the achievement of service quality:

Lack of visibility: Service quality problems are not always visible to the service provider. They need more investigations to define them precisely.

Difficulties in assigning service problems to specific reasons: Sometimes it is hard to identify the stage of the service delivery that creates a specific problem in the service outcome. It is hard to attribute quality problems to a particular stage of service delivery.

Time required to improve service quality: Because service quality is more dependent on people rather than machines and systems, service quality problems require major efforts over a long period of time to be resolved. Improvement will be taking place mainly on people and behaviors more than on machines and apparatus.

Delivery uncertainties: Due to people behavior, control and consistency of uniform service delivery and quality is complicated by the individual and unpredictable nature of people.

2.3.5 Customer Satisfaction vs. Service Quality

(Hernon and Nitecki 2001) have studied the concept of service quality and mentioned that service quality and customer satisfaction are not synonymous concepts. (Al-Saggaf 1999) mentioned that the dominant model of customer satisfaction in the service quality literature as is follows: “Customer satisfaction is a summary cognitive and affective reaction to a service incident.” As (Hernon and Nitecki 2001) mentioned that service quality is an evaluation of specific attributes and behaviors and this judgment is perceptive. However, customer satisfaction could result from a specific or unique transaction or, in the case of overall satisfaction, it is a cumulative impression based on the result of several contacting with a service provider over time. (Hernon and Whitman 2001) also identified the difference between satisfaction and service quality by viewing “service quality” as dealing with customer’s expectations and “satisfaction” as dealing more with customer’s perception and emotions to a specific service event or the cumulative experiences that a customer has with a service provider.

It is obvious that service quality and customer satisfaction are closely related. Customer could be satisfied by a specific service even though that the range of service quality is not high (Parasuraman et al. 1985). Comparing customer expectations with service delivered will results in a determination of how much is the service quality, because service quality is highly determined by the conformance to customer expectations. In order to satisfy the consumer, the service provider must insure that the perceived service should match or exceed the customer expectations. Customer’s expectations towards a particular services are also changing with respect to factors like time, increase in the number of encounters with a particular service, competitive environment, etc.

(Seth et al. 2005). (Parasuraman et al. 2004) defined service quality as a comparison to excellence in service perceived by the customer, while (Bitner 1990) defined service quality as “The consumer’s overall impression of the relative inferiority, superiority of the organization and its services.” Assessments of service quality attained from a comparison of planned service level and perceived service level while customer satisfaction results from comparison of predicted service or (customer requirements) and service outputs (Zeithaml et al. 1993).

2.4 Six-Sigma and Service Quality

Organizations everywhere are under pressure to maintain high level of quality of services, and meet their customer requirements and expectations with reasonable and competitive costs. That’s why a large portion of companies and organizations adopt the Six-Sigma approach as a methodology for quality improvement. Six-Sigma has evolved through the accumulation of efforts of researchers in the field of scientific management and continuous management theories (Aboelmaged 2010). Six-Sigma could be described as a strategy that allows companies and organizations to drastically focus on continuous improvement in everyday business activities and processes to increase customer satisfaction (Andersson et al. 2006). In industrialized nations, services have become the dominant sector of the economy. Recently, a number of articles have focused on the importance of Six-Sigma for services and the challenges of applying this quality improvement methodology to service operations. The Six-Sigma wave has spread from the US to the European Union, Japan, and Canada and is gradually becoming popular in India and other less developed countries (Nakhai and Neves 2009). By observing the various Six-Sigma definitions in the literature, it is found that it reflects a basic philosophy. It is a customer-focused methodology that drives out waste, increase levels of quality, and enhance the financial performance of organizations (Chua 2001).

The root of using the “sigma” term to describe the quality of the process was introduced by Walter Shewhart in 1922 when he proposed a concept of three sigma along both sides of the mean. Outputs outside the three sigma in both sides of the normal curve will lead to a defect, and some process intervention is needed. Six-Sigma’s target for perfection is to achieve no more than 3.4 defects and/or errors per million opportunities (DPMO) which is mostly applicable to manufacturing. This is where the “Six-Sigma” name originated. Sigma (σ) is the symbol used to refer to the standard deviation or measure of variation in a process. The greater the number of sigmas within specification limits, the less variations and fewer defects and more consistency of the process. A Six-Sigma level of performance means that we can fit in six standard deviations or sigmas between the process centre and the nearest specification limit. It is too hard and expensive if we try to achieve Six-Sigma in all processes. We need to focus on the most critical ones that are very important or critical to customer requirements (Chua 2001).

In spite of a number of success stories for applying Six-Sigma to manufacturing organizations, there is still doubt on the opportunities of success in applying Six-Sigma in the service industry. The popularity of using Six-Sigma in service industries was growing over time especially in banks, shipping, hospitals, financial services, invoicing, billing, payroll, customer order entry, airlines, baggage handling, and utility services (Antony et al. 2007). Six-Sigma today has evolved from simply a measurement of quality to an overall business improvement strategy for a large number of companies around the world (Antony 2006).

Some famous service organizations such as J P Morgan, American Express, Zurich Financial Services, BT, Lloyd TSB, GE Medical Systems, GE Capital Corp, Mount Carmel Health System, Virtua Health, , Bank of America, and Citibank have adopted Six-Sigma as a route for improvement and business strategy (Antony 2006; Chakrabarty and Tan 2007). One of the ways of spreading the use of Six-Sigma in service industries is that manufacturing companies have started

applying Six-Sigma to their service operations (Antony et al. 2007). Many authors such as (Craven et al. 2006; Davison and Al-Shaghana 2007) have seen Six-Sigma as an organizational change strategy leading to changing the culture of the organization and increase in customer satisfaction.

One of the main objectives of Six-Sigma is to reduce the defect rate in processes through the effective implementation of proper statistical tools and techniques. This will result in improving customer satisfaction, enhance quality of service, and reduce the costs of poor quality. One of the registered benefits of Six-Sigma is that Motorola has spent 170 million dollars on education and training of employees in three consecutive years. As a result, Motorola has saved 2.2 billion dollars in terms of cost of poor quality. The primary ways to achieve Six-Sigma quality level is to reduce the cause of quality or process related problems before they are transferred into defects. Six-Sigma is not about counting defects in process. This leads to focusing of fire prevention rather than firefighting strategies (Antony 2006). The objective of Six-Sigma strategy in service processes is to understand how defects occur, causes of these defects, and then to devise process improvements to prevent or reduce the occurrence of these defects which lead to increasing customer satisfaction (Antony et al. 2007).

2.4.1 Six-Sigma in the Service Industry

In a service industry, it is hard to measure and control the service processes due to high amounts of noise including uncontrollable input factors such as emotions and moods of the person providing the service. One of the main purposes of introducing Six-Sigma in service industry is to understand the process which creates the defects and devise process improvement activities to reduce the occurrence of such defects, and establish and map the key processes that are critical to customer satisfaction requires focus mainly on the input variables that have significant effects on the outputs in line with customer requirements (Antony 2006; Antony et al. 2007). Even though

Six-Sigma relies on using statistical tools, it is not about collecting a wide range of statistical tools and applying complicated techniques. In fact, service organizations do not need many of the tools and techniques to be used as one package. The majority of quality related problems and processes in service organizations can be conducted by using simple Six-Sigma tools such as process mapping, cause and effect analysis, Pareto analysis, control charts and so on.

The benefits of adopting Six-Sigma in the service industry could include transformation of the organization culture from the firefighting mode to the fire prevention mode; reduce costs of poor quality; reduce service operation costs and increase market share; reduce defect rate and the non-value added process steps in critical processes; increase awareness of a range of problem solving tools and techniques leading to increase quality of services provided; and contribute to customer satisfaction. Improving and maintaining consistency in the level of service provided through elimination of variability, better management decisions due to reliance on data and facts rather than assumptions and guessings will improve customer satisfaction through reduction of variability, and achieve faster service delivery through process improvements (Antony et al. 2007).

2.4.2 Tools and Techniques for Service Process Performance Improvement

The purpose of this section is to look at the commonly and widely used Six-Sigma tools and techniques in the service industry. Examples of service process performance tools include process maps, flowcharts, cause and effect analysis, Pareto analysis, Failure Mode and Effect Analysis (FMEA), histograms, and control charts. Some of the tools are relevant for more than one stage of the methodology. Even though Six-Sigma tools are not new, they were brought together to provide a well-stocked toolbox. It was observed in the literature that many service organizations are gaining significant benefits through the application of the basic Six-Sigma tools. It was mentioned that the basic tools of quality control would be able to tackle 80 percent of quality or process related

problems. Any output Y is a function of process inputs X 's. The successful implementation of Six-Sigma requires systematic and disciplined application of tools and techniques. Although the tools and techniques used by Six-Sigma are not new, the strength and success lie in the integration of these tools and techniques into the DMAIC phases of Six-Sigma methodology (Antony 2006; Antony et al. 2007; Nakhai and Neves 2009). Six-Sigma methodology makes use of several steps in order to conduct the improvement journey. These steps are included in the DMAIC, D: definition of the problem (determine which processes to improve), M: measurement of the problem (collect all the necessary data); A: analysis of data to discover the root causes for the problem. I: improvement efforts to remove the root causes of defects. C: controlling and monitoring processes and improvements (reduce defects by making changes to in the process) (Antony 2006). It was observed in previous research that many service organizations are getting benefits from the implementation of the simple tools of Six-Sigma methodology such as process mapping, Voice Of Customer, cause and effect analysis, and FMEA (Antony et al. 2007; Chakrabarty and Tan 2007).

2.4.2.1 Process Map

Process map is a graphical representation of the flow of the process steps and activities presenting how inputs are processed through process steps producing final product or service (Beady Fall 2005). (Sokovic et al. 2005) define process map as a graphical illustration of a process flow that shows the steps of the process. It tells us about the logic of the process, areas of potential improvement, enables the viewing of the system where one can identify flow of resources and information, tasks, decisions, requirements for input and output of certain tasks in the process, location of bottlenecks, non-value adding tasks and activities, and personnel responsible for delivering inputs and outputs, . Every process map should result by the efforts of teamwork, not by

a single person sitting on his computer because it is impossible that just one person could have all the knowledge and details about the process.

(Biazzo 2002) defines process mapping as “Process mapping consists of constructing a model that shows the relationships between the activities, people, data and objects involved in the production of a specified output.” Pyzdek (2003) defines process mapping as “a graphic representation of a process showing the sequence of tasks.” (Su et al. 2006) have used the process mapping technique to modify and improve service quality for a specific service organization using a combination of Lean and Six-Sigma methodology. Even though process mapping does not provide comprehensive solutions, but it acts as a diagnostic tool and a requirement for successful process improvement (AL-SUDAIRI).

In a service process map, some activities are processing information, others are interactions with customers, and still others are decision points. A process map is a precise definition of the service delivery system. It is one of the essential tools for improvement because it enables the viewing of the system. With a good process map one can identify:

- Flow of people, work, and information
- Activities, queues, and decisions, which are essential in measuring cycle time of flowing units in a process
- Value adding activities and non-value adding activities.

According to (Al-Sudairi 2005; Kalman 2002; Su et al. 2006), a process map acts as a part of the define phase of the Six-Sigma DMAIC methodology. Characteristics of a process map are as follow:

- Is a graphical tool to demonstrate the way a process is currently working
- Is best created by a team through “walking the process” considering the realities of the work processes.

- Describes value added and non-value added steps, Inputs, outputs, bottleneck steps, and opportunities for improvement
- Is used to begin every process
- Is a tool to gain process knowledge
- Provides inputs to Cause and Effect Matrix (C&E) and Potential Failure Mode Effect Analysis (FMEA)
- Is not a process flowchart; it shows inputs and outputs of each of the process steps as well as responsible personnel for controlling inputs and outputs. It could give a detailed and clear picture of how the process steps are implemented.

2.4.2.2 Cause and Effect Matrix (C&E) Analysis

Cause and Effect matrix (C&E) is one of the Six-Sigma tools used to prioritize the impact of the input variables (X's) (also called Key Process Input Variables (KPIV)) for each task in the process on the output variables (Y's) reflecting customer requirements represented by Voice Of Customer (VOC). A Cause-and-Effect Matrix is quantitatively relates process steps to process inputs and correlates to process outputs. It uses process map and cause-and-effect diagrams as an essential source of information. Each step in the process is ranked (scored) to determine relative importance. The CE matrix template provides a framework for this evaluation. It is an extension of the fishbone diagram and is used to identify the few process input variables that provide the greatest impact on the key process outputs (Sokovic et al. 2005; Thomas Pyzdek 2010).

The outputs are rated by order of importance according to the customer point of view, while the inputs are scored in terms of their relationship to outputs by the people involved in the process. After the development of the CE matrix, few important inputs are resulted by getting the highest ranking scores among the all process inputs and act as the most important inputs affecting process

output. This is done by the implementation of Pareto charts. With the help of the Pareto chart, domains of possible improvement are clearly identified. The important inputs are ordered by their ultimate importance and a new improvement projects regarding these affecting inputs could be established in order to increase process efficiency and customer satisfaction. The total value for each input parameter is obtained by multiplying the rating of output importance (VOC) with value given to each input parameters and adding across for each parameter.

Using a CE matrix, all the KPIV can be rank ordered with respect to the importance of the variable. The results obtained can be used for other analysis and optimizations such as FMEA (Sokovic et al. 2005).

2.4.2.3 Voice Of Customer (VOC)

Voice of the customer is a process used to capture the requirements or feedback from the customers to provide them with a service or product that meets their needs. It is a term that is used in business to describe the process of finding out what your customer's requirements and needs are. This is accomplished by using surveys, process observations, focus groups, field reports, customer complaints, and direct discussion or interviews with customers as a way of gathering the data needed. The voice of the customer is the essential reason for conducting continuous improvement efforts for the process. It should be the ultimate target in the evaluation of existing processes and the design of new processes. A failure to meet customer needs could lead the customer to move to another supplier. In any business process improvement initiative, the voice of the customer should always be present to ensure that:

- a) The product is aligned to customer need.
- b) Any improvement objectives should comply with customer requirement.

2.4.2.4 Failure Mode and Effect Analysis (FMEA)

Failure Mode and Effects Analysis (FMEA) is a systematic analysis of potential failure mode aimed at preventing failures. It is proposed to be a preventive action process carried out before implementing of service or changes in current service processes. It is a way to identify the failures, effects, and causes of failure within a process or product, and then, eliminate or reduce them. It is a tool widely used in analysis, improvement, and control phases of the Six-Sigma DMAIC methodology to identify, prioritize and eliminate known potential failures, and address problems and errors in the system. It is a systemized group of activities that are intended to recognize and evaluate the potential failure of a product or process, identify actions that could eliminate, mitigate, or reduce the likelihood of the potential failure and document the entire process (Chuang 2007; Rotondaro and De Oliveira 2001).

As defined by (Vermilion 2007), “Failure Mode and Effects Analysis (FMEA) is a logical, proactive technique that is used to identify and eliminate potential causes of failures.” (Stamatis 2003) also defines FMEA as “FMEA is a methodology that helps identify potential failures and recommends corrective action(s) for fixing these failures before they reach the customer.” In the service industry, FMEA is critical because in the absence of early alert of failure mode, once a service failure has occurred and resulting in customer dissatisfaction, any corrective actions taken by the service provider after that will likely to be useless and it is not easy to retrieve customer trust again. FMEA is a technique that promotes systematic thinking about process steps progress and performance of activities in terms of the following questions:

- What could go wrong?
- How badly might it go wrong?
- What needs to be done to prevent failures?

FMEA is intended to recommend and take actions that reduce the likelihood of a process failure. It is used to identify weaknesses in the process, predict what might happen as a result of those weaknesses, and initiate a process improvement to minimize the risk of undesired failures. FMEA not only identifies the most potential failure mode but also provides the effects and possible causes for each of the most critical failure mode. This denotes that the preventive actions for these failure modes from occurring should be the top focus in the service processes. FMEA is a procedure to identify and analyze each potential failure mode in a system to determine:

- How a process can fail in meeting the customer needs and the possible failure effects on the process
- The severity of each potential failure mode
- Causes of the failure
- The current control plan denoted for preventing failures, and actions to be taken to repair them.

A service business must understand what customers really need and then deliver its service accordingly. A service failure occurs when customers' expectations are not met. Similar to service quality and satisfaction, it is customers' perception that determines whether a service failure occurred even in the companies with the best strategic plans and the tightest quality control procedures and the service was performed. Combining a process chart that shows all transactions constituting the service delivery process with service failure analysis that identifies critical potential failure mode and take the preventive actions becomes a very important issue in the services. The goal of FMEA is to predict how and where systems designed to detect errors might fail. It is used to analyze tasks comprising the whole process to evaluate each step in terms of risk of failures accompanying the implementation of such steps. Literature regarding FMEA in service industries are not widely found (Chuang 2007; Rotondaro and De Oliveira 2001).

There are two distinct types of FMEA; design FMEA and process FMEA. Design FMEA is used to examine the components of the process to identify the potential failures during the early design stage of the service category. This tool is used to evaluate the correctness of the KPIV those associated with the process steps. Process FMEA is used to analyze the processes used to produce the service. It is more applicable for the service industry after the service was launched. In the service industry including FM in universities, we need both of the two FMEA processes. Even if FMEA is used in the design stage before launching the service, it doesn't give total immunity to the system and the risk of failures evolved is still available, which leads to continuous tracing of all activities and conducting continuous improvement actions to the process. Process FMEA used to analyze existing systems and evaluate steps KPIV in order to prevent failures that lead to customer dissatisfaction. All FMEAs are team based, and there is one person who is responsible for coordinating the FMEA process (Spath 2003).

(Vermilion 2007) mentioned the advantages of adopting FMEA as a tool for failure prediction and control over other methods as:

- Identifying cause and effect of known and potential failures before their occurrence
- Documenting failures so they could be tracked over time
- Making responsibility easier to identify
- Facilitating continuous improvement
- Creating a common language by both technical and non-technical people in the organization that can be easily understood.

2.4.3 Critical Success Factors of Six-Sigma

In order to adopt Six-Sigma as a business strategy for process improvement, we should take care of some tips and notes those affecting the success of the implementation of Six-Sigma:

- Identify which process in the service delivery needs more attention.
- The selected process for improvement should have a great impact and affect the customer satisfaction.
- Define the service defects through the process and how to measure it.
- Apply the proper Six-Sigma tools and techniques in order to define, measure, analyze, improve, and control process.
- Verify the improvements made by Six-Sigma campaign by collecting data before and after implementation then compare how much progress attained.
- Always remember that Six-Sigma is a long term improvement strategy, and it should not be treated as an instant way for change.

The identification of critical success factors for Six-Sigma implementation will help organizations to consider them when they prepare an appropriate implementation plan (Antony 2006; Kwak and Anbari 2006). From intensive literature survey in journals related to quality improvement and Six-Sigma, It was shown that the critical success factors for a Six-Sigma program to succeed are in importance order as follows:

- Top management unlimited commitment and support.
- Linking Six-Sigma to business strategy
- Customer focus
- Project management skills
- Understanding of Six-Sigma methodology
- Project selection and prioritization
- Management of cultural change
- Well trained people on how to use the tools and techniques

- A framework to specify which tool or technique to use
- A well cooperative personnel in contact to the improvement processes.
- Project tracking and reviews
- Incentive program
- Availability of resources

(Antony et al. 2007; Kumar 2007; Kwak and Anbari 2006; Raisinghani et al. 2005)

2.4.4 Differences Between Six-Sigma and Other Quality Initiatives

When compared with TQM, Six-Sigma has many differentiated characteristics. While TQM promotes employee participation and self-managed teams, Six-Sigma is driven by organization's champions (black, green, and yellow belts); Six-Sigma projects are more often cross-functional than TQM department-based projects. The backbone of the Six-Sigma methodology is the well-known five steps of the DMAIC process (Nakhai and Neves 2009).

(Schroeder et al. 2008) have identified four main advantages of Six-Sigma over TQM. These advantages involve use of structured method for process improvement, the focus on financial and business results, and time, and use of a part time and full time improvement specialists (Green belt and black belt). (Antony and Banuelas 2002) mentioned that TQM focuses on fixing the quality problems regardless of the cost.

Many researchers said that many people realize that there is nothing new in Six-Sigma compared to other quality initiatives such as TQM, but some aspects of Six-Sigma which make it different from other quality initiatives were noted as follow:

- Six-Sigma methodology integrates the human elements (customer focus, culture change, belt system infrastructure, etc.) and process elements of improvement (process management, measurement system analysis, statistical analysis of process data, etc.).

- Each tool and technique in Six-Sigma has a role to play and when, where, why and how these tools and techniques should be applied.
- Six-Sigma creates a belt infrastructure of champions, master black belt, black belts, and green belts that conduct, lead, and deploy the approach.
- Six-Sigma decisions rely on facts and data rather than assumptions and guesses.
- Six-Sigma adopts the idea of statistical thinking and enhances the implementation of statistical tools and techniques for defect reduction efforts (Antony 2006).

Recent studies about Six-Sigma have focused on the relation between Six-Sigma and Lean production. A Lean Six-Sigma terminology was introduced to combine Six-Sigma and Lean. Many researchers such as (Andersson et al. 2006; Arnheiter and Maleyeff 2005; Chang and Su 2007; Näslund 2008) have described how both Six-Sigma and Lean complement each other by constructing a strong framework for both eliminating process waste and variation because Lean is concerned with eliminating waste and Six-Sigma is mainly about reducing variation and improving processes.

2.4.5 Challenges for Implementation of Six-Sigma

The application of Six-Sigma in services is growing. There are various challenges could be faced when applying Six-Sigma in service industries. The following are some of these challenges and limitations:

- Data collection, where data collection from service sectors is more difficult than in manufacturing. In service, unlike manufacturing, in most cases customers are the source of data. Also, much of the data in services collected manually by interviewing or surveys while it is automatic in most cases in manufacturing.

- Measurement of customer satisfaction in services is more complicated due to the human behavioural and emotional interaction associated with the service delivery. Because measurements in service processes is different and more difficult than manufacturing, it should acquire relevant skills and training which are more convenient to service industry.
- It is hard in service sectors to introduce metrics that rely on Defect Per Million Opportunity (DPMO) to measure process performance.
- The resistance to change in service is much higher in services due to not touching directly the benefits of change and improvement as in manufacturing.
- The use of flowcharts and process map is uncommon in services. Activities in many cases are not described in process term.
- Service processes are subjected to uncontrollable factors and noise such as sociological, psychological, and personnel factors.

In services, most decisions impressions are taken depending on judgment of human perception. Voice of customer (VOC) or Critical To Quality (CTQ) is varying by the time, and service organizations should update and refine what make customer satisfied all the time. Service processes and improvement depends more on human and organizational change than on the changes in manufacturing processes.

The way of presenting the recommendation and improvement report by Six-Sigma in a statistical language rather than business language causes some confusion and recipients will not fully understand the reports content, as only a few managers have sufficient statistical background. Sharing results in a language understood by the employees will enhance their motivation and perception about the benefits of Six-Sigma strategy. Different certification bodies with different procedures for qualifying black belts and green belts makes all black belts or green belts not

equally capable. Six-Sigma project selection in many organizations adopting Six-Sigma strategy will still be based on subjective judgment (Antony 2004; Antony 2006; Antony 2007; Antony 2007; Antony et al. 2007; Frings and Grant 2005).

2.5 Dimensions and Determinants of Service Quality and Quality Models

Quality in a service organization is a measure of the extent to which the service delivered meets the customer's expectations (Ghobadian et al. 1994). If the ideal quality lies at one end of the quality stream and the unacceptable quality lies at the opposite end, the points in between represent different gradations of service quality. The perception of quality is influenced not only by service outcomes, but by the service process too. Quality of service is determined by customer perception of quality not by the service provider. That is why it is very important for the service provider to determine the customer requirements precisely, so the service delivery should meet these requirements. Customer requirements are a variable changed by many factors like time, place, type of service provided, culture, past experience, word of mouth, market communication, price, needs, and level of same service provided by other competitors (benchmarking). Seth, Deshmukh, & Vrat, 2005 during their coverage and reviewing of many service quality models, indicated that customer don't always use the best quality service, but they might instead chose services on the basis of their own assessment of value of service. In general, customers' service expectations are constantly rising, while their tolerance for poor service decreases.

Quality problems in service organizations are the result of the mismatch between the customer expectations and the actual quality delivered to the customer, which is the perceived quality. Quality of service is divided into quality of process and quality of outcome.

Service quality models are needed by organizations to identify quality deficits and to launch quality improvement plans. A service quality model attempts to show the relationship between

process variables, so it can describe the actuality of the business processes. A quality model should enable the organizational management to identify source of quality, discover the quality problems, pinpoint the causes of the observed quality problems, and offer possible courses of action. Quality model could be effective in providing an overview of factors affecting the service quality of organization, facilitate understanding of tasks and processes, help clarifying and showing service quality deficits, and provide a framework for launching a quality improvement program (Ghobadian et al. 1994). Each model has its limitations. Models can be viewed as simplified versions of reality. They suggest that there are simple relationships between complex phenomenon, and that systems operate by rules of cause and effect.

Existing quality concepts and models help a lot in understanding and monitoring different directions of thinking about how to develop a model for a specific service industry that involve all factors affecting quality of service in that field of service with all its exclusiveness. The importance of a model is not its illustration of factors associated in affecting such service, but it provides a direction for improvement through extensive study of what influencing factors and sub-factors affecting quality of service, and how to address specific input variables that greatly impacting customer satisfaction and improve these inputs in order to increase customer satisfaction. This is the link between a model for a specific service industry and efforts toward improving service quality through the usage of different quality improvement methods and methodologies.

Seth, Deshmukh, & Vrat, 2005 list some factors controlling the evaluation of such a service quality model. None of the models studied have satisfied all these factors. These controlling factors are (Seth et al. 2005):

- . Identification of factors affecting service quality.
- . Flexibility to account for changing nature of customers perceptions.
- . Directions for improvement in service quality.

- . Suitability to develop a link for measurement of customer satisfaction.
- . Diagnosing the needs for training and education of employees.
- . Flexible enough for modifications as per the changes in the environment/conditions.
- . Suggests suitable measures for improvements of service quality both upstream and downstream the organization in focus.
- . Identifies future needs (infrastructure, resources) and thus provide help in planning.
- . Accommodates use of IT in services.
- . Capability to be used as a tool for benchmarking

Nitin Seth and S.G. Deshmukh (2005), mentioned that service quality model factors are different according to the type of service provided. Also, even though there are many differences and diversions in service quality models, but there are some common links and similarities between them:

- Majority of models studied by the researcher and mentioned in many other researches support the view of evaluating service quality by comparing their service quality expectation with their perceptions of service quality they have experienced. Deep understanding of factors affecting the perceived service will lead to effective service improvement and narrow or close the gap between perceived service quality and expected service quality.
- The main components of most quality models which mostly impact customer perception are the production of service and the delivery of service means that what customer actually receive and how he is receiving the service (Gronroos 1993)
- Most models divide service quality components or determinants into factors and sub-factors (Haywood-Farmer 1988).

- Many service quality models are based on the SERVQUAL gap model proposed by Parasuraman et al. (1988).

Actually, and as mentioned by several authors, there is no universal model that meets all the different contexts and situations in which service quality operates (Agus et al. 2007). Based on their study, (Parasuraman et al. 1985) have developed a service quality (SERVQUAL) model, which explicitly states, “Perceived service quality is the result of the consumer’s comparison of expected service with perceived service.” (Hernon and Nitecki 2001) noted that for any organization to survive in the highly competitive market, the organization should serve its customers and should realize that customers are the best judge of the quality of services they use and provided by the organization. Many researchers such as (Brady and Cronin Jr 2001; Cronin Jr and Taylor 1992; Lehtinen and Lehtinen 1991) have tried to investigate service quality in various dimensions. They consider that not all service-quality determinants have the same effect on consumer quality perceptions and satisfaction. (Ghobadian et al. 1994) claims that service quality involves three dimensions:

- The technical quality of service, concerning the condition of the service. (What is delivered).
- The functional quality of the service encounter that is concerned with the interaction between the service provider and the customer. (How it is delivered)
- The common or corporate image. This is related to the consumer’s perception of the service organization.

Ghobadian (1994) hypothesized that the technical quality of a service has a minor impact on the consumers’ perceptions of quality, while the functional quality has a major importance in perceived service quality. (Lehtinen and Lehtinen 1991) argued that service quality could be expressed in

terms of “process quality” and “output quality.” Process quality relates to how service is delivered, that is, the customer judges process quality during the service performance, while output quality relates to the quality of the service after the service is performed or delivered, that is, the customer judges output quality of service after the service is performed. (Kim 2003) has mentioned seven major dimensions in his dissertation in the context of service industries: security, consistency, attitude, conditions, completeness, availability, and training. (Parasuraman et al. 1985) have identified ten determinants of service quality that may relate to any service, then later, in 1988, the ten dimensions of service quality were merged into five dimensions; Tangibles, Reliability, Responsiveness, Assurance, and Empathy (Parasuraman et al. 1988).

(Parasuraman et al. 1988) developed a service quality instrument, SERVQUAL, to measure customer perception of service quality. The researchers assume in their model that perception of quality results from comparisons between customer expectation and actual service performance. The model contains 22 sub-factors for assessing customer perception of service quality. The 22 sub-factors were grouped into the mentioned five dimensions.

The gap between expected service and perceived service is a measure of service quality. The “SERVQUAL Model” gives insights about the gaps between client expectations of service quality and service provider standards.

2.5.1 Importance of Determinants

The nature of the service will specify the importance of utility value of each determinant of quality. Each type of services has its own factors and determinants affecting the quality of service beside the common factors mentioned before for all or most service types. It becomes clear that FM services at universities and high educational institutes has its own factors and determinants affecting quality of service which even they are not too far from determinants affecting other

services but they have their specialty and exclusiveness. In order for the service delivery to be effective, three major factors need to be managed and controlled:

- Employee selection; wrong employee's act can cause a detrimental effect for the service delivery and play a major role in customer dissatisfaction. People should be subjected to well defined criteria and standards in order to be hired for service delivery (Berry et al. 1990).
- Control over personnel; sometimes managers have their own action in a trial to correct or fix or compensate the lack of experience of some employees. This could have a dangerous result leading to lack of confidence for employees and increasing variability in service delivery. Over management should be avoided by good selection and training of employees (Bitner 1990).
- Employee empowerment; the way the organization treat its employees will greatly influence the way the employees will treat customers. If employees are treated with indifference, this kind of treatment will be most likely the way that they will treat the customers. One key component in the delivery of customer service is personnel attitude. Employees are not likely to treat customers any better than they are treated by the company for which they work.

There are many service quality models described by researches in this field. Table 3 illustrates a set of models mentioned in literature with a brief description for each model. The schematic illustration of these models and others is shown in Appendix 2.

Table 3: Various Quality models used in the service industry

Model	Primary focus of the model
Technical and functional quality model (Gronroos 1993)	Three components of service quality were identified: technical quality; functional quality; and image

Quality gap analysis (Parasuraman et al. 1985)	They developed a model based on ten dimensions and five types of gaps representing the difference between customer expectation and quality performance. This model based on ten dimensions structure.
Extended model of service quality (SERVQUAL) (Parasuraman et al. 1988)	The ten dimensions were reduced to five. The SERVQUAL model had modified in 1991 and 1994 with little variation from the 1988 version.
A conceptual model for service quality (Haywood-Farmer 1988)	This model is based essentially on three service quality components: physical and procedural, behavioral, and judgmental. Each of these components consists of several factors.
Synthesized model of service quality (Brogowicz et al. 1990)	This model defines three factors affecting technical and functional quality of service; company image, external influences and traditional marketing activities.
Performance only model (Brady et al. 2002)	They mentioned that service quality is valued by performance not by performance vs. expectations. They rely on SERVPERF (service performance) service measurement system to measure service performance.
Ideal value model of service quality (Mattsson 1992)	This model argues for a value approach representing customer satisfaction. Two values incorporating satisfaction: ideal standard and experienced outcome.
Evaluated performance and normed quality model (Teas 1993)	The model proposed the following two frameworks for service quality: evaluated performance (EP) framework, and normed quality model.
Improving service quality with information technology (Berkley and Gupta 1994)	This model describes how information technology could used to improve service quality. This model could be benefit in determining the most appropriate information technology for a certain service, and identify the commonly used information technology in that service.
Attribute and overall affect models (Dabholkar 1996)	These two alternative models are proposed to depict the technology based self services. First is the attribute model based on consumer expectations from the service, second is overall affect model based on the consumer's feelings toward the use of technology.
Model of perceived service quality and satisfaction (Spreng and Mackoy 1996)	This model focused on the distinction between perceived service quality and satisfaction.
PCP attribute model (Philip and Hazlett 1997)	This model is based on the SERVQUAL model and gives some critics to this model. The PCP

	model is based on three main levels of attributes; pivotal, core, and peripheral (P-C-P).
Retail service quality and perceived value model (Sweeney et al. 1997)	The model examined how customer perception affected by service quality at the point of purchase. Two models were compared: Model one, both functional service quality and technical service quality perceptions are directly influence value perceptions. Model two, both functional quality and technical quality are not directly influencing value perception.
Service quality, customer satisfaction, and customer value model (Oh 1999)	An integrative model combining service quality, customer value, and customer satisfaction focusing mainly on hotels service industry.
Antecedents and mediator model (Dabholkar et al. 2000)	This model try to provide a better understanding of conceptual issues related to service quality. The model lists some factors affecting service quality and then customer satisfaction.
INTSERVQUAL - Internal service quality model (Frost and Kumar 2000)	The model describes service quality for internal marketing. The model designed based on the GAP model. It evaluated the GAP model dimensions for internal customers and internal suppliers.
Internal service quality Data Envelopment Analysis (DEA) model (Soteriou and Stavrinides 2000)	A DEA model developed for bank services to assess bank branches performance, and how to measure and improve internal customer service quality
Service quality in internet banking. Internet banking model (Broderick and Vachirapornpuk 2002)	This model describes service quality of internet banking. It proposes and tests a service quality model of Internet banking.
IT based services and service quality model in consumer banking (Zhu et al. 2002)	The model explores the impact of information technology on service quality in customer banking. The model link the new customer perceived IT services with traditional SERVQUAL dimensions. It described factors affecting customer perceptions of IT based bank services.
E-service quality. A model of virtual service quality dimensions (Santos 2003)	The model described proposed determinants of e-service quality. If proposed two types of dimensions: incubative dimensions consists of ease of use, appearance, structure and layout, linkage, and content; and active dimensions consists of reliability, efficiency, support, security, communication, and incentives.

2.6 Justification for this Research

Facility services at universities are characterized by their diversity and multiple-tasked nature. Each service category for FM could be unique and need to be handled individually in an ad hoc fashion. For this reason, it is usually difficult to standardize them, and all or most services are provided with their own standard procedure. This is one of the main differences between FM services and other service industries, its diversity. This made developing a quality model through gathering, describing, and relating different factors to the FM service quality a difficult task. FM services, as all service industries, suffer from elements such as heterogeneity, difficulties in identifying sources of the quality problems, designing, organizing, and managing the different services.

Because most FM services could be considered as belonging to the passive approach as described earlier, the area suffers from both resource constraints, and evolving customer expectations. This leads to starting to think about new strategies and ways on how to achieve customer satisfaction within these constraints. FM service quality at universities follows mainly the process focus approach rather than customer focus or value focus, because of the relatively little direct contact with customers. Customers usually use and perceive services without direct contact with the FM department even when they report a problem or have a complaint. Since customers end up evaluating FM services in some way, it is important that a customer focus is introduced into them.

Up to this point, information and knowledge available in literature has built a good foundation on how to propose a service quality model for FM facilities at universities. Also, by studying six-sigma methodology and tools, and by accessing to previous research and on using six

sigma in the service industries, a logical next step is to investigate if and how six-sigma can be used in modeling and improving FM services at universities.

CHAPTER 3 RESEARCH METHODOLOGY

The research methodology is presented through five sections in this chapter. Sections one and two discuss the factors-based service quality model initially proposed for the study, discussing factors affecting quality of services provided by FM units at universities. This was based on an extensive literature review, as well as in depth interviews with people in the FM field at different levels of hierarchy in management and execution. Section three covers the designed research tool (survey instrument) for data collection, addressing different services delivered by FPM department at Wayne State University, based on present customers' perceptions for these services, through ratings and prioritization of service categories needing further improvement. Section four and five discuss the implementation of the Six-Sigma DMAIC methodology and tools to improve a selected FPM service category, specifically WSU FPM's GIRF (General Improvement Request Form) process.

3.1 Construction of the Initial Quality Model

The proposed model in this research was devised after reviewing the literature and screening several models used for different types of services as well as interviewing people associated with facilities' service delivery, including different management levels, building engineers, building coordinators, WSU staff, and graduate students. The devised model was proposed to cover all circumstances and variables encountered in FM services at universities. The model components were analyzed, discussed, and modified using appropriate Six-Sigma quality tools such as Nominal Group Technique (NGT) and cause and effect diagram. The devised model Fig. 1 is an attempt to show the significant factors of the FM service organization that influence the perception of service

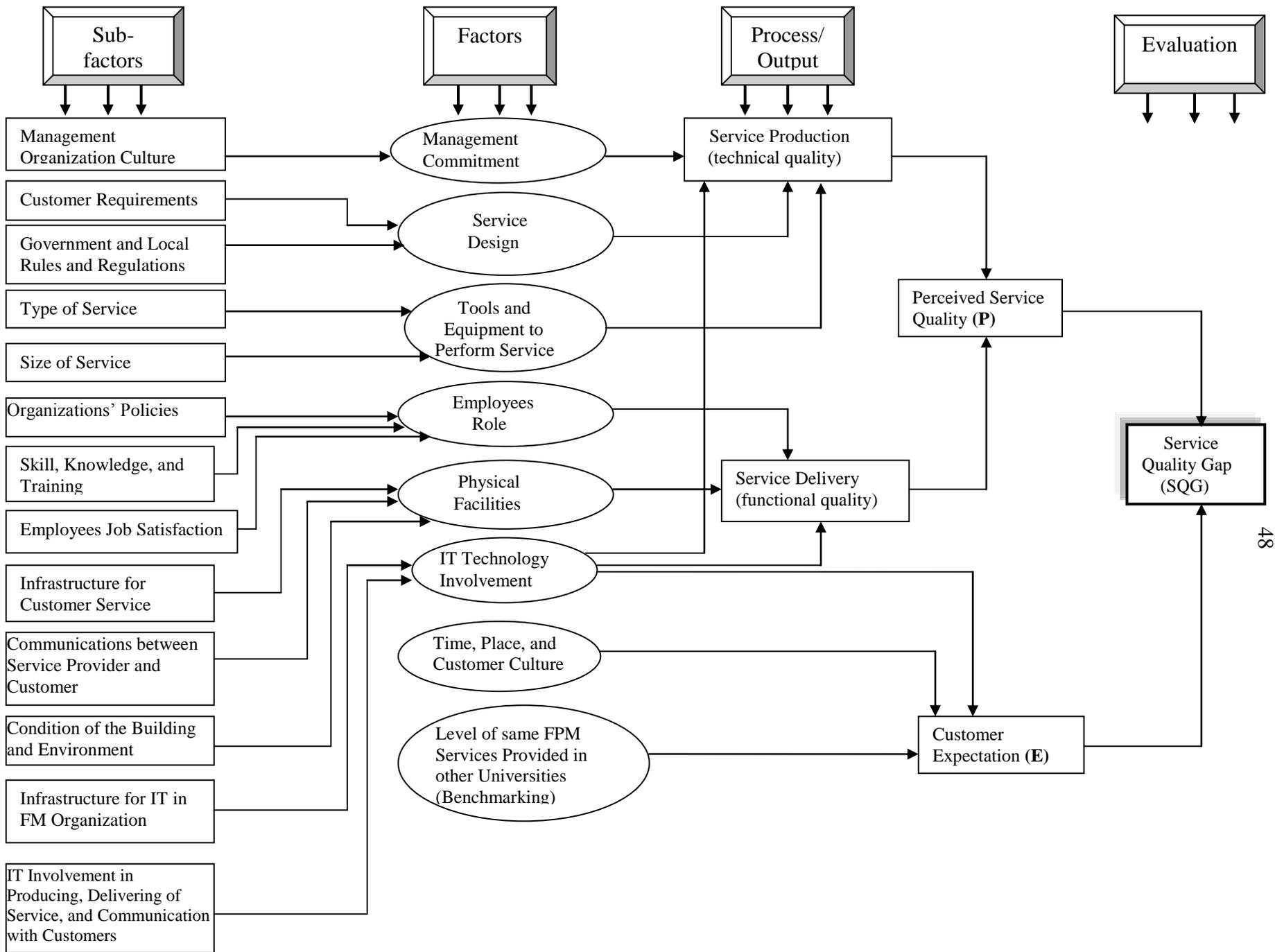


Figure 1: The initial model for facilities' service quality

quality. It shows the interactions and linkages between factors and sub-factors.

In the proposed model, we've tried to attempt to show the significant activities of the FM service organization that influence the perception of quality and customer expectations. It shows the interactions between these activities and the linkage between them and quality service model components. Two main components are identified in the proposed model which are mainly controlling and governing the perceived service quality; service production component (method), and service delivery component (outcome). The difference between the perceived service quality P and customer expectations E indicates a gap "service quality gap" SQG. Both service quality perception and service quality expectations are determined by the customers. The less matching between perception and expectations, the worse is the service provided.

3.1.1 Service Production Component

It is the method used to provide the service. Service production has a great effect in the evaluation of perceived service, because the service provided by the facilities management units is not standardized. Four factors affect the service production; management commitment, service design, tools and equipment to perform service, and IT technology involvement, as shown in Fig. 1

3.1.1.1 Management Commitment

It includes providing required resources, removing obstacles, responding to customer concerns, and conducting quality/process improvement plans.

3.1.1.2 Service Design

It consists of plans, procedures, methodologies, and specifications on how to conduct the service production. There are two sub-factors influencing the design of services: customer requirements, and government and local rules and regulations.

Customer requirements: The main drive of service design is the customer requirements because service quality is achieved through the understanding of and conformance with customer requirements and expectations.

Government and local institutional rules and regulations: The design of services should comply with governmental and institutional rules and regulations.

3.1.1.3 Tools and Equipment to Perform Service

It consists of tools, equipment, manpower, and level of technology available for the facility department to produce the service. There are two sub-factors affecting the use of tools and equipment: type of the service and size of the service delivered.

Type of the service: Some types of service (e.g. aviation) need high sophisticated tools and devices while other services need less advanced technology and tools. FM services in universities are characterized by their diversity and customized services.

Size of the service: It plays a large role in using tools and equipment. The larger the service the more will be the need for more tools and sophisticated equipment when the service production becomes more complicated. It is the linking of service and the information technology strategy of the organization (which is covered in next section). It describes the use of IT for improving FM service quality.

3.1.1.4 IT Involvement

It is the linking of service and the information strategy of the organization. It describes the use of IT for improving FM service quality. IT is widely applied in services and plays a big role in reducing time, efforts, and costs of producing and delivering services. This affects the service quality perception by the customers. Service quality components could be improved by the utilization of advanced IT technologies. There are two sub-factors affecting the benefits of using IT in FM services: Infrastructure for IT in FM organization; and IT involvement in producing, delivering of service, and communication with customers.

Infrastructure for IT in FM organization: this includes the data storage facilities, ability to use computer systems through the internet to send and receive information, requests, and follow up the progress in implementing projects and services.

IT involvement in producing, delivering of service, and communication with customers: this includes how much the FM utilizes IT facilities and capabilities available to produce, deliver, and communicate with customer.

3.1.2 Service Delivery Component

It is the other component affecting the perceived service quality. Three factors affect the service delivery: employee's role, physical facilities, and IT technology involvement.

3.1.2.1 Employee's Role

It is the effect of employees in delivering the service. Employee's role is influenced by three sub-factors; organizational policies; skill, knowledge and training; and employee's satisfaction with the work environment.

Organizational policies: It is the policies and regulations implemented by the management effectively deliver the service to the customer.

Skill, knowledge, and training: Skill is the ability of employees to do their work in the proper way, right the first time, within an acceptable period of time. Skill could be obtained by training and experience. Knowledge is the technical information about how to do the job. It is acquired by training and experience. Training is needed to build skills and knowledge. The more skilled and knowledgeable the employees, the more efficient the service delivery (less time, fewer errors/omissions).

Employee's job satisfaction: It does increase the effectiveness of service delivery. The more satisfied employees with their work environment, the higher the quality service that will be provided to the customer. Satisfaction could be attained by promotions and motivations of employees by management through good communications.

3.1.2.2 Physical Facilities

It is the physical appearance of all sub-factors related to delivering the service. This includes infrastructure for customer service (providing capabilities to serve the customer the better way), communication between service provider and customer, and even employees' dress and uniform. Physical facilities fulfill the dual function of production and marketing of service. It has a great influence on customer perception on service quality. Three sub-factors affect the physical facilities factor: Infrastructure for customer service, communications between service provider and customer, and condition of the building and environment.

Infrastructure for customer service: This related to the condition of equipment used by FM agents contacting customers, skills and capability of FM personnel to deal with these equipment, and appearance of FM personnel in contact with customers.

Communications between service provider and customer: The interpersonal behavior of FM service agents with customer, appearance of personnel, and the way they treat customers.

Condition of the building and environment: The state of facilities goods, physical condition of the buildings and the environment.

Customer expectation part of the model is a description of what customer expects from the service delivery in order to be satisfied. It is a measure of customer requirements needed to put into service design and specifications by FM. Customer expectations are collected through asking customer about their expectations from the service delivery by surveys, questionnaire, interviews, or complains. It is affected by three variables: IT technology involvement; time, place, and customer culture; level of same FM service provided in other universities (benchmarking).

3.2 Evaluating the Critical Factors for the Service Quality Model

In order to address, identify, and validate the critical factors affecting the perceived service quality in the proposed model, a case study was carried out at WSU as an example of a large higher learning institution. The goal was to assess, measure, analyze, validate and prioritize the different critical factors composing the model. The goal was also to assess the status of quality management at WSU FPM in order to devise improvements in the service quality area. These measures help better understand quality management practices and to relate these factors to service quality performance, which reflect to a large extent the FM performances at other universities. The reason behind choosing WSU as an example of a large learning institution is that it has most of the facilities services mentioned earlier in the previous chapter, so it has common services with other universities plus that it is easier for the researcher to contact, interview, and brainstorm with WSU FPM expert personnel representing different management and practical levels. In addition, to have access to their documents, data, and getting their feedback provided a distinct advantage.

A number of sub-factors were developed to measure, rate, and prioritize each factor. These sub-factors define the scope and meaning of each factor. The sub-factors for each factor were reviewed to establish content validity.

Factors and sub-factors affecting and influencing customer perception of the service quality shown in the initial model for facilities' service quality (Fig. 1) were arranged in a fishbone as causes and sub-causes, and the effect was represented by the customer perception of service quality (Fig.2). Thus, FM service quality failure at universities (the effect) is explained by causes related to the factors affecting the quality of service. For the testing, reviewing, and finalizing of the proposed model, the Nominal Group Technique (NGT) was conducted to review, organize, prioritize, and rank the different factors and their sub-factors affecting the quality of service.

As a part of the revision, refinement, and validation of the proposed model, and continuing efforts to study, analyze and improve the quality of services delivered by FPM, we conducted a Nominal Group Technique exercise with five building engineers who were nominated by the FPM department at WSU as they are the most knowledgeable, skilled and experienced staff among the building engineers.

The Nominal Group Technique (NGT) is a methodology for achieving team consensus through a structured variation of a small-group discussion. It is designed to allow every member of the group to express their ideas and minimizes the influence of other participants. NGT is used to generate a lot of ideas, and it strives to assure all members participate freely without influence from other participants. Also, it can be used to identify priorities or select a few alternatives for further

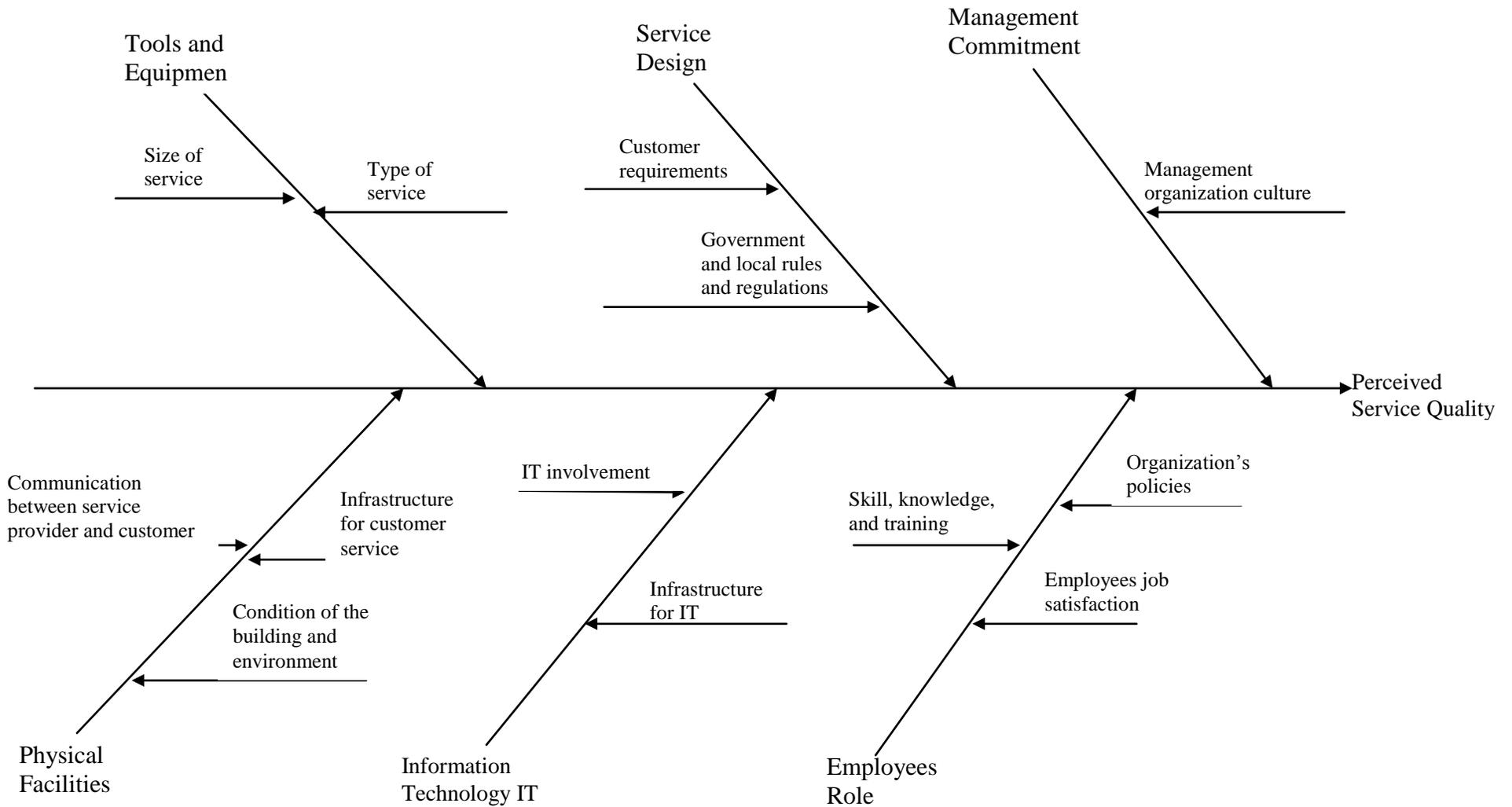


Figure 2: The Cause and Effect diagram relating Service Quality to factors and sub-factors affecting service quality

examination. NGT gathers information by asking participants to respond to questions posed by a moderator, and then group members are asked to prioritize the ideas or suggestions regarding factors affecting service quality of all group members. The process ensures equal participation of each member of the team in making a choice among several options or alternatives, prevents the domination of a single person, encourages all individuals to participate, and results in a set of prioritized factors and sub-factors that represent the group's preferences (Carney et al. 2008; Deip et al. ; Lloyd-Jones et al. 1999).

The stated problem to be discussed in our case was prioritizing and ranking the factors and sub-factors affecting quality of services provided by FM at universities. All factors and sub-factors affecting service delivery were printed in tables and distributed to all group members. Through a brainstorming session, each team member was asked to generate silently his own comments, additions, and notes regarding these factors and sub-factors. Each idea or additional variable was written on an index card.

In order to apply the NGT technique, the following steps were followed:

- The team members were welcomed, mentioning the importance of each member's contribution, and an indication of how the group's output will be used.
- The factors proposed by the researcher (moderator) affecting the quality of service delivery were explained to the group. The moderator clarified the member's roles and group's objectives. (Each team member was provided a copy of the fishbone diagram and companion tables containing all factors and sub-factors).

- Each member was provided sheets of papers to write notes, suggestions, and additions to factors/sub-factors individually without any discussion with any other member of the team.
- Through a brainstorming session, each team member generated silently his own comments, additions, and suggestions regarding the factors affecting quality of services provided. Each idea or additional variable was written on an index card and then handed to the moderator.
- Suggestions were written on the board by the moderator and discussions were opened on each sub-factor, including the clarification of any ambiguities. One suggestion/idea was discussed at a time. Duplicated ideas were consolidated or eliminated.
- After coming up with the final review of factors/sub-factors affecting service quality, each member rated or prioritized reviewed sub-factors using a scale of 1 to the number of the sub-factors in any factor group. (Example: if we have 8 sub-factors under a given factor, the members rated them from 1 (lowest importance) to 8 (highest importance)).
- All ratings from the participants were added together, and the highest total rating number was considered the most important sub-factor, followed by the next highest total, and so on.
- Sub-factors with very low ratings were eliminated from the list of factors affecting quality of services delivered by FPM. A Pareto chart showing the most important sub-factors and factors was also constructed. A new cause and effect diagram was constructed with the revised factors and sub-factors resulting from the NGT session. The NGT form constructed by the researcher containing each factor and its sub-factors given to the group members is shown in Appendix 3.

The factors and sub-factors under each factor are illustrated below:

Factor 1- Role of top management (Organization Culture)

- Extent to which top management show responsibility for service quality.
- Extent to which top management supports long-term continuous improvement programs.
- Comprehensiveness of the goal setting regarding improving service quality.
- Degree to which top management rely on quality service improvement as a way to increase profit.
- Extent to which service quality goals and objectives are understood among the organizations' employees.
- Degree to which top management and divisions managers consider quality improvement as a way to increase profit, reliability, and credibility.

Factor 2- Service Design

- Extent to how much people involved in service design are aware of quality improvement.
- Carefulness of service design and review before launching the service.
- Extent of analysis of customer requirements in the service design.
- The extent of considering customer requirements in the service design.
- Clarity of service specifications and procedures.
- Quality of the designed service related to cost.

Factor 3- Tools and equipment to perform service

- Extent of mechanization of all service processes.
- Extent of suitability of the used tools for the type of service conducted.
- Extent of labor skill in using tools and machines.
- Degree of the novelty of the used tools and equipment.

- How fast tools and equipment are repaired and maintained if it malfunctioned.

Factor 4- Employee's roles

- Specific work skill training given to employees.
- Team building and group dynamic training for employees.
- Quality related training given to employees.
- Quality related training given to managers and supervisors.
- Training in using statistical techniques.
- Commitment of the top management to the employees training.
- Availability of training programs and resources in the organization.
- Extent to which employees involvements programs in increasing quality of service delivered are implemented.
- Amount of feedback provided to employees on their performance in increasing quality of service.
- Degree of participation and involvement of employees in organizational decision making.
- Extent of the quality awareness among the employees is contributing to increase the level of service delivery.
- Extent of employee motivation.
- Effect of labor union in increasing the quality of service delivery.

Factor 5- Physical facilities

- How comfortable and decent are the facility management offices and building.
- Degree of respect and appreciation that the facility management officers and employees in contact to customers are treating customers.

- How sophisticated is the equipment used for running computer software, programs, and data storage facilities.
- How easy is it for the customer to contact and communicate to the right person in the facility management organization.

Factor 6- IT technology involvement:

- Availability of information regarding process inputs, outputs, and customer requirements.
- Ease of use and effectiveness of IT utilities to reduce time and efforts to communicate with customers.
- Ease of use of IT utilities in producing and delivering FPM services.
- How much sophisticated the IT technology used in the FPM service quality to ease service processes and reduce cost and time to deliver the service.

3.3 Customer Service Evaluation System and Data Collection

An evaluation instrument (survey) for this research was designed for the collection of data on customer perception of quality associated with the different service categories provided by FPM at Wayne State University, which is used as a case study for this research. The survey acts as a measuring tool for different services provided by the FPM and is expected to spark process improvements, enhance the communication among different sections of the department, and to obtain input on customer requirements through comments and complaints. The survey was intended to be measurable, representative, and comprehensive. The initial draft of the survey was constructed after interviewing many of the university's building coordinators and building engineers. A better understanding of the services was facilitated, and some of the frequent problems were clarified by them. The selection of the service categories was based on an in-

depth study of the services provided by different large universities in the US, after consulting and reviewing them with the FPM department management at WSU. The services contained in the first version of the survey were expanded and analyzed, and more detailed service descriptions were provided in the final form. The final form of the survey was finalized with the cooperation and consultant of the FPM management at Wayne State University.

Some survey forms received from the respondents included written comments in addition to the ratings. This customer feedback was crucial information needed to analyze results and to design the brainstorming sessions resulting in the cause and effect diagrams. The survey was sent to one hundred twenty building coordinators at WSU, graduate students who consume services in their laboratories, and some of the University's employees and staff, who were selected randomly. The survey was distributed by email and personally "by hand" to stress the importance of feedback on service quality, and to describe in person the way they can fill out the form, and to answer any questions to clarify any ambiguity in the survey.

Among 550 of distributed surveys, we got a response from a total of 205 participants involving building coordinators, graduate students, and staff. Appendix 4 represents the survey used for data collection.

It was assumed that the customer expectation for all service categories was "the perfect service" that could be provided, which was rated by a score of 10 out of 10. Data collected was analyzed by using the Six-Sigma DMAIC methodology and tools.

Services rated in the survey are listed below:

- 1- Restroom fixtures: Services related to restroom readability and cleanliness.
- 2- Water fountains: Readability of drinking water fountains
- 3- Interior lighting: Interior lightings in buildings

- 4- Exterior lighting: Lights outside buildings
- 5- Winter comfort: Heating air in winter time
- 6- Summer comfort: Cooling air in summer time
- 7- Elevators: Readability of elevators
- 8- Door hardware and keys: Door fixture, locks, and keys services
- 9- Ceilings: Condition of ceilings
- 10- Floors: Cleanliness of floors
- 11- Painting: Painting services inside and outside buildings
- 12- Maintenance work request: Request for maintenance form and procedure
- 13- GIRF work request: Request for general improvement request form for building and labs renovations
- 14- Overall satisfaction with work processes (by the customer): How much satisfied is the customer by FPM services.

3.3.1 Rating Scale

To enable customers to rate each service category, a 10 point interval rating was used as previously explained. We suggested five intervals of ratings; very bad service, poor service, service needs improvement, satisfied customers, and excellent service. Each level of rating gives an idea on how much customers are satisfied with services delivered. Table 4 shows the rating scale for the survey. The survey was designed to be simple, easy to understand by customers, and not needing much time to be filled. Space was provided for the customers to share their ideas and suggestions on the form so we could get their feedback as the voice of customer (VOC). Data was thus collected and analyzed, identifying those service categories that were rated to be poor or needing improvement. The data collection form was distributed among all the WSU buildings

coordinators, and personnel who use laboratories and other facilities. All survey respondents are in essence customers of the services provided.

Table 4: Rating scale for the survey used in the research

Interval	Rating	Description
0-3	Very bad service (totally unsatisfied)	Unsatisfied customer
4-5	Poor service	A need for better service
6-7	Service needs improvement	Still needs improvement
8	Satisfied customers	Acceptable service
9-10	Excellent service	Service reached and exceeded customer expectations.

3.4 Analysis by using Six-Sigma

The Six-Sigma toolkit was used through different stages of the DMAIC methodology for improving a specific process. The GIRF service category was selected for this purpose for process and quality improvement, because of its importance to FPM and its complexity presenting challenges. The DMAIC offers well defined steps for problem solving and/or process improvement, its framework includes: (D) problem definition; (M) measurement of the problem (how much the problem is bad and VOC assessment); (A) analyze the root causes of the problem (determine root causes of defects, and identify critical process inputs those impacting the process outputs); (I) improvement of processes (remove or mitigate the root causes of the problem, and demonstrate improvements); (C) controlling of the process (develop a control system to monitor and continuous process improvement). Table 5 contains the statistical and Six-sigma tools used in this research. Fig. 3 relating each six-sigma tool to a particular phase of the DMAIC methodology. It is usual to use a tool for more than one phase.

Table 5: Statistical and Six-Sigma tools used in improving the (GIRF process)

Tool	Description
Descriptive Statistics: Mean, Mode, Median, Range, Variance, Standard Deviation, Coefficient of Variation, Histograms	Centrality, Tendency and data location, Variability and dispersion, frequency and distribution of interval data.
Voice of Customer.	Capturing the customer needs and requirements.
Nominal Group Technique (NGT)	A brainstorming technique used to assess, review, evaluate, and finalize the proposed service quality model.
Process map	A graphical representation of GIRF process flow that identifies the steps of the process, the input and output variables, and the opportunities for improvements.
Cause and Effect diagram	Shows the relationship of factors or causes (inputs) those affecting the performance of the effect (output).
Cause and Effect Matrix	Used to prioritize the degree of the affect input variables (X's) have on the output variables (Y's) and rank them in order of impacting the outputs
Pareto Charts	Arranging data so that the few vital factors that are causing most of the problems reveal themselves.
Failure Mode and Effect Analysis (FMEA).	Used to rank, prioritize, and control the possible causes of failure as well as to develop and implement preventive actions.

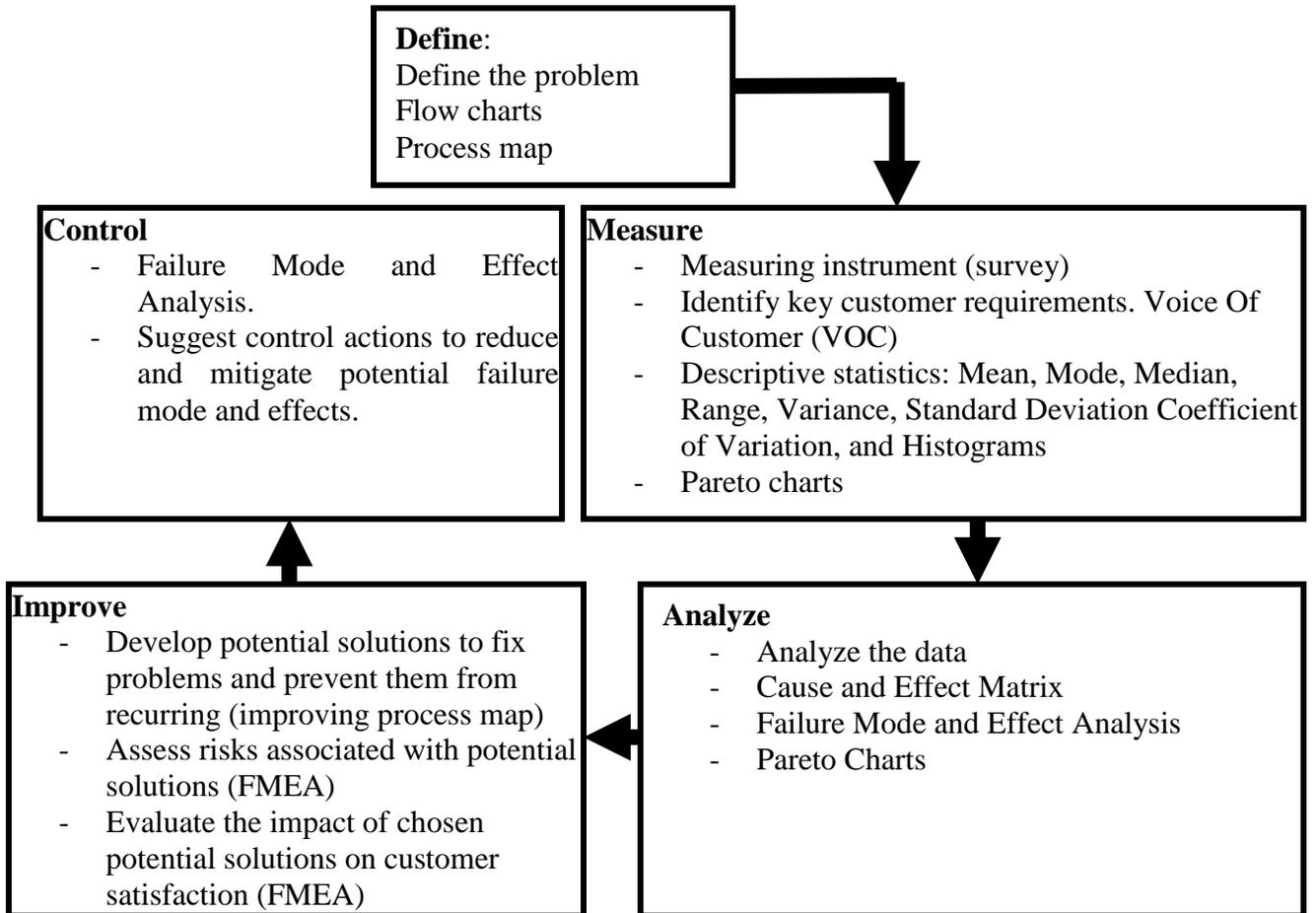


Figure 3: Schematic diagram relating Six-Sigma tools utilized in the GIRF process improvement to a particular DMAIC phase.

3.4.1. Define Phase

Service problems and quality shortcuts arise after the data collection are identified. GIRF service category was identified for further improvement, and current GIRF process flowcharts were prepared.

3.4.2. Measure Phase

One of the major benefits of Six-Sigma is that it is a data-driven analytical approach. One of the goals of the measure phase was to pinpoint the location or source of a problem as precisely as possible through a measuring instrument (survey) and identify key customer requirements

through customer feedback. Also, the descriptive statistics such as; mean, mode, median, range, variance, standard deviation, coefficient of variation, and histograms were utilized as a part of the measure phase.

3.4.3. Analyze Phase

This includes evaluating and analyzing measurement data, identifying root causes of the problem through cause and effect matrix, and establishing and confirming the vital few process inputs. The verified causes form the basis for solutions in the improve phase.

3.4.4. Improve Phase

Modifying and optimizing the processes based on the data analysis and results comprise the essence of this phase. It is expected that the proposed solutions will solve the problem. Changes were made to the GIRF process flowchart, in response to customer needs and requirements. Proposed solutions to the potential problems and defects associated with the GIRF process were generated through FMEA.

3.4.5 Control Phase

This phase entailing demonstrating current controls for the GIRF process, proposing control actions to reduce the intensity of process defects and failures, monitoring proposed improvements to reduce and mitigate the effects of potential failures in the GIRF process, and taking appropriate actions as required.

3.5 Description of the Main Six-Sigma Tools Used in GIRF Process (Process Map, Cause and Effect Matrix, and FMEA)

3.5.1 Process Map

To fulfill stated improvement objective for the GIRF process, a series of interviews were conducted by interviewing key individuals involved in the GIRF process at FPM (Planning and Design division). Several meetings are set with them as a starting point of the improvement process. The Planning and Design division is located in the FPM headquarter at the Wayne State University campus. The division is responsible for all GIRF projects for the universities' buildings. The main questions were asked to the well knowledge FPM staff are:

- Is there any existing flowcharts or process maps depicting the GIRF process?
- Do you have detailed documents including inputs and outputs of each task in the process?

As consequences of a serious of meetings, the current flowchart was reviewed with FPM agents involved in the process in order to refine and validate all the tasks and activities of the process. They've provided us with detailed explanations on the nature of the GIRF projects, their roles in coordinating the job, how they are conducting projects, how to go through all the steps of each project process, and who are their customers. They provided us with comprehensive detailed flowchart for the whole GIRF process with all decision points, alternatives, and ways of conducting the GIRF process.

Implemented GIRF process maps tables have these components:

- Process steps or tasks: These are the tasks that transform the inputs of the process into the outputs of the process.

- Inputs (Xs): These are the key process input variables (KPIV) that are required to perform a process step and add value in producing the outputs
- Responsible personnel for delivering inputs and outputs
- Outputs (Ys): They are the key variables resulting from the performance of the process step.

3.5.2 Cause and Effect (C&E) Matrix

The CE matrix relates the key inputs to the key outputs for a process (customer requirements) using the process map as the primary source. It is used to determine which process inputs and steps have the most impact on customer satisfaction or process output (were translated to the cause and effect matrix as Y's or outputs of the process (KPOV)). This technique pinpoints the critical few KPIV's that must be addressed to improve the KPOV's by using Pareto analysis. The few most impactful inputs were addressed to improve these selected processes. Surveys, process observations, focus groups, field reports, customer complaints, and direct discussion or interviews with customers act as a way of gathering the data needed.

The methodology used in developing the CE matrix can be described as follows:

- Identify the key process outputs or KPOV. It reflects the needs and expectations of the customer (VOC), translated into measurable terms and used in the process. The way of capturing the voice of the customer in this research is basically dependent on interviewing customers so that there is a chance to get all customer requirements, needs, and complaints. The following voice of customer requirements for the GIRF process were captured and established as a Critical To Quality factors (CTQ): 1. project duration, 2. total project cost, 3. project quality (in terms of defects, rework, and quality of materials and workmanship), and 4. cost estimation reliability. Explanation follows.

1. Project duration: In most cases, project duration has extended for reasons attributed to the contractor or to the customers. Even though funding problems could lead directly to a delay, most delays in project completion were caused by contractors' inability to adhere to schedule.
 2. Total project costs: This is one of the most significant problems bothering customers. Projects start with an estimated budget and end with expenditures more than what was originally estimated. This could lead to complicated disputes with contractors on who are responsible for the increased project total costs.
 3. Project quality in terms of defects, rework, and quality of materials. It was found from the interviewed customers that quality of work done is one of their biggest concerns. In many cases, customers were not satisfied with the quality of work done in terms of materials and finishes.
 4. Cost estimation reliability: It is linked to the total project cost. One of the main reasons for an acceptable total project cost is the reliability and precision of project cost estimation. It is one of the factors contributing to customer trust and confidence on the estimate.
- Place the process outputs across the top of the matrix and rank their importance according to the customer point of view. Each output was weighted and given a number reflecting how much is this output is important for the customer. The maximum rating number is 5 and the minimum is 1.
 - For each process step, identify the key process inputs KPIV. This information was imported from the process map which acts as a source of information for the CE matrix. KPIV's are rated by people involved in the process and related to the outputs. The rating

of process steps is based on the strength of the relation with KPOV. Each process step is then ranked or scored (on a scale of 0-10) to determine relative importance of each input in regard to the output.

- Total input ratings is calculated by multiplying each input rating by each output rating; then the values calculated and their summation connote the importance of each of the inputs relative to the outputs.

Adopted scoring for strength of relation as incorporated in the CE matrix are as follows:

0-3 Very low correlation (irrelevant), vl

4low, l

5-7 medium, m

8-9 High, h

10 Very high, vh

3.5.3 Failure Mode and Effect Analysis (FMEA)

Based on the information available from the process maps and CE matrices, the FMEA framework was used to prioritize the critical potential failure mode of the different GIRF service processes to take the required actions to reduce potential failures, and improve the GIRF service processes performance. We used FMEA in the analysis, improvement, and control phases of the DMAIC methodology. In the analysis phase, we determined if there is a high risk of failure and if the failures are detectable. The improvement phase, focused on evaluating the impact of proposed changes, so we can make changes which reduce the risk, and allow us to keep track of how well we did with respect to this reduction. After defining these steps in the process, and in the KPIV's as mentioned in the process map, all potential failure modes in the existing system were

identified and addressed. This determines how these failures affect the process and customer outcomes.

The FMEA procedure we used consists of the following steps:

1. Review the process: Using the process operation description identifies process steps. Each process step may have multiple potential failure modes
2. List and describe all failure modes at each step in the process.
3. Relate the possible causes, effects, and risks of each of failure. For each potential failure mode, there are potential effects, which have impacts on the customers.
4. Assign a severity rating for each effect
5. Assign an occurrence rating for each failure mode. How frequently do these failures occur?
6. Assign detection rating for each failure mode and/or effects. Do we have any current process control? If we do, what is the ability to detect the failure?
7. Define responsibility (management, engineers, designers, developers, employees etc)
8. Calculate the Risk Priority Number (RPN) for each effect
9. Prioritize the failure mode for action based on RPN values
10. Take action to eliminate or reduce the high-risk failure mode
11. Provide suitable follow-up or corrective actions for each type of failure mode
12. Calculate the resulting RPN as the failure mode are reduced or eliminated after improvement.

The RPN is used to rank the need for corrective actions to eliminate or reduce the potential failure mode. Multiplying the severity score by the occurrence score and the probability of detection score will result in Risk Priority Number (RPN). The RPN's are used to determine the risk of potential failures and prioritize the needed preventive actions accompanied by the resource allocations before the service is delivered to a customer. The RPN was calculated based on the existing information on the potential failure mode for the different GIRF processes.

Information included the severity of the failure, frequency of the occurrence of the failure, and the ability of the system to detect the failures before the customer perceives them (detection).

RPN is calculated as:

$RPN = S * O * D$ Where

S: Severity- The impact of a failure as a result of a particular failure mode. Severity considers the undesirable consequences of a failure determined by the degree of customer dissatisfaction.

O: Occurrence- Frequency at which a certain failure occurs.

D: Detection- The likelihood that the detection methods used or the current process controls will detect and correct a potential failure mode before a customer is inconvenienced.

Degree of Severity, Probability of Occurrence, and Detectability are ranked on a 1-10 scale, where 1 is lowest severe value and 10 is the highest severe value. There are no absolute rules for identifying a critical failure based on (RPN).

Failure mode: It generally describes the way the failure occurs.

Failure effect: The consequences of a failure mode on the ensuing steps and the ultimate outcome of the process. The effect is described in terms of what the people involved in the process and/or the customer might experience.

CHAPTER 4 RESULTS AND DISCUSSION

4.1 Quality Modeling

The main descriptive statistics carried out for the collected data are: mean service ratings, Standard Error of the mean (SE mean), standard deviation, variance, coefficient of variation (CV), minimum, maximum, mode, median, and range. The Minitab statistical software and the Microsoft Excel software were used to analyze the data. The results of these statistics are included in table 6.

Table 6: Service Rating Statistics

Service category	Total count	N	N*	Mean	S.E Mean	St.Dev.	Variance
1.Restroom fixtures	205	204	1	6.821	0.154	2.198	4.831
2.Water fountains	205	204	1	6.850	0.147	2.097	4.397
3.Internal lighting	205	205	0	7.339	0.131	1.872	3.503
4.Exterior lighting	205	199	6	7.188	0.134	1.890	3.572
5.Winter comfort	205	202	3	6.067	0.173	2.465	6.076
6.Summer comfort	205	203	2	5.934	0.169	2.409	5.805
7.Elevators	205	201	4	7.286	0.151	2.140	4.579
8.Door hardware and keys	205	205	0	7.476	0.148	2.121	4.499
9.Ceilings	205	203	2	6.973	0.140	2.001	4.005
10.Floors	205	203	2	6.899	0.129	1.832	3.357
11.Painting	205	202	3	6.874	0.142	2.012	4.050
12.Maintenance work request	205	185	20	6.346	0.169	2.293	5.260
13.GIRF work request	205	111	94	5.955	0.240	2.528	6.389
14. Satisfaction with work processed.	205	186	19	7.078	0.130	1.768	3.125

Service category	Coef. Var.	Min	Median	Max	Range	Mode	N for mode
1. Restroom fixtures	32.22	0	7	10	10	7	40
2. Water fountains	30.61	0	7	10	10	7	41
3. Interior lighting	25.5	0	8	10	10	8	45
4. Exterior lighting	26.29	0	8	10	10	8	55
5. Winter comfort	40.63	0	6	10	10	8	36
6. Summer comfort	40.54	0	6	10	10	7	34
7. Elevators	29.37	0	8	10	10	8	43
8. Door hardware and keys	28.37	0	8	10	10	8	47
9. Ceilings	28.7	0	7	10	10	8	44
10. Floors	26.56	1	7	10	9	7	45
11. Painting	29.28	0	7	10	10	7,8	42
12. Maintenance work request	36.14	0	7	10	10	7	41
13. GIRF work request	42.45	0	6	10	10	7,8	21
14. Satisfaction with work processed.	24.98	2	7.5	10	8	8	61

N: number of filled cells. N*: number of unfilled cells. N +N*= Total count.

4.1.1 Observations from the Survey Results

Maintenance work request, winter comfort, summer comfort, and GIRF work request show the lowest values of the mean ratings (6 or below). Measuring these service categories need more attention and should be high priority in taking improvement actions. The mean, median and mode are very close to each other, proving a centrality of the ratings for these four areas. There is an inverse relationship between means and both variance and coefficients of variation. As the mean goes up, both the variance and coefficient of variation go down. This means that as a

service category is rated high there is less variability of ratings among customers. It is observed that most of the minimum values of service category ratings were closer to the minimum rating value, which is (0), while the max values of each service category equaled to the maximum rating value which is (10).

4.1.1.1 Service Categories Histogram

The histogram plot is used in this research to display customer service ratings for all service categories in one plot, and for each service category as well.

4.1.1.1.1 Mean Service Category Rating for Services

The plot in Fig 4 shows the mean ratings of all service categories.

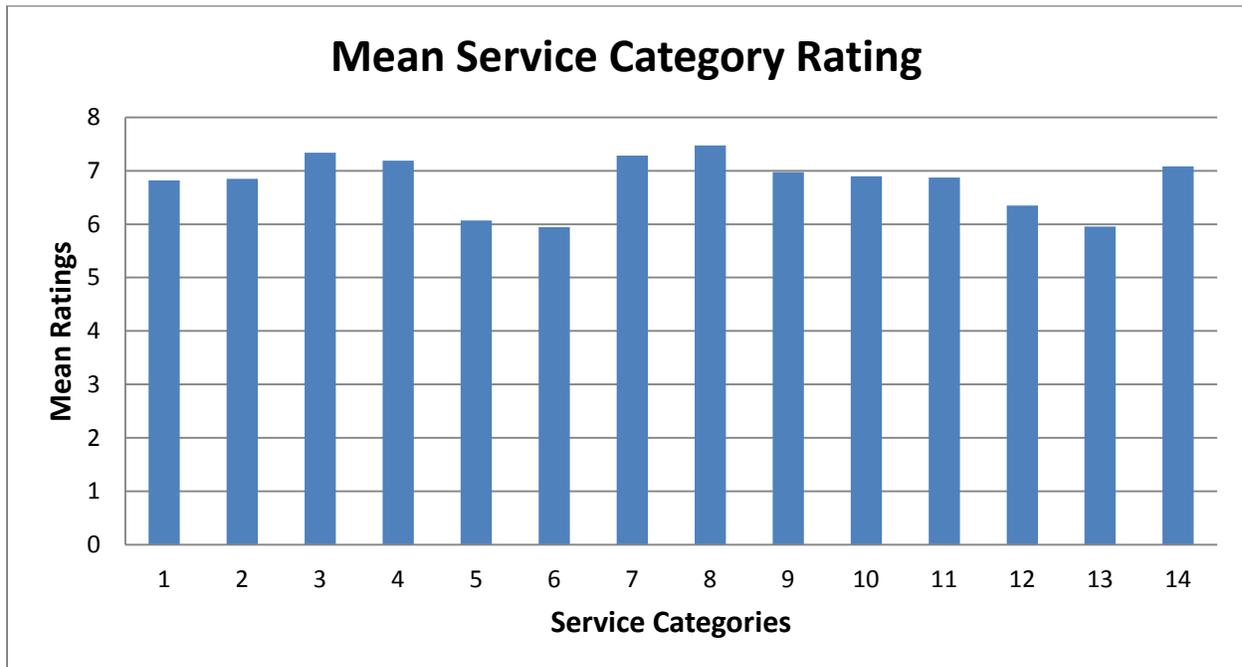


Figure 4: The mean rating histogram for all services.

It is observed that services 5,6, 12, and 13 (winter comfort, summer comfort, maintenance work request, and GIRF) are the services most in need of improvement because of

their low ratings compared with ratings of other services. One of these four services (GIRF) was selected for further improvement. Services 3,4,7, and 8 (Lighting, Exterior lighting, Elevators, and Door hardware and keys) show the highest rating among service categories.

4.1.1.1.2 Histograms of each Service Quality Rating

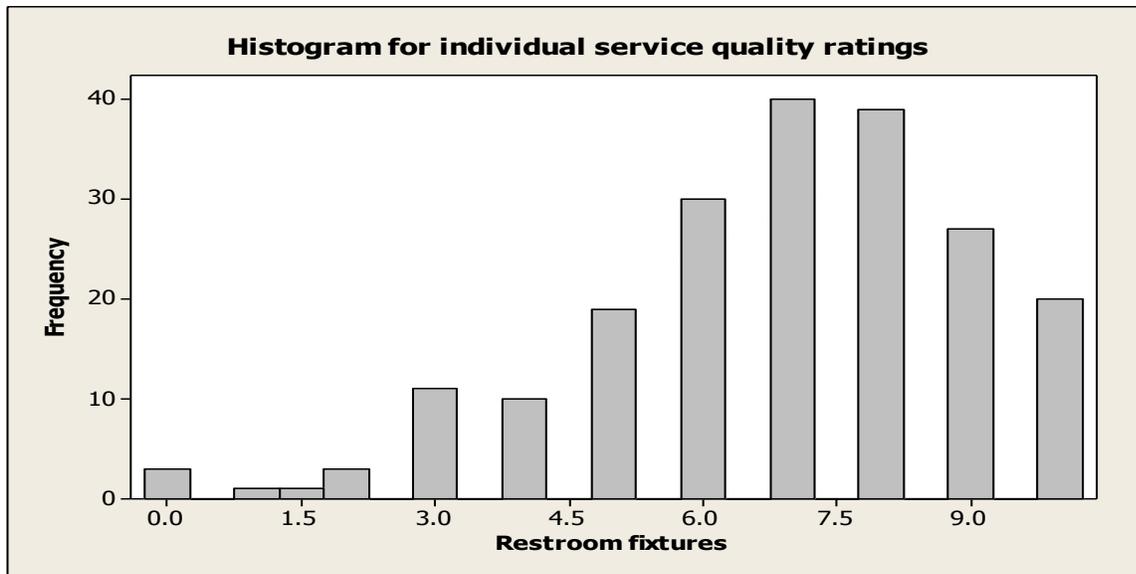


Figure 5: Restroom fixtures histogram

In Fig. 5, most of the ratings are clustered between 6 and 8 and the mean rating value is 6.821, mode is 7, and coefficient of variation is 32.22

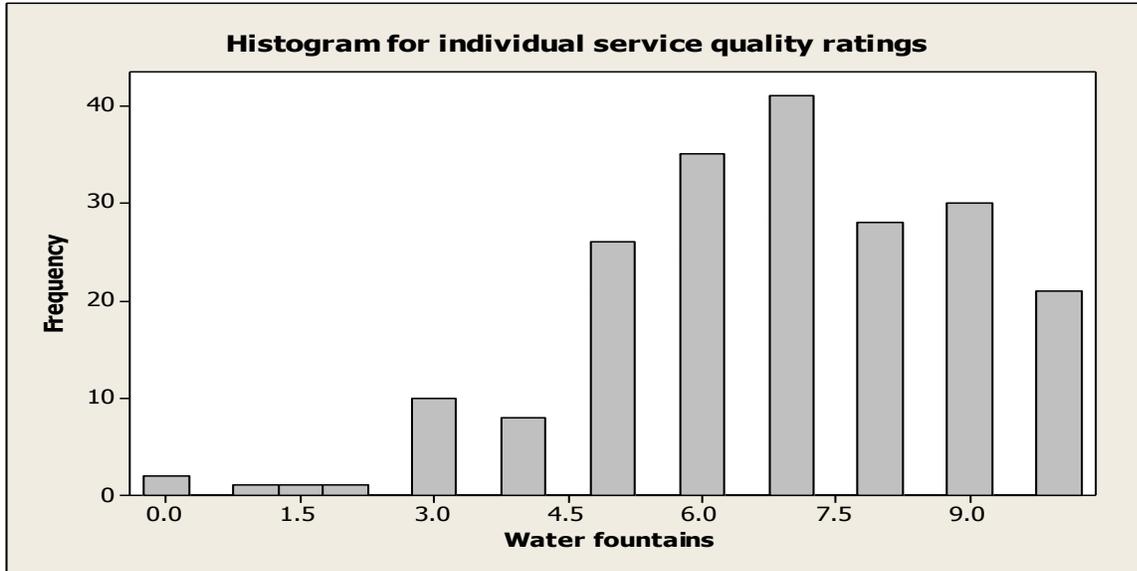


Figure 6: Water fountains histogram

In Fig. 6, most of the ratings are between 5 and 9. The mean rating is 6.85, mode is 7, and coefficient of variation is 30.61.

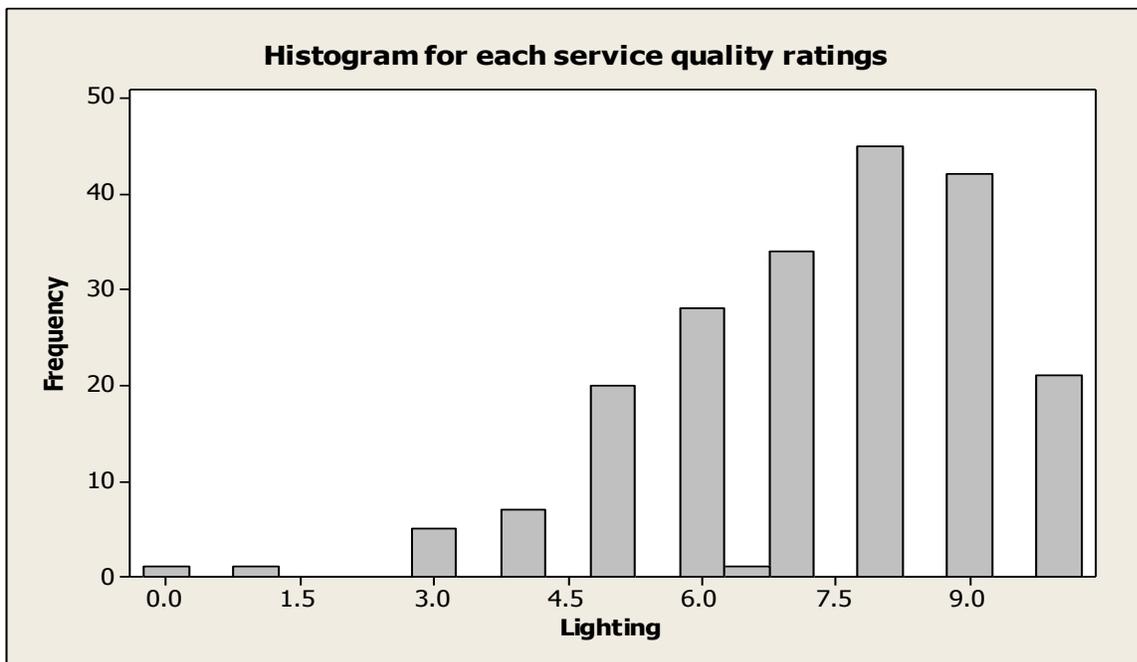


Figure 7: Interior lighting histogram

In Fig.7, one of the services that customer receive the highest satisfaction. More than 50% of data lie between 8 and 10. The mean rating is 7.339, mode is 8, and coefficient of variation is 25.5

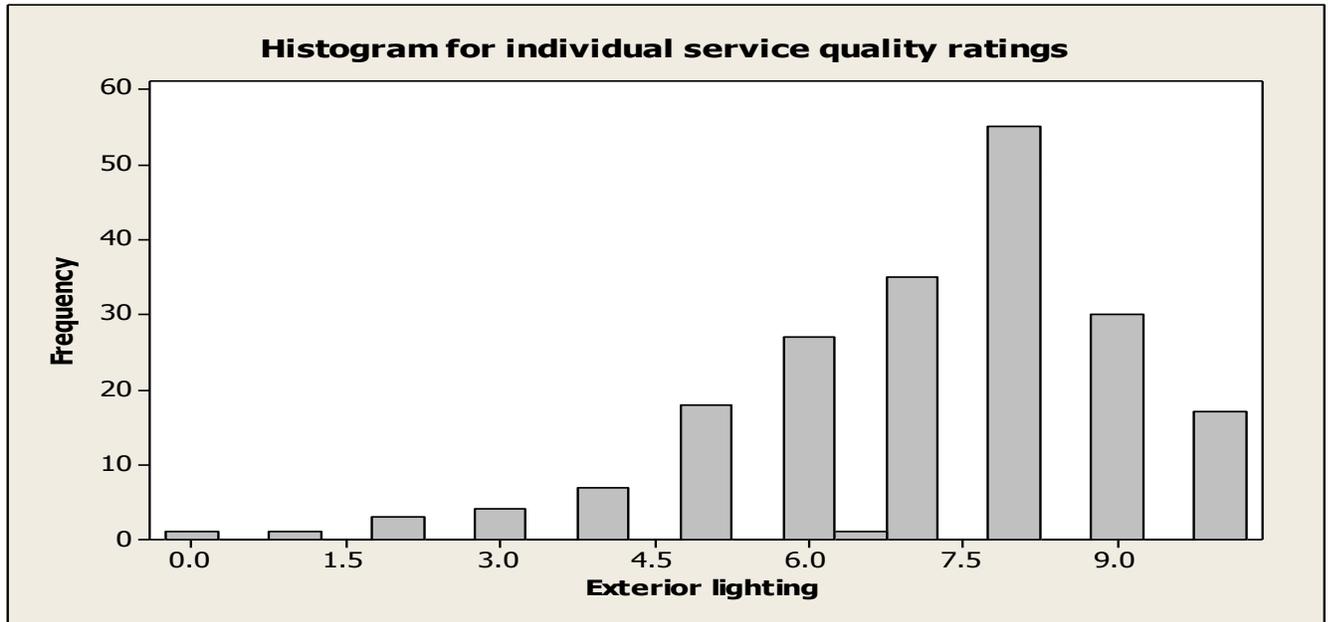


Figure 8: Exterior lighting histogram

In Fig. 8, a sign of satisfaction could be observed since the mean rating is 7.188, mode is 8, and coefficient of variation is 26.29. Most of the data values lie between 7 and 10.



Figure 9: Winter comfort histogram

In Fig.9, one of the services which needs improvement. Most of the data is clustered between 5 and 8. Mean is 6.067, one mode is 8 and a second mode is 5, and coefficient of variation is 40.63

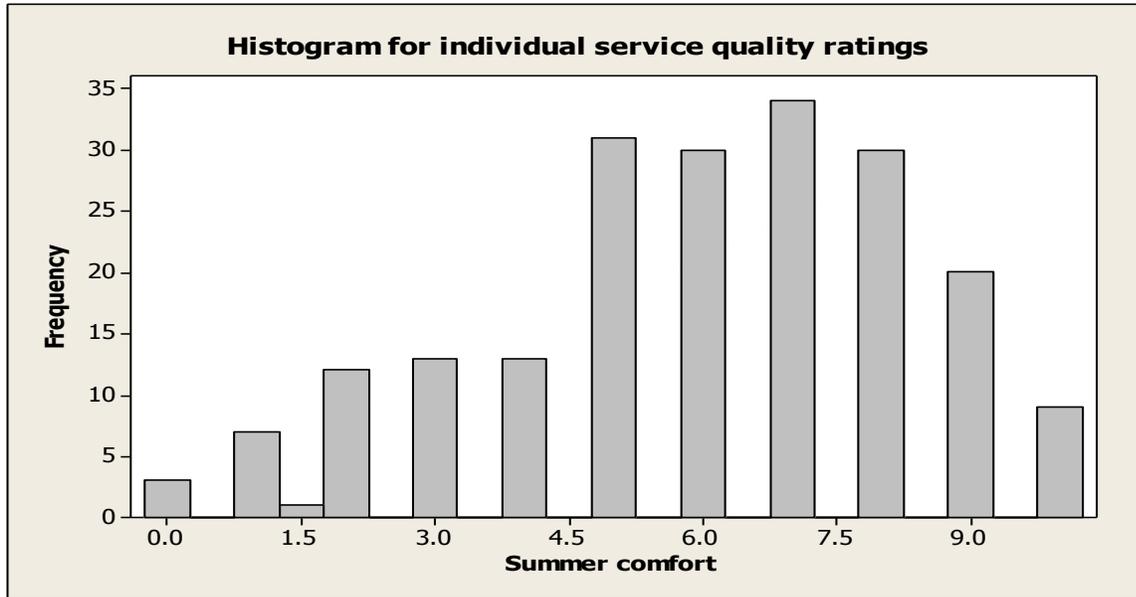


Figure 10: Summer comfort histogram

Fig. 10 has almost the same behavior of the winter comfort histogram. People feel lesser satisfaction with the heating and cooling systems. Mean is 5.934 , mode is 7 ,and coefficient of variation is 40.54

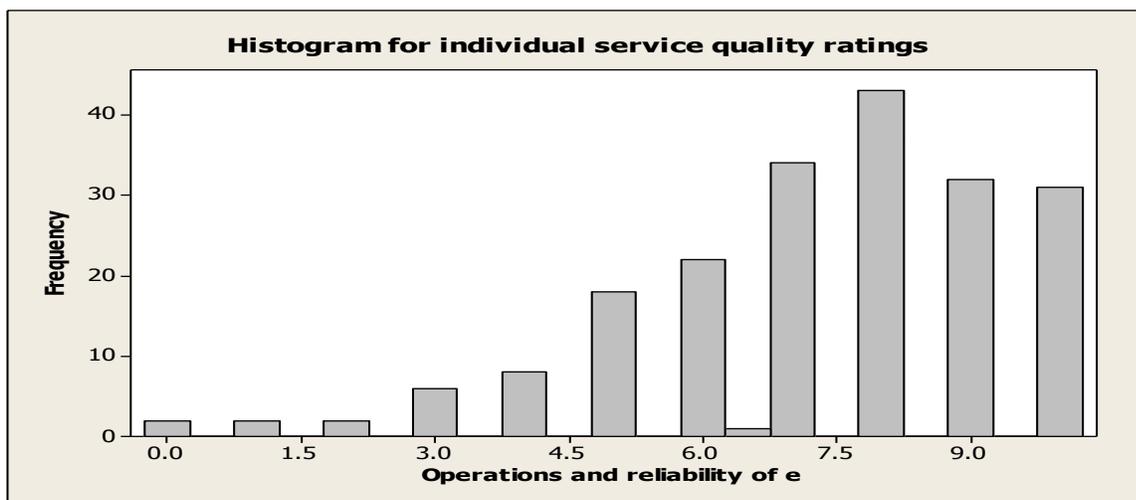


Figure 11: Elevators histogram

Operation and reliability of the elevators (Fig. 11) is one of the services receiving higher customer ratings. The strict safety procedures and the outsider contractors are responsible for maintaining elevators. They are contributing to the high customer satisfaction. Mean rating is 7.286, mode is 8 and the coefficient of variation is 29.37.

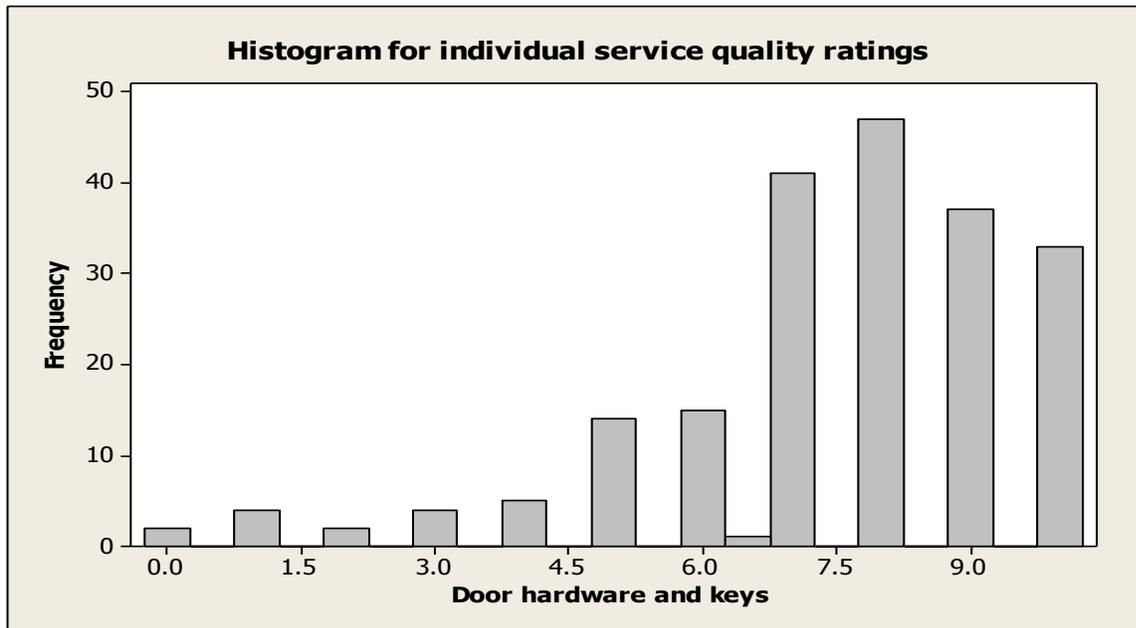


Figure 12: Door hardware and keys histogram

Fig. 12 shows that the mean rating value is 7.476 which considered the highest mean service rating values, mode is 8, and coefficient of variation is 28.37. As the mean rating value goes up, the coefficient of variation goes down due signifying less variability of ratings among customers.

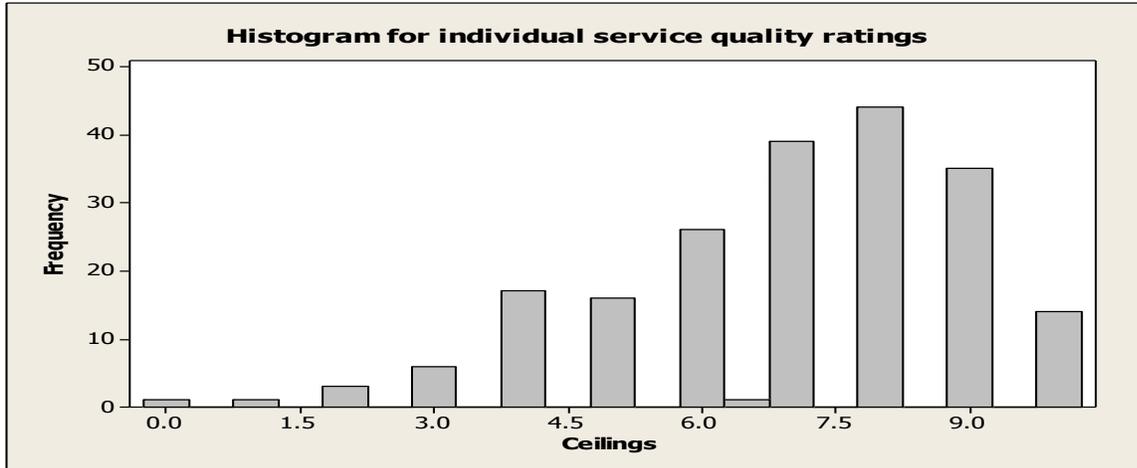


Figure 13: Ceilings histogram

Fig. 13 shows an average rating of 6.973, mode is 8, and coefficient of variation is 28.7

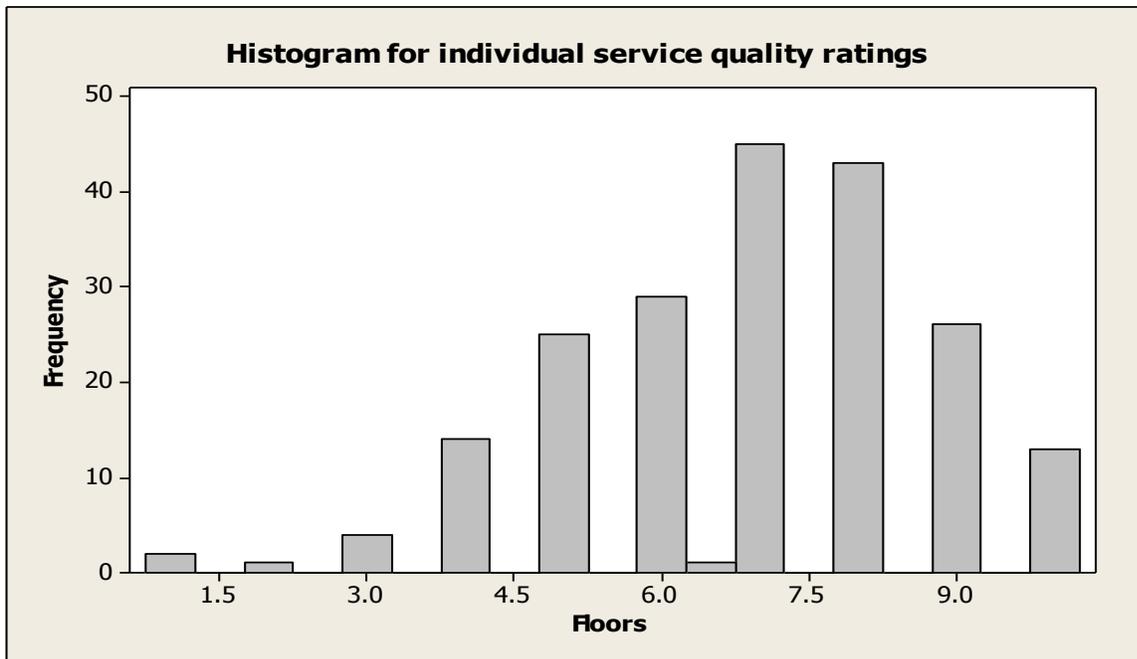


Figure 14: Histogram for Floors.

Fig. 14 shows that the average rating is 6.899 which is in acceptance range comparing with some other lower rating averages. Coefficient of variation is 26.56 and mode is 7.

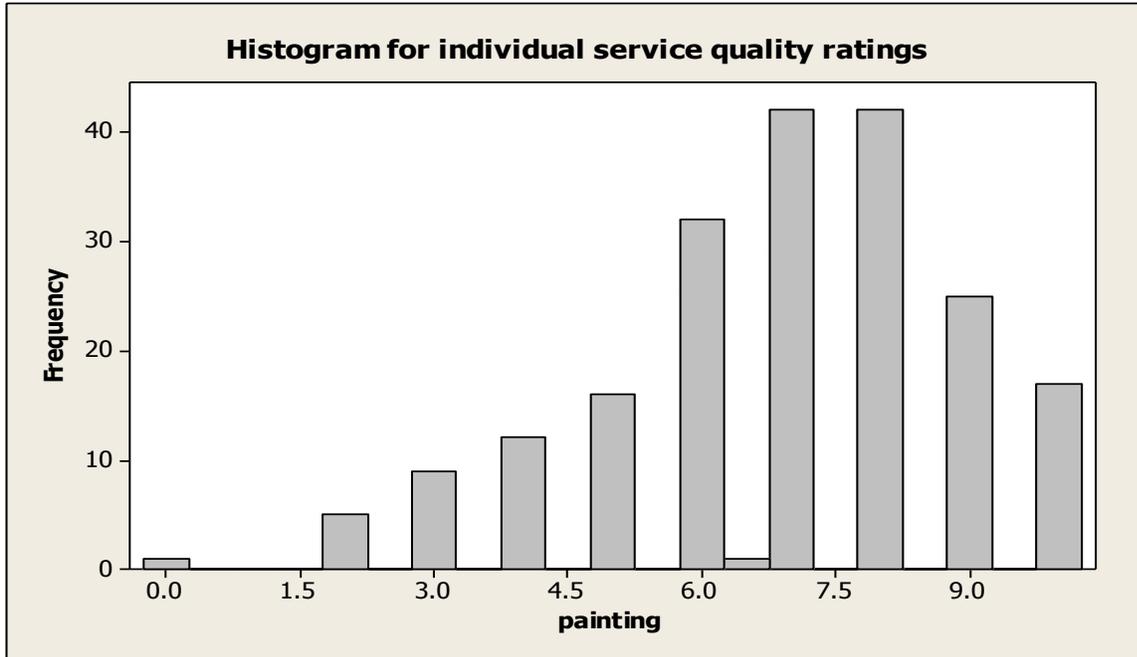


Figure 15: Histogram for Painting

Fig. 15 shows that the mean rating value is 6.874, mode is 7&8, and the coefficient of variation is 29.28

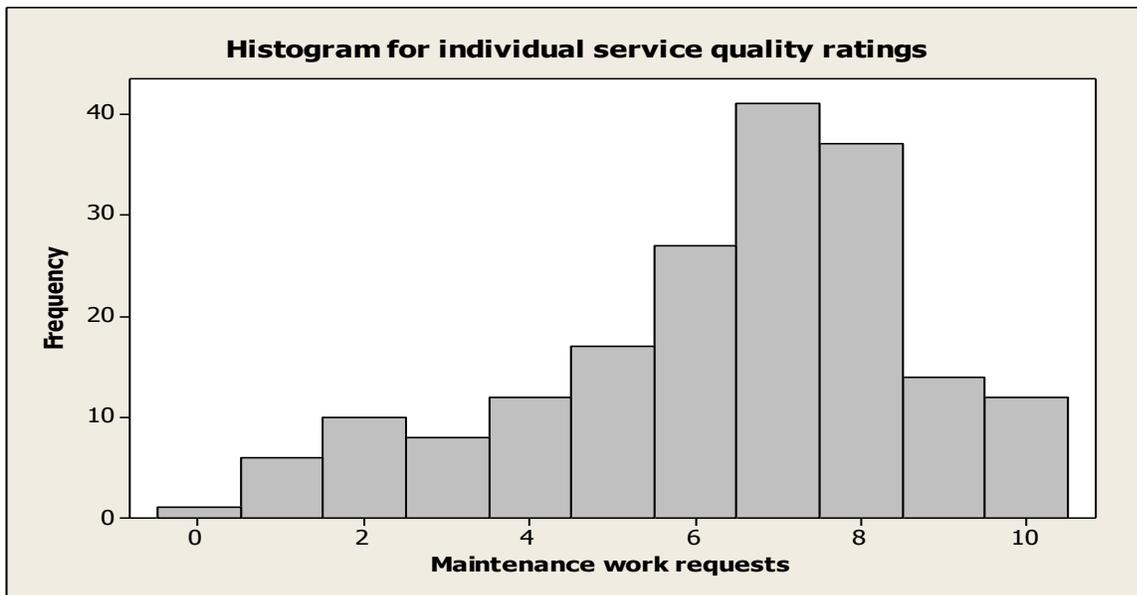


Figure 16: Maintenance work requests histogram

Fig. 16 shows that the maintenance work request is one of the services that need improvement because its rating is just above 6. Mean rating value is 6.346, mode is 7, and coefficient of variation is 36.14

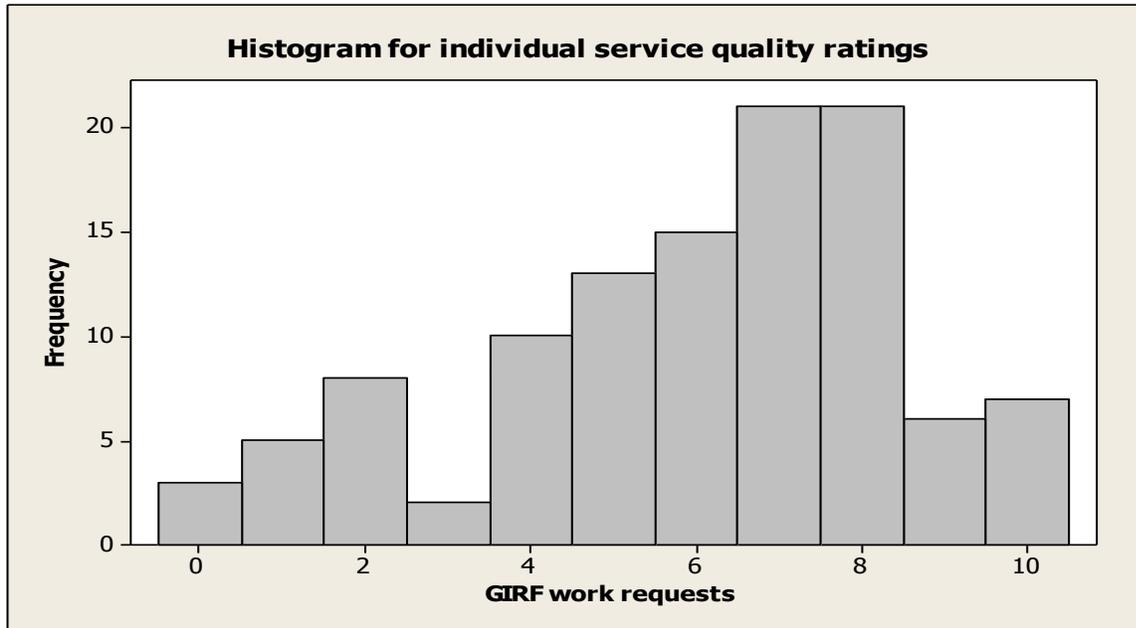


Figure 17: GIRF work requests histogram.

Fig. 17 shows the GIRF service that was selected for further improvement. Mean rating value is 5.955 which is low compared with other service ratings; mode is 7 and 8, and coefficient of variation is 42.45, which is very high.



Figure 18: Overall satisfaction with work performed histogram

Fig. 18 shows how much customers are satisfied with work performed for fixing service problems. The mean rating value is 7.078, mode is 8 and the coefficient of variation is 24.98 which reflect the high mean rating value. Figure 19 shows all service category ratings in one chart.

4.1.1.2 Coefficient of Variation Histogram (CV)

It was revealed by the Minitab computations that there is an inverse relationship between the average mean of the service category and its coefficient of variation. Plotting service categories vs. coefficient of variation will strengthen and confirm the trend of service categories-mean of rating relationship showed in previous histograms. Figure 20 shows the relationship between service categories ratings and their coefficient of variation.

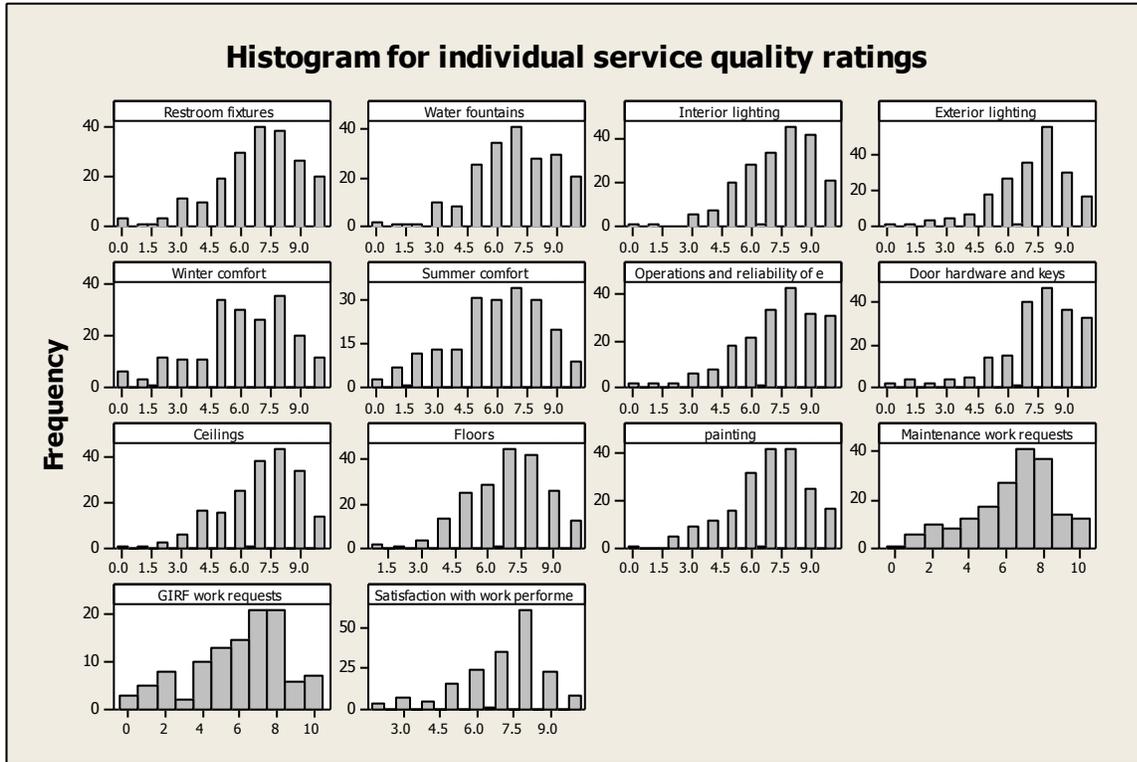


Figure 19: All separate service histograms in one chart.

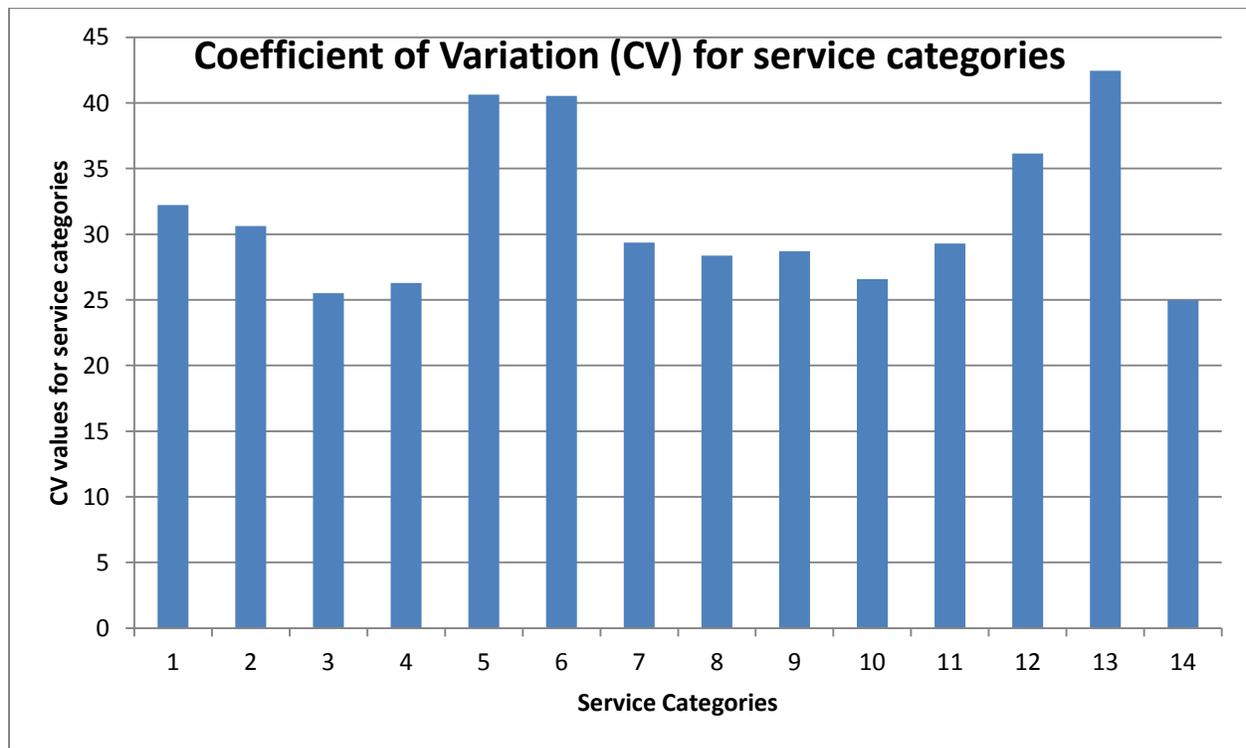


Figure 20: Histogram of Coefficient of Variation (CV) vs. service categories.

It is observed that when comparing Fig.20 with the one of mean service ratings, there is an inverse relationship. Service categories showing high mean ratings are showing lower CV's. Services 5, 6, 12 and 13 (summer comfort, winter comfort, maintenance work request, and GIRF work request) show the lowest mean rating while they show the highest coefficient of variation. This is pointing to the wide variation among customers in evaluating these service categories. For lower CV ratings, we've found a high service mean ratings reflecting that customers are consistently satisfied with services. Since CV is a statistical measure used for comparing diversity and variability of results within groups (it is a measure of dispersion of data relative to the mean, it was used here to compare variability among service categories as mentioned above). This represented the relative dispersion or the Coefficient of Variation.

4.1.1.3 Pareto Plot for Service Rating Means

Pareto charts were utilized to identify the most critical service categories requiring attention and improvement. Usually in the construction of a Pareto chart, data is sorted from the highest to lowest value after which an accumulative percentage is calculated. However, in our case, because we were looking at the lowest rated service categories as the most categories need attention, we've reversed the data to be sorted from lower to higher values as shown in Fig 21. We can categorize service categories according to the most urgent need for improvement into three groups; Group 1 is comprised of summer comfort, winter comfort, maintenance work request, and GIRF work request services. Group 2 includes restroom fixtures, water fountains, painting, floors, ceilings, and satisfaction with work performed services. Group3 encompasses exterior lighting, elevators operations, interior lighting, and door hardware and keys. It is obvious that the services in Group 1 need the most urgent care, followed by the services in Group 2; then lastly the services of Group 3.

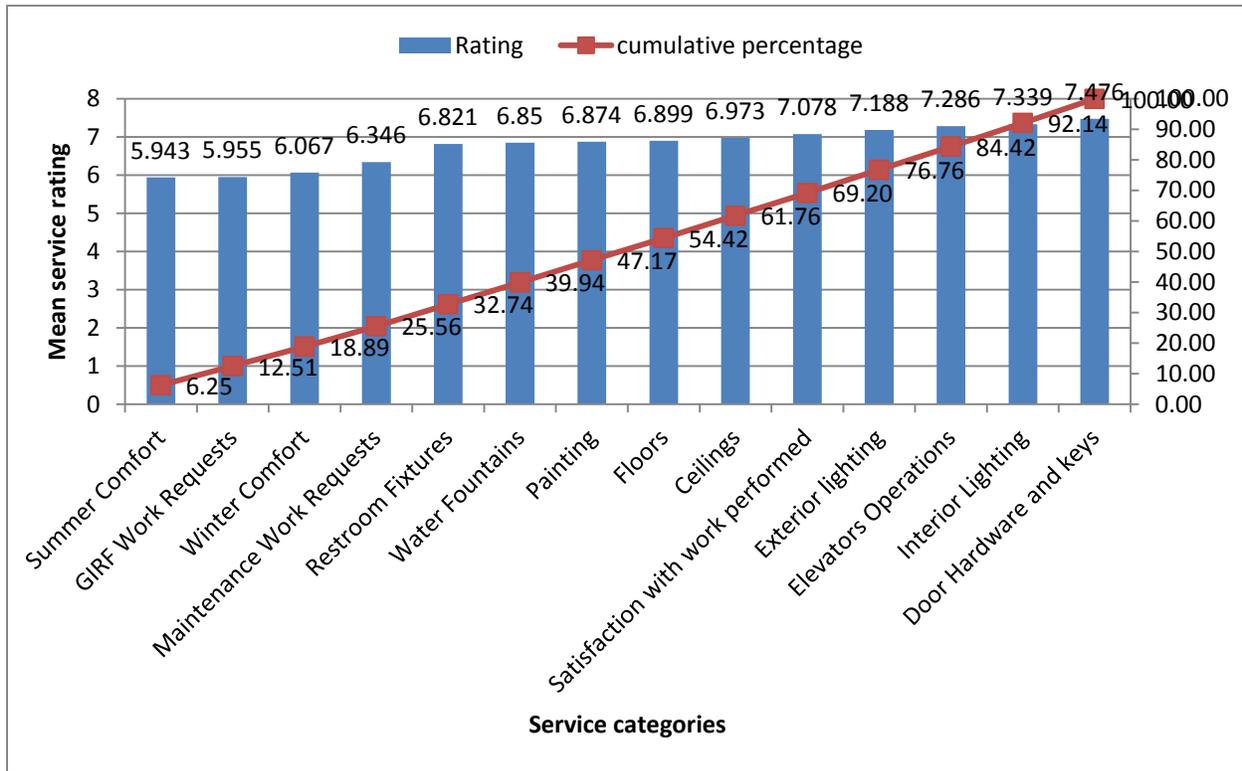


Figure 21: Pareto chart for service categories needing improvement.

4.1.2 Service Model Validation and Factors Affecting Quality of Services (The Nominal Group Technique-NGT)

The existing fish bone diagram and its attached tables were subjected to an in-depth review by the NGT group to modify and refine the factors/sub-factors affecting service quality using input from the group. As a result, some factors and sub-factors were added and some were consolidated. The revised list of factors and sub-factors resulted in a new fishbone diagram relating the factors and sub-factors to the quality of services delivered (Fig. 22). Table 7 contains the revised factors/sub-factors obtained through the work of the NGT group.

Fig 22 shows the fishbone containing all factors and sub-factors affecting service quality resulted from the NGT review and modifying of existing factors and sub-factors in the initial model shown in chapter 3.

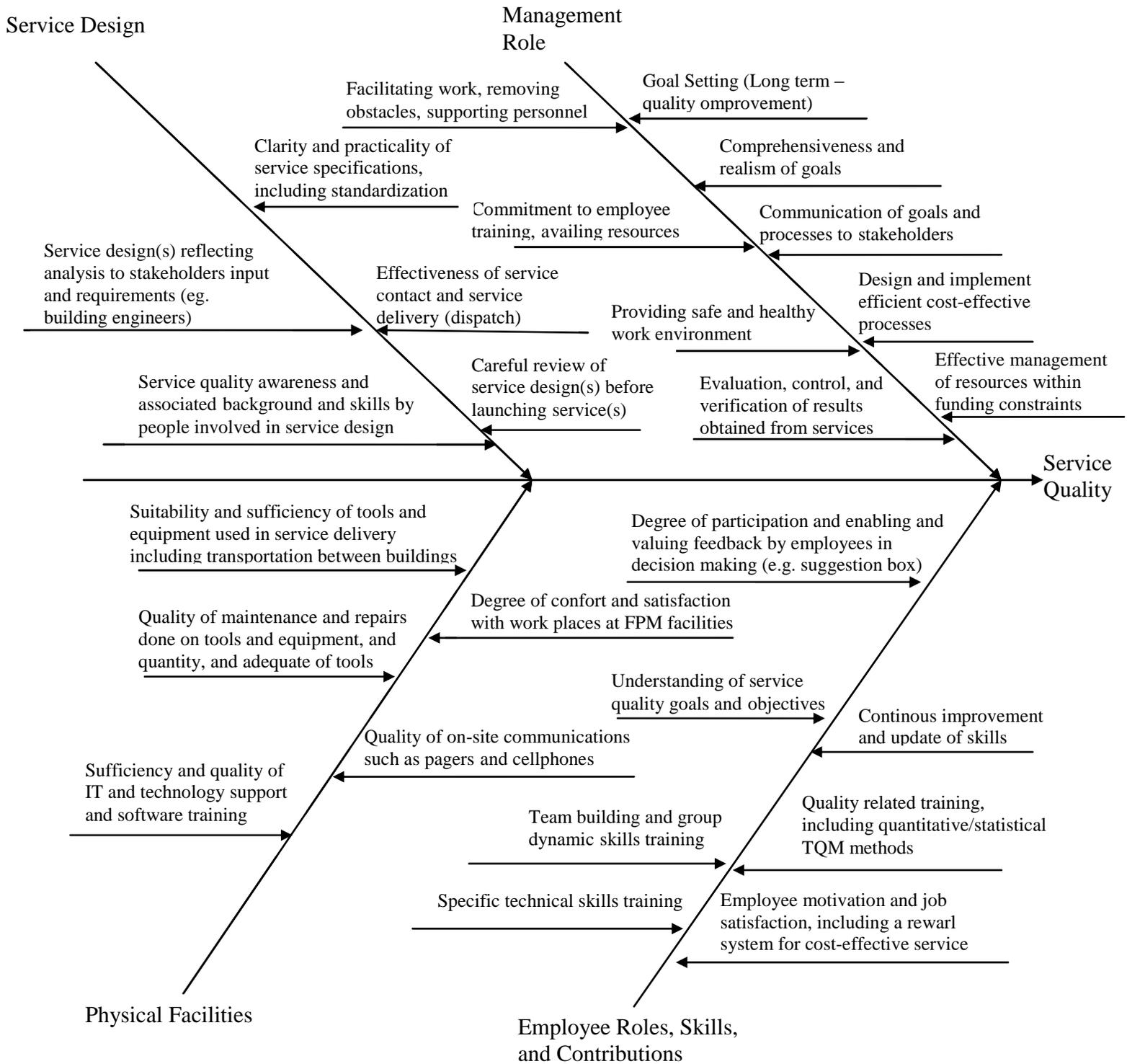


Figure 22: NGT Modified fish bone before prioritizing factors and sub-factors

Table 7: Factors and sub-factors of the fishbone diagram

Symbol	Factor/sub-factor description
F1: Management Role	Goal settings, providing resources within available funding, removing obstacles, supporting personnel, employee relation, design& implement improvement processes & plans.
F11	Goal setting (long term-quality improvements).
F12	Comprehensiveness and realism of goals.
F13	Communication of goals and processes to stakeholders.
F14	Facilitating work, removing obstacles, supporting personnel.
F15	Design and implement efficient cost-effective processes.
F16	Effective management of resources within funding constraints.
F17	Commitment to employee training, availing resources.
F18	Providing a safe and healthy work environment
F19	Evaluation, control, and verification of results obtained from services
F2: Service Design	Quality centered and customer focused service design (plans, procedures, method, specifications, meeting all applicable laws, rules, and regulations aimed at efficient, practical and cost effective delivery of service work.
F21	Service quality awareness and associated background and skills by people involved in service design
F22	Careful review of service design(s) before launching service(s).
F23	Service design(s) reflecting analysis of stakeholder input and requirements (e.g. building engineers)
F24	Clarity and practicality of service specifications, including standardization
F25	Effectiveness of service contact and service delivery (dispatch) system (timely and satisfactory response).
F3: Physical Facilities	Physical appearance of all sub-factors related to service. This includes tools, equipment, manpower, technology and communication systems, and even employees' dress and uniform used in producing the service.
F31	Suitability and sufficiency of tools and equipment used in service delivery including transportation between buildings
F32	Quality of maintenance and repairs done on tools and equipment, and quantity, and adequate of tools
F33	Sufficiency and quality of IT and technology support and software training
F34	Degree of comfort and satisfaction with work places at FPM facilities
F35	Quality of on-site communications such as pagers and cellphones
F4: Employee Roles, Skills and Contributions	Skills, knowledge, and motivation of employees.
F41	Continuous improvement and update of skills.

F42	Specific technical skills training.
F43	Team building and group dynamic skills training.
F44	Quality related training, including quantitative/statistical TQM methods.
F45	Understanding of service quality goals and objectives.
F46	Degree of participation and enabling and valuing feedback by employees in decision making (e.g. suggestion box)
F47	Employee motivation and job satisfaction, including a reward system for cost-effective service

Following this step, the final form of sub-factors was rated by the NGT group in terms of the relative importance of the individual sub-factor. The most important one has got the highest score, and the remaining ones were scored on a descending scale. The maximum possible score (R) in any category was the number of sub-factors listed under that factor. For example, under the factor F1, management role, the maximum score would be 9 and the minimum score would be 1 because there are 9 sub-factors constituting the factor. The individual scores for each sub-factor were added together to obtain a total score, and the sub-factors were ranked from the highest total to the lowest. In addition, the mean, standard deviation and coefficient of variation for each sub-factor were calculated separately. These results are shown in Table 8.

Table 8: NGT group ratings summary

Symbol	Factor/sub-factor description	R1	R2	R3	R4	R5	Total R	Mean	St.Dev.	Coeff. of Var.
F1 (management role)	Goal settings, providing resources within available funding, removing obstacles, supporting personnel, employee relation, design& implement improvement processes & plans.									
F11	Goal setting (long term-quality improvements).	3	1	2	4	2	12	2.4	1.14	0.48
F12	Comprehensiveness and realism of goals.	5	9	4	3	3	19	3.8	2.49	0.66
F13	Communication of goals and processes to stakeholders.	9	2	7	5	8	31	6.2	2.77	0.45

F14	Facilitating work, removing obstacles, supporting personnel.	8	5	6	6	7	32	6.4	1.14	0.18
F15	Design and implement efficient cost-effective processes.	4	6	3	1	6	20	4	2.12	0.53
F16	Effective management of resources within funding constraints.	2	3	5	7	4	21	4.2	1.92	0.46
F17	Commitment to employee training, availing resources.	7	4	8	8	5	32	6.4	1.82	0.28
F18	Providing a safe and healthy work environment	6	7	9	9	9	40	8	1.41	0.18
F19	Evaluation, control, and verification of results obtained from services	1	8	1	2	1	13	2.6	3.05	1.17
F2: Service design	Quality centered and customer focused service design (plans, procedures, methods, specifications, meeting all applicable laws, rules, and regulations aimed at efficient, practical and cost effective delivery of service work.									
F21	Service quality awareness and associated background and skills by people involved in service design	5	5	3	2	3	18	3.6	1.34	0.37
F22	Careful review of service design(s) before launching service(s).	3	4	2	5	5	19	3.8	1.30	0.34
F23	Service design(s) reflecting analysis of stakeholders input and requirements (e.g. building engineers)	4	2	4	4	2	16	3.2	1.10	0.34
F24	Clarity and practicality of service specifications, including standardization	1	3	5	3	4	16	3.2	1.48	0.46
F25	Effectiveness of service contact and service delivery (dispatch) system (timely and satisfactory response).	2	1	1	1	1	6	1.2	0.45	0.37
F3: Physical Facilities										
F31	Suitability and sufficiency of tools and equipment used in service delivery including transportation between buildings	4	5	4	5	3	21	4.2	0.84	0.20

F32	Quality of maintenance and repairs done on tools and equipment, and quantity, and adequate of tools	3	4	5	4	2	18	3.6	1.14	0.32
F33	Sufficiency and quality of IT and technology support, and software training	3	1	2	5	5	16	3.2	1.79	0.56
F34	Degree of comfort and satisfaction with work places at FPM facilities.	1	1	2	1	1	6	1.2	0.45	0.37
F35	Quality of on-site communications such as pagers, and cellphones	2	2	3	3	4	14	2.8	0.84	0.30
F4: Employee roles, skills and contribution	Skills, knowledge, and motivation of employees.									
F41	Continuous improvement and update of skills.	3	1	4	6	4	18	3.6	1.82	0.50
F42	Specific technical skills training.	4	6	6	4	7	27	5.4	1.34	0.25
F43	Team building and group dynamic skills training.	1	3	2	3	5	14	2.8	1.48	0.53
F44	Quality related training, including quantitative/statistical TQM methods.	5	2	7	2	1	17	3.4	2.51	0.74
F45	Understanding of service quality goals and objectives.	2	5	1	1	6	15	3	2.35	0.78
F46	Degree of participation by employees in decision making; enabling and valuing feedback (e.g. suggestion boxes)	7	7	5	5	2	26	5.2	2.05	0.39
F47	Employee motivation and job satisfaction including reward system for cost effective services	6	4	3	7	3	23	4.6	1.82	0.39

The rating order of all sub-factors affecting the quality of services was established in descending order as follows:

F18 Providing a safe and healthy work environment

- F31 Suitability and sufficiency of tools and equipment used in service delivery including transportation between buildings
- F42 Specific technical skills training
- F22 Careful review of service design(s) before launching service(s)
- F46 Degree of participation by employees in decision making; enabling and valuing feedback (e.g. suggestion boxes)
- F21 Service quality awareness and associated background and skills by people involved in service design
- F32 Quality of maintenance and repairs done on tools and equipment, and quality, and adequate of tools
- F14 Facilitating work, removing obstacles, supporting personnel
- F17 Commitment to employee training, availing resources
- F13 Communication of goals and processes to stakeholders
- F47 Employee motivation and job satisfaction including reward system for cost effective services
- F23 Service design(s) reflecting analysis of stakeholders input and requirements (e.g. building engineers)
- F24 Clarity and practicality of service specifications, including standardization
- F33 Sufficiency and quality of IT and technology support, and software training
- F35 Quality of on-site communications such as pagers, and cellphones
- F41 Continuous improvement and update of skills
- F44 Quality related training, including quantitative/statistical TQM methods
- F16 Effective management of resources within funding

- F15 Design and implement efficient cost-effective processes
- F45 Understanding of service quality goals and objectives
- F12 Comprehensiveness and realism of goals
- F43 Team building and group dynamic skills training
- F19 Evaluation, control, and verification of results obtained from services
- F11 Goal setting (long term-quality improvements)
- F25 Effectiveness of service contact and service delivery (dispatch) system (timely and satisfactory response)
- F34 Degree of comfort and satisfaction with work places at FPM facilities

The total scores were plotted as a bar chart as shown in Fig. 23 using the “significant few” Pareto concept, one can choose to incorporate just those sub-factors considered important in a further revised fishbone diagram based on 70-30, or 60-40 percent ratios. The resultant fishbone based on a 70 percent cutoff is illustrated in Figure 24. The numbers above each column indicate the degree of importance of the sub-factor. The higher the number the more

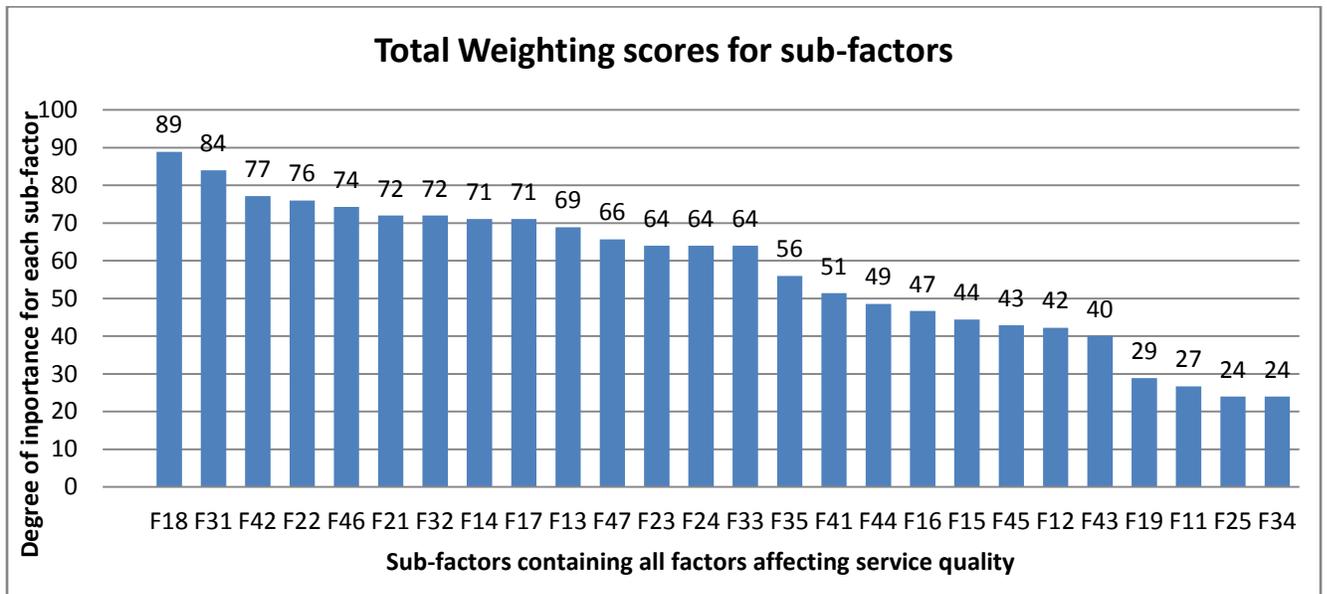


Figure 23: Total weighting scores for sub-factors from NGT session

important is the sub-factor. For example, for sub-factor F18, the total NGT ratings for this sub-factor is 40 out of 45 which is the highest rating that could be attained for this sub-factor. By dividing the rating over the highest rating that could be attained for the sub-factor, we got the importance of the sub-factor as a percentage. In the same manner, a 60% cut off is presented in a separate fish bone diagram in Fig. 25 which indicates the sub-factors rated over 60%.

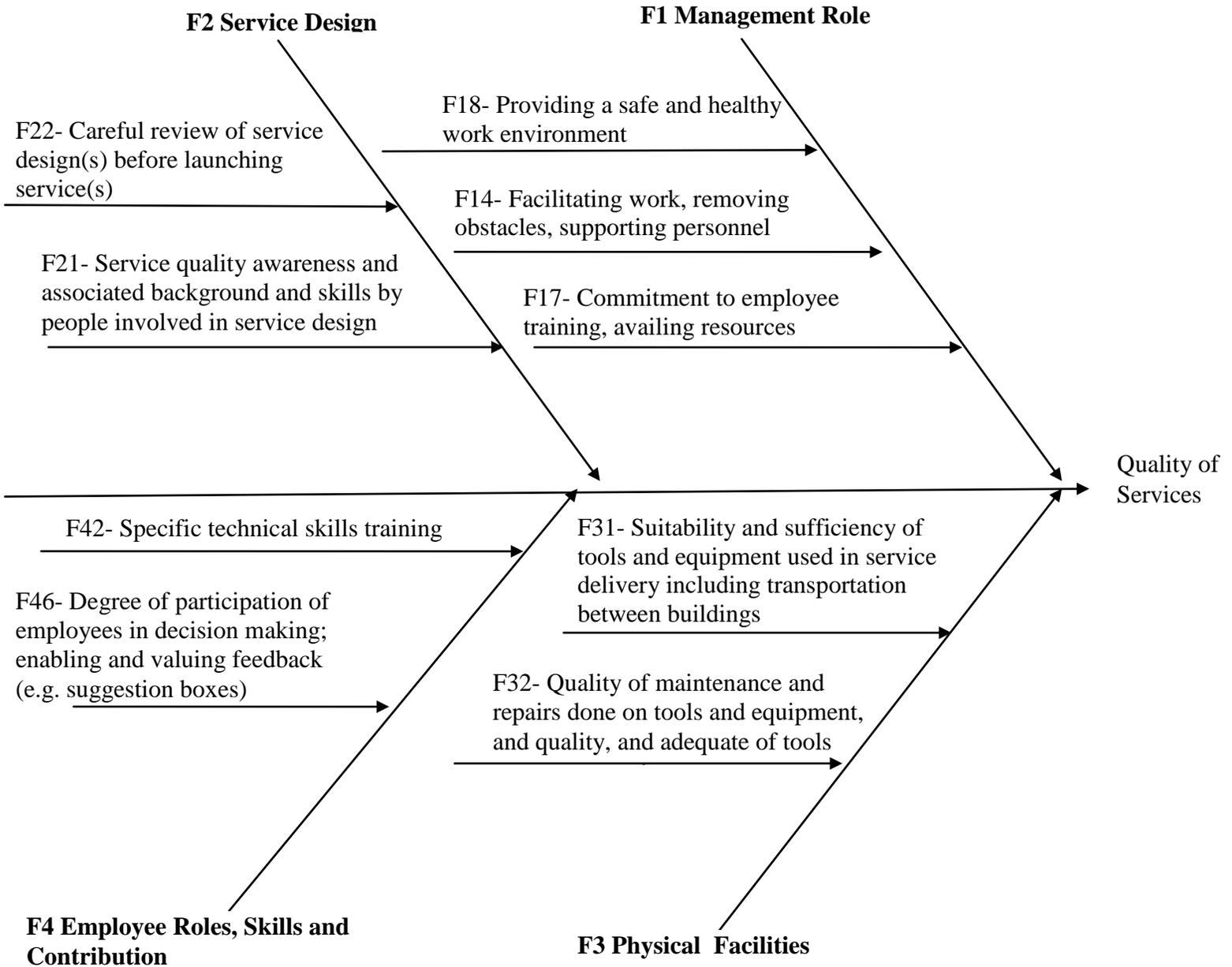


Figure 24: Further revised fishbone diagram based on a 70 percent cutoff

In continuing analysis and refinement of the revised fishbone diagram, we captured an opportunity to refine it further by considering the 60 percent cutoff option start with F18 as the highest ranked sub-factor and ending with F33 as a lowest ranked sub-factor. This resulted in a final modified fishbone diagram. Figure 25 shows the final revised fishbone diagram with the factors and sub-factors affecting customer perception for service quality and Fig. 26 shows the modified model resulting from NGT review and modifications.

The second revised model is different from the initial one (Fig. 1) in the following aspects:

- Factors affecting customer perception of service quality are reduced and consolidated.
- New sub-factors are added and some are eliminated as they were not considered important for service quality. Fourteen sub-factors were identified to have the highest impact on service quality (affecting customer perception).
- The Information Technology (IT) factor was consolidated within physical facilities factor and continuous to affect customer expectation the same as in the initial model.
- Factors affecting customer expectations were modified to contain more realistic factors directly affecting customer expectation for service quality.

According to what resulting from NGT session, the final modified model is shown on Fig. 26

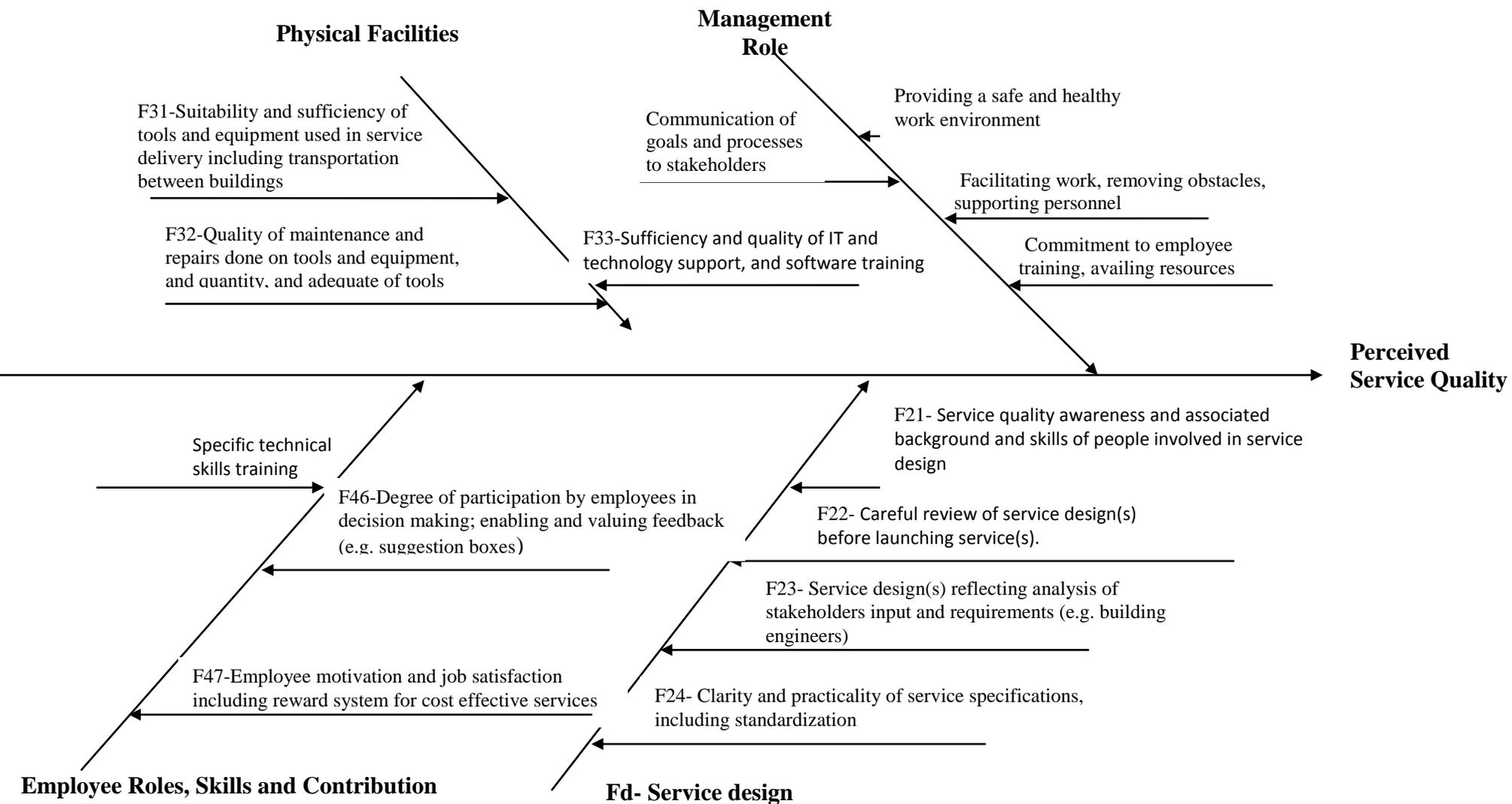


Figure 25: Final Fishbone diagram with the new classification of factors and sub-factors affecting FPM service quality based on 60% cutoff

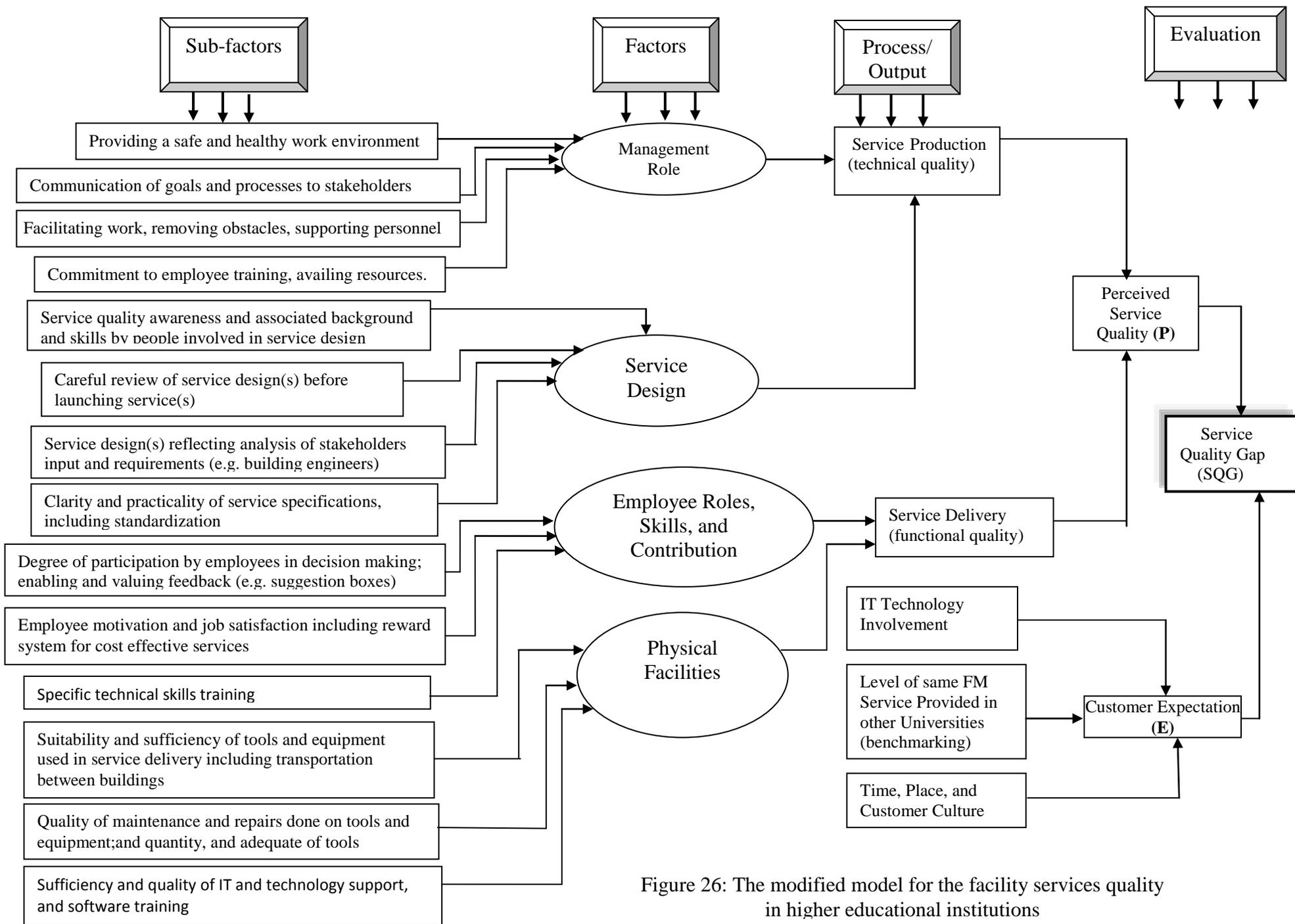


Figure 26: The modified model for the facility services quality in higher educational institutions

4.2 Quality/Process Improvement

4.2.1 Process Mapping

Because of the extensive size and complexity of the existing flowchart provided by FPM, we sought opportunities for simplification of the processes and ultimately identifying improvement strategies. This was attempted through the development of a GIRF process map. First, a macro flowchart was established in order to indicate the major sub-processes (Fig. 27). Second, a flowchart of decisions was created as illustrated in (Fig. 28) along the execution of the process map. Third, a detailed flowchart with associated process maps were created to depict further detailed process tasks and activities (Figs 29, 30, 31, 32). The main objective of the detailed study and illustration of the (GIRF) flowcharts and process maps was to establish a comprehensive and detailed process map of the GIRF service process to identify improvement opportunities to the existing process. This is one of the main tools of the measure phase of the Six-Sigma DMAIC methodology. The original detailed GIRF flowchart is divided into four GIRF sub-processes depending on decisions taken through the process. The four GIRF sub-processes are:

Just do it process (JDI) (Fig. 29)

Cost estimated project with no schematic design and no bidding (CEP) (Fig 30)

Cost estimated project with schematic design and no bidding (CEPD) (Fig 31)

Cost estimated project with schematic design and bidding (CEPDB) (Fig 32)

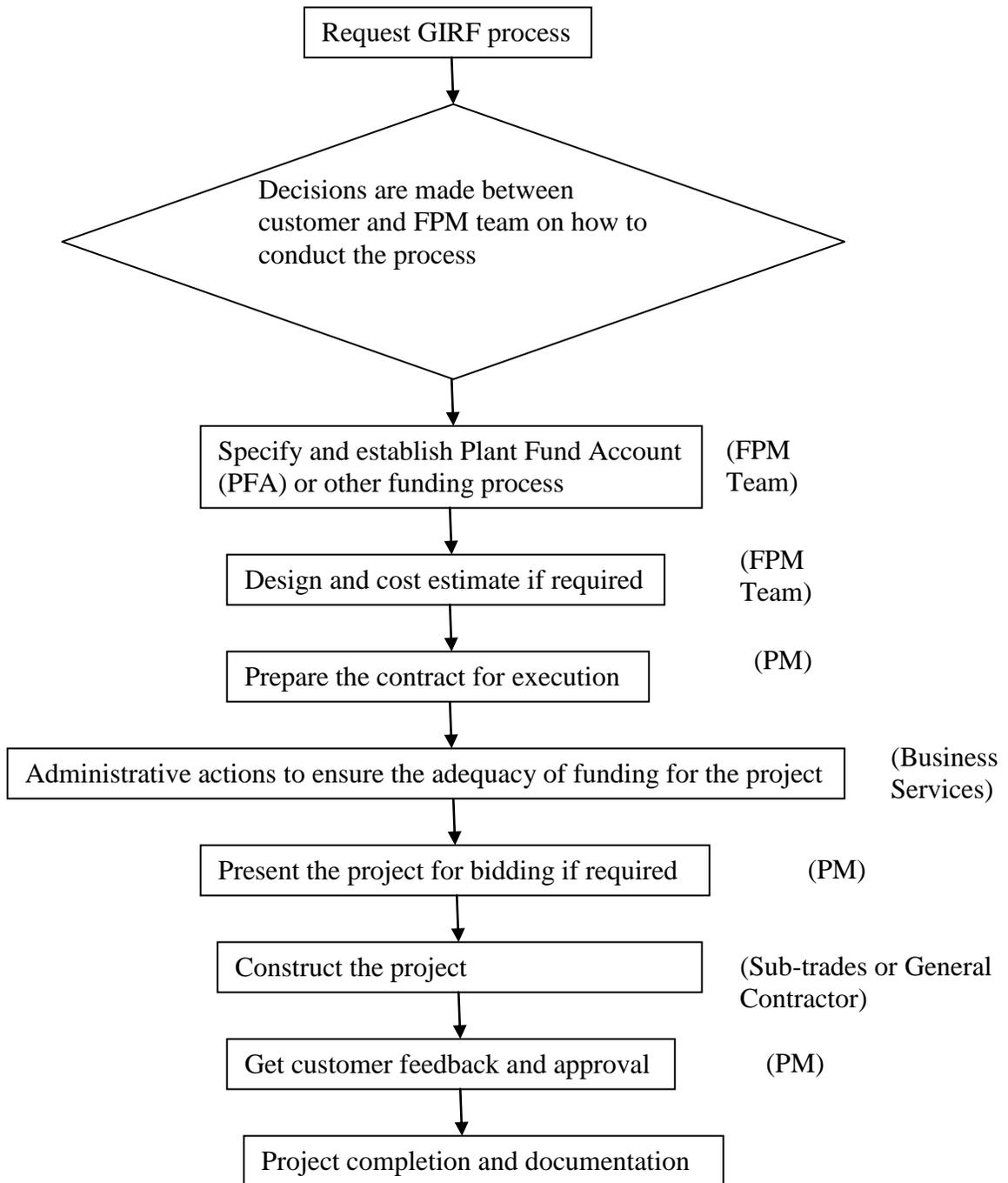


Figure 27: Macro flowchart for major sub-processes for GIRF

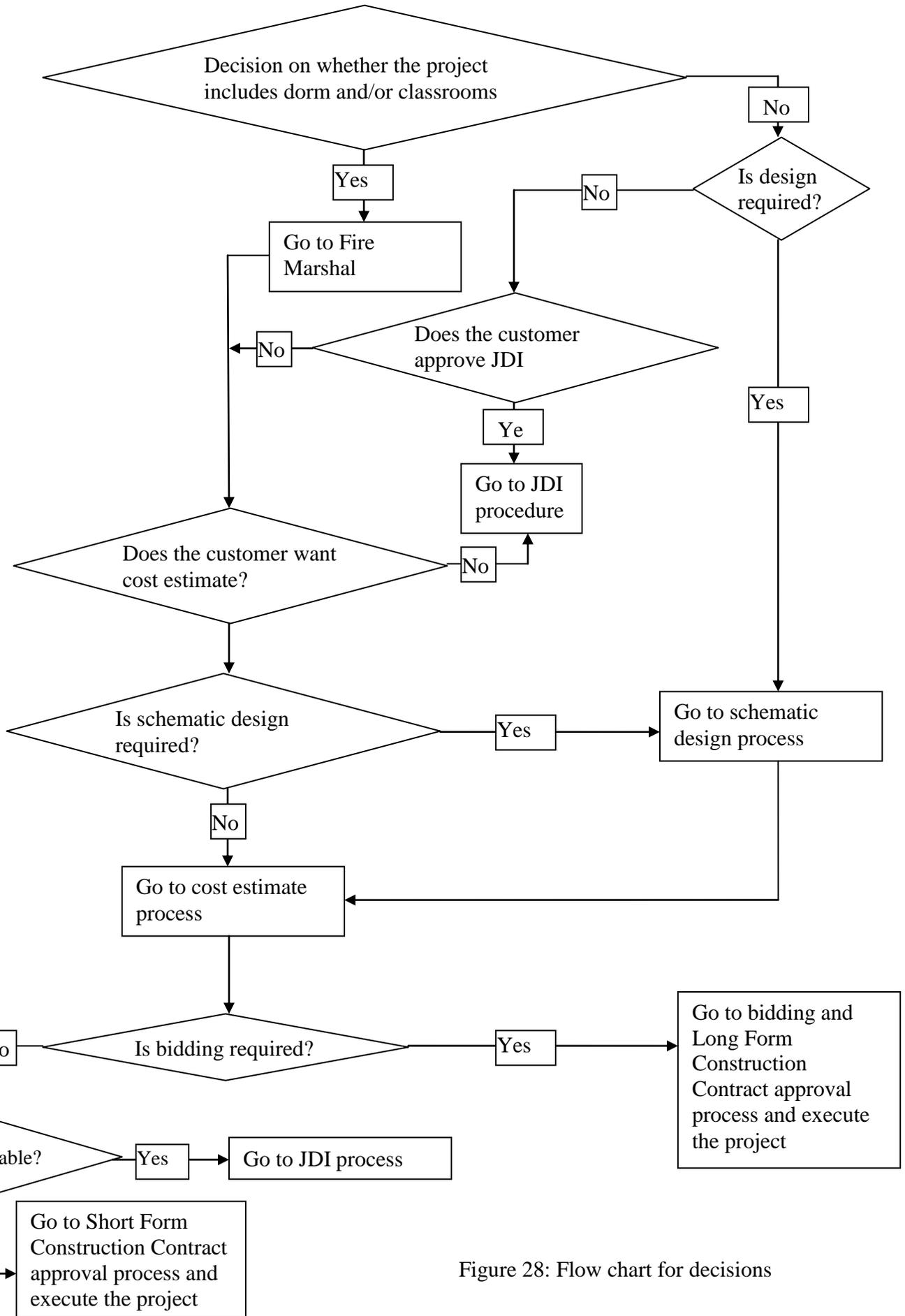


Figure 28: Flow chart for decisions

4.2.1.1 New Simplified FlowCharts for the Different GIRF Sub-Processes

The current master GIRF flowchart containing the totality of tasks and activities is very hard to follow and propose improvements on. Because of the GIRF process complexity and diversity in duties and tasks, the current master flowchart was divided into four GIRF sub-processes according to the degree of complexity of the GIRF sub-process. Degree of complexity of the GIRF projects is affected by the degree of GIRF process itself plus the complexity of customer funding process. For example FPM may consider a complex GIRF project under the JDI category just because customer can afford the cost. Some tasks are common in all of the four GIRF sub-processes, especially in the way customer requesting a project and the way FPM planning and design team acknowledging the project.

JDI projects are characterised usually by their simplicity and low funding. As mentioned previously, we could find complex projects under JDI just because customer requested accomplishing the project by this way and is ready to bear the cost.

Cost estimated projects are usually without major complications and both FPM planning and design team and the customer will agree about not needing any design. In this case, customer will accept or reject the project cost estimate submitted by the FPM planning and design team.

Cost estimate with design projects are usually more complicated than the previous GIRF sub-processes. It includes design processes and costs are higher. The customer needs to agree on both design and cost estimate of the project.

Cost estimated with design and bidding projects are usually the most complex projects in terms of design and costs. They need to be bid by the many prequalified/preapproved contractors.

Analysis of processes through process maps can help identify changes and related actions in the process to make improvements; such as reducing process cycle time, decreasing defects,

reducing costs, reducing non-value added activities, and increasing productivity. All of these actions will contribute to increased customer satisfaction. There is several improvement opportunities proposed for the current GIRF sub-processes:

- First, each step in the flowchart was revised in order to specify whether this step will add value to the process or no. Non-value adding activities are identified for possible elimination or at least to reduce the time duration of these activities. Some non-value-adding activities, even when not directly increasing the value of the process, may be required by the organization's current process structure. Non-value adding activities are categorized into two types: (a) activities that are necessary to the structure and the logic of a process but don't add value because it increases time and cost. They are called control activities. They are marked light shadowed in the GIRF sub-processes flowcharts. If it is not possible to eliminate these activities, at least they will be kept to a minimum. (b) activities that are neither necessary to the structure nor to the logic of the process. These are called delay processes. Examples for this kind of activities are waiting for specific tool/material, and waiting for funds or finance for the GIRF project. This type of activities should be eliminated from a process as much as possible.
- Reduce the time elapsed in getting different approvals for all tasks need approval. This is because getting an approval could take longer than normal and delays the overall process, because higher managers who give approvals are busy with other assignments according to the nature of their duties.
- Rework is another form of non-value-adding activities that should be eliminated, which may promote another opportunity for improvement.

Non-value added activities were shadowed by a gray color on the flowcharts. The light dark shadow means that these activities are control activities. Even though these activities are necessary

for the process but efforts should be focused on reducing cycle time for each of these activities. The dark shadow activities on the flowchart show non-value adding activities those can be addressed and possibly removed.

1. Simplified JDI GIRF sub-process flowchart

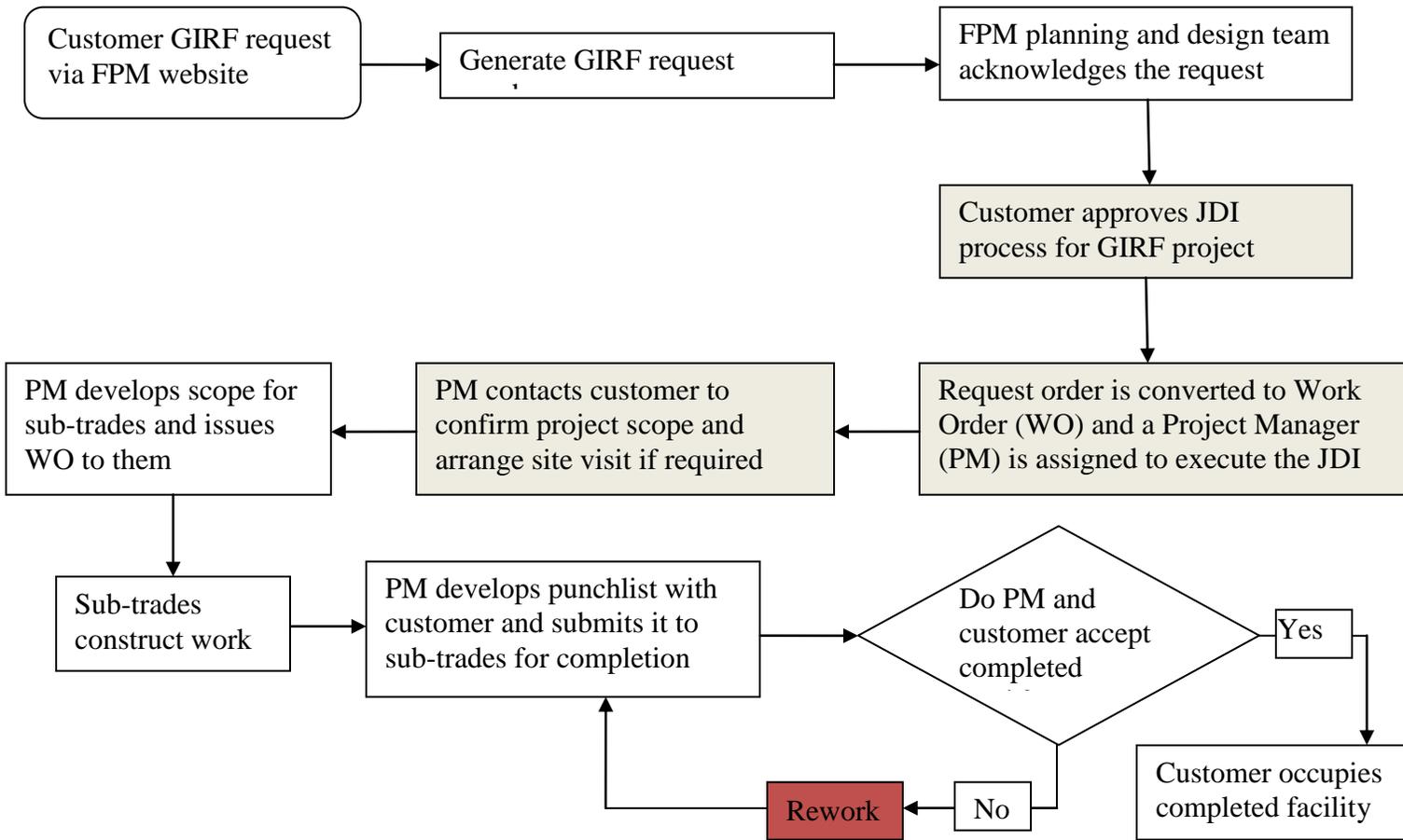


Figure 29: Just Do It (JDI) sub-process flowchart

Table 9 shows all inputs, outputs, and responsibility details of the flowchart tasks and activities.

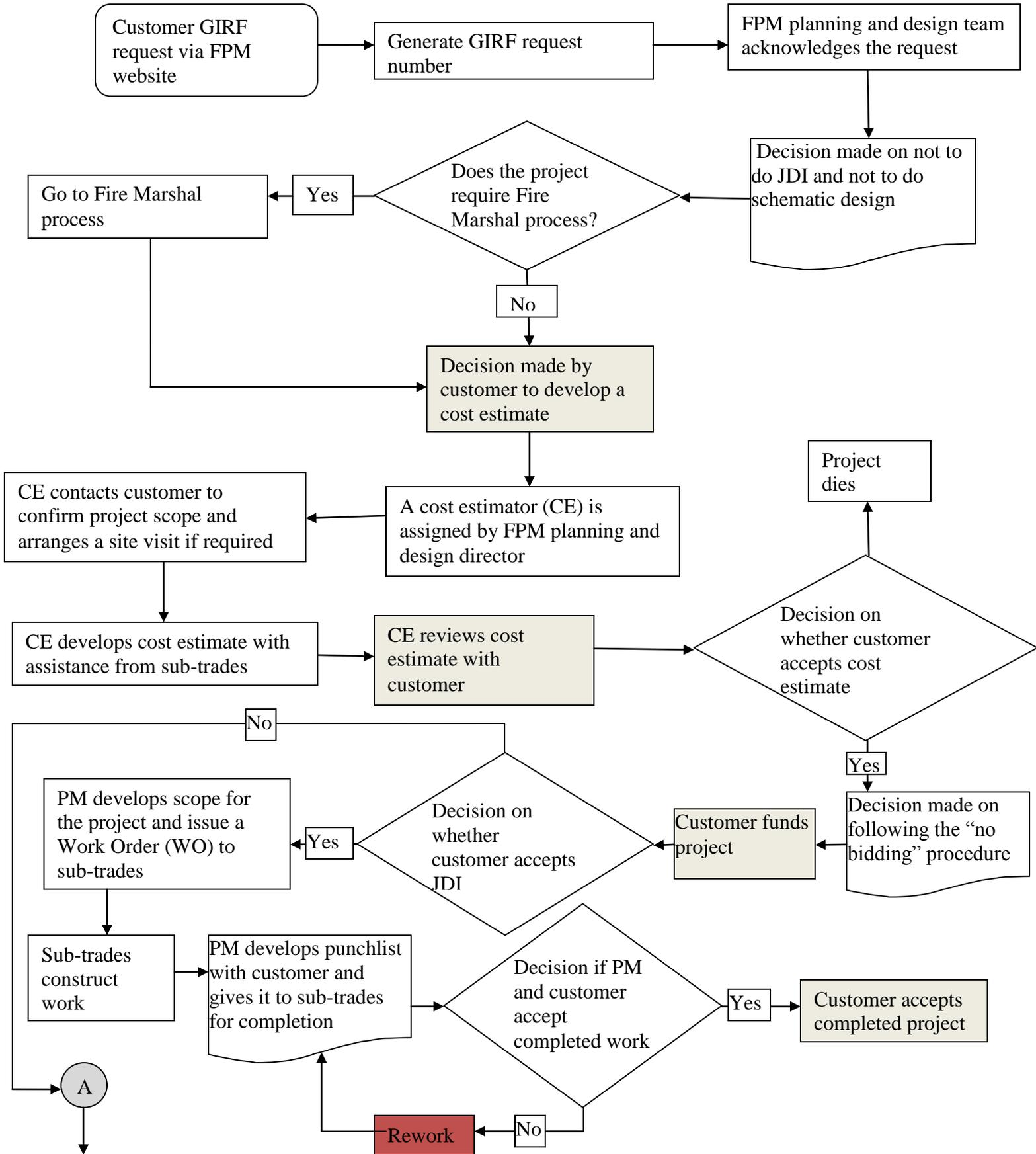
Fig.29. Fig.29 and Table 9 together represent the process map for the JDI sub-process.

Table 9: Input-output-responsibility matrix for JDI sub-process

	Process Step	Input	Responsibility	Output	Responsibility
1	Customer GIRF request via FPM website	GIRF request	Customer	The customer request received	FPM
2	Generate GIRF request number	GIRF request	Customer	GIRF request number	FPM
3	FPM Planning and Design Team acknowledges the request	GIRF request	Customer	Confirm and approve GIRF request	FPM
4	Customer approves JDI process for GIRF project	Discussion on how to conduct the project	Customer and FPM	Proceed to JDI procedure	Customer and FPM
5	Request order is converted to Work Order (WO) and a Project Manager (PM) is assigned to execute the JDI process	GIRF request order to do the project through JDI procedure	Customer	WO created and a PM is assigned to the project	FPM
6	PM contacts customer to confirm project scope and arrange site visit if required	WO request	PM	Project scope confirmed and a decision of site visit is made	PM
7	PM develops scope for sub-trades and issues WO to them	WO request (after possible site visit based changes)	PM	WO was issued to sub-trades	PM
8	Sub-trades construct work	WO was issued to sub-trades	PM	Project constructed	Sub-trades
9	PM develops punchlist with customer and submits it to sub-trades for completion	Constructed project	Sub-trades	A punchlist created and submitted to sub-trades	PM and customer
10	Sub-trades complete punchlist	Created punchlist	PM and customer	Punchlist sub-factors completed	Sub-trades
11	Do PM and customer accept completed work?	Punchlist sub-factors completed	Sub-trades	Accept work or rework	PM and customer
12	If yes, customer occupies completed facility	Work accepted	PM and customer	Project completed	Customer
13	If no, rework and go back to step 9	Work not accepted	PM and customer	Rework	Sub-trades

Because the JDI sub-process is used typically for simple low-cost projects, the tasks and activities associated with this sub-process are less complicated and considered straight forward tasks in most cases. A project manager is assigned to execute the JDI project. He contacts sub-trades with work order to construct work; after the work is performed then he develops a punchlist with customer and submits it to sub-trades for corrective action and completion. PM and customer either accept the completed work, or return it back to sub-trades for rework with the expectation that the deficiencies are corrected. Three activities are considered as control non-value adding activities (customer approves JDI process for GIRF project, request order is converted to work order (WO) and a project Manager (PM) is assigned to execute the JDI process, PM contacts customer to confirm project scope and arrange site visit if required) , while one activity considered as a non-value delaying activity (rework). Precautions should be taken to eliminate or reduce these previously mentioned activities to a minimum. Time, costs, and resources can be saved by reducing or eliminating the mentioned activities. Well trained, skilled, and knowledgeable sub-trades will greatly impact improvements, with good management commitment and support. The input-output – responsibility matrix table for each GIRF sub-process was created to support the flowchart to form a complete process map for sub-processes. The process map plays a big role in tracking and resolving potential problems and pursues improvement opportunities for the sub-processes.

2. Cost estimate, no design and no bidding (CEP) GIRF sub-process flowchart



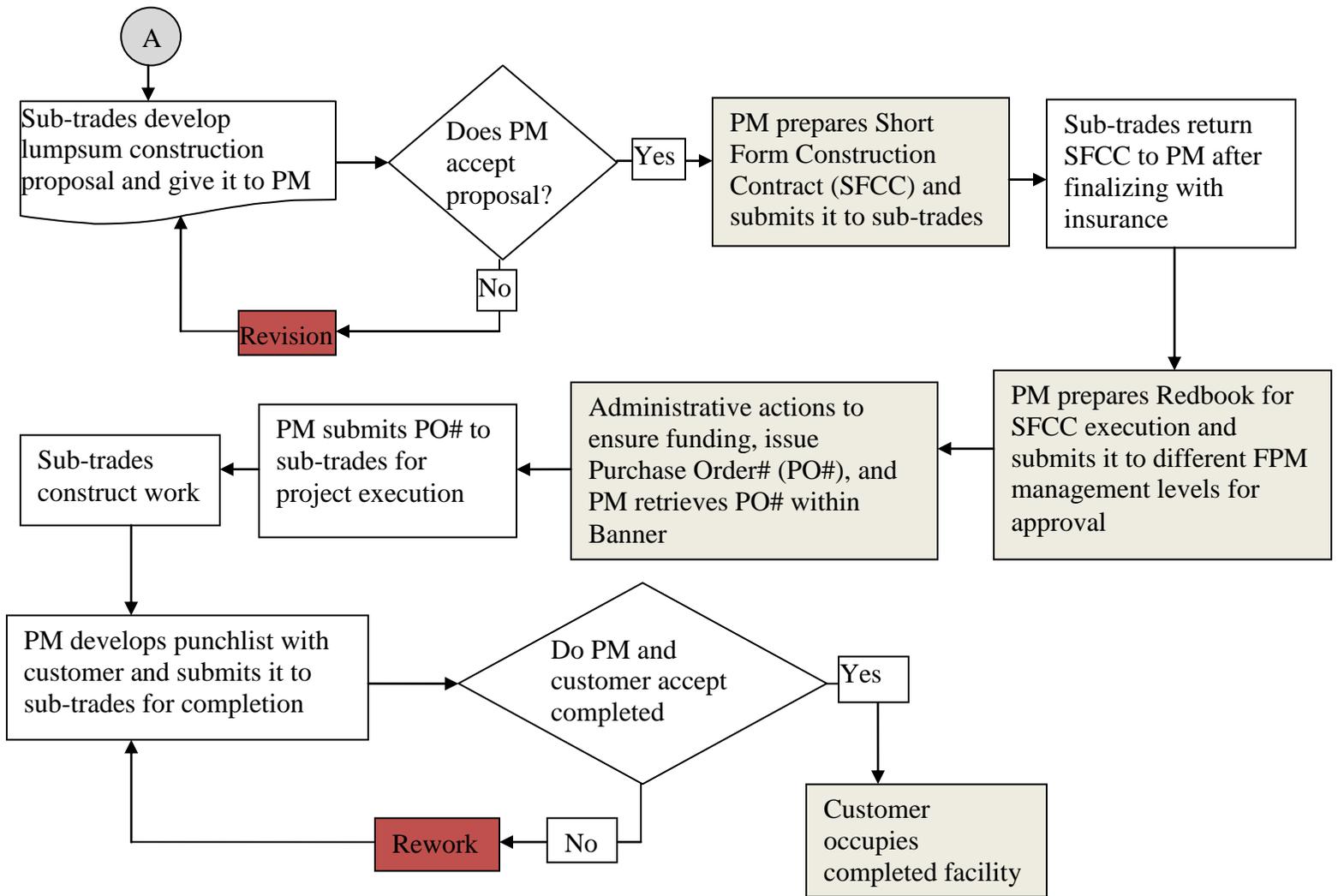


Figure 30: Cost estimate, no design and no bidding (CEP) sub-process flowchart

Fig. 30 and Table 10 represent the process map for CEP sub-process. CEP is a little more complicated process than JDI because of the addition of cost estimation process before getting customer agreement on whether to go forward in executing processing the project or stopping it.

Table 10: Input-output-responsibility matrix for a CEP sub-process

	Process Step	Input	Responsibility	Output	Responsibility
1	Customer GIRF request via FPM website	GIRF request	Customer	The customer request received by FPM	FPM
2	Generate GIRF request number	GIRF request	Customer	GIRF request number	FPM
3	FPM Planning and Design Team acknowledges the request	GIRF request	Customer	Confirm and approve GIRF request	FPM
4	Decision made on not to do JDI and not to do schematic design	Discussion on how to conduct the project	Customer and FPM	A decision of conducting the project with cost estimate, without schematic design, and no bidding	Customer and FPM
5	Does the project require Fire Marshal process?	If project includes classroom and/or dorm	FPM	Decision to go to Fire Marshal or not	FPM
6	If yes, go to Fire Marshal process	The project includes classroom and/or dorm	FPM	Fire Marshal procedure is followed	FPM
7	Decision made by customer to develop a cost estimate	Decision to develop cost estimate	Customer	Start cost estimate process	FPM
8	A cost estimator (CE) is assigned by FPM Planning and Design	GIRF request	Customer	CE is assigned to the project	FPM
9	CE contacts customer to confirm project scope and arranges a site visit if required	GIRF request	Customer	Project scope is confirmed	CE and customer
10	CE develops cost estimate with assistance of sub-trades	Confirmed project scope	CE and customer	Cost estimate for the project is developed	CE
11	CE reviews cost estimate with customer	Developed cost estimate	CE	A revision on the cost estimate if needed	CE and customer

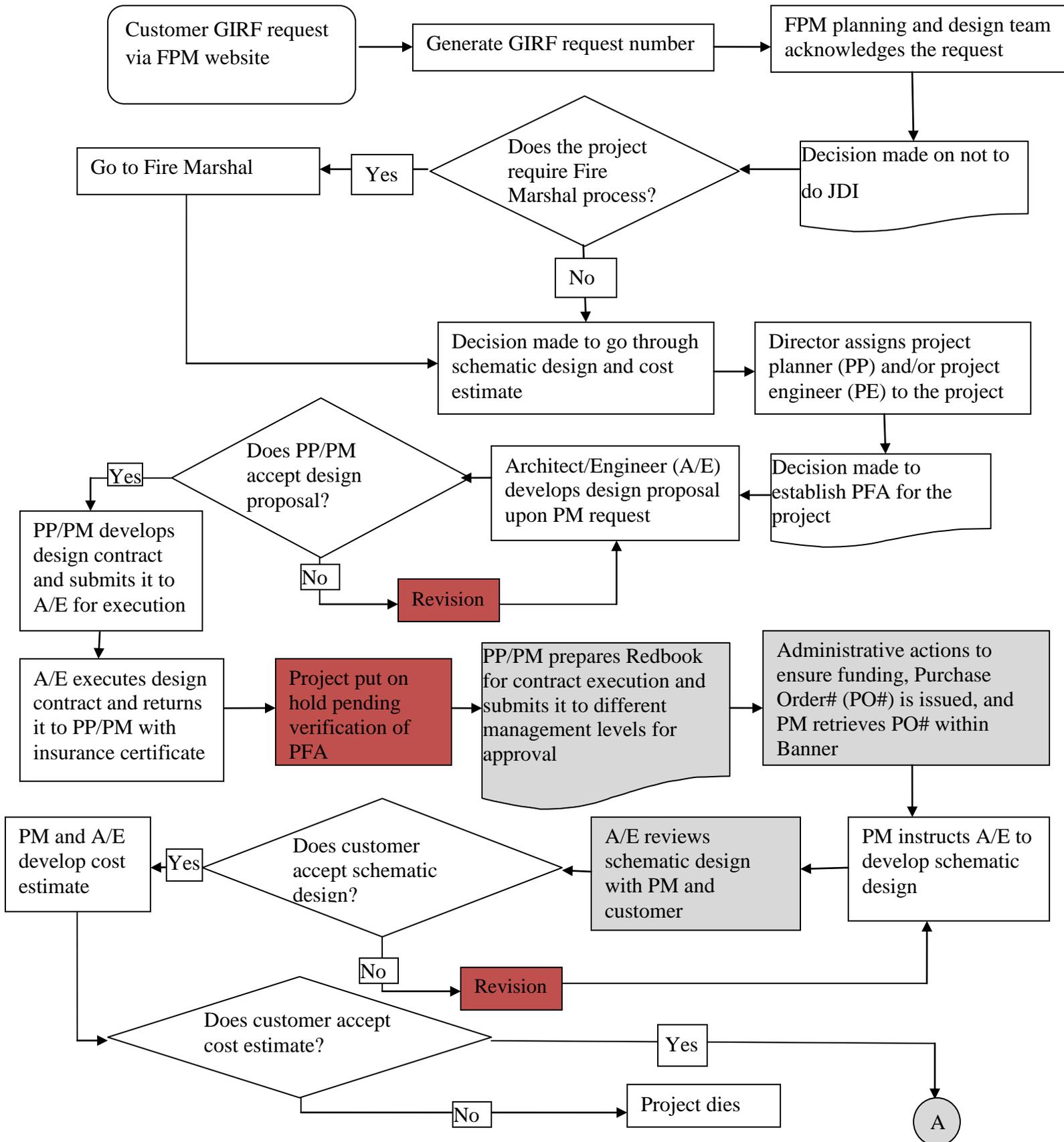
12	Decision on whether customer accepts cost estimate	Developed/revise cost estimate	CE and customer	Decision to accept or refuse	Customer
13	If no, project dies	Developed/revise cost estimate	CE and customer	Project discontinued (or put on hold pending new funding)	FPM and customer
14	If yes, decision made on following the “no bidding” procedure	Developed cost estimate	CE	Implement “no bidding procedure”	FPM and customer
15	Customer funds project; based on decision on how to fund the project (PFA vs. IRB or direct billing)	Developed cost estimate	CE	Decision to fund the project by either PFA, IRB, or direct billing	Customer
16	Decision on whether customer accepts JDI	Developed cost estimate and decision on how to fund the project	CE and customer	Start the process	FPM
17	If yes for step 16, PM develops scope for the project and issue a Work Order (WO) to sub-trades	Go to sub-process JDI steps 6-13			
18	If no for step 16, Sub-trades develop lumpsum construction proposal and give it to PM for evaluation	A cost estimate, and other project documents	CE and FPM	Lump sum construction proposal is developed and submitted to PM	Sub-trades
19	Does PM accept proposal?	Lump sum construction proposal	Sub-trades	Decision to accept or refuse	PM
20	If yes, PM prepares Short Form Construction Contract (SFCC) and submits it to sub-trades for execution	Accepted lump sum construction proposal	PM	SFCC is prepared and submitted to sub-trades	PM
21	If no, revision of proposal	Lump sum construction proposal	Sub-trades	Revised proposal	Sub-trades

22	Sub-trades return SFCC to PM after finalizing proposal with insurance certificate	SFCC submitted to sub-trades	PM	Completed SFCC	Sub-trades
23	PM prepares Redbook for SFCC execution and submits it for approval by different FPM management levels	Completed SFCC	Sub-trades	SFCC approvals by different management levels	Different FPM management levels
24	Administrative actions to ensure funding existence; issue Purchase Order# (PO#); and PM retrieves PO# within Banner	Approved SFCC	Different FPM management levels	Administrative actions completed and PO# is issued	Clerks and purchasing department
25	PM submits PO# to sub-trades for project execution	PO# issued within Banner	Purchasing department	PO# submitted to sub-trades	PM
26	Sub-trades construct work	PO#	PM	Work constructed	Sub-trades
27	PM develops punchlist with customer and submits it to sub-trades for completion	Constructed work	Sub-trades	Punchlist is submitted to sub-trades	PM and customer
28	Do PM and customer accept completed work?	Completed punchlist	Sub-trades	Decision to accept or not	PM and customer
29	If no, rework and go to step 27	Completed punchlist	Sub-trades	Rework	Sub-trades
30	If yes, Customer occupies completed facility	Completed punchlist	Sub-trades	Project completed	

Eight of the sub-process activities (decision made by customer to develop a cost estimate, Cost Estimator (CE) reviews cost estimate with customer, customer funds project, customer accepts completed project, PM prepares Short Form Construction Contract (SFCC) and submits it to sub-trades, PM prepares Redbook for SFCC execution and submits it to different FPM management

levels for approval, administrative actions to ensure funding, issue purchase order# (PO#), and PM retrieves PO# within Banner, and customer occupies completed facility) were classified as non-value adding control activities where as three other activities were considered as non-value adding delay activities (rework and revision activities). These activities need to be minimized in time duration or eliminated in order to reduce cost and duration of the project. After cost estimation, the customer can accept the JDI method of constructing the project, or can go with the other alternative which involves a lumpsum contract with sub-trades, and use of a Short Form Construction Contract (SFCC). If customer decides to go with the JDI method after the cost estimation process, then all activities of cost estimation will be considered non-value added delay activities, and will directly contribute to increasing both project duration and cost. Also, it was revealed that decision points are bottleneck spots contributing to increasing project duration. Some decisions take long time especially for situations relating to funding and accepting design proposals with the SFCC. Because of that, most non-value adding activities are either funding related, or dependent on preparing and reviewing of designs and contracting activities, and subsequent approvals. Administrative actions are reported to also be a part of causes of project delays. Management should control and improve administrative procedures to make the paperwork flow easier. Funding procedures vary according to the nature of the project and the way the customer likes to fund the project. Plant Fund Account (PFA) process differs from IRB and Direct Bill. Each has its own procedure and complications. These complications are responsible for some delay in project duration. The SFCC approval process entails a long series of approvals. Even though of these approvals are important, they extensively contribute to project delay. Each activity improvement could be the basis of a whole Six-Sigma project, and management should apply all Six-Sigma techniques to prioritize the most critical activities needing improvement to plan their improvement strategies accordingly.

3. Cost estimate; schematic design, and no bidding (CEPD) GIRF sub-process flowchart



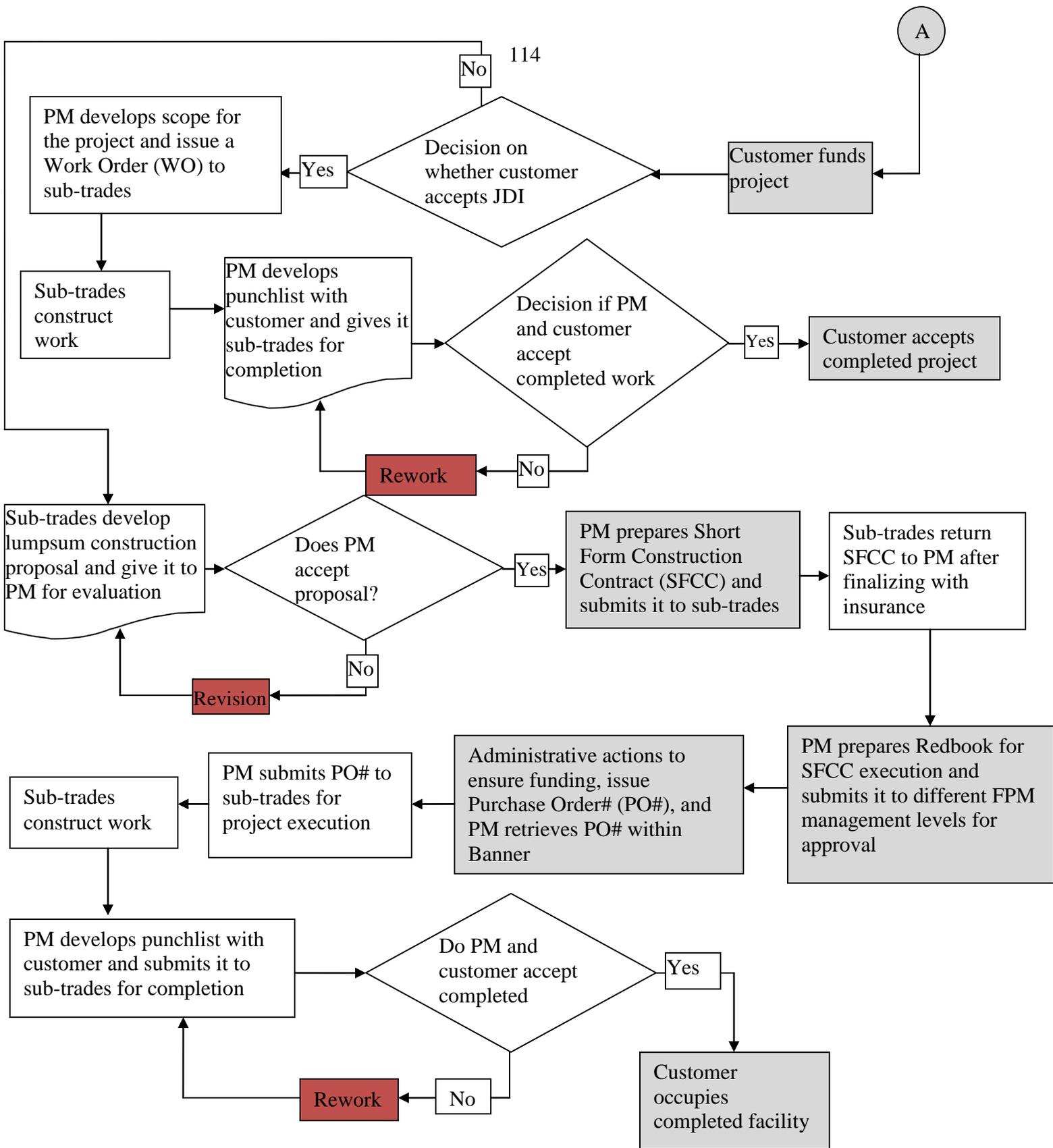


Figure 31: Cost estimate; schematic design, and no bidding (CEPD) sub-process flow chart

Table 11: Input-output-responsibility matrix for CEPD sub-process

	Process Step	Input	Responsibility	Output	Responsibility
1	Customer GIRF request via FPM website	GIRF request	Customer	The customer request received by FPM	FPM
2	Generate GIRF request number	GIRF request	Customer	GIRF request number	FPM
3	FPM Planning and Design team acknowledges the request	GIRF request	Customer	Confirm and approve GIRF request	FPM
4	Does the project require Fire Marshal process?	If project includes classroom and/or dorm	FPM	Decision to go to Fire Marshal or not	FPM
5	If yes, go to Fire Marshal process	The project includes classroom and/or dorm	FPM	Fire Marshal procedure is followed	FPM
6	Decision made to go to schematic design and cost estimate	Decision made to develop schematic design and cost estimate	FPM and customer	Start schematic design and cost estimate process	FPM
7	Director assigns project planner (PP) and/or project engineer (PE) to the project	Decision to start schematic design and cost estimate	FPM	PP and/or PM is assigned to the project	FPM
8	Decision made to establish PFA for the project	Customer contacted on how the project will be funded	FPM and customer	Decision to fund the project by PFA	FPM and customer
9	Architect/Engineer (A/E) develops design proposal upon PM request	PM request for design proposal	PM	Developed design proposal	A/E
10	Does PP/PM accept design proposal?	Developed design proposal	A/E	Decision to accept or not	PP/PM
11	If no, rework and go to step 9	Design not accepted	PP/PM	Redevelop design proposal	A/E

12	If yes, PP/PM develops design contract and submits it to A/E for execution	Accepted design proposal	PP/PM	Design contract developed and submitted to A/E	PP/PM
13	A/E executes design contract and returns it to PP/PM with insurance certificate	Developed design contract	PP/PM	Executed design contract with insurance certificate	A/E
14	Decision to start project or not based on verification of funding	Verification of funding	Customer and FPM	Funding verified or not verified	Customer and FPM
15	If yes go to step 17	Funding verified	Customer and FPM	Go to step 17	FPM
16	If no, project stays on hold or die	Funding not verified	Customer and FPM	Project stays on hold or die	Customer
17	PP/PM prepares Redbook for contract execution and submits it for approval by different management levels	Executed design contract with insurance certificate	A/E	Redbook for contract execution approved by different management levels	Different FPM management levels
18	Administrative actions to ensure funding existence, Purchase Order# (PO#) is issued, and PM retrieves PO# within Banner	Approved design contract	Different FPM management level	Administrative actions completed and PO# is issued	Staff and Purchasing Department
19	PM instructs A/E to develop schematic design	Issued PO# within Banner	Purchasing Department	Developed schematic design	A/E
20	A/E reviews schematic design with PM and customer	Developed schematic design	A/E	Reviewed schematic design	PM and customer
21	Does customer accept schematic design?	Reviewed schematic design	PM and customer	Decision to accept or not	PM and customer
22	If no, Rework and go to step 19	Not accepted schematic design	PM and customer	Redevelop schematic	A/E

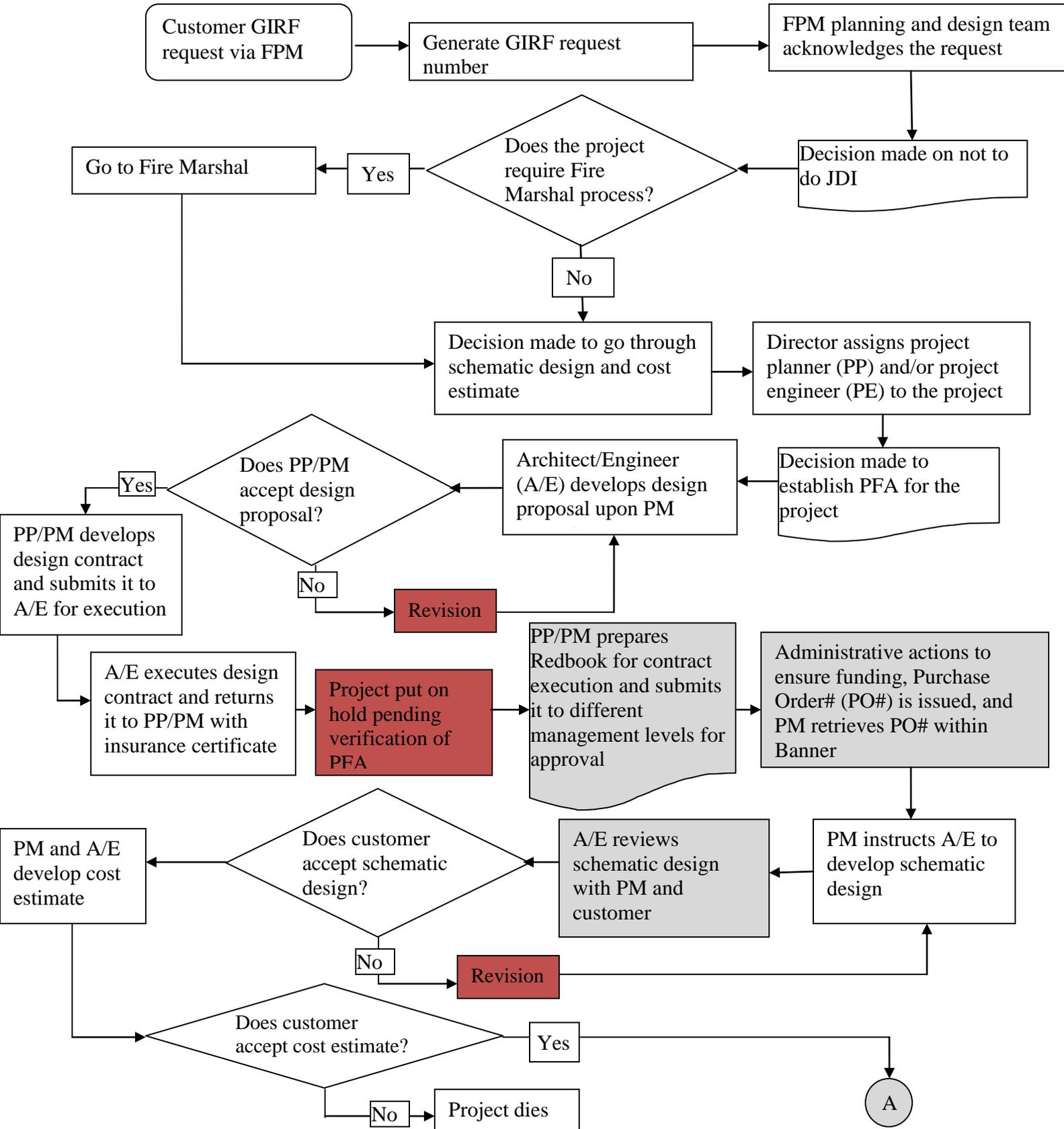
				design	
23	If yes, PM and A/E develop cost estimate	Accepted schematic design	PM and customer	Developed cost estimate	PM and A/E
24	Does customer accept cost estimate?	Developed cost estimate	PM and A/E	Decision to accept or not	Customer
25	If no, project dies	Developed/revised cost estimate	PM and A/E	Project discontinued (or put on hold)	Customer and FPM
26	Customer funds project; based on decision on how to fund the project (PFA vs. IRB or direct billing)	Developed cost estimate	PM and A/E	Decision to fund the project by either PFA, IRB, or direct billing	Customer
27	Decision on whether customer accepts JDI	Developed cost estimate and decision on how to fund the project	PM and customer	Start the process	FPM
28	If yes for step 27, PM develops scope for the project and issue a Work Order (WO) to sub-trades	Go to sub-process JDI steps 6-13			
29	If no for step 27, Sub-trades develop lump sum construction proposal and give it to PM for evaluation	A cost estimate, and other project documents	PM and A/E	Lump sum construction proposal is developed and submitted to PM	Sub-trades
30	Does PM accept proposal?	Lump sum construction proposal	Sub-trades	Decision to accept or refuse	PM
31	If yes, PM prepares Short Form Construction Contract (SFCC) and submits it to sub-trades for execution	Accepted lump sum construction proposal	PM	SFCC is prepared and submitted to sub-trades	PM
32	If no, revision of proposal	Lump sum construction	Sub-trades	Revised proposal	Sub-trades

		proposal			
33	Sub-trades return SFCC to PM after finalizing proposal with insurance certificate	SFCC submitted to sub-trades	PM	Completed SFCC	Sub-trades
34	PM prepares Redbook for SFCC execution and submits it for approval by different FPM management levels	Completed SFCC	Sub-trades	SFCC approvals by different management levels	Different FPM management levels
35	Administrative actions to ensure funding existence; issue Purchase Order# (PO#); and PM retrieves PO# within Banner	Approved SFCC	Different FPM management levels	Administrative actions completed and PO# is issued	Clerks and purchasing department
36	PM submits PO# to sub-trades for project execution	PO# issued within Banner	Purchasing department	PO# submitted to sub-trades	PM
37	Sub-trades construct work	PO#	PM	Work constructed	Sub-trades
38	PM develops punchlist with customer and submits it to sub-trades for completion	Constructed work	Sub-trades	Punchlist is submitted to sub-trades	PM and customer
39	Do PM and customer accept completed work?	Completed punchlist	Sub-trades	Decision to accept or not	PM and customer
40	If No, Rework and go to step 37	Completed punchlist	Sub-trades	Rework	Sub-trades
41	If yes, Customer occupies completed facility	Completed punchlist	Sub-trades	Project completed	

Fig.31 and Table 11 together represent the process map for CEPD sub-process. The main difference between CEP and CEPD sub-processes is the design process introduced in the latter one. Many extra activities are introduced in this sub-process including assigning project planner

and/or project manager, the presence of architect/engineers to develop design proposals and preparing design contract for approval. The design contract approval process is a long design approval process starting with project planner who prepares the design contract execution folder and submits it to the FPM Vice President (VP) who finally approves it after a series of intermediate approvals. Probability of design contract rework is high since each approval step could result in a rework. That's why the contract execution approval is considered a bottleneck spot causing the creation of non-value added activities and hence leading to extension in project duration. A cycle of administrative processes also exist for checking purchase request with available budget balance. Initial budget verification is conducted before the design process starts. A long administrative process results in issuing a purchase order which is retrieved by the project manager through Banner. Customer needs to agree on both the design proposal and project cost estimate before starting to execute the project. If the customer does not accept either the design proposal and/or the cost estimate, the project will die or put on hold. After customer acceptance, the same procedures for CEP will be repeated and there is a possibility for the customer to return to the JDI procedure. In this case, all previous steps and activities are considered non-value added activities. This is a good reason for reviewing the sequence of the sub-process and reducing the possibility to adopt JDI as a process for constructing the project at this advanced step of CEPD process. All non-value added activities are identified on the flowchart (Fig.31). These are administrative, funding, approval, and rework activities which are believed to contribute to increasing both duration and cost of the project.

4. Cost estimate, schematic design, and bidding (CEPDB) GIRF sub-process flowchart



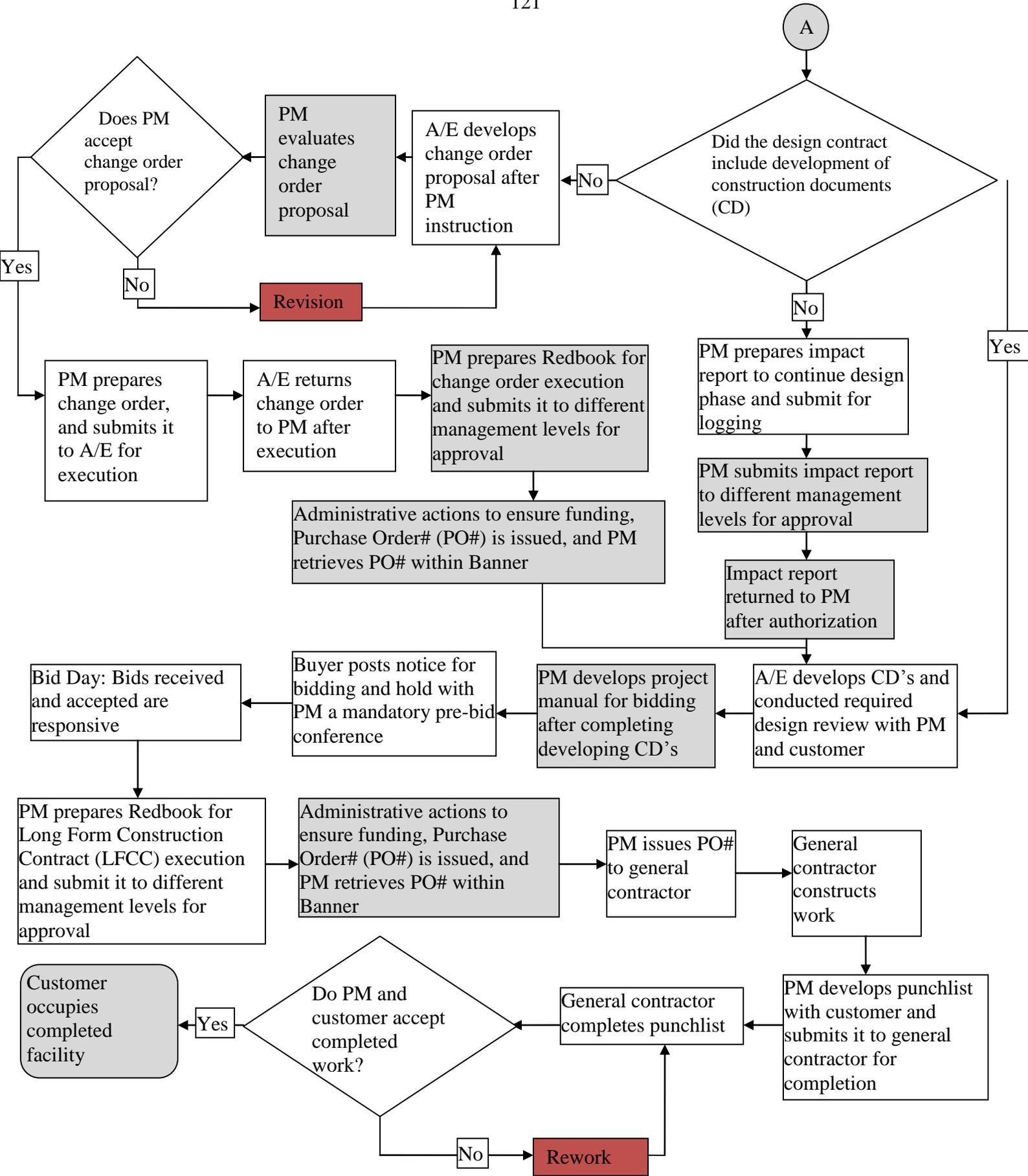


Fig. 32: Cost estimate, schematic design, and bidding (CEPDB) sub-process flowchart

Table 12: Input-output-responsibility matrix for CEPDB sub-process

	Process Step	Input	Responsibility	Output	Responsibility
1	Customer GIRF request via FPM website	GIRF request	Customer	The customer request received by FPM	FPM
2	Generate GIRF request number	GIRF request	Customer	GIRF request number	FPM
3	FPM planning and design team acknowledges the request	GIRF request	Customer	Confirm and approve GIRF request	FPM
4	Does the project require Fire Marshal process?	If project includes classroom and/or dorm	FPM	Decision to go to Fire Marshal or not	FPM
5	If yes, go to Fire Marshal process	The project includes classroom and/or dorm	FPM	Fire Marshal procedure is followed	FPM
6	Decision made to go to schematic design and cost estimate	Decision made to develop schematic design and cost estimate	FPM and customer	Start schematic design and cost estimate process	FPM
7	Director assigns project planner (PP) and/or project engineer (PE) to the project	Decision to start schematic design and cost estimate	FPM	PP and/or PM is assigned to the project	FPM
8	Decision made to establish PFA for the project	Customer contacted on how the project will be funded	FPM and customer	Decision to fund the project by PFA	FPM and customer
9	Architect/Engineer (A/E) develops design proposal upon PM request	PM request for design proposal	PM	Developed design proposal	A/E
10	Does PP/PM accept design proposal?	Developed design proposal	A/E	Decision to accept or not	PP/PM
11	If no, rework and go to step 9	Design not accepted	PP/PM	Redevelop design	A/E

				proposal	
12	If yes, PP/PM develops design contract and submits it to A/E for execution	Accepted design proposal	PP/PM	Design contract developed and submitted to A/E	PP/PM
13	A/E executes design contract and returns it to PP/PM with insurance certificate	Developed design contract	PP/PM	Executed design contract with insurance certificate	A/E
14	Decision to start project or not based on verification of funding	Verification of funding	Customer and FPM	Funding verified or not verified	Customer and FPM
15	If yes go to step 17	Funding verified	Customer and FPM	Go to step 17	FPM
16	If no, project stays on hold or die	Funding not verified	Customer and FPM	Project stays on hold or die	Customer
17	PP/PM prepares Redbook for contract execution and submits it for approval by different management levels	Executed design contract with insurance certificate	A/E	Redbook for contract execution approved by different management levels	Different FPM management levels
18	Administrative actions to ensure funding existence, Purchase Order# (PO#) is issued, and PM retrieves PO# within Banner	Approved design contract	Different FPM management level	Administrative actions completed and PO# is issued	Staff and Purchasing Department
19	PM instructs A/E to develop schematic design	Issued PO# within Banner	Purchasing Department	Developed schematic design	A/E
20	A/E reviews schematic design with PM and customer	Developed schematic design	A/E	Reviewed schematic design	PM and customer
21	Does customer accept schematic design?	Reviewed schematic design	PM and customer	Decision to accept or not	PM and customer
22	If no, rework and go to step 19	Not accepted schematic design	PM and customer	Redevelop schematic design	A/E

23	If yes, PM and A/E develop cost estimate	Accepted schematic design	PM and customer	Developed cost estimate	PM and A/E
24	Does customer accept cost estimate?	Developed cost estimate	PM and A/E	Accept or not	Customer
25	If no, project dies	Developed/revised cost estimate	PM and A/E	Project discontinued (or put on hold)	Customer and FPM
26	If yes, a decision made to go to "bidding"	Accepted cost estimate	Customer	Decision to conduct the project with the "bidding procedure"	FPM and customer
27	Did the design contract include development of construction documents (CD)?	Design contract	PM	Yes or No	FPM
28	If no, there are two options: option 1: PM prepares impact report to continue design phase and submit for logging	Design contract	PM	Impact report prepared	PM
29	PM submits impact report for approval by different management levels	Prepared impact report	PM	Impact report submitted for approval by different management levels	PM
30	Impact report returned to PM after authorization	Approved impact report	Different FPM management levels	Approved impact report returned to PM	AVP
31	Option 2: A/E develops change order proposal after PM instruction	Design contract	PM	Change order proposal developed	A/E
32	PM evaluates change order proposal	Developed change order proposal	A/E	Evaluated change order proposal	PM
33	Does PM accept	Evaluated change	PM	Accept or not	PM

	change order proposal?	order proposal			
34	If no, Rework and go to step 31	Change order proposal not accepted	PM	Rework	A/E
35	If yes, PM prepares change order, and submits it to A/E for execution	Accepted change order proposal	PM	Change order prepared and submitted to A/E	PM
36	A/E returns change order to PM after execution	Submitted change order to A/E	PM	Change order executed and returned back to PM	A/E
37	PM prepares Redbook for change order execution and submits it for approval by different management levels	Executed change order	A/E	Redbook for change order prepared and submitted to different management levels for approval	PM
38	Administrative actions to activate funding, Purchase Order# (PO#) is issued, and PM retrieves PO# within Banner	Approved Redbook for change order	FPM different management levels	Administrative actions conducted and PO# issued	Clerks and purchasing department
39	If yes for step27, A/E develops CD's and conducted required design review with PM and customer	Issued PO# within Banner	Purchasing department	CD's developed, required design reviewed	A/E, PM, and customer
40	PM develops project manual for bidding after completing CD's	Developed CD's, and reviewed design	A/E, PM, and customer	Project manual for bidding is developed	PM
41	FPM posts notice for bidding and holds a mandatory pre-bid conference with qualified bidders	Developed project manual for bidding	PM	Notice for bidding posted; prebid conference is held	FPM

42	Bid Day: Bids received and accepted if “responsive”	Prebid conference conducted	PM and FPM	Received bids	PM and FPM
43	PM prepares Redbook for Long Form Construction Contract (LFCC) execution and submit it for approval by different management levels	Received bids	PM and FPM	Redbook for LFCC prepared and submitted for approval by different management levels	PM
44	Administrative actions to ensure funding, Purchase Order# (PO#) is issued, and PM retrieves PO# within Banner	Redbook for LFCC prepared and submitted for approval	PM	Administrative actions conducted and PO# issued	Clerks and purchasing department
45	PM issues PO# to general contractor (GC)	Administrative actions conducted and PO# issued	Clerks and purchasing department	PO# issued to GC	PM
46	GC constructs work	PO# issued to GC	PM	Work constructed	GC
47	PM develops punchlist with customer and submits it to GC for completion	Constructed work	GC	Punchlist developed and submitted to GC	PM
48	GC completes punchlist	Submitted punchlist to GC	PM	Punchlist completed	GC
49	Do PM and customer accept completed work?	Completed punchlist	GC	Decision to accept or not	PM and customer
50	If no, rework and go to step 48	Constructed work not accepted	PM and customer	Rework	GC
51	If yes, Customer occupies completed facility	Constructed work accepted	PM and customer	Project completed	

The CEPDB sub- process is considered the most complicated sub-process among all the four GIRF sub-processes. It is usually conducted for projects with large budgets and requires more

sophisticated stuffing. It involves schematic designs and project cost estimate; then the project will put on bid to get all pre-approved sub-contractors to participate. When the cost estimation and schematic designs are conducted for the CEPD sub-process, the difference is the decision to go through bidding process. Once the bidding decision is made, another decision will be if the design contract includes development of construction documents (CD) and contract administration (CA) services. If yes, this will eliminate the process of CD and CA preparation. If no, there are two options: The first is that an impact report to continue the design phase, then get authorization from different intermediate and high management levels. The second is to develop a change order proposal and submit the design change order for approval followed by administrative actions to create a purchase order number (retrieved by PM through Banner), then the architect/engineer is ready to develop the CDs. After this, the project will be ready for the bidding process which leads to assigning a general contractor to do the project. A long form construction contract (LFCC) approval process will be conducted at this stage involving additional administrative procedures for issuing a purchase order to the PM through Banner. PM will issue the purchase order to the general contractor to start constructing project which is executed through multiple CA processes and actions (not included in the process map). Finally, the customer and PM will prepare a punchlist and submit it to the general contractor for completion. The entire process can be long and have potential for bottlenecks, delays, costs escalations, and quality issues. Sixteen activities were addressed as non-value added. Some of them are control activities and others are delay activities. The improvement of each activity could involve a unique Six-Sigma project. These activities are mainly related to getting approvals for each sub-procedure in the process such as contract execution, change order execution, and impact report authorization, and so on. Other activities are related to the long complicated administrative process in different stages of the project. Lack of knowledge, skills, and training for employees can increase the duration of the administrative

paperwork. Rework actions are very common in different steps of the process. Management should verify a solid design and control plans for each project to avoid the repetition of rework actions. This will come through employee motivation, training, and incentives. Funding activities still act as bottleneck sites in both providing the fund by the customer or by administrative checking and processing of funds. Large projects are not very frequent in FM services at universities, but they need good preparation of design, administrative, supervisory, and managerial staff. This will be attained by continuous improvement of employees' skills, training, and motivation.

4.2.2 Cause and Effect Matrix (CE matrix)

Tables 13-16 are the CE matrices for the four GIRF sub-processes. Each matrix was developed following the previously established sequence. To pinpoint the critical few key process input variables KPIVs, that must be addressed to improve the key process output variables KPOVs, the cause and effect matrix for each GIRF sub-process was performed, which was followed by a Pareto chart (Figs. 33-36) prioritizing the highest impact input variables affecting the outputs.

Table 13: Cause and effect matrix for the JDI GIRF sub-process

Rating of importance to customers			Key process output variables (KPOV)				Rank %	Total
			4	5	5	3		
	Process step	Key process input variables (KPIV)	<i>Project duration</i>	<i>Total project cost</i>	<i>Project quality</i>	<i>Project cost estimate reliability</i>		
1	Customer GIRF request via FPM website	Time and effort for customer to request a GIRF process	0	0	0	0		0
2	FPM Planning and Design Team acknowledges the request	Knowledge, skill and time availability of FPM Planning and Designing Team	6 (m)	6 (m)	6 (m)	5 (m)	17%	99
3	The project requires Fire Marshal process	Turnaround time with Fire Marshal procedure	8 (h)	6 (m)	6 (m)	0 (vl)	15.7%	92
4	Request order (RO) is converted to Work Order (WO) and a Project Manager (PM) is assigned to execute the JDI process	Work (time) involved in converting RO to WO.	4 (l)	5 (m)	6 (m)	0 (vl)	12%	71
5	Sub-trades construct work	Sub-trades knowledge, training level, experience and motivation	9 (h)	8 (h)	10 (vh)	0 (vl)	21.5%	126
6	PM develops punchlist with customer and submits it to sub-trades for completion	Accuracy and completeness of punchlist (punchlist reflects all project sub-factors)	6 (m)	6 (m)	8 (h)	0 (vl)	16%	94
7	Do PM and customer accept completed work? Assume no	Rework needed for completion of punchlist sub-factors by sub-trades	7 (h)	7 (h)	8 (h)	0 (vl)	17.6%	103

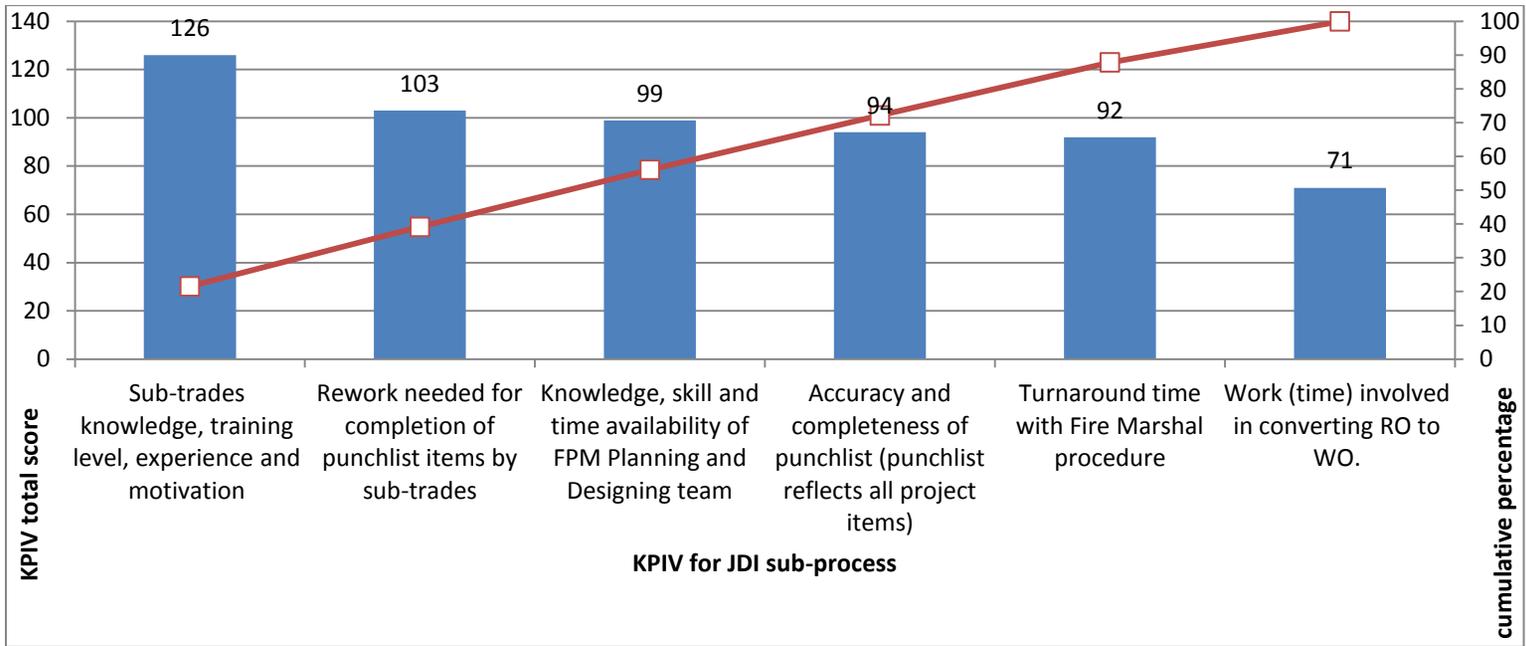


Figure 33: Pareto chart for CE matrix for the JDI GIRF sub-process

Process steps mentioned in the process map (Table 13) are consolidated into seven main steps or activities. For each step, the key process input variable(s) (KPIV) associated with a particular task were developed. Each KPIV was given a numerical weight value according to its importance to the outputs, and each weight value was classified as very low (vl), low (l), medium (m), high (h), very high (vh). KPIVs are linked to variables directly affecting outputs and are a good fit with the developed model. These variables include: time needed for implementing the task; knowledge and skill of the Planning and Design Team; sub-trades knowledge, training level, experience and motivation; cost and time required for rework actions. Total weighting for KPIVs shows that three KPIVs are more impactful on the outputs and are prioritized for possible future improvement of the JDI sub-process. Three tasks contribute to around 60% of the total impact on outputs; they are:

- Sub-trades knowledge, training level, experience and motivation
- Rework needed for completion of punchlist sub-factors by sub-trades
- Knowledge, skill and time availability of FPM Planning and Designing Team

All KPIVs total weights are plotted on a Pareto chart (Fig.33) showing the highest impact KPIVs and the cumulative percentage of the KPIVs.

Table 14: Cause and effect matrix for the cost estimated project, no design, no bidding (CEP) GIRF sub-process

			Key process output variables (KPOV)					
Rating of importance to customers			4	5	5	3		
	Process step	Key process input variables (KPIV)	<i>Project duration</i>	<i>Total project cost</i>	<i>Project quality</i>	<i>Project cost estimate reliability</i>	<i>Rank %</i>	<i>Total</i>
1	Customer GIRF request via FPM website	Time and effort for customer to request a GIRF process	0	0	0	0		0
2	FPM Planning and Design Team acknowledges the request	Knowledge, skill and time availability of FPM Planning and Designing Team	6 (m)	6 (m)	6 (m)	5 (m)	8.2%	99
3	The project requires Fire Marshal process	Turnaround time with Fire Marshal procedure	8 (h)	6 (m)	6 (m)	0 (vl)	7.6%	92
4	CE develops cost estimate with assistance from sub-trades and reviews it with customer	Accuracy of project cost estimate	6 (m)	10 (vh)	6 (m)	10 (vh)	11.1%	134
5	Customer funds project and selects PFA as funding mechanism	The effect of selecting PFA as funding mechanism (complexity)	10 (vh)	8 (h)	6 (m)	7 (h)	10.9%	131
6	Project put on hold pending verification of PFA	Lack of availability of funds until PFA is verified	10 (vh)	8 (h)	5 (m)	0 (vl)	8.7%	105
7	Sub-trades develop lumpsum construction proposal and submit it to PM for evaluation	Time required for proposal submission and approval	8 (h)	9 (h)	9 (h)	8 (h)	12.1%	146
8	PM prepares Short Form Construction Contract (SFCC) and submits it to sub-trades for execution	Timeliness and accuracy of SFCC	6 (m)	7 (h)	9 (h)	0 (vl)	8.6%	104
9	PM prepares Redbook for SFCC execution and submits it	Time for getting FPM management approval for the	10 (vh)	5 (m)	10 (vh)	5 (m)	10.8%	130

	to different FPM management levels for approval	SFCC execution						
10	Administrative actions to ensure funding, issue Purchase Order# (PO#), and PM retrieves PO# within Banner	Timeliness and efficiency of ensuring funding, issuing PO#, and retrieving it from Banner	9 (h)	8 (h)	5 (m)	6 (m)	9.9%	119
11	PM and customer do not accept completed work (punchlist)	Time and costs associated with completing punchlist	10 (vh)	8 (h)	9 (h)	7 (h)	12.1%	146

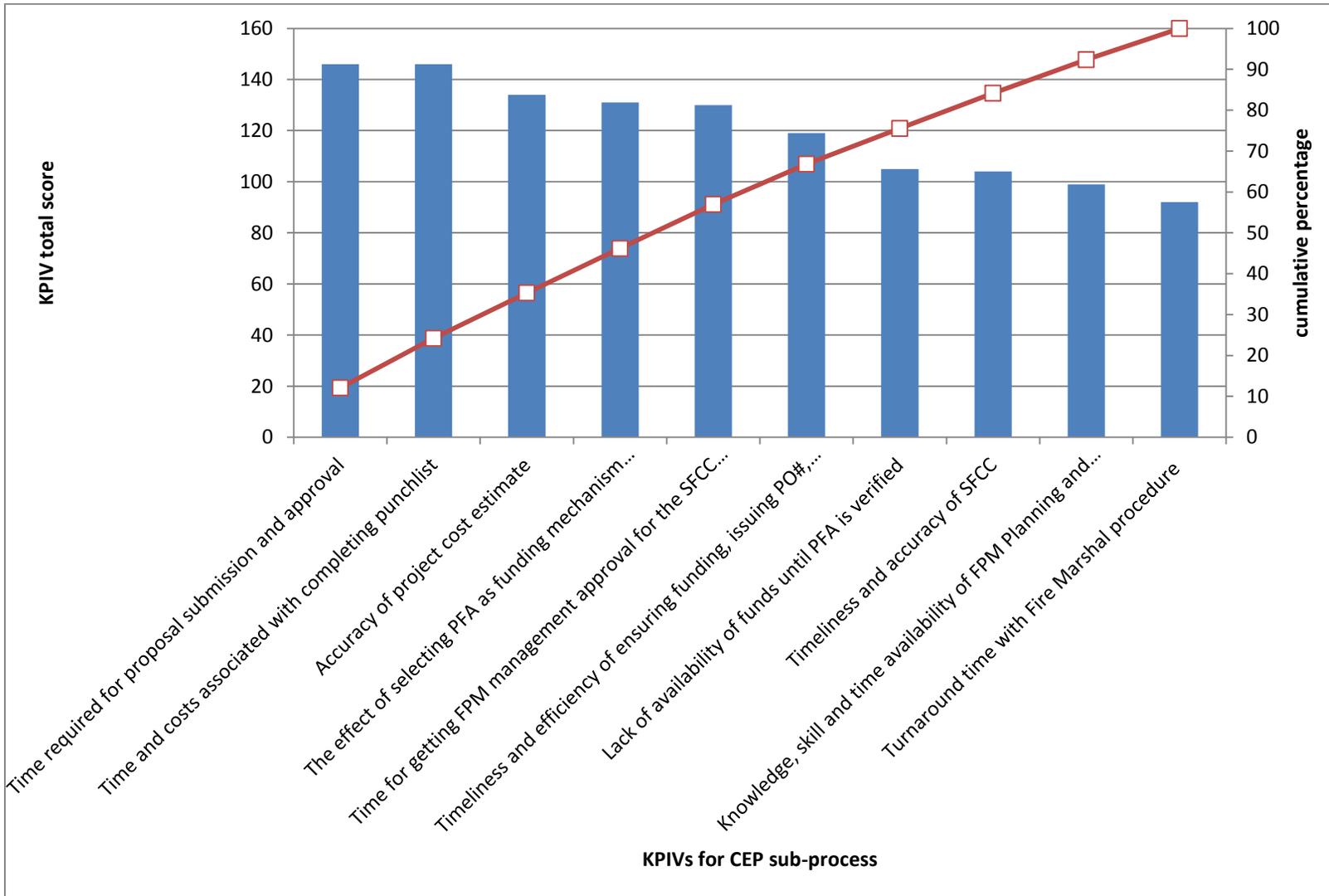


Figure 34: Pareto chart for CE matrix for the cost estimated project, no design, no bidding (CEP) GIRF sub-process

For CEP sub-process, process tasks shown in the process map (Table 14 and Fig.34) were consolidated into eleven tasks. The first three tasks are repetitive in all GIRF sub-processes because they are needed in the beginning of each GIRF project regardless of whether it is JDI, CEP, CEPD, or CEPDB. The first task KPIV is ranked zero all the time in all GIRF sub-processes because it has no effect on the outputs, and it is shown on the table just as an example of KPIVs not affecting the sub-process outputs. After plotting sub-process KPIVs scores on a Pareto chart (Fig. 34), five out of eleven KPIVs were selected for potential further improvements. These KPIVs are presented below in descending order of impact:

- Time required for proposal submission and approval
- Time and costs associated with completing punchlist
- Accuracy of project cost estimate
- The effect of selecting Plant Fund Account (PFA) as funding mechanism (complexity)
- Time for getting FPM management approval for the SFCC execution

These KPIVs are representing around 60% of the total sub-process KPIVs impact on outputs.

Three of the five KPIVs are concerned with time required to finish the task. These tasks are approval tasks and the punchlist preparation task. Two of the tasks are funding verification and cost estimation related tasks. The more accurate the project cost estimate, the more chance for the project to finish on time. This is because increased project cost during the implementation may cause failure of providing funding sources for the extra costs. Also PFA funding mechanism is a complex process needing multiple approval and administrative processes.

Table 15: Cause and effect matrix for the cost estimated, schematic design and no bidding project (CEPD) GIRF sub-process

Rating of importance to customers			Key process output variables (KPIV)				Rank %	Total
			4	5	5	3		
	Process step	Key process input variables (KPIV)	<i>Project duration</i>	<i>Total project cost</i>	<i>Project quality</i>	<i>Project cost estimate reliability</i>		
1	Customer GIRF request via FPM website	Time and effort for customer to request a GIRF process	0	0	0	0		0
2	FPM Planning and Design Team acknowledges the request	Knowledge and skill; time availability of FPM Planning and Designing Team	6 (m)	6 (m)	6 (m)	5 (m)	5.3%	99
3	The project requires Fire Marshal process	Turnaround time with Fire Marshal procedure	8 (h)	6 (m)	6 (m)	0 (vl)	4.9%	92
4	Decision made to establish PFA for the project	The effect of selecting PFA as funding mechanism (complexity)	10 (vh)	8 (h)	6(m)	7 (h)	7%	131
5	A/E develops design proposal upon PM's request	Time spent for and accuracy of developed design proposal	8 (h)	7 (h)	9 (h)	9 (h)	7.5%	139
6	PP/PM accept design proposal? Assume no	Time spent by PP/PM to review and accept design proposal	7 (h)	6 (m)	8 (h)	5 (m)	6%	113
7	Customer funds project and selects PFA as funding mechanism	The effect of selecting PFA as funding mechanism (complexity)	10 (vh)	8 (h)	6 (m)	7 (h)	7%	131
8	Project put on hold pending verification of PFA	Lack of availability of funds until PFA is verified	10 (vh)	8 (h)	5 (m)	0 (vl)	5.6%	105

9	PP/PM prepares Redbook for design contract execution and submits it to different management levels for approval	Time of getting FPM management approval	10 (vh)	9 (h)	8 (h)	7 (h)	7.8%	146
10	Does customer accept schematic design and cost estimate? Assume no	Rework time and cost of redeveloped schematic design and cost estimate	8 (h)	9 (h)	9 (h)	9 (h)	8%	149
11	Sub-trades develop lumpsum construction proposal and submit it to PM for evaluation	Time required for proposal submission and approval.	8 (h)	9 (h)	9 (h)	8 (h)	7.8%	146
12	PM prepares Short Form Construction Contract (SFCC) and submits it to sub-trades for execution	Timeliness and accuracy of SFCC	6 (m)	7 (h)	9 (h)	0 (vl)	5.6%	104
13	PM prepares Redbook for SFCC execution and submits it to different FPM management levels for approval	Time for getting FPM management approval for the SFCC execution	10 (vh)	5 (m)	10 (vh)	5 (m)	7%	130
14	Administrative actions to ensure funding, issue Purchase Order# (PO#), and PM retrieves PO# within Banner	Timeliness and efficiency of ensuring funding, issuing PO#, and retrieving it from Banner	9 (h)	8 (h)	5 (m)	6 (m)	6.4%	119
15	Sub-trades construct work	Sub-trades knowledge, training level, experience and motivation	9 (h)	7 (h)	9 (h)	0 (vl)	6.2%	116
16	PM and customer do not accept completed work (punchlist)	Time and costs associated with completing punchlist	10 (vh)	8 (h)	9 (h)	7 (h)	7.8%	146

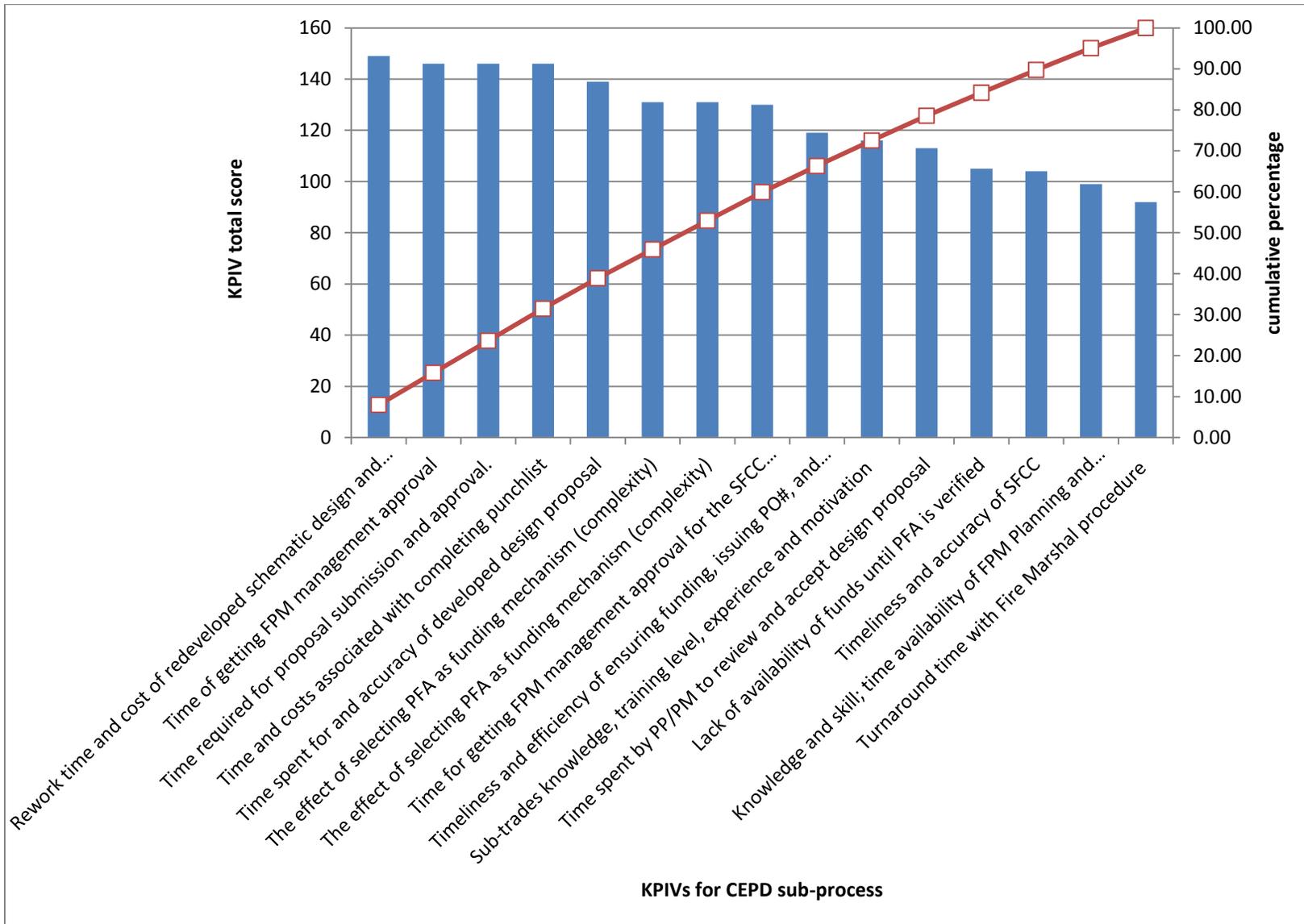


Figure 35: Pareto chart for CE matrix for the cost estimated project, schematic design, no bidding CEPD GIRF sub-process

As GIRF sub-process complexity increases, the number of tasks for each sub-process are increased. The CEPD process map tasks were consolidated in the CE matrix (Table 15) to sixteen. The first three tasks are repetitive in the rest of sub-processes. Pareto chart for PKIVs scores are plotted in (Fig. 35). Five KPIVs of highest total scores were selected for further potential improvement for the sub-process. These KPIVs are shown below in descending order of impact on outputs:

- Rework time and cost of redeveloped schematic design and cost estimate
- Time of getting FPM management approval
- Time required for proposal submission and approval
- Time and costs associated with completing punchlist
- Time spent for and accuracy of developed design proposal

It was thought that schematic design rework is the most contributing in increasing project duration. Also, project cost estimate greatly affects customer satisfaction because of the funding problems and challenges created with imprecise project cost estimation. It was found that this event is more frequent in projects with schematic designs. Time for getting FPM management approval for many tasks is one of the impacting factors on project duration accompanied with time associated with completing the punchlist. In order to conduct improvements, FPM management should create Six-Sigma teams for each of the tasks mentioned. The goals should be to:

- Reduce rework process in design/redesign.
- Review and control the cost estimating process.
- Review the process for getting approval for key tasks in order to reduce approval time.
- Reduce time and cost for completing the punchlist by exerting more control on related actions.

Table 16: Cause and effect matrix for the cost estimated, schematic design, with bidding project (CEPDB) GIRF sub-process

			Key process output variables (KPOV)					
Rating of importance to customers			4	5	5	3		
	Process step	Key process input variables (KPIV)	<i>Project duration</i>	<i>Total project cost</i>	<i>Project quality</i>	<i>Project cost estimate reliability</i>	<i>Rank %</i>	<i>Total</i>
1	Customer GIRF request via FPM website	Time and effort for customer to request a GIRF process	0	0	0	0		0
2	FPM Planning and Design Team acknowledges the request	Knowledge, skill and time availability of FPM Planning and Designing Team	6 (m)	6 (m)	6 (m)	5 (m)	4.7%	99
3	The project requires Fire Marshal process	Turnaround time with Fire Marshal procedure	8 (h)	6 (m)	6 (m)	0 (vl)	4.4%	92
4	Decision made to establish PFA for the project	The effect of selecting PFA as funding mechanism (complexity)	10 (vh)	8 (h)	6 (m)	7 (h)	6.2%	131
5	A/E develops design proposal upon PM's request	Time spent for and accuracy (precision) for developed design proposal	8 (h)	7 (h)	9 (h)	9 (h)	6.6%	139
6	PP/PM accept design proposal? Assume no	Time spent by PP/PM to review and accept design proposal	7 (h)	6 (m)	8 (h)	5 (m)	5.4%	113
7	Customer funds project and selects PFA as funding mechanism	The effect of selecting PFA as funding mechanism (complexity)	10 (vh)	8 (h)	6 (m)	7 (h)	6.2%	131
8	Project put on hold pending verification of PFA	Lack of availability of funds until PFA is verified	10 (vh)	8 (h)	5 (h)	0 (vl)	5%	105
9	PP/PM prepares Redbook for design contract execution and submits it for approval by different management levels	Time of getting FPM management approval	10 (vh)	9 (h)	8 (h)	7 (h)	6.9%	146

10	Does customer accept schematic design and cost estimate? Assume no	Rework time and cost of redeveloped schematic design and cost estimate	8 (h)	9 (h)	9 (h)	9 (h)	7.1%	149
11	Did the design contract include development of construction documents (CD) and (CA) services? Assume no, and consider options 1 and 2 Option 1: PM prepares impact report to continues with design phase; and submits it for logging. Option 2: A/E develops change order proposal at PM's direction	Time and costs needed to prepare and approve impact report. Time and costs needed to prepare and accept a change order proposal	8 (h)	8 (h)	7 (h)	6 (m)	5.9%	125
12	PM prepares Redbook for change order execution and submits it for approval by different management levels	Time of getting FPM management approval for the Redbook for change order execution	7 (h)	8 (h)	7 (h)	6 (m)	5.8%	121
13	Assume yes for step11, A/E develops CD's and conducts required design review with PM and customer	Time of developing and completing CD's after design review	8 (h)	5 (m)	8 (h)	5 (m)	5.3%	112
14	PM develops project manual for bidding after completing CD's	Time spent by PM to develop project manual for bidding	6 (m)	7 (h)	6 (m)	5 (m)	4.9%	104
15	PM prepares Redbook for Long Form Construction Contract (LFCC) execution and submits it to different management levels for approval	Time for getting FPM management approval for preparing LFCC	9 (h)	8 (h)	8 (h)	5 (m)	6.2%	131

16	PM issues PO# to General Contractor (GC) and GC constructs work	Knowledge, training level, experience, efficiency, and reliability of general contractor to construct work	9 (h)	8 (h)	9 (h)	5 (m)	6.5%	136
17	PM develops punchlist with customer and submits it to GC for completion; and GC completes punchlist	Accuracy and completeness of punchlist	9 (h)	6 (m)	9 (h)	5 (m)	6%	126
18	Is completed work accepted by FPM and customer? Assume no	Time and costs associated with completing punchlist	10 (vh)	8 (h)	9 (h)	7 (h)	6.9%	146
19	If yes, customer occupies facility		0	0	0	0		0

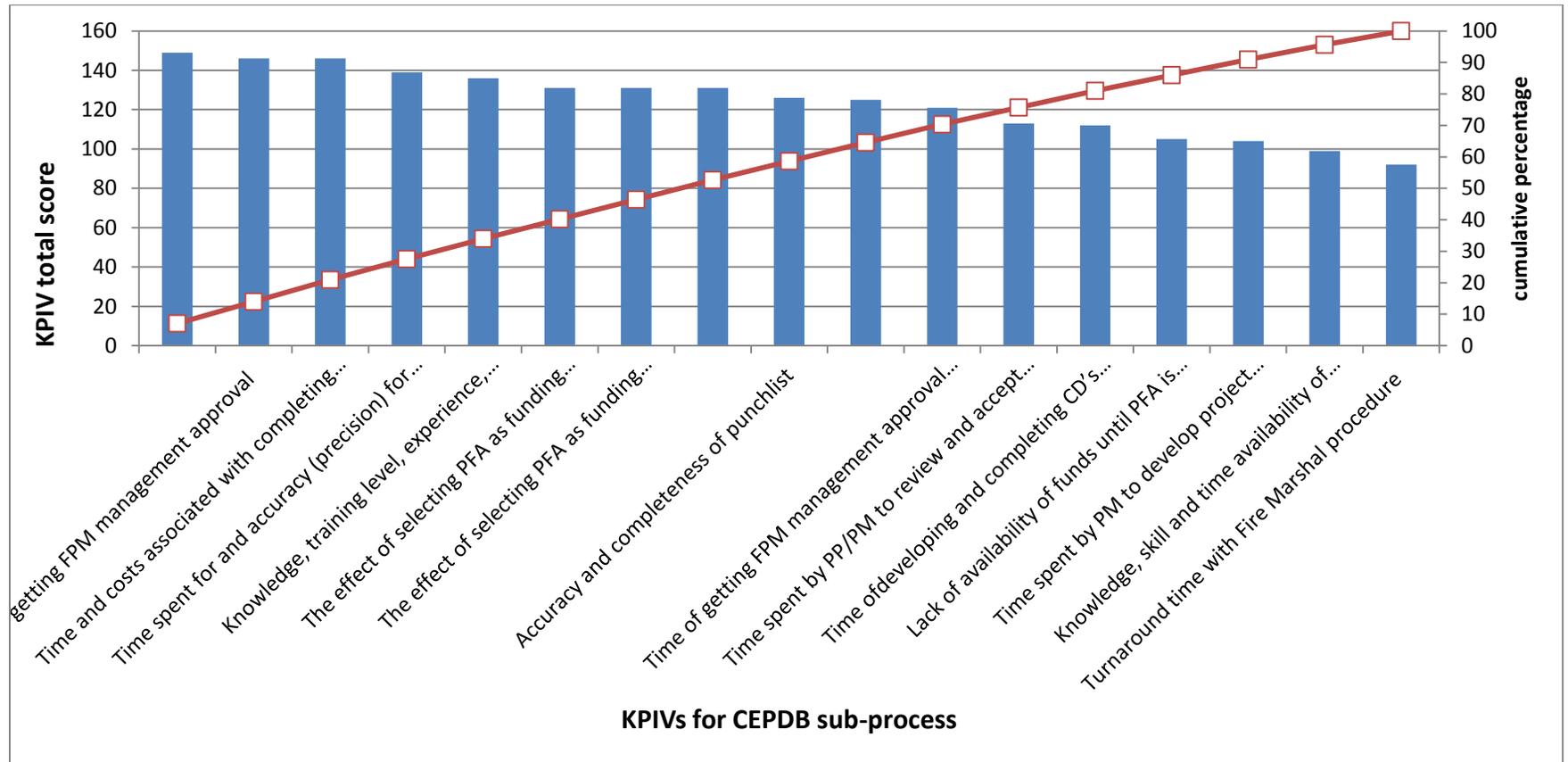


Figure 36: Pareto chart for CE matrix for the cost estimated project, schematic design, and bidding CEPDB GIRF sub-process

CEPDB is considered to be the most complicated GIRF sub-process. It is usually linked to projects with higher cost and longer time durations. Sub-process tasks were consolidated to nineteen as it shown on Table 16. All KPIVs associated to tasks were ranked according to their strength of impacting on outputs, and their total scores are plotted on a Pareto chart (Fig. 36) to prioritize the impact of the input variables for each task in the process on the outputs. According to the Pareto chart findings, five KPIVs were selected for further improvement. These KPIVs are shown below in a descending order of impact

- Rework time and cost of redeveloped schematic design and cost estimate
- Time of getting FPM management approval
- Time and costs associated with completing punchlist
- Time spent for and accuracy (precision) for developed design proposal
- Knowledge, training level, experience, efficiency, and reliability of general contractor to construct work.

It was noted that most of these KPIVs found in CEPDB sub-process were mentioned as the most impactful KPIVs in the CEPD sub-process indicating that both sub-processes are subjected mainly to same sources of problems, and need to be improved in the same way. One KPIV for the CEPDB sub-process in particular is the qualification of the general contractors in terms of knowledge, training level, experience, efficiency, and reliability. It was revealed that lack of qualification of a general contractor has great affect on project costs, duration, and quality of the work performed. Based on our interviews, many disputes and conflicts between customer and FPM regarding GIRF projects are attributed to the general contractor qualifications to perform the job.

4.2.3 Failure Mode and Effect Analysis FMEA

For all GIRF sub-processes, areas of greatest concern (critical failure mode) that are most important for the process were selected according to the highest RPN scores, and Pareto charts were used to prioritize the most hazardous risks needed to be eliminated or mitigated to increase process efficiency and customer satisfaction. Recommendations regarding elimination or mitigation the effect of failures modes were set, and responsibilities for carrying out the task were determined. Critical potential failure modes were addressed, and the KPIVs creating the most hazardous potential failures in different GIRF processes were identified via Pareto analysis charts. Tables 17-20 show the FMEA procedure and Pareto chart (Figs. 37-40) for each of the GIRF sub-processes.

Table 17:FMEA for the JDI GIRF sub-process

Process Step	Key Process Input	Potential Failure Mode(s)	Potential Failure Effects	Severity	Potential Causes of Failure	Occurrence	Current Controls for Prevention/Detection	Detection	Risk Priority Number (RPN)	Recommended Actions	Responsibility
Customer GIRF request via FPM website	Time and effort of customer to request a GIRF process	Faulty or incomplete reporting the problem	Delay in correcting errors and/or completing information	2 (Low)	Unfocused customer; reporting form lacks clarity	7		2	28	Design the GIRF form to include all required information, discuss with customer all required information after placing the request	Customer
FPM planning and design team acknowledges the request	Knowledge, skill and time availability of FPM Planning and Design Team (PD)	Improper handling of the request; errors and omissions in design	Project time delay; increased project costs,	9	Lack of knowledge/skills to handle the request	3		7	189	Assign knowledgeable and skilled people for planning and design work of the project	FPM Planning and Design Team (PD)
The project requires Fire Marshal process	Turnaround time with Fire Marshal procedure	Faulty determination of if project requires Fire Marshal; incomplete documents required by Fire Marshal process	Project time delay	5	Lack of knowledge/ skill of FPM PD Team in submitting required documents to submit to Fire Marshal	4		5	100	Skills training for members of FPM PD Team; double check documents before submitting to Fire Marshal	FPM PD Team

Request order (RO) is converted to Work Order (WO) and a Project Manager (PM) is assigned to execute the JDI process	Time and effort involved in converting RO to WO.	Faulty and/or incomplete processing converting RO to a WO	Faulty and/or incomplete execution of project (not meeting project/ customer requirements); project time delays and cost increase due to rework	6	Lack of skill for the PM; inadequate communication with customer to confirm his request	3		7	126	Double check WO before submitting it to sub-trades for project construction; better communication with customer to fully understand requirements	PM
Sub-trades construct work	Sub-trades knowledge, skill training level, experience and motivation	Faulty and/or incomplete construction; reworks needed to correct deficiencies	Project time delay and cost increase; substandard quality	9	Lack of sub-trades knowledge, skills, training, and motivation of the sub-trades	2		6	108	Improve sub-trade selection & oversight	Sub-trades
PM develops punchlist with customer and submits it to sub-trades for completion	Accuracy and completeness of punchlist (punchlist reflects all project sub-factors)	Faulty or incomplete punchlist	Project time delay and cost increase caused by rework on punchlist and sub-factors not included in original punchlist	8	Lack of focus and skill	2		5	80	Double check the punchlist before submitting it to sub-trades	PM
Do PM and customer accept completed work? Assume no	Amount of rework needed for completion of punchlist sub-factors by sub-trades	Substantial rework needed for some project tasks	Increasing time and cost of the project	8	Lack of skill, knowledge, training, and motivation of the sub-trades	5		6	240	Improve sub-trade selection & oversight	Sub-trades

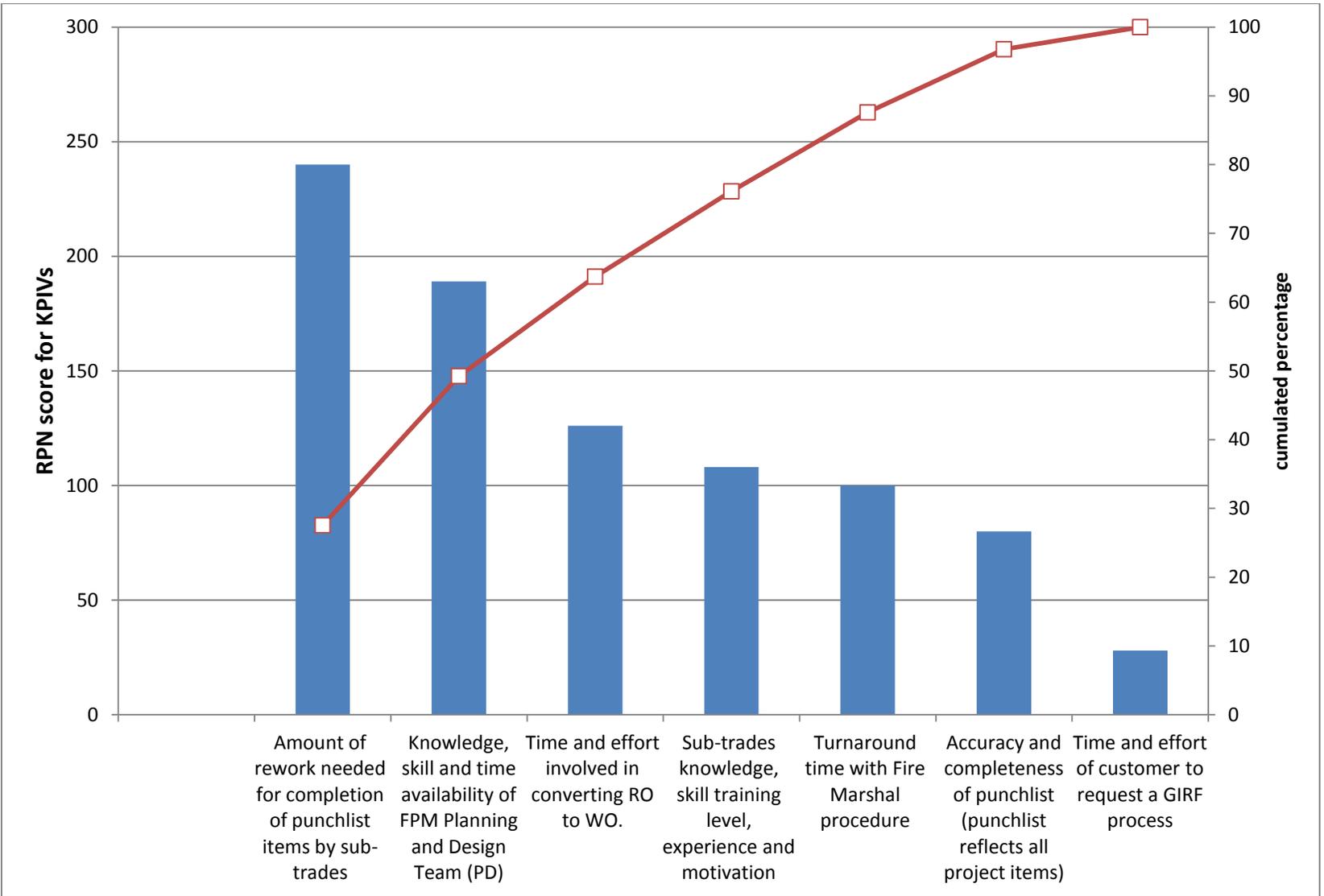


Figure 37: Pareto chart prioritizing the most impact hazardous on the process output for the JDI GIRF sub-process

For JDI process, three KPIV were determined to be prioritized for improvement and take more attention in eliminating potential risks associated with these KPIVs. These KPIVs representing about 70% of total risk:

- Amount of rework needed for completion of punchlist items by sub-trades
- Knowledge, skill and time availability of FPM Planning and Design Team (PD)
- Time and effort involved in converting RO to WO.

Table 18: FMEA for cost estimated no design no bidding (CEP) GIRF sub-process

Process Step	Key Process Input	Potential Failure Mode(s)	Potential Failure Effects	Severity	Potential Causes of Failure	Occurrence	Current Controls for Prevention/Detection	Detection	Risk Priority Number (RPN)	Recommended Actions	Responsibility
Customer GIRF request via FPM website	Time and effort of customer to request a GIRF process	Faulty or incomplete reporting the problem	Delay in correcting errors and/or completing information	2 (Low)	Unfocused customer; reporting form lacks clarity	7		2	28	Design the GIRF form to include all required information, discuss with customer all required information after placing the request	Customer
FPM planning and design team acknowledges the request	Knowledge, skill and time availability of FPM Planning and Design Team (PD)	Improper handling of the request; errors and omissions in design	Project time delay; increased project costs,	9	Lack of knowledge/skills to handle the request	3		7	189	Assign knowledgeable and skilled people for planning and design work of the project	FPM Planning and Design Team (PD)

The project requires Fire Marshal process	Turnaround time with Fire Marshal procedure	Faulty determination of if project requires Fire Marshal; incomplete documents required by Fire Marshal process	Project time delay	5	Lack of knowledge/ skill of FPM PD Team in submitting required documents to submit to Fire Marshal	4		5	100	Skills training for members of FPM PD Team; double check documents before submitting to Fire Marshal	FPM PD Team
CE develops cost estimate with assistance from sub-trades and reviews it with customer	Accuracy of project cost estimate	Faulty or incomplete estimation for the project cost	Substantial variation between the initial estimated cost and the Total project cost; customer may not accept the high faulty estimated cost because it will be over his funding capability	9	Lack of knowledge/ skills for both the CE and sub-trades in cost estimation; faulty or incomplete information submitted to the CE from the FPM PD Team	5		6	270	Assign knowledgeable and skilled people for cost estimation; double check all detailed estimated costs for the project especially the hidden costs; double check documents received from FPM PD Team.	CE and sub-trades

Customer funds project and selects PFA as funding mechanism	The effect of selecting PFA as funding mechanism (complexity)	Funding resources not available on time, administrative problems regarding the transformation of money to FPM account	Project time delay	7	Customer cannot confirm funding the project on time, unforeseen institutional transactional problems and regulations regarding money transfer	3		4	84	Customer should confirm his funding resources, and transactional process should be explained to the customer very clearly in the early stages of the project	Customer and FPM
Project put on hold pending verification of PFA	Lack of availability of funds until PFA is verified	Project time delay (project fund is not confirmed)	Project time delay; increased project costs	6	Customer unable to confirm project funding on time; unforeseen institutional transactional problems/ delays in fund transfer	4		4	96	Customer should confirm his funding resources, and transactional process should be explained to the customer very clearly in the early stages of the project	Customer
Sub-trades develop lumpsum construction proposal and submit it to PM for evaluation	Time required for proposal submission and approval	Faulty and/or incomplete lumpsum construction proposal	Project time delay; increased project costs	4	Lack of skill/ knowledge, training for sub-trades, lack of focus	7		4	112	More training and motivation for existing sub-trades, skill should be of the highest priority when hiring new sub-trades	Sub-trades

PM prepares Short Form Construction Contract (SFCC) and submits it to sub-trades for execution	Timeliness and accuracy of SFCC	Errors and omissions in SFCC	Project time delay	5	Lack of knowledge, skills, and lack of focus	4		6	120	Assign knowledgeable and skilled PM; more focus, double check prepared SFCC	PM
PM prepares Redbook for SFCC execution and submits it to different FPM management levels for approval	Time for getting FPM management approval for the SFCC execution	Errors and omissions in Redbook for SFCC; Redbook approval takes long time	Project time delay	5	Lack of Knowledge/skills for PM; bureaucratic procedures in getting approval of different management levels	4		4	80	Assign knowledgeable and skilled PM; more focus; facilitating the higher management procedure for approval	PM and different management levels
Administrative actions to ensure funding, issue Purchase Order# (PO#), and PM retrieves PO# within Banner	Timeliness and efficiency of ensuring funding, issuing PO#, and retrieving it from Banner	Administrative actions take long time, Some mistakes and/or missed information in the PO	Project time delay; increased project costs	5	Bureaucracy in the administrative actions, lack of focus, lack of knowledge/skills for some administrative employees	6		4	120	Facilitating the administrative procedures, more focus, more training and motivation for the employees	Administrative/purchase departments
PM and customer do not accept completed work (punchlist)	Time and costs associated with completing punchlist	Rework needed for some project tasks	Project time delay; increased project costs	8	lack of knowledge/skills, training, and motivation for sub-trades	5		6	240	More training and motivation for the sub-trades	Sub-trades

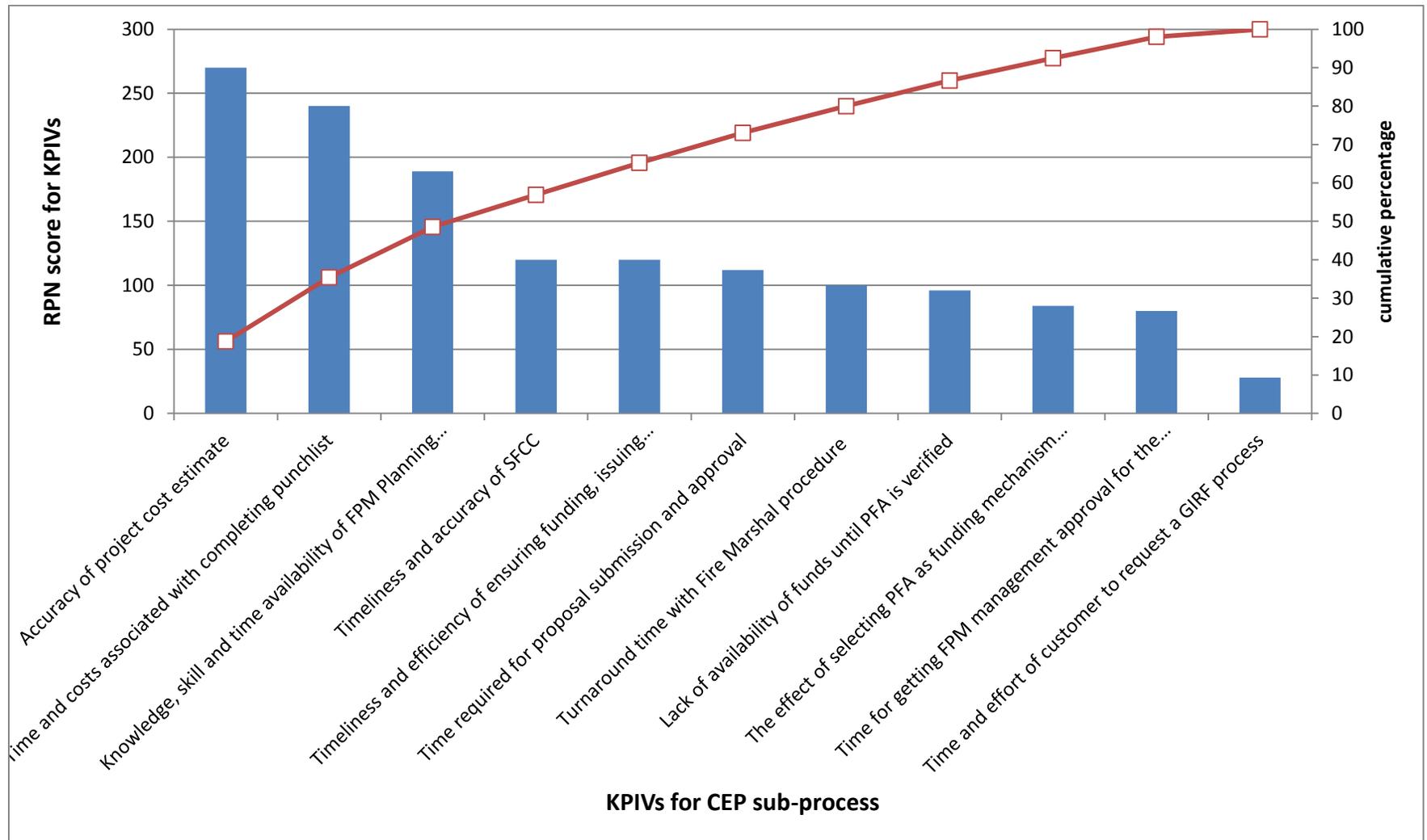


Figure 38: Pareto chart prioritizing the highest impact hazards on the process output for the cost estimate no design no bidding (CEP) GIRF sub-process

For cost estimated sub-process, three KPIVs representing about 50% of total risk were chosen for further improvement.

- Accuracy for project cost estimate
- Time and costs associated with completing punchlist
- Knowledge, skill and time availability of FPM Planning and Design Team (PD)

They are directly touching KPOV's and also are linked to the model since some of these inputs are mentioned in the model as directly affecting the customer perception for service quality.

Table 19: FMEA for cost estimated – schematic design (CEPD) GIRF sub-

Process Step	Key Process Input	Potential Failure Mode(s)	Potential Failure Effects	Severity	Potential Causes of Failure	Occurrence	Current Controls for Prevention/Detection	Detection	Risk Priority Number (RPN)	Recommended Actions	Responsibility
Customer GIRF request via FPM website	Time and effort of customer to request a GIRF process	Faulty or incomplete reporting the problem	Delay in correcting errors and/or completing information	2 (Low)	Unfocused customer; reporting form lacks clarity	7		2	28	Design the GIRF form to include all required information, discuss with customer all required information after placing the request	Customer
FPM planning and design team acknowledges the request	Knowledge, skill and time availability of FPM Planning and Design Team (PD)	Improper handling of the request; errors and omissions in design	Project time delay; increased project costs,	9	Lack of knowledge/skills to handle the request	3		7	189	Assign knowledgeable and skilled people for planning and design work of the project	FPM Planning and Design (PD) Team
The project requires Fire Marshal process	Turnaround time with Fire Marshal procedure	Faulty determination of if project requires Fire Marshal; incomplete documents required by Fire Marshal process	Project time delay	5	Lack of knowledge/ skill of FPM PD Team in submitting required documents to submit to Fire Marshal	4		5	100	Skills training for members of FPM PD Team; double check documents before submitting to Fire Marshal	FPM PD Team

A/E develops design proposal upon PM's request	Time spent for and accuracy of developed design proposal	Developed design proposal takes longer than scheduled; errors and omissions in design; design developed in a way that doesn't save costs	Project time delay due to redesign to get customer acceptance	4	Lack of knowledge/ skills for A/E; incomplete information about the project; pile up of designs needed to be developed by A/E	5		4	80	Assign knowledgeable and skilled A/E to prepare designs; do not pile up design jobs by hiring more designers when need	A/E
PP/PM accept design proposal? Assume no	Time spent by PP/PM to review and accept design proposal	design proposal not accepted	Project time delay due to redesign to get customer acceptance	4	Lack of knowledge/ skills and experience for A/E; faulty or incomplete or faulty information about the project	5		4	80	Assign knowledgeable, skilled A/E to prepare designs; motivate local designers	PM
Customer funds project and selects PFA as funding mechanism	The effect of selecting PFA as funding mechanism (complexity)	Funding resources not available on time, administrative problems regarding the transformation of money to FPM account	Delay time for project completion, confusing detailed project schedules	7	Customer cannot confirm funding the project on time, unforeseen transactional problems and regulations regarding money transfer	3		4	84	Customer should confirm his funding resources, and transactional process should be explained to the customer very clearly in the early stages of the project	Customer and FPM

Project put on hold pending verification of PFA	Lack of availability of funds until PFA is verified	Delaying in project finishing time.	project schedules messed up leading to project time delay	6	Customer cannot confirm funding the project on time, unforeseen transactional problems and regulations regarding money transfer	4		4	96	Customer should confirm his funding resources, and transactional process should be explained to the customer very clearly in the early stages of the project	Customer
PP/PM prepares Redbook for design contract execution and submits it to different management levels for approval	Time of getting FPM management approval	Incomplete or faulty information included in Redbook for design contract execution; Redbook approval takes long time	Project time delay	4	Lack of knowledge, skills, and training for PP/PM; not enough focus, no double check before submit Redbook	5		4	80	Double check the Redbook before submitting, facilitate the procedure of higher management approval process	PP/PM, different management levels
Does customer accept schematic design and cost estimate? Assume no	Rework time and cost of redeveloped schematic design and cost estimate	Schematic design and/or cost estimate not accepted	project time delay; project die	7	Customer budget is limited, cost estimation is not reliable or over customer expectation	4		3	84	Double check designs and cost estimation before submit it to customer	Customer
Sub-trades develop lumpsum construction proposal and submit it to PM for evaluation	Time required for proposal submission and approval	Developed lumpsum construction proposal is not accurate and/or not completed	Delay time for finishing the project,	4	Lack of skill for sub-trades, lack of focus	7		4	112	More training and motivation for existing sub-trades, skill should be of the highest priority when hiring new sub-trades	Sub-trades

PM prepares Short Form Construction Contract (SFCC) and submits it to sub-trades for execution	Timeliness and accuracy of SFCC	Prepared SFCC in not accurate, some required information in the contract is not included.	Time delay for the project	5	Lack of skill, lack of focus	4		6	120	More knowledge and skills for PM, more focus, double checking the prepared SFCC	PM
PM prepares Redbook for SFCC execution and submits it to different FPM management levels for approval	Time for getting FPM management approval for the SFCC execution	Redbook for SFCC in not well prepared, Redbook approval take long time	Time delay for the project	5	Lack of PM skills, burocratic procedures, for getting Higher level management approval	4		4	80	More knowledge and skills for PM, more focus, facilitating the higher management procedure for approval	PM and different management levels
Administrative actions to ensure funding, issue Purchase Order# (PO#), and PM retrieves PO# within Banner	Timeliness and efficiency of ensuring funding, issuing PO#, and retrieving it from Banner	Administrative actions take long time, Some mistakes and/or missed information in the PO	Time delay for the project, cost increased	5	Burocracy in the administrative actions, lack of focus, lack of knowledge and skills for some administrative employees	6		4	120	Facilitating the administrative procedures, more focus, more training and motivation for the employees	Administrative/purchase departments
PM and customer do not accept completed work (punchlist)	Time and costs associated with completing punchlist	Rework needed for some project tasks	Increasing time and cost of the project	8	lack of skill, training, and motivation for the sub-trades	5		6	240	More training and motivation for the sub-trades	Sub-trades

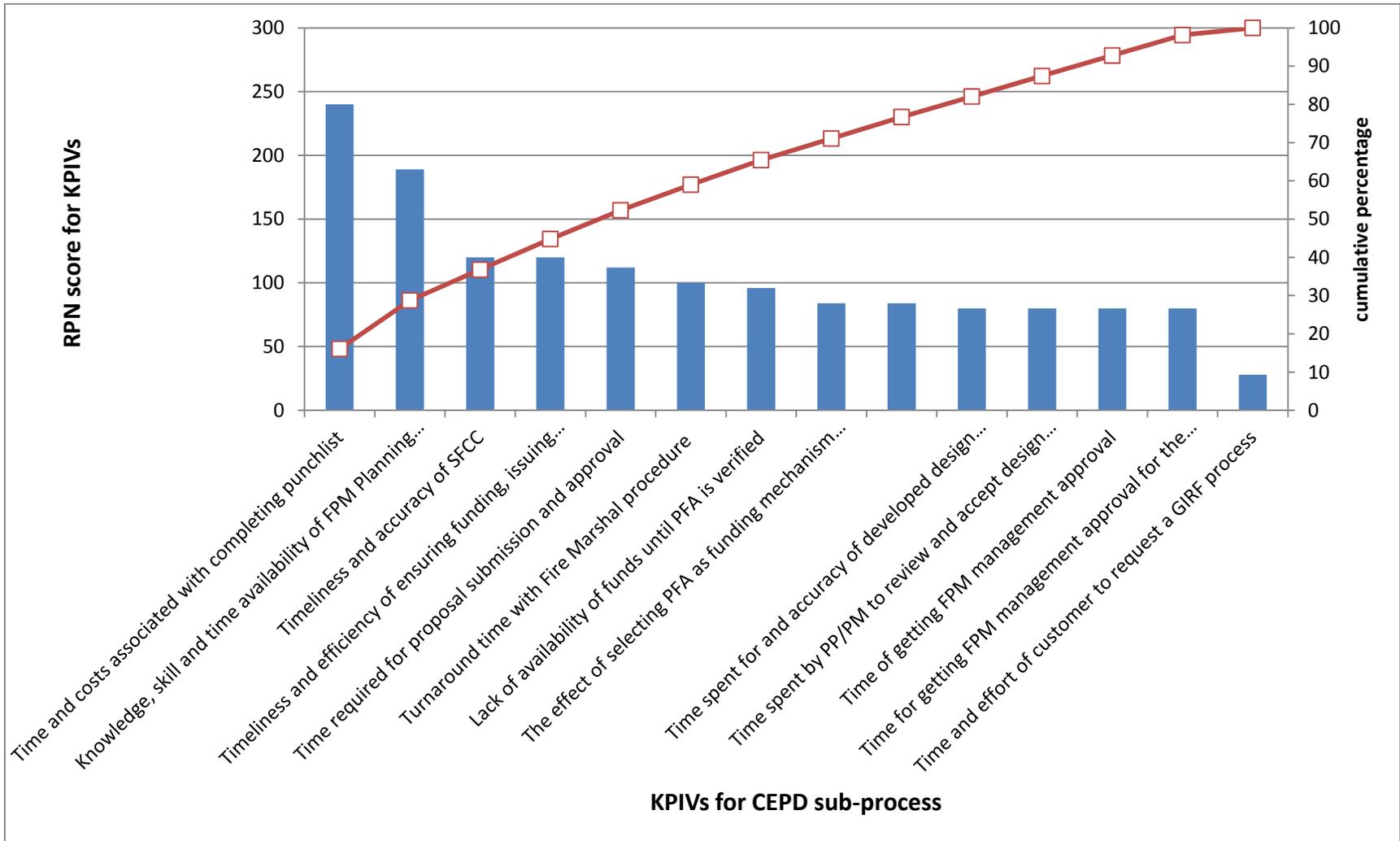


Figure 39: Pareto chart prioritizing the most impact hazardous on the process output for the cost estimate, design, no bidding (CEPD) GIRF sub-process

For cost estimate and schematic design sub-process, five KPIVs representing more than 50% of total risk were chosen for further improvement.

- Time and costs associated with completing punchlist
- Knowledge, skill and time availability of FPM Planning and Design Team (PD)
- Timeliness and accuracy of SFCC
- Timeliness and efficiency of ensuring funding, issuing PO#, and retrieving it from Banner
- Time required for proposal submission and approval

Table 20: FMEA for cost estimated, schematic designed, and bidding (CEPDB) GIRF sub-

Process Step	Key Process Input	Potential Failure Mode(s)	Potential Failure Effects	Severity	Potential Causes of Failure	Occurrence	Current Controls for Prevention/Detection	Detection	Risk Priority Number (RPN)	Recommended Actions	Responsibility
Customer GIRF request via FPM website	Time and effort of customer to request a GIRF process	Faulty or incomplete reporting the problem	Delay in correcting errors and/or completing information	2 (Low)	Unfocused customer; reporting form lacks clarity	7		2	28	Design the GIRF form to include all required information, discuss with customer all required information after placing the request	Customer
FPM planning and design team acknowledges the request	Knowledge, skill and time availability of FPM Planning and Design Team (PD)	Improper handling of the request; errors and omissions in design	Project time delay; increased project costs,	9	Lack of knowledge/skills to handle the request	3		7	189	Assign knowledgeable and skilled people for planning and design work of the project	FPM Planning and Design Team (PD)

The project requires Fire Marshal process	Turnaround time with Fire Marshal procedure	Faulty determination of if project requires Fire Marshal; incomplete documents required by Fire Marshal process	Project time delay	5	Lack of knowledge/ skill of FPM PD Team in submitting required documents to submit to Fire Marshal	4		5	100	Skills training for members of FPM PD Team; double check documents before submitting to Fire Marshal	FPM PD Team
A/E develops design proposal upon PM's request	Time spent for and accuracy of developed design proposal	Developed design proposal takes longer than scheduled, has mistakes, bad design and doesn't save costs.	will take extra time to redesign and make the proper design accepted by customer	4	Lack of skill and experience for A/E, lack of information about the project, pile up of designs needed to be developed by A/E	5		4	80	Assign skilled A/E to prepare designs, do not pile up design jobs by hiring more designers when need	A/E
PP/PM accept design proposal? Assume no	Time spent by PP/PM to review and accept design proposal	Project delayed	will take extra time to redesign and make the proper design accepted by customer	4	Lack of skill and experience for A/E, lack of information about the project	5		4	80	Assign skilled A/E to prepare designs, motivate local designers	PM

Customer funds project and selects PFA as funding mechanism	The effect of selecting PFA as funding mechanism (complexity)	Funding resources not available on time, administrative problems regarding the transformation of money to FPM account	Delay time for project completion, confusing detailed project schedules	7	Customer cannot confirm funding the project on time, unforeseen transactional problems and regulations regarding money transfer	3		4	84	Customer should confirm his funding resources, and transactional process should be explained to the customer very clearly in the early stages of the project	Customer and FPM
Project put on hold pending verification of PFA	Lack of availability of funds until PFA is verified	Delaying in project finishing time.	in project schedules leading to project finishing time delay	6	Customer cannot confirm funding the project on time, unforeseen transactional problems and regulations regarding money transfer	4		4	96	Customer should confirm his funding resources, and transactional process should be explained to the customer very clearly in the early stages of the project	Customer
PP/PM prepares Redbook for design contract execution and submits it to different management levels for approval	Time of getting FPM management approval	Redbook for design contract execution has missed information, long time for higher management approval procedure	Project time delay	4	PP/PM are not enough skilled or well trained, not enough focus, no double checking before submit the Redbook,	5		4	80	Double check the Redbook before submitting, facilitate the procedure of higher management approval process	PP/PM, different management levels

Does customer accept schematic design and cost estimate? Assume no	Rework time and cost of redeveloped schematic design and cost estimate	Project delay waiting for redesign and redo cost estimate, project die or put on hold	project time delay, project die	7	Customer budget is limited, cost estimation is not reliable or over customer expectation	4		3	84	Double check designs and cost estimation before submit it to customer	Customer
Did the design contract include development of construction documents (CD) and (CA) services? Assume no, and consider options 1 and 2 Option 1: PM prepares impact report to continues with design phase; and submits it for logging. Option 2: A/E develops change order proposal at	Time and costs needed to prepare and approve impact report. Time and costs needed to prepare and accept a change order proposal	Incomplete impact report information; incomplete change order proposal information	Project time delay	5	Lack of knowledge and/or skills for the PM, no double check after preparing both impact report or change order proposal	5		4	100	Skilled and Assign knowledge, and skilled PM for the project, double check after preparing impact report or change order proposal	PM, A/E

PM's direction											
PM prepares Redbook for change order execution and submits it for approval by different management levels	Time of getting FPM management approval for the Redbook for change order execution	Incomplete information in the Redbook for change order, long time for higher management approval procedure	Project time delay	4	PP is not enough skilled or well trained, not enough focus, no double checking before submit the Redbook,	5		4	80	Skilled and knowledge PM should be assigned for the project, double check after preparing The Redbook for change order execution	PM
Assume yes for step 11, A/E develops CD's and conducts required design review with PM and customer	Time of developing and completing CD's after design review	CD's are not completed, PM and/or customer not accepting the design	Project time delay, increasing project costs	5	Lack of knowledge/ skills; pile up of work need to be done	5		4	100	Assign knowledgeable, skilled and trained A/E; made actions to do the jobs without piling up	A/E
PM develops project manual for bidding after completing CD's	Time spent by PM to develop project manual for bidding	Incomplete or confusing information in the project manual for bidding; long time spent for developing the manual	Project time delay; may cause bidders get confused about the project	5	PM do not aware with all aspects of the bidding, CD's information is not completed	4		4	80	PM should be aware of all bidding aspects, PM should have knowledge how to prepare project manual for bidding as simple as possible	PM

PM prepares Redbook for Long Form Construction Contract (LFCC) execution and submits it to different management levels for approval	Time for getting FPM management approval for preparing LFCC	Incomplete information in the Redbook for LFCC, long time for higher management approval procedure	Project time delay due to reworking the Redbook	5	Lack of knowledge/skills, and training for PM; not enough focus; no double check before submit the Redbook	5		4	100	Assign knowledgeable, skilled and trained PM for the project; double check after preparing The Redbook for LFCC	PM
PM issues PO# to General Contractor (GC) and GC constructs work	Knowledge, training level, experience, efficiency, and reliability of general contractor to construct work	Incomplete or missed information in PO# to make GC construct work; work not constructed according to specifications	Project time delay, increased project costs; disputes with GC	8	Purchasing department who issues PO# is not aware of all aspects and details of the project; GC staff are under qualification qualified to do the job	5		5	200	Double check PO# before issuing, carefully select the GC who has the ability to do the job according to specifications	PM
PM develops punchlist with customer and submits it to GC for completion; and GC completes punchlist	Accuracy and completeness of punchlist	Punchlist do not cover all the project tasks; substandard quality in punchlist completion by GC	Project time delay; increased project costs due to reworking	7	Not enough focusing when preparing punchlist; Lack of GC staff knowledge; skills, and training	6		5	210	Double check punchlist before submitted to GC; carefully selecting GC according to strict specifications	PM

Is completed work accepted by FPM and customer? Assume no	Time and costs associated with completing punchlist	Project completion is not accepted by customer	Project time delay; increased project costs due to reworking	7	Lack of GC staff knowledge; skills, and training	6		5	210	carefully selecting GC according to strict specifications	GC
If yes, customer occupies facility											

For cost estimate, schematic design, and bidding process, four KPIVs are responsible for around 50% of total risk, and need further improvement. These inputs are

- Accuracy and completeness of punchlist
- Time and costs associated with completing punchlist
- Knowledge, training level, experience, efficiency, and reliability of general contractor to construct work
- Knowledge, skill and time availability of FPM Planning and Design Team (PD)

A new session of FMEA meeting should be carried out after implementing recommendations, and a new RPN scores should be obtained. As a sign of progress in process improvement, the new RPN scores should be lower than the originals before implementing recommendations. Perhaps one of the most important issues in dealing with the FMEA is that an FMEA must be done with a team. An FMEA completed by an individual is only that individual's opinion and does not meet the requirements or the intent of an FMEA. FMEA is a very powerful technique, a little bit tedious, time consuming and exhausting but shows great results when it is applied.

CHAPTER 5 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

This study was divided into two main parts; first was to construct a service quality model for higher learning institutions, and second was to demonstrate the potentiality of using Six-Sigma methodology to improve services delivered by facility management units in higher educational institutions. The FPM department at WSU was selected as a case study for implementing service process improvements. One of the services delivered, General Improvement Request Form, (GIRF) was chosen for further improvement in accordance with feedback obtained from customers (users of services). The customer satisfaction survey results showed that it was the service needing the most improvement.

As a result of the literature survey conducted, it was revealed that there are many service quality models and each model had its limitations. Models are in essence a simplified version of reality. They suggest that there are complex relationships between output and input factors, and that systems operate by rules of cause and effect.

An initial model was created to depict the critical factors affecting quality of services delivered by FM units at higher education institutions. Studying of different previous service quality models led to the fact that each model was affected by the type of service in question and none of them could be used as a general model with universal applicability. In order to review, refine, modify, and validate the model, a Nominal Group Technique session was conducted. As a result, a modified model was developed depicting critical factors affecting quality of services provided by higher institution FM service units. Four main factors were found to affect the customer perception for service quality. Each factor is influenced by its sub-factors. A total of fourteen sub-factors were identified. The customer expectation was found to be affected by three

main factors influencing the main customer requirements and needs. The difference between customer perception and expectations form the service quality gap at the end which needs to be narrowed as much as possible. Even though the devised model was developed after a deeper review of different service quality models and with reference to the facilities services provided by many of the large universities in the US, it is applicable to Wayne State University WSU, because the NGT team was formed mainly from the WSU FPM department, and it is reflecting the WSU FPM facilities point of view. We have seen for instance, that in prioritizing the safety sub-factors the team naturally reflects its own concern. The model in general, provides a framework for doing similar modeling and process improvement initiatives at other universities, since it is the first modeling effort focusing on higher education institution FM units.

A number of Six-Sigma tools representing different phases of the Six-Sigma DMAIC methodology were implemented in the improvement of the GIRF service processes. GIRF process was divided into four sub-processes (Just do it sub-process, cost estimated sub-process, cost estimated with schematic design sub-process, and cost estimate with schematic design and bidding sub-process) to facilitate understanding and proposing improvement actions,

The existing flowchart was studied for this purpose to gain a deep understanding of the flow and details of related steps, and tables of input/output and responsibilities were created for each sub-process to form with flowcharts a complete process map. This helped to propose improvements on the process to increase efficiency and reduce non-value added activities in the process. These activities are shown with a grey shadow on the sub-processes flowcharts. The flowchart for the GIRF sub-processes were modified to eliminate delays due to bottlenecks and non-value adding activities such as rework, and reducing the time elapsed in getting different approvals for all key tasks was recommended.

The Cause and Effect Matrix was implemented to prioritize the impact of input variables on the output variables representing customer requirements. This includes determination of which process inputs and steps have the most impact on customer satisfaction or process output. In order to clarify customer requirements, voice of customer input was obtained through interviewing customers, monitoring complaints, and reviewing customer comments on the survey returns. Customer comments were rephrased into four main customer requirements which could be measured and controlled representing what is called Critical To Quality (CTQ). These were Project duration, Total project cost, Project quality (in terms of defects, rework, and quality of materials and workmanship) and Cost estimation reliability. Using Pareto analysis, the critical few key processes input variables (KPIVs) having most impact on the key process output variables (KPOVs) were identified and addressed for each GIRF sub-process for further improvement to increase process efficiency. For JDI sub-process, three of the six tasks input comprising the process were chosen. These task inputs contribute of around 60% of the total impact on outputs. These input variables are:

- Sub-trades knowledge, training level, experience and motivation
- Rework needed for completion of punchlist sub-factors by sub-trades
- Knowledge, skill and time availability of FPM Planning and Designing Team

For cost estimated sub-process, five input variables were selected through Pareto chart for further improvement. These inputs are:

- Time required for proposal submission and approval
- Time and costs associated with completing punchlist
- Accuracy of project cost estimate
- The effect of selecting PFA as funding mechanism (complexity)

- Time for getting FPM management approval for the SFCC execution

For cost estimated, schematic design, no bidding sub-process, five input variables were selected for further improvement. These inputs variables are:

- Rework time and cost of redeveloped schematic design and cost estimate
- Time of getting FPM management approval
- Time required for proposal submission and approval
- Time and costs associated with completing punchlist
- Time spent for and accuracy of developed design proposal

For cost estimated, schematic design, and bidding sub-process, five out of seventeen input variables were selected for further improvement. . These inputs are:

- Rework time and cost of redeveloped schematic design and cost estimate
- Time of getting FPM management approval
- Time and costs associated with completing punchlist
- Time spent for and accuracy (precision) for developed design proposal
- Knowledge, training level, experience, efficiency, and reliability of general contractor to construct work.

In order to conduct improvements, management should start with these tasks as improvement projects and assign a Six-Sigma team to analyze and improve these processes. The main objectives of the improvement efforts should be reducing approval time for the mentioned tasks, reviewing and controlling the cost estimation process before launch, and directing an improvement team formed from different branches to brainstorm, carefully review the PFA process map, and propose improvement actions to reduce the complexity of the PFA process, along with simplifying the funding verification process. These will greatly affect customer perception on the quality of service provided by FPM.

A plan for detecting a greater number of possible failure causes for the GIRF sub-processes and preventing process failures was established through the FMEA method by analyzing failure mode as a preventive action for potential failures. Process map and CE matrix acted as a source of information for the FMEA. Potential failures, effects, causes, responsibilities for carrying out the task, process step Risk Priority Number (RPN) to rank the need for corrective actions, and recommended actions to propose changes to control and reduce the risk were determined on the FMEA tables. Assigned failure modes were prioritized according to the highest RPN, and recommended actions were identified in order to eliminate, mitigate, or reduce the likelihood of the potential failure mode in the process. Areas of greatest concern (critical failure mode) that are most important for the process were selected according to the highest RPN scores, and Pareto charts were used to prioritize the most critical risks that needed to be eliminated or mitigated to increase process efficiency and customer satisfaction.

For JDI sub-process, Three KPIVs representing about 70% of total risk were selected for further improvement.

- Amount of rework needed for completion of punchlist sub-factors by sub-trades
- Knowledge, skill and time availability of FPM Planning and Design Team (PD)
- Time and effort involved in converting RO to WO.

For cost estimated sub-process, three KPIVs representing about 50% of total risk, were chosen for further improvement.

- Accuracy of project cost estimate
- Time and costs associated with completing punchlist
- Knowledge, skill and time availability of FPM Planning and Design Team

For cost estimated schematic design and no bidding sub-process, five KPIVs representing more than 50% of total risk were chosen for further improvement.

- Time and costs associated with completing punchlist
- Knowledge, skill and time availability of FPM Planning and Design Team
- Timeliness and accuracy of SFCC
- Timeliness and efficiency of ensuring funding, issuing PO#, and retrieving it from Banner
- Time required for proposal submission and approval

For cost estimated schematic design and bidding sub-process, four KPIVs were found to be responsible for around 50% of total risk, and needed further improvement. These inputs are

- Accuracy and completeness of punchlist
- Time and costs associated with completing punchlist
- Knowledge, training level, experience, efficiency, and reliability of general contractor to construct work
- Knowledge, skill and time availability of FPM Planning and Design Team

The GIRF process improvement study was a good example of how important it is to communicate with customer and how to translate customer requirements into customized service process design, production and delivery. All factors mentioned in the FM service quality model developed were found to be affecting the GIRF process as seen in the process maps, CE analysis, and FMEA.

5.1 Recommendations for further research

- Even though there are similarities in most of the services provided by FM units at universities, there are some questions on whether conducting a case study at one of the universities produces and apply the results applicable to all universities, and represent a real reliable model that could be applied to FM at universities in general. This point needs further investigation in the future.

- Customer expectations are dynamic and influenced by many factors. One of the recommended future studies regarding FM services is how to explore, measure, and prioritize these factors. Customer expectations are generally not sufficiently focused on by FM universities' units for their services. This is an area that needs more attention and how best to do this can be investigated.
- Measurement of customer satisfaction in FM services at universities is quite complicated due to the human behavioral and emotional factors associated with the service delivery. There is a need to research how relevant skills and training can be optimized for FM services at universities. Voice of customer (VOC) varies with time, and service organizations should update and refine their approach and processes to make customer satisfied on a continuous basis.

APPENDIX 1**SOA Survey on Universities' FPM Services**

<http://www.ifma.org/about/what-is-facility-management>

<http://www.facilities.wayne.edu/>

<http://www.fpm.iastate.edu/>

<http://www.cdc.gov/healthyyouth/evaluation/pdf/brief7.pdf>

<http://www.plantops.umich.edu/>

https://fpm-www3.fpm.wisc.edu/fpm_portal/Default.aspx

<http://www.colorado.edu/facilitiesmanagement/>

<http://www.fm.arizona.edu/>

<http://opb.msu.edu/facilities/index.asp>

<https://www.mnsu.edu/facilities/>

<http://www.fm.msstate.edu/>

<http://www.ucdenver.edu/about/departments/FacilitiesManagement/Pages/FacilitiesManagement.aspx>

http://www.shsu.edu/~ppl_www/

<http://fod.osu.edu/>

<http://www.csu.edu/PFPM/contact.htm>

<http://facilities.illinoisstate.edu/>

<http://www.facilities.yale.edu/>

<http://medfacilities.stanford.edu/facilities/>

<http://www.campuservices.harvard.edu/energy-facilities>

www.fm.ucla.edu/

Detailed Description of Universities' Facility Services

1. Construction services

Construction services consists of renovation, painting, cabinetry, upholstery and furniture repair, sign and graphics, glass shop, and spray and finishing shop.

Renovation: provides the following services: full renovation services, carpentry, electrical, plumbing, mechanical, masonry, and plaster.

Painting: provides the following services: spray painting, furniture refinishing, graffiti removal, electrostatic painting, exterior and interior painting.

Cabinetry: a shop that produces different types of furniture such as: cabinets (laboratory, office, kitchen, and storage unit), counter tops (laminated, solid surfaces, hardwood), custom projects (reception counters, conference rooms, ...), shelving (plastic, chemical resistant, ...), and doors and frames (solid wood, plastic laminate, repair existing doors, windows frames, pictures frames).

Upholstery and furniture repair: wood furniture repair, reupholstery services, sports and therapy equipment, transportation materials, and auditorium seating

Sign and graphics: providing signage and window films

Glass shop: services provided skylight repairs, mirrors, screen replacement, entrance systems/doors, windows replacement

Spray and finishing shop: furniture restoration, wood antiquing (desk), spray finishing (steelcase colors), stripping and refinishing, contemporary finishes, seal and clear finishes, and mood affecting colors.

2. Facilities Maintenance

Facilities maintenance includes: HVAC, plumbing, pumps, steam distribution and insulation, electrical systems, fire systems, elevators, roofing, metal work, machine repair and preventive maintenance. Facilities maintenance usually has the following common activities:

Building automation services: implements schedule and operational changes for various types of equipment, and monitors alarm conditions and energy efficient system operation.

Facilities maintenance electric shop: consists of the technical and electrical construction workgroups in order to respond to situations involving equipment and power failures.

Hospital maintenance: maintains the universities' hospital's physical environment and provides maintenance services. It consists of some shops such as electrical shop, industrial electrical shop, plumbing shop, and painting.

Mechanical systems: consists mainly of two branches: plumbing, and air conditioning. Each one of the two branches contains shops. Plumbing shops include plumbing systems shop, pumps and steam systems shop, and insulation and asbestos abatement shop. Air conditioning shops include chiller systems shop, mechanical AC shop, HVAV controls/building automation shop, temperature control / test and balance shop.

Roof, metal shops & elevators: The roofing shop provides complete roofing services including installation, maintenance, repair and seasonal cleaning. The metal shops consist of the following shops; heating service, sheet-metal shop, machine shop, welding shop, and millwright shop. The elevator shop provides all vertical transportation maintenance and repairs including elevators and escalators.

Zone or building maintenance: responsible for providing maintenance for different buildings of the campus.

3. Facilities' Building and Ground Services

It provides building services, ground services, landscape architecture, pest management, waste management services.

Building services: provides cleaning services to university administrative and academic buildings on campus.

Ground services: responsible for street and sidewalk sweeping, snow removal, and trash removals.

Landscape architecture: provides landscape design and installation services. They assist in landscape renovations, develop landscape plans, working drawings and provide project management during the installation.

4. Facility Administration Services

It provides expertise in three main areas: finance, facilities' Information Technologies [IT], and facility's payroll & accounts payable.

Finance: responsible for budget administration, financial oversight and general accounting support for the various units within facilities' operations.

Facilities' information technologies [IT]: responsible for all areas of network, computer, and information services all over the different administrative and academic departments.

Facilities' payroll & accounts payable: payroll processing, processing invoice payments, human resources.

5. Utilities and Facilities Engineering

Minimize energy consumption, creating awareness about energy and resource conservation, coordinating strategies for improving energy efficiency, and providing an efficient electrical distribution system.

6. Work Control and Management

Serves as the single point of contact for facilities' operations with clients, provides preventive maintenance planning and quality assurance inspections, coordination for estimates, shutdowns, and projects. The Facilities Operations Call Center (FOCC) is the communications hub of facilities operations and the front line communications with campus departments.

7. Architecture, Engineering, and construction Services

It is responsible for managing the design and construction activities for all university's capital projects. The project management responsibilities include selection of all consultants and construction contractors, and leadership throughout all stages of design and construction.

8. Occupational Safety and Environmental Health Services

Consists of the following sectors:

Biological and laboratory safety: promoting research safety and assuring sound laboratory management by providing services such as; certification services, hazardous procedures manual and safety training development, research facility planning and design, and safety coordinators.

Environmental protection & permitting: provides assistance to all university departments in managing environmental issues. They provide services in these areas; storage tank management program, chemical use compliance, research activities, property redevelopment.

Emergency preparedness: provides resources, guidance, and training of the university community in matters related to emergency preparedness, response, and recovery.

Environmental sustainability: reduce waste generation, pollution prevention, and recycling activities.

Fire safety service: responsible for ensuring compliance with applicable fire safety regulations.

Hazardous materials management: responsible for the collection and proper disposal of chemical, radioactive, and biological waste generated during teaching, research, and clinical operations.

Industrial hygiene and safety: protects university staff from workplace injury and illness by assisting departments in anticipating, evaluating, and controlling potential health and safety hazards.

Operational safety and community health: provides community health support for food service establishments on campus, drinking water issues, pesticide usage, and swimming pool issues.

Radiation safety service: provides the radiological safety training, professional guidance, and technical support necessary to establish and implement an effective radiation safety program at the university.

9. Public Safety Services

It provides information about police services as well as parking enforcement, communications center, criminal investigations, and other units.

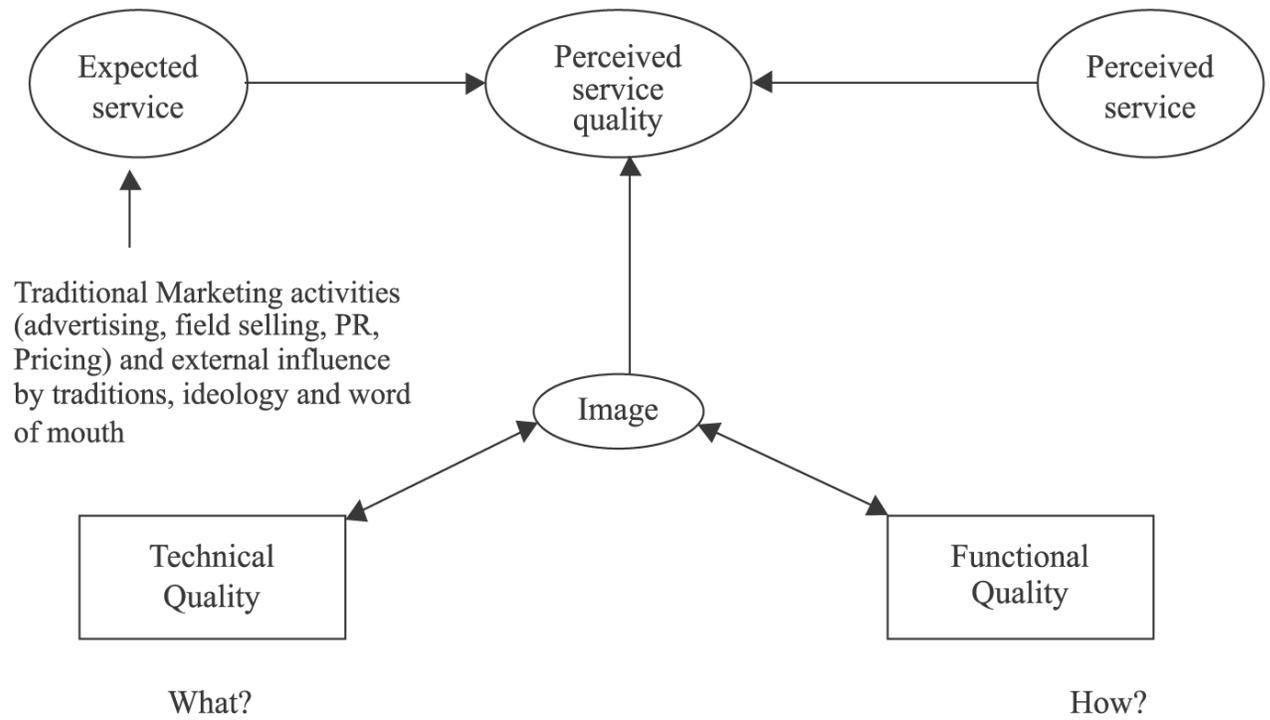
10. Parking and Transportation Services

It provides maps, bus routes, schedules, parking permit and vehicle lease options as well as brief construction updates that may affect the university community.

APPENDIX 2

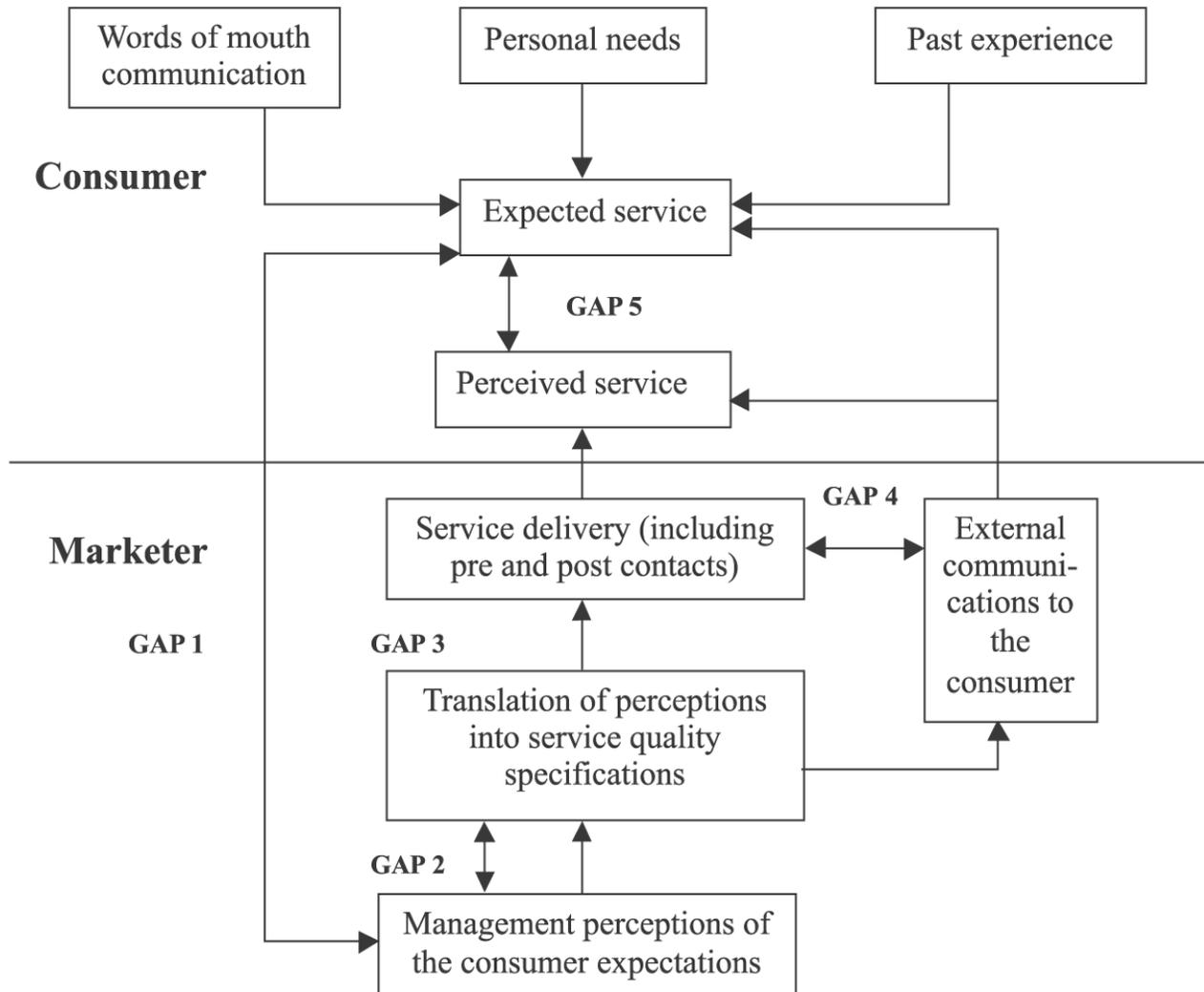
Service Quality Models

1. Technical and functional quality model (Gronroos, 1984)



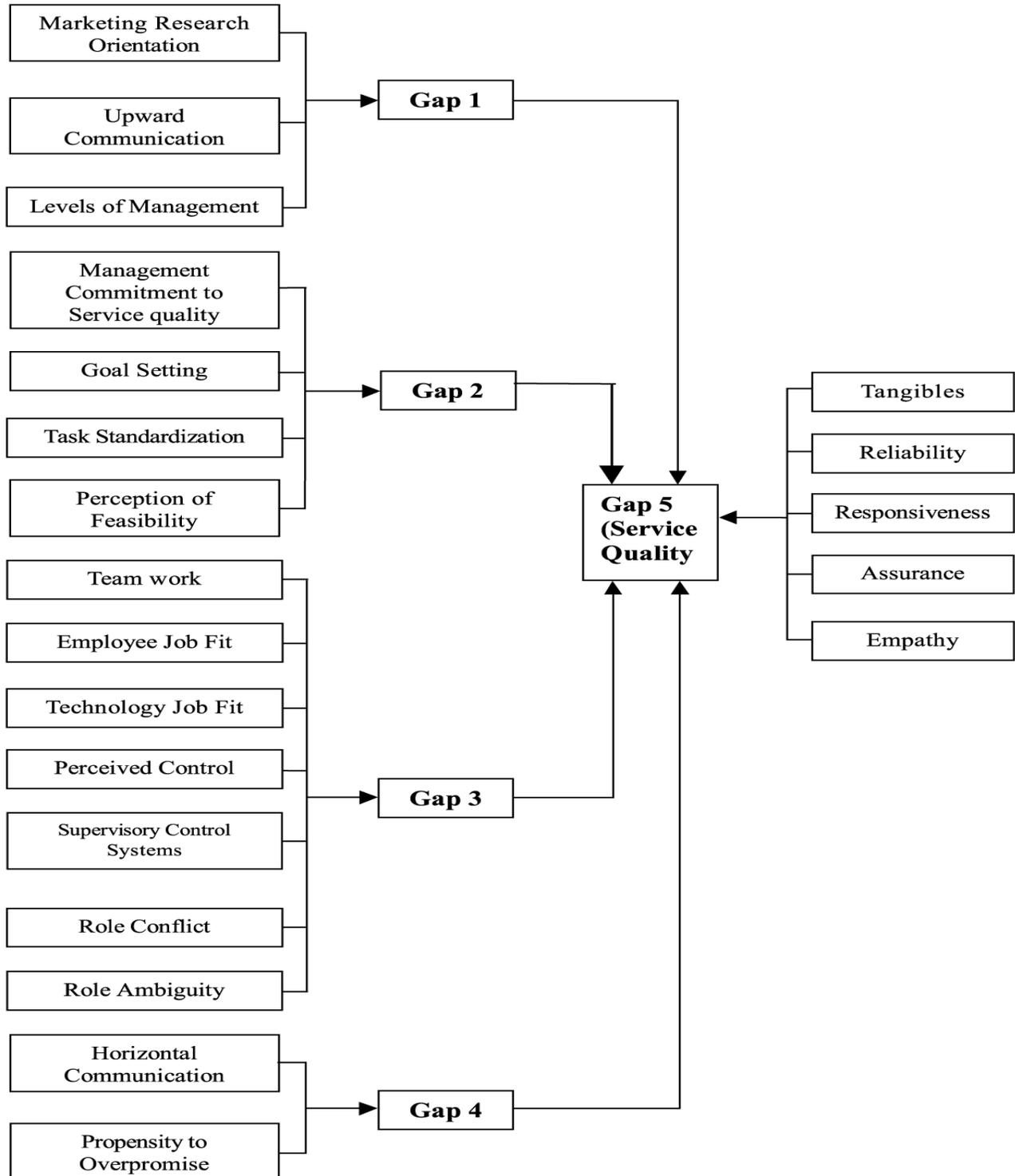
Source: Grönroos (1984)

2. GAP model (Parasuraman et al., 1985)



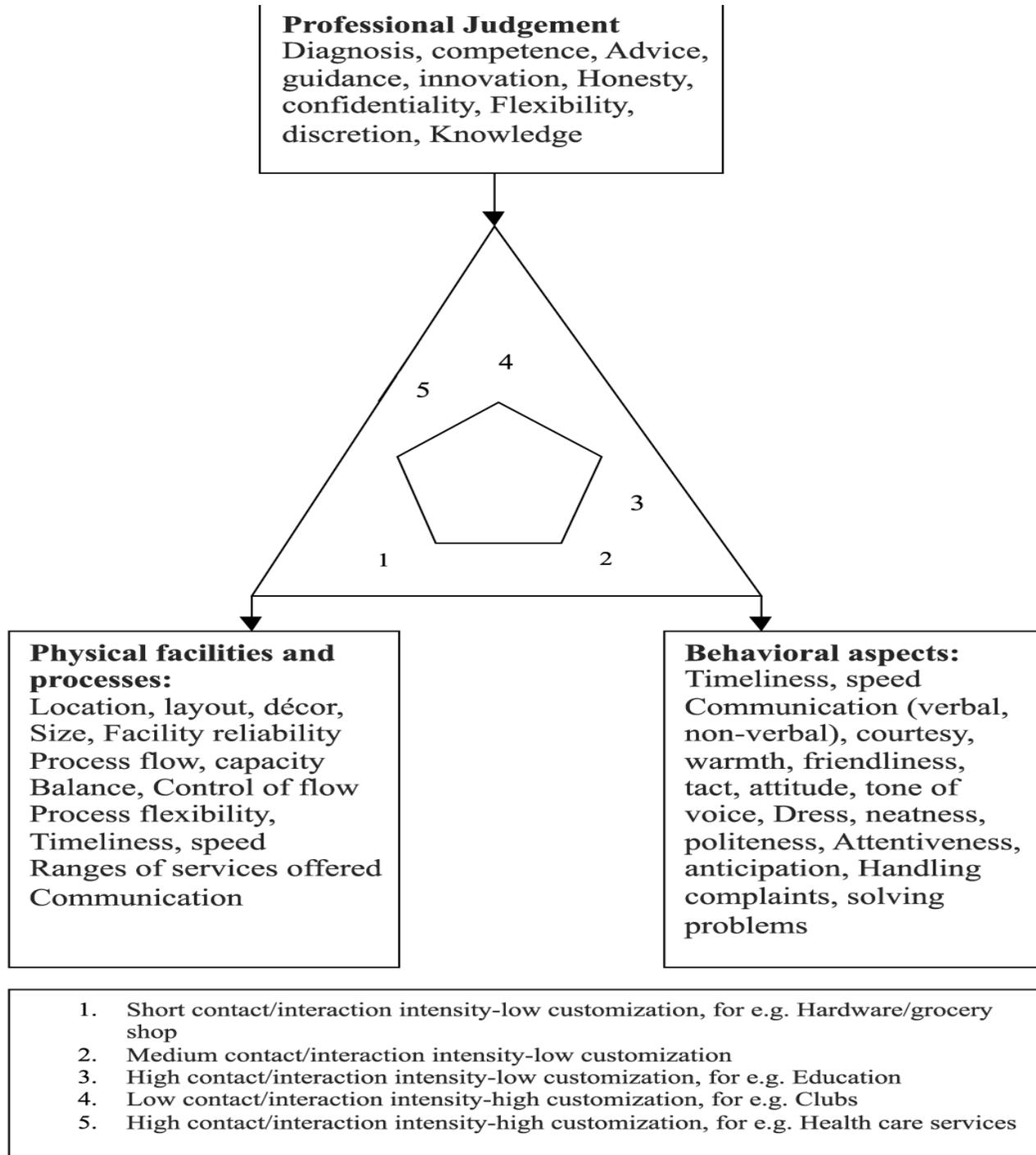
Source: Parasuraman *et al.* (1985)

3. Extended model of service quality



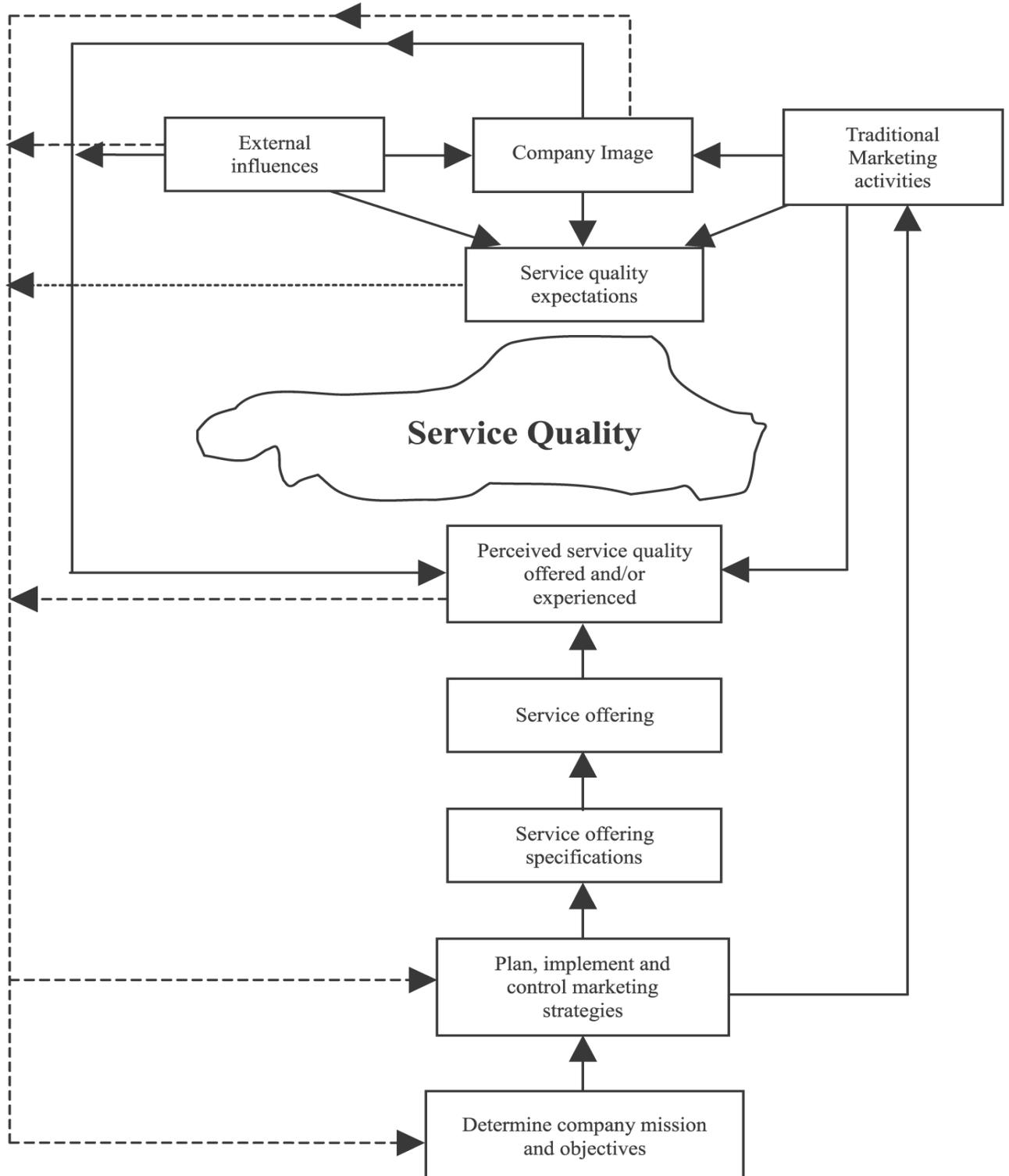
Source: Zeithaml *et al.* (1988)

4. Attribute service quality model (Haywood-Farmer, 1988)



Source: Haywood-Farmer (1988)

5. Synthesised model of service quality (Brogowicz et al., 1990)

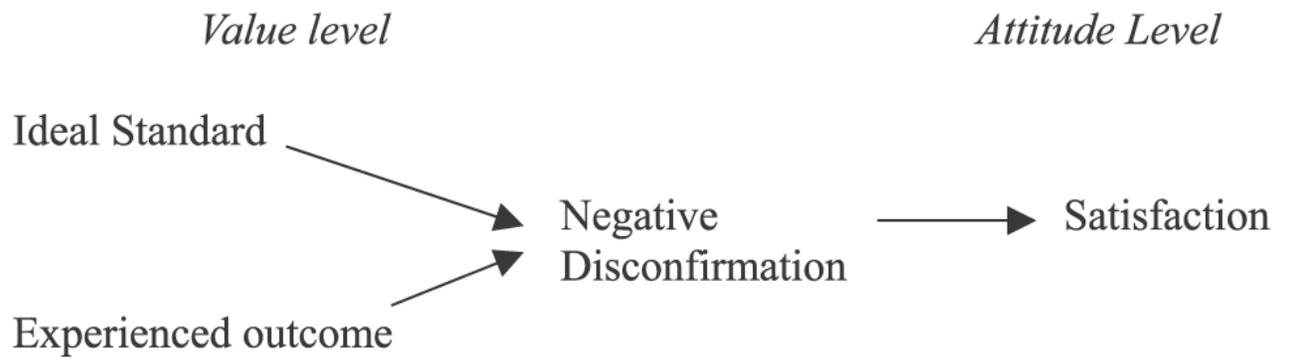


Source: Brogowicz *et al.* (1990)

6. Performance only model (Cronin and Taylor, 1992)

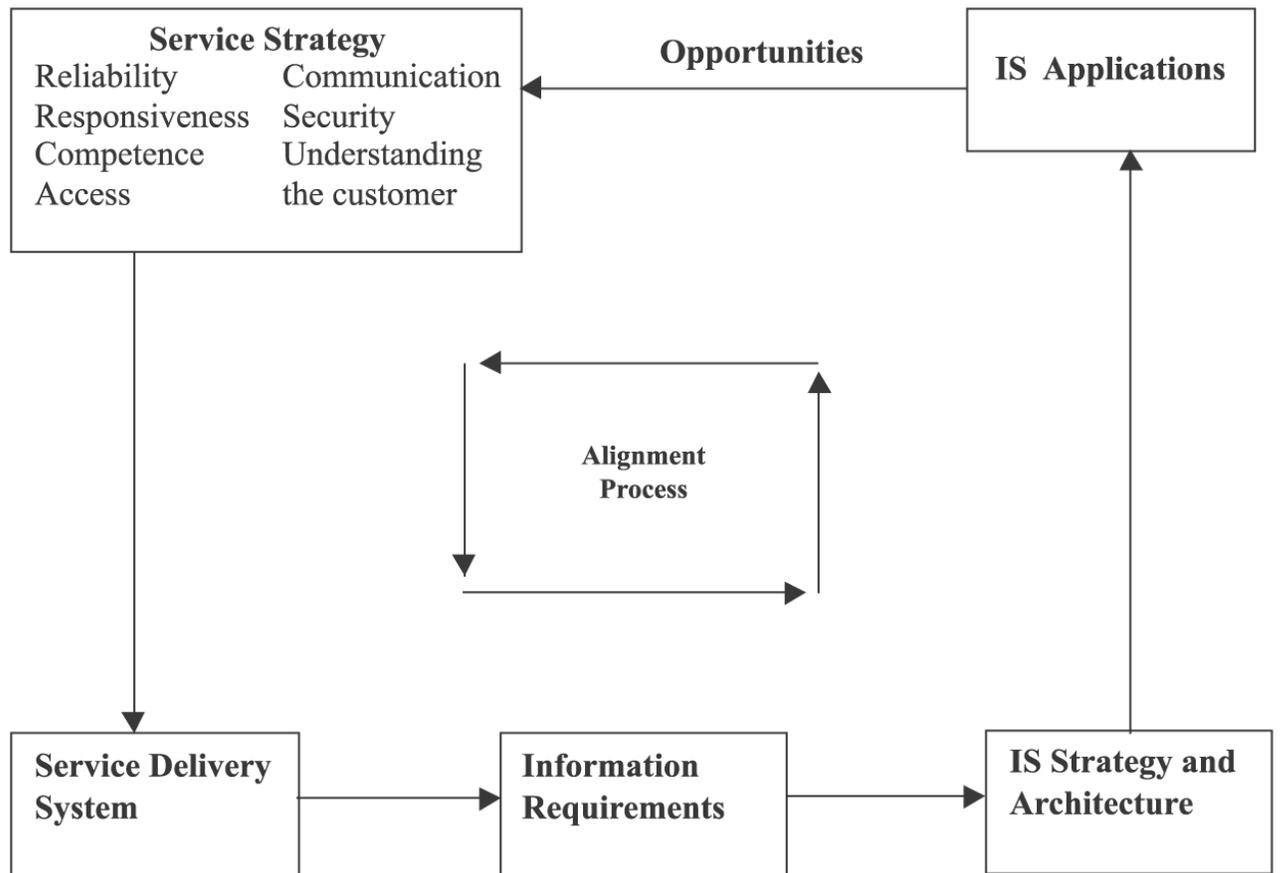
Not available

7. Ideal value model of service quality (Mattsson, 1992)



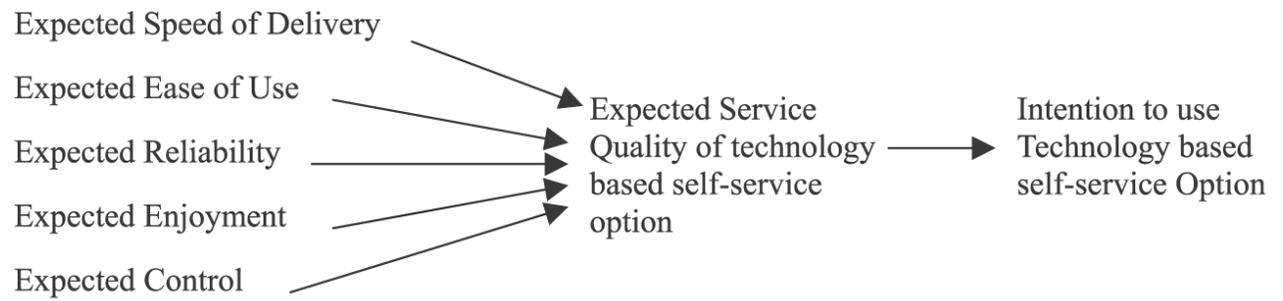
Source: Mattsson (1992)

8. Evaluated performance and normed quality model (Teas, 1993) not available
9. IT alignment model (Berkley and Gupta, 1994)

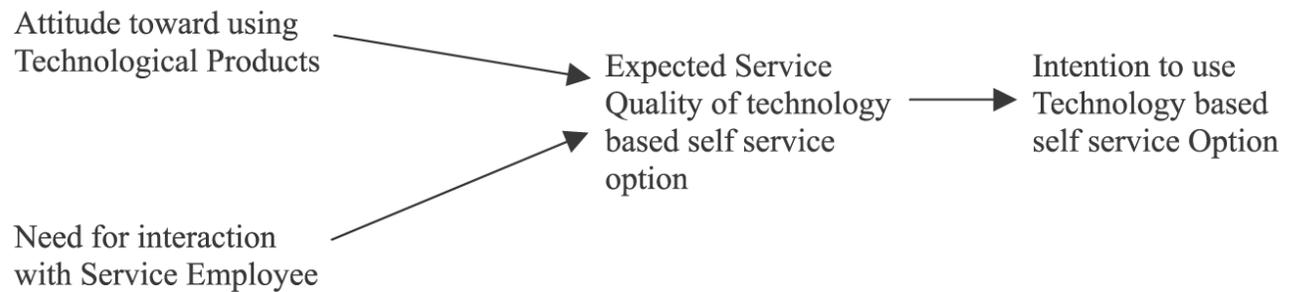


Source: Berkley and Gupta (1994)

10. Attribute and overall affect model (Dabholkar, 1996)



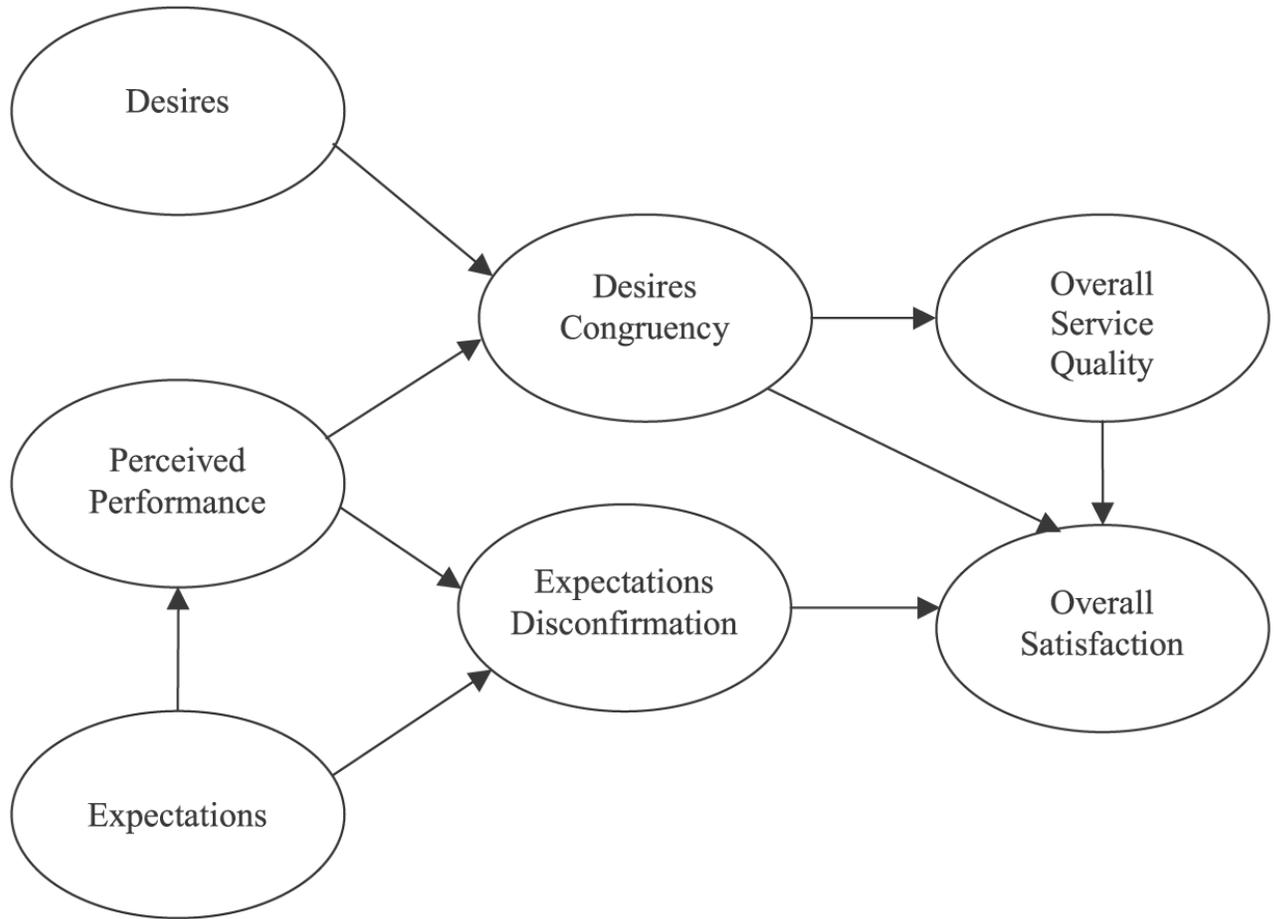
(a) Attribute Based Model



(b) Overall Affect Model

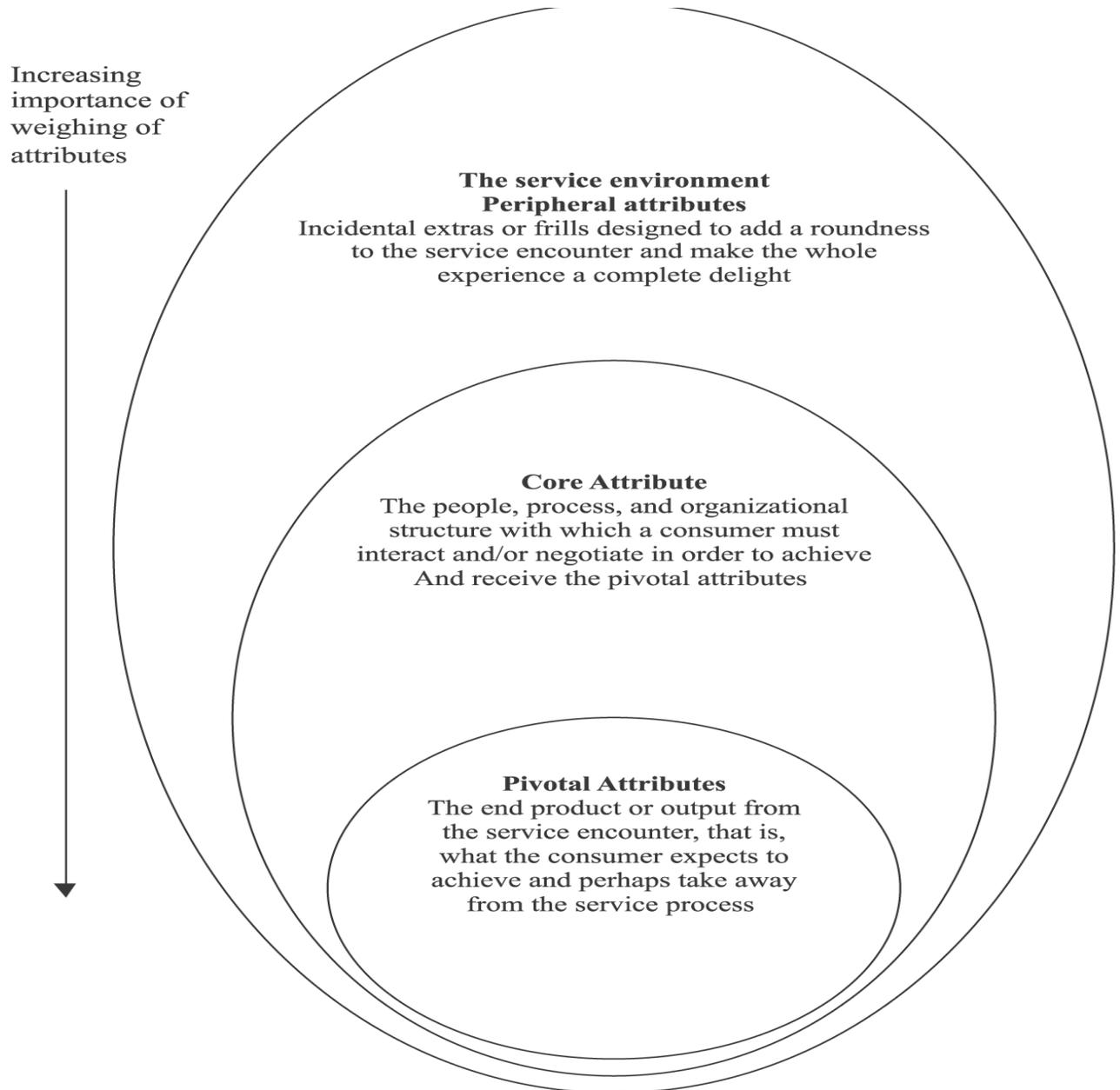
Source: Dabholkar (1996)

11. Model of perceived service quality and satisfaction (Spreng and Mackoy, 1996)



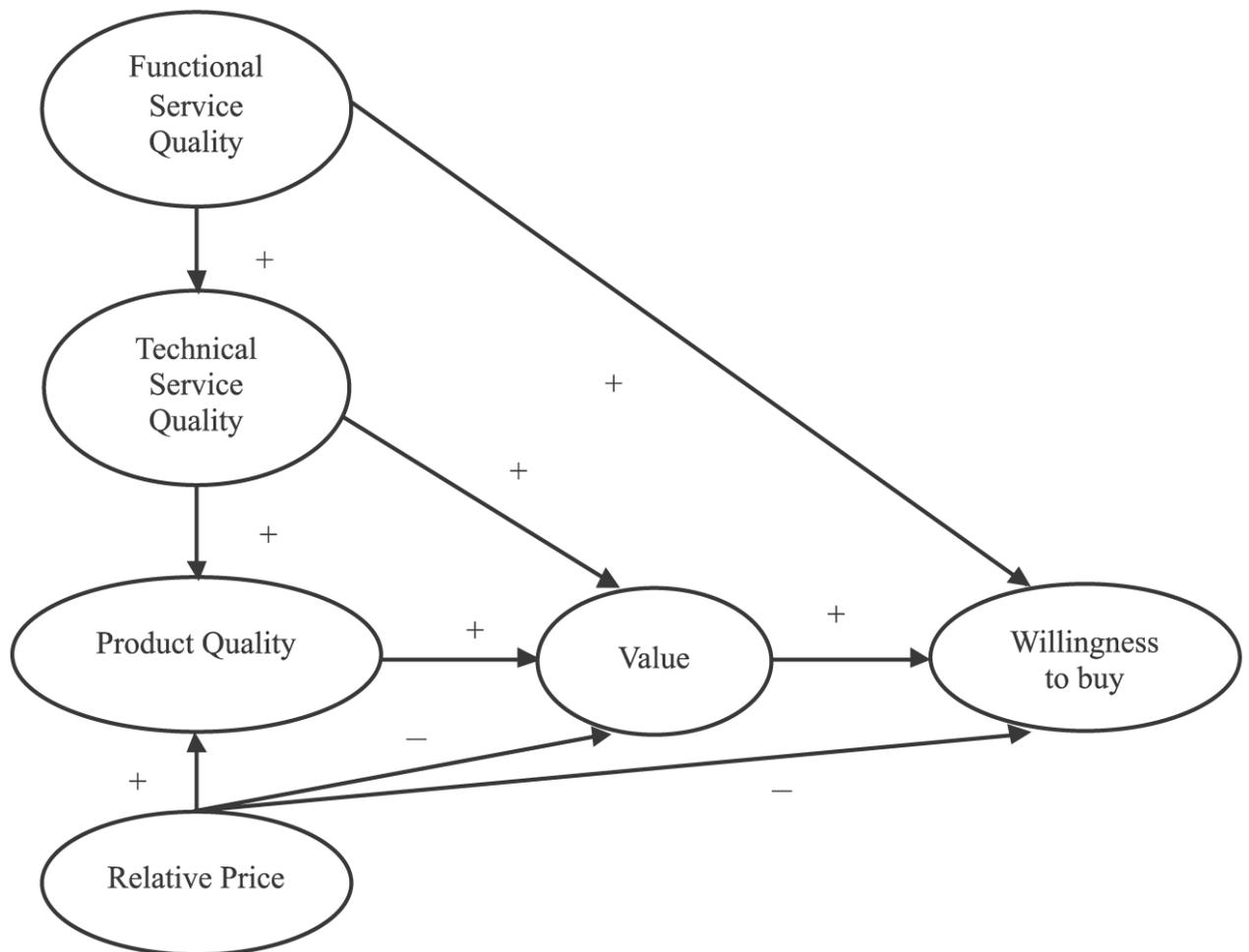
Source: Spreng and Mackoy (1996)

12. PCP attribute model (Philip and Hazlett, 1997)



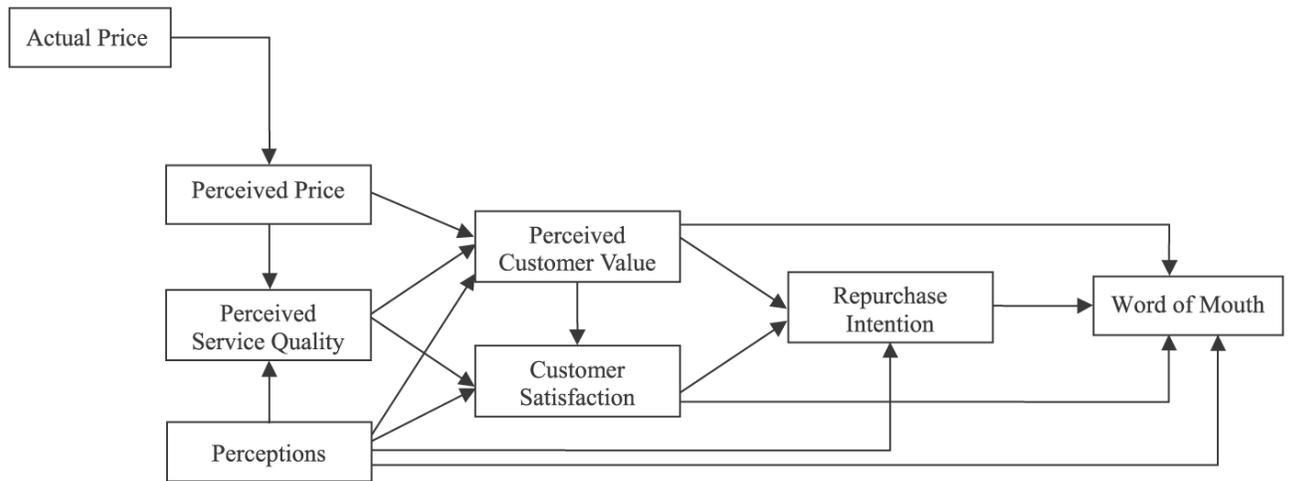
Source: Philip and Hazlett (1997)

13. Retail service quality and perceived value model (Sweeney et al., 1997)

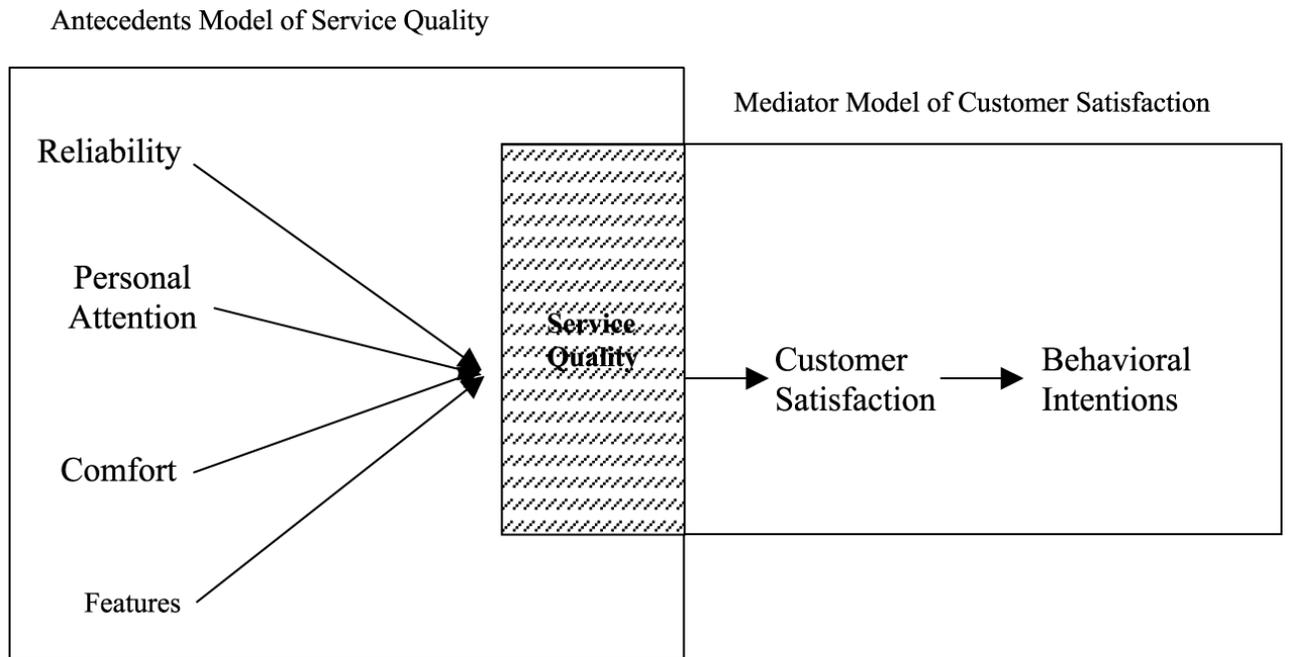


Source: Sweeney *et al.* (1997)

14. Service quality, customer value and customer satisfaction model (Oh, 1999)

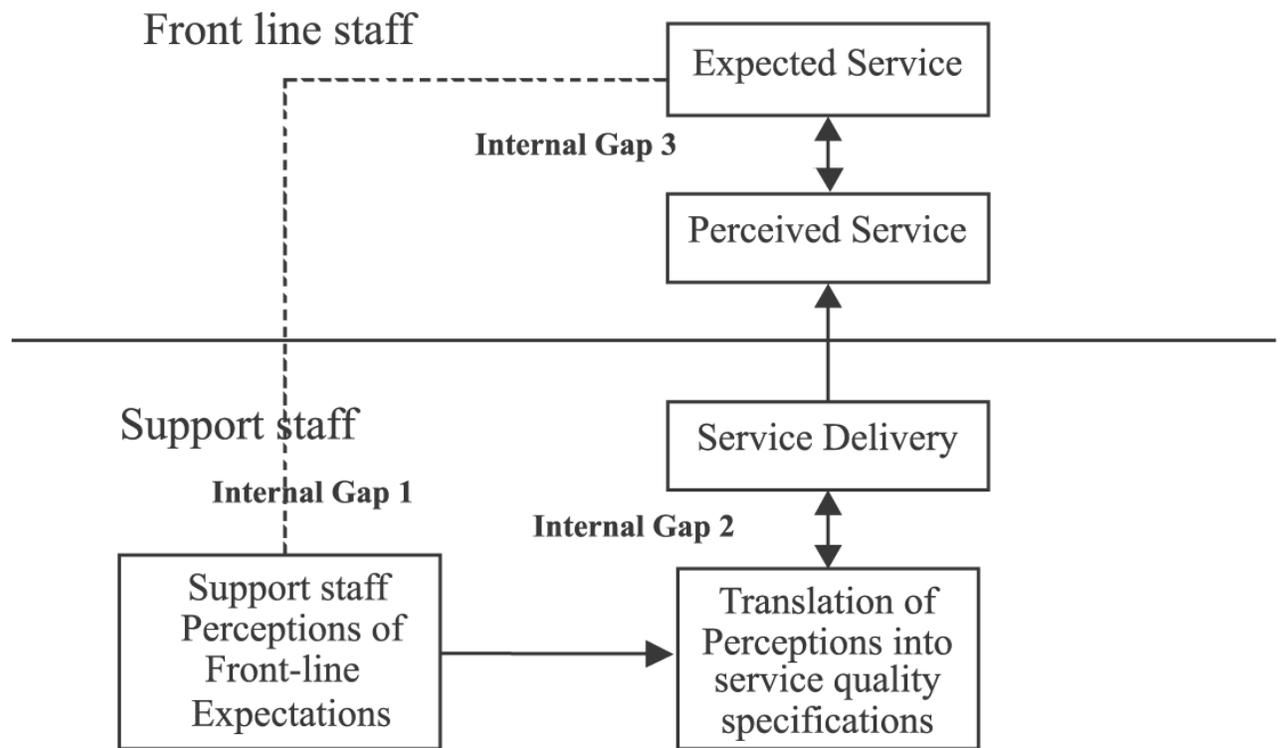


15. Antecedents and mediator model (Dabholkar et al., 2000)



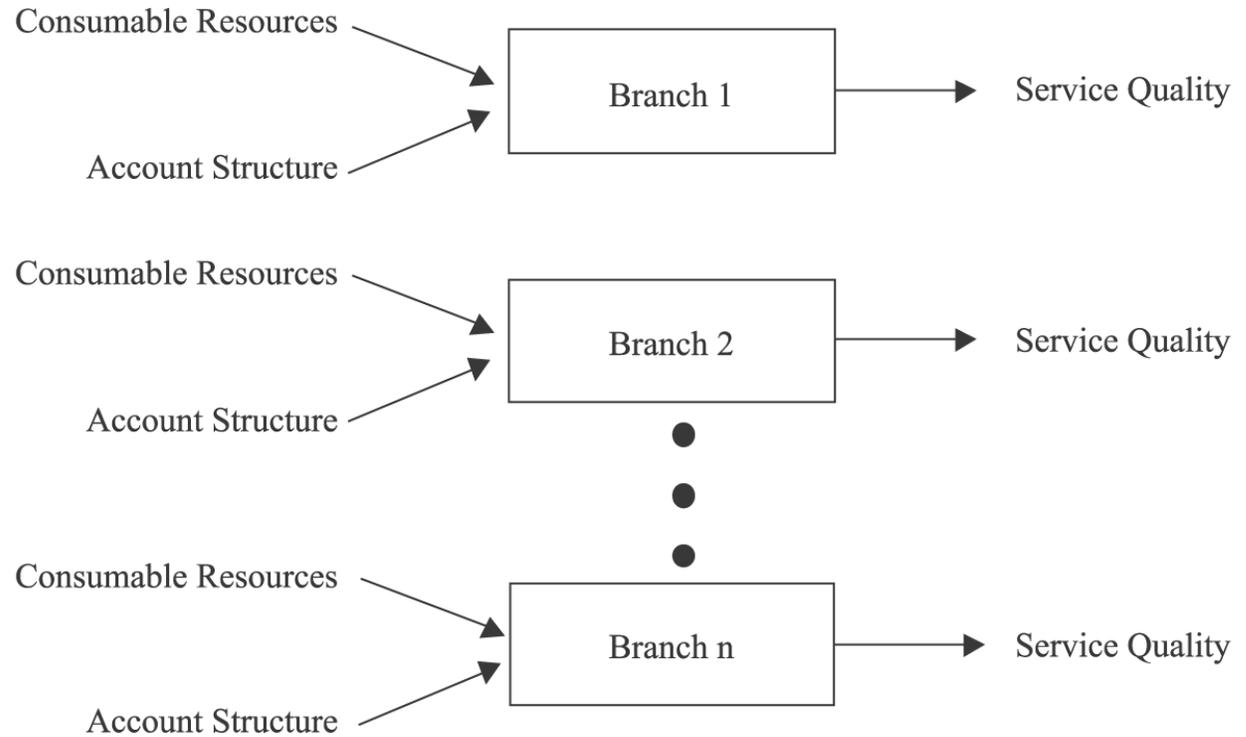
Source: Dabholkar *et al.* (2000)

16. Internal service quality model (Frost and Kumar, 2000)



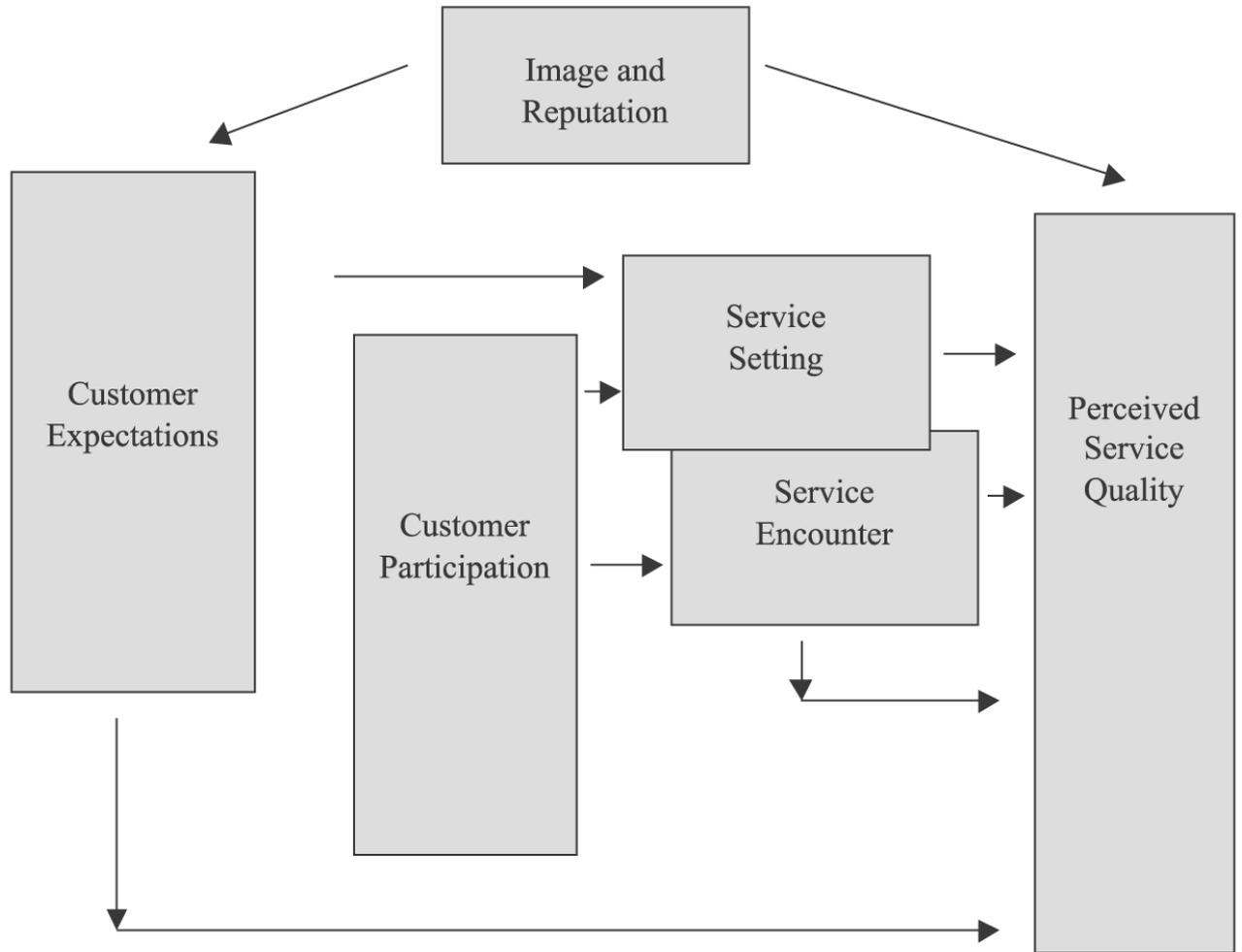
Source: Frost and Kumar (2000)

17. Internal service quality DEA model (Soteriou and Stavrinides, 2000)



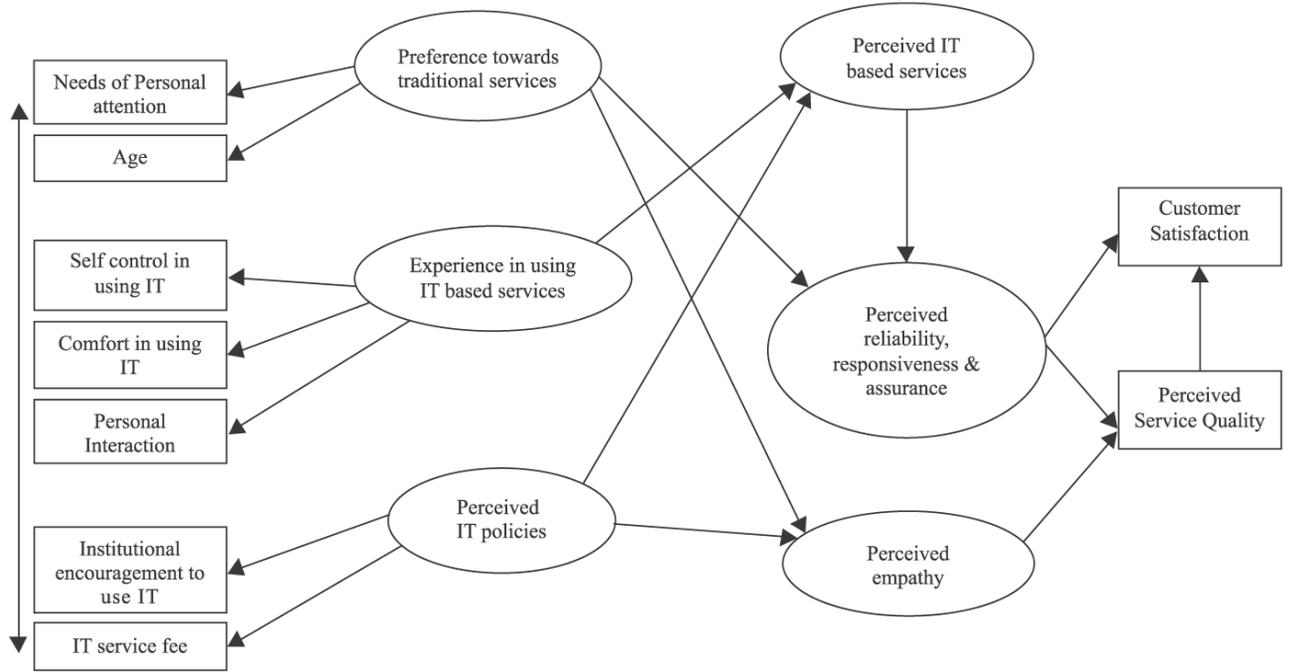
Source: Soteriou and Stavrinides (2000)

18. Internet banking model (Broderick and Vachirapornpuk, 2002)



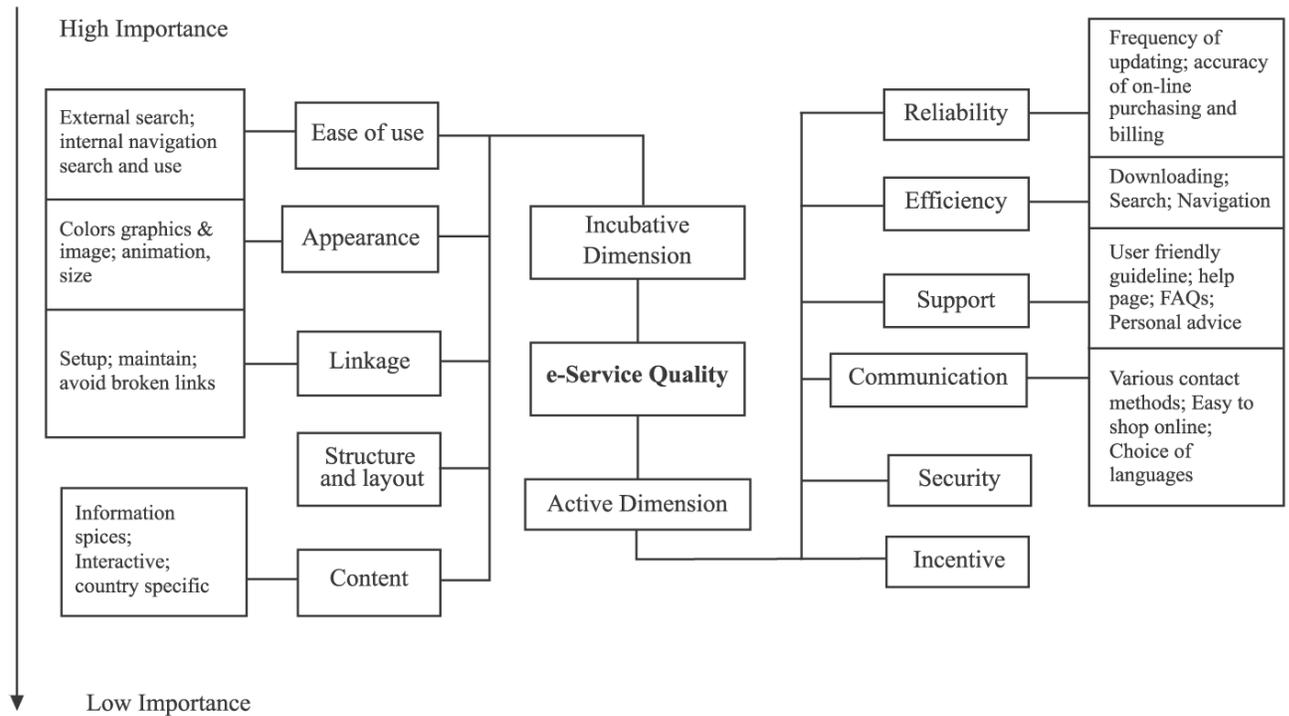
Source: Broderick and Vachirapornpuk (2002)

19. IT-based model (Zhu et al., 2002)



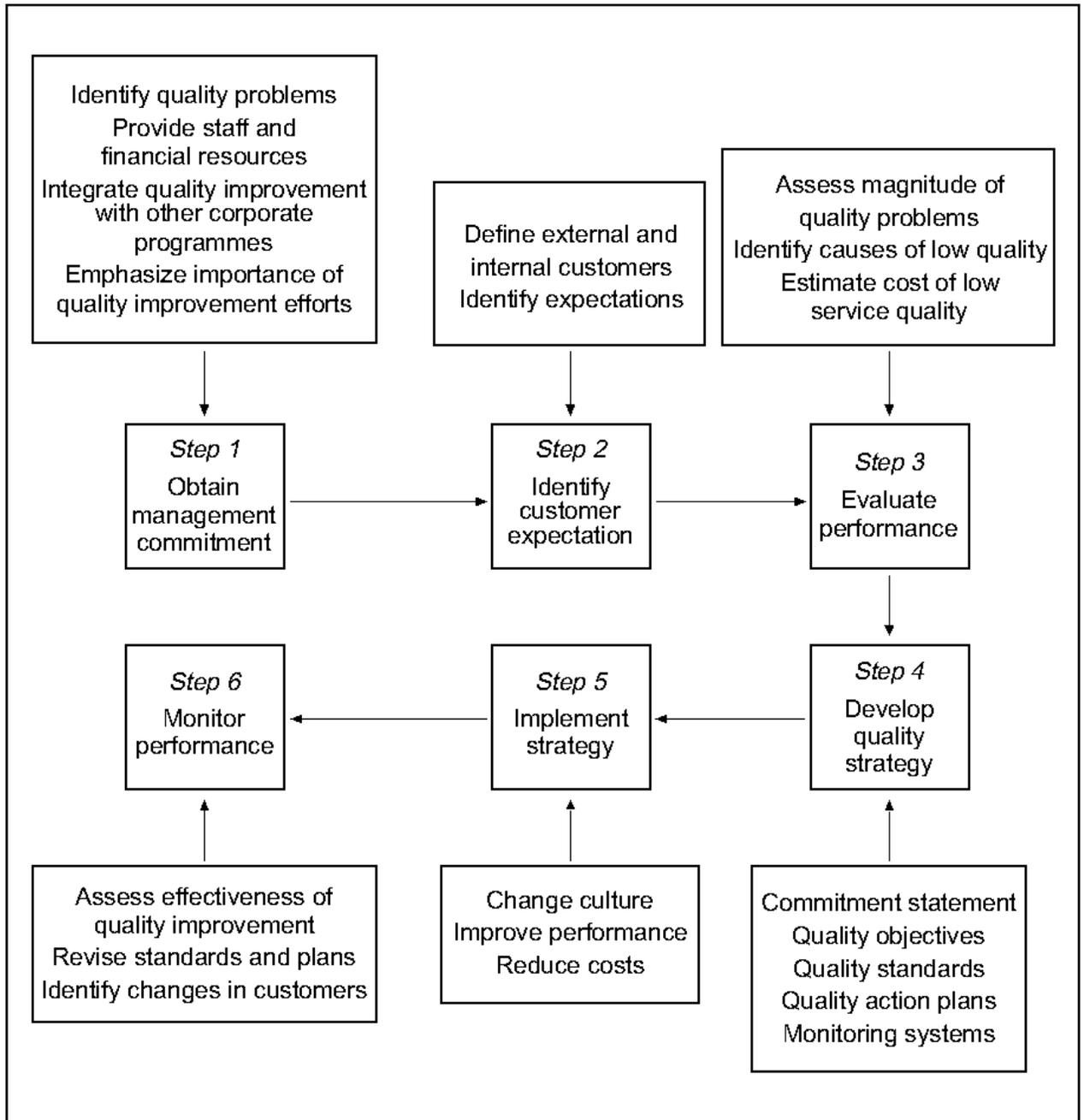
Source: Zhu *et al.* (2002)

20. Model of e-service quality (Santos, 2003)

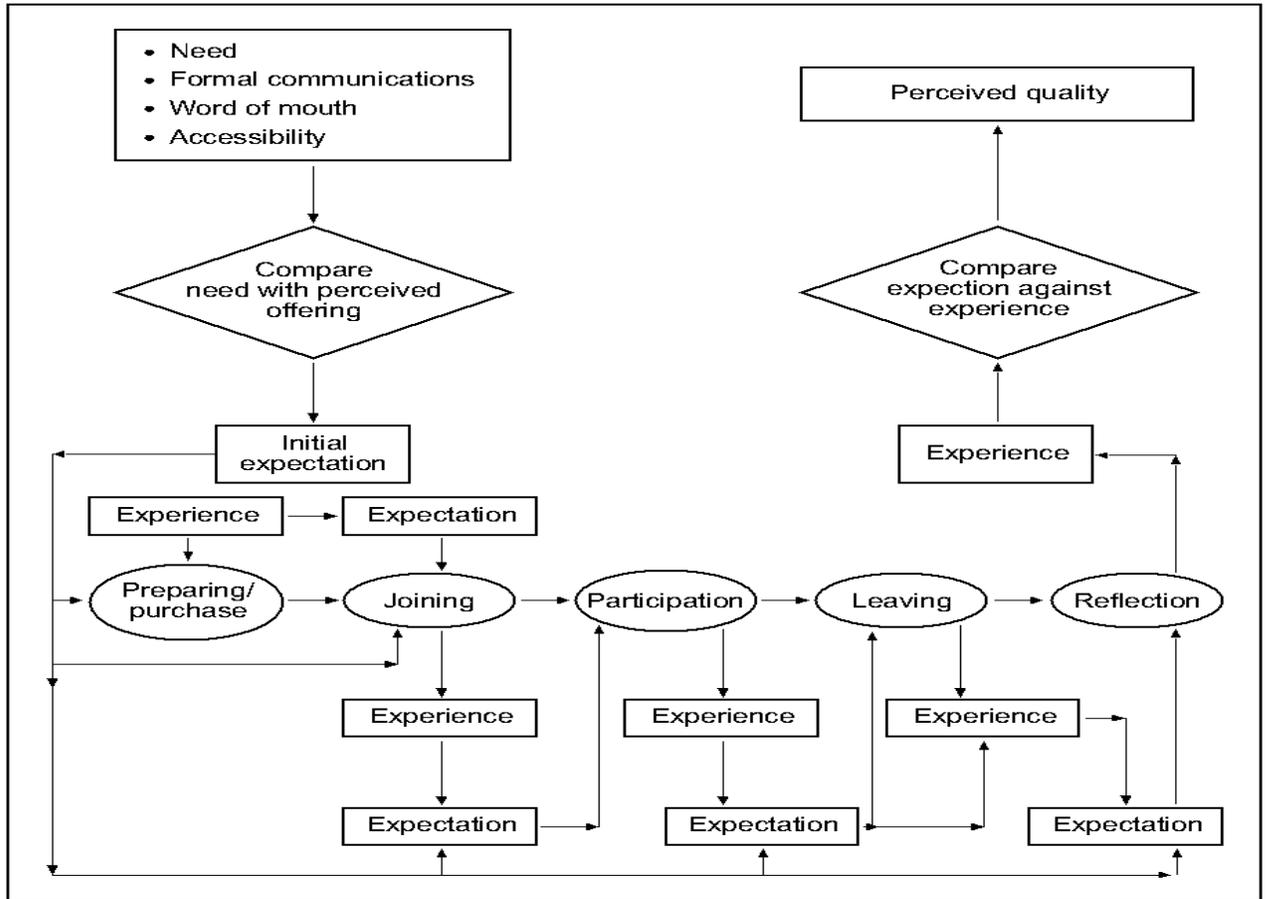


Source: Santos (2003)

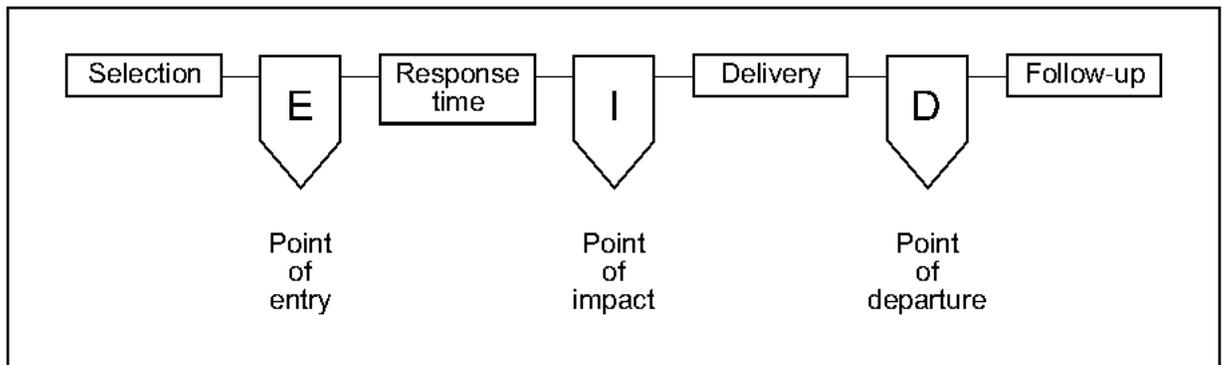
21. Organizational service quality model (Moore)



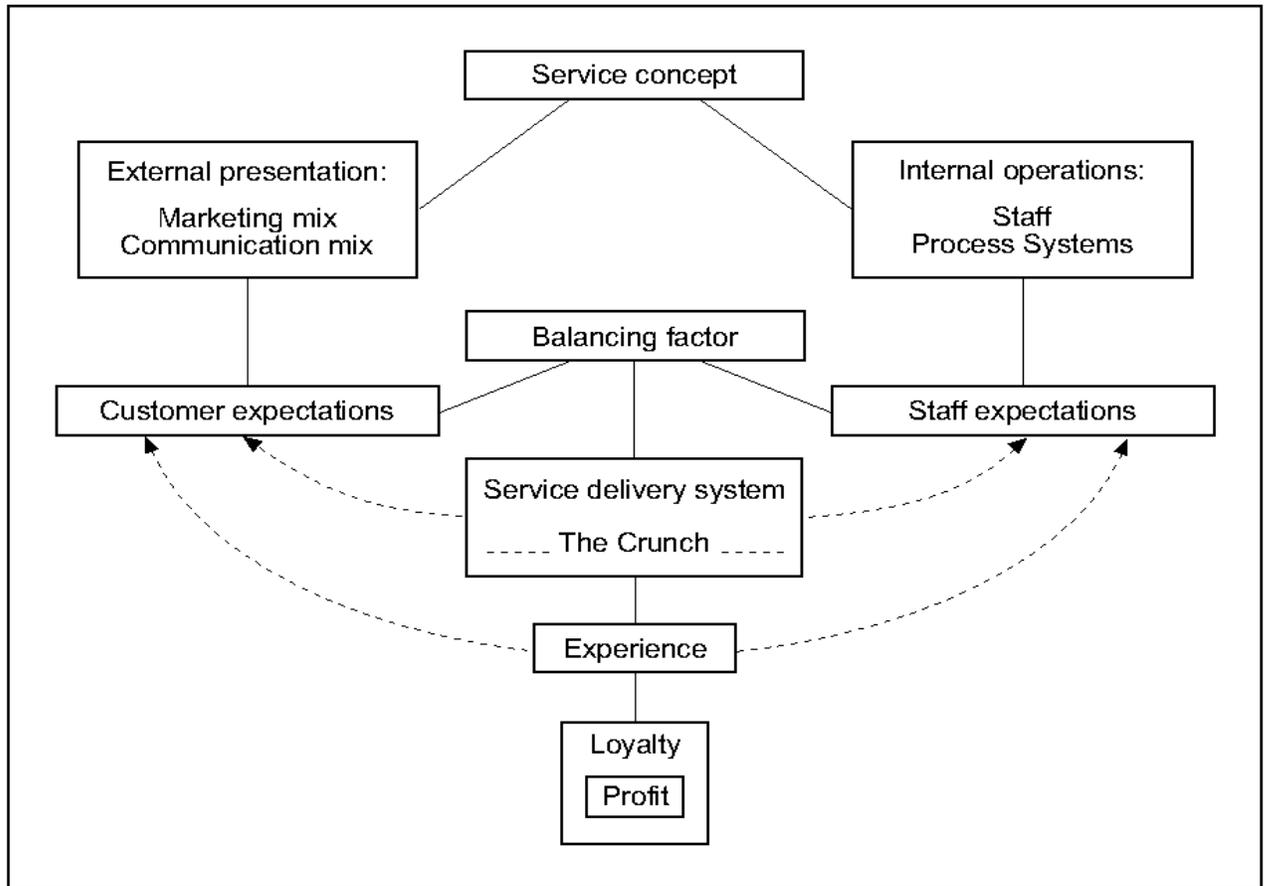
22. Service journey (Nash)



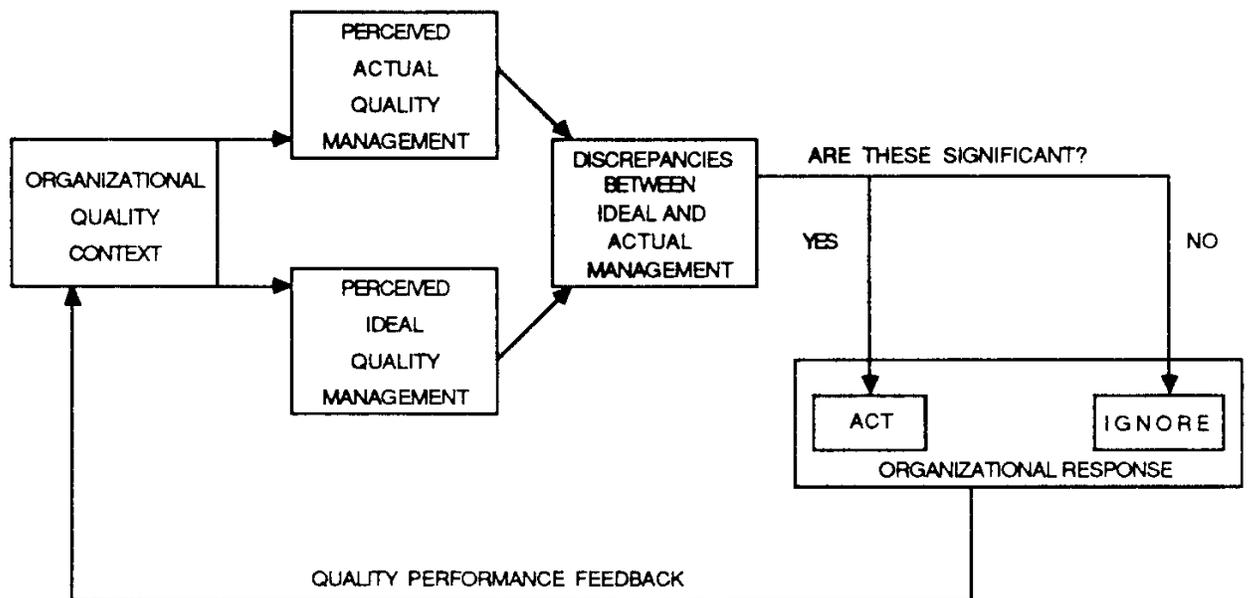
23. The customer processing operations framework (Johnson)



24. Behavioural service quality model (Beddowes et al)



25. System-structural view of quality management(Saraph, Benson, and Schroeder)



APPENDIX 3**NGT chart for rating sub-factors composing each factor affecting the quality of service**

Symbol	Factor/sub-factor Description	R1	R2	R3	R4	R5	Total R
F1 (Factor 1)							
F11 (Sub-factor1)							
F12 (Sub-factor 2)							
F13 (Sub-factor 3)							
F14 (Sub-factor4)							
F1X (Sub-factor X)							

APPENDIX 4

The Measuring Instrument

Facilities services assessment survey

Hello. My name is **Mohsen Isa**, A PhD student at Wayne State University. I am working on my dissertation on the

“Quality Improvement in University Facilities Management Services by using Six-Sigma”

Please, I'd like you to rate the following services for the last two years at WSU. Rating ranges from 0-10. Ratings of 0 to 3 are considered very weak services. Ratings from 4 to 5 are considered weak services. From 6 to 7 are considered good services. 8 is considered very good. Finally, 9 to 10 are considered excellent services.

Thank you for taking the time to complete this survey. This is an academic research, and is not sponsored by the WSU Facility Planning and Management Department (FP&M). Your feedback is important to us in how we can better improve the services provided by (FP&M). This survey should only take about 5 minutes of your time. Your answers will be completely anonymous.

Please specify if you are: a student/employee Or a Building Coordinator

	Service Type	Rating0-10
1	Plumbing and water leaks	
	A- Restroom fixtures	<input type="text"/>
	B- Water fountains	<input type="text"/>
2	Electrical Systems and lighting	
	A- Interior lighting	<input type="text"/>
	B- Exterior lighting	<input type="text"/>
3	Heating, Ventilation, and Air Conditioning (HVAC) including pipe fitting.	
	A- Winter comfort	<input type="text"/>
	B- Summer comfort	<input type="text"/>
4	Elevators	
	A- Operations and reliability	<input type="text"/>
5	Other service	
	A- Door hardware and keys	<input type="text"/>
	B- Ceilings	<input type="text"/>
	C- Floors	<input type="text"/>
	D- Painting	<input type="text"/>

The measuring instrument (p2)

6	Response time	
	A- Maintenance work requests	<input type="checkbox"/>
	B- GIRF work requests (General Improvement Request Form)	<input type="checkbox"/>
7	Satisfaction with work performed	<input type="checkbox"/>

Please provide your comments below, including any recommendations for improvements.

REFERENCES

- Aboelmaged, M. G. (2010). "Six Sigma quality: a structured review and implications for future research." *International Journal of Quality & Reliability Management*, 27(3), 268-317.
- Agus, A., Barker, S., and Kandampully, J. (2007). "An exploratory study of service quality in the Malaysian public service sector." *International Journal of Quality & Reliability Management*, 24(2), 177-190.
- Al-Saggaf, H. A. (1999). "Measuring quality in the service industry." King Fahd University of Petroleum and Minerals.
- Al-Sudairi, A. A. (2005). "Identifying Improvement Opportunities to Maintenance Programs Through Process Mapping." *Emirates Journal for Engineering Research*, 10(2), 69-80.
- Anantatmula, S. P. V. (2004). "Criteria for measuring knowledge management efforts in organizations." George Washington University.
- Andersson, R., Eriksson, H., and Torstensson, H. (2006). "Similarities and differences between TQM, six sigma and lean." *The TQM magazine*, 18(3), 282-296.
- Antony, J. (2004). "Some pros and cons of Six Sigma: an academic perspective." *The TQM magazine*, 16(4), 303-306.
- Antony, J. (2006). "Six sigma for service processes." *Business Process Management Journal*, 12(2), 234-248.
- Antony, J. (2007). "Is Six Sigma a management fad or fact?" *Assembly Automation*, 27(1), 17-19.
- Antony, J. (2007). "What is the role of academic institutions for the future development of Six Sigma?" *International Journal of Productivity and Performance Management*, 57(1), 107-110.

- Antony, J., Antony, F. J., Kumar, M., and Cho, B. R. (2007). "Six sigma in service organisations: Benefits, challenges and difficulties, common myths, empirical observations and success factors." *International Journal of Quality & Reliability Management*, 24(3), 294-311.
- Antony, J., and Banuelas, R. (2002). "Key ingredients for the effective implementation of Six Sigma program." *Measuring Business Excellence*, 6(4), 20-27.
- Arnheiter, E. D., and Maleyeff, J. (2005). "The integration of lean management and Six Sigma." *The TQM magazine*, 17(1), 5-18.
- Beady, S. (Fall 2005). "War on Waste: A study of the application of Six-Sigma DMAIC process improvement methodology." Master of Science, California State University Dominguez Hills
- Dominguez Hills.
- Beady, S. (Fall 2005). "Waste On War." Master in Quality Assurance, California State University Dominguez Hills.
- Berkley, B. J., and Gupta, A. (1994). "Improving service quality with information technology." *International Journal of Information Management*, 14(2), 109-121.
- Berry, L. L., Zeithaml, V. A., and Parasuraman, A. (1990). "Five imperatives for improving service quality." *Sloan Management Review*, 31(4), 29-38.
- Best, R., Langston, C., and De Valence, G. (2003). "Workplace strategies and facilities management: building in value."
- Biazzo, S. (2002). "Process mapping techniques and organisational analysis: Lessons from sociotechnical system theory." *Business Process Management Journal*, 8(1), 42-52.
- Bitner, M. J. (1990). "Evaluating service encounters: the effects of physical surroundings and employee responses." *The Journal of Marketing*, 69-82.

- Brady, M. K., Cronin, J. J., and Brand, R. R. (2002). "Performance-only measurement of service quality: a replication and extension." *Journal of Business Research*, 55(1), 17-31.
- Brady, M. K., and Cronin Jr, J. J. (2001). "Some new thoughts on conceptualizing perceived service quality: a hierarchical approach." *The Journal of Marketing*, 34-49.
- Broderick, A. J., and Vachirapornpuk, S. (2002). "Service quality in internet banking: the importance of customer role." *Marketing Intelligence & Planning*, 20(6), 327-335.
- Brogowicz, A. A., Delene, L. M., and Lyth, D. M. (1990). "A synthesised service quality model with managerial implications." *International Journal of Service Industry Management*, 1(1), 27-45.
- Candlin, D., and Day, P. "Introducing TQM in a service industry." THE INSTITUTE OF QUALITY ASSURANCE, 132-132.
- Carney, O., McIntosh, J., and Worth, A. (2008). "The use of the nominal group technique in research with community nurses." *Journal of Advanced Nursing*, 23(5), 1024-1029.
- Chakrabarty, A., and Tan, K. C. (2007). "The current state of six sigma application in services." *Managing Service Quality*, 17(2), 194-208.
- Chang, C. M., and Su, C. T. (2007). "Service process design and/or redesign by fusing the powers of Design for Six Sigma and Lean." *International Journal of Six Sigma and Competitive Advantage*, 3(2), 171-191.
- Chua, R. C. H. (2001). "What you need to know about Six Sigma." *Productivity Digest*(December), 37-44.
- Chuang, P. T. (2007). "Combining service blueprint and FMEA for service design." *The Service Industries Journal*, 27(2), 91-104.

- Craven, E. D., Clark, J., Cramer, M., Corwin MD, S. J., and Cooper MD, M. R. (2006). "NewYork-Presbyterian Hospital uses Six Sigma to build a culture of quality and innovation." *Journal of Organizational Excellence*, 25(4), 11-19.
- Cronin Jr, J. J., and Taylor, S. A. (1992). "Measuring service quality: a reexamination and extension." *The Journal of Marketing*, 55-68.
- Dabholkar, P. A. (1996). "Consumer evaluations of new technology-based self-service options: an investigation of alternative models of service quality." *International Journal of research in Marketing*, 13(1), 29-51.
- Dabholkar, P. A., Shepherd, C. D., and Thorpe, D. I. (2000). "A comprehensive framework for service quality: an investigation of critical conceptual and measurement issues through a longitudinal study." *Journal of retailing*, 76(2), 139-173.
- Davison, L., and Al-Shaghana, K. (2007). "The link between six sigma and quality culture—an empirical study." *Total Quality Management & Business Excellence*, 18(3), 249-265.
- Dean Jr, J. W., and Bowen, D. E. (1994). "Management theory and total quality: improving research and practice through theory development." *Academy of management review*, 392-418.
- Deip, P., Thesen, A., Motiwalla, J., and Seshardi, N. "Nominal Group Technique."
- Frings, G. W., and Grant, L. (2005). "Who moved my Sigma... Effective implementation of the Six Sigma methodology to hospitals." *Quality and Reliability Engineering International*, 21(3), 311-328.
- Frost, F. A., and Kumar, M. (2000). "INTSERVQUAL—an internal adaptation of the GAP model in a large service organisation." *Journal of Services Marketing*, 14(5), 358-377.

- Gale, B. (1994). "Customer satisfaction—relative to competitors—is where it's at. Strong evidence that superior quality drives the bottom line and shareholder value." *Marketing and Research Today*, 22(1), 39-53.
- Gale, B. T., and Klavans, R. (1985). "Formulating a quality improvement strategy." *Journal of business strategy*, 5(3), 21-32.
- Ghobadian, A., Speller, S., and Jones, M. (1994). "Service quality: concepts and models." *International Journal of Quality & Reliability Management*, 11(9), 43-66.
- Gronroos, C. (1993). "A service quality model and its marketing implications." *European Journal of marketing*, 18(4), 36-44.
- Harry, M., and Schroeder, R. (2006). *Six sigma: the breakthrough management strategy revolutionizing the world's top corporations*, Crown Business.
- Haywood-Farmer, J. (1988). "A conceptual model of service quality." *International Journal of Operations & Production Management*, 8(6), 19-29.
- Hernon, P., and Dugan, R. E. (2002). *An action plan for outcomes assessment in your library*, Amer Library Assn.
- Hernon, P., and Nitecki, D. A. (2001). "Service quality: A concept not fully explored." *Library Trends*, 49(4), 687-708.
- Hernon, P., and Whitman, J. R. (2001). *Delivering satisfaction and service quality: A customer-based approach for libraries*, Amer Library Assn.
- Hope, C., and Mühlemann, A. (1997). *Service operations management: strategy, design, and delivery*, Prentice Hall London.
- Jayyousi, K. W. (2001). "Development and implementation of a service quality rating system for facilities management in urban public school districts."

- Kalman, H. K. (2002). "Process mapping: Tools, techniques, & critical success factors." *Performance Improvement Quarterly*, 15(4), 57-73.
- Kim, Y. (2003). "Measuring and Assessing Internet Service Quality at Public Libraries." PhD, University of Wisconsin-madison.
- Kumar, M. (2007). "Critical success factors and hurdles to Six Sigma implementation: the case of a UK manufacturing SME." *International Journal of Six Sigma and Competitive Advantage*, 3(4), 333-351.
- Kwak, Y. H., and Anbari, F. T. (2006). "Benefits, obstacles, and future of six sigma approach." *Technovation*, 26(5), 708-715.
- Lee, K.-L. (2002). "Critical Success Factors of Six Sigma Implementation and the Impact on Operations Performance." Doctor of Engineering Dissertation, Cleveland State University.
- Lehtinen, U., and Lehtinen, J. R. (1991). "Two approaches to service quality dimensions." *Service Industries Journal*, 11(3), 287-303.
- Lewis, R. C., and Booms, B. H. (1983). "The marketing aspects of service quality." *Emerging perspectives on services marketing*, 65(4), 99-107.
- Lloyd-Jones, G., Fowell, S., and Bligh, J. G. (1999). "The use of the nominal group technique as an evaluative tool in medical undergraduate education." *MEDICAL EDUCATION-OXFORD-*, 33, 8-13.
- Mattsson, J. (1992). "A service quality model based on an ideal value standard." *International Journal of Service Industry Management*, 3(3), 18-33.
- McLennan, P. (2004). "Service operations management as a conceptual framework for facility management." *Facilities*, 22(13/14), 344-348.
- Miller, W. J. (1997). "Development and Testing of A Quality Management Impact Model." Doctor of Philosophy, Georgia State University.

- Nakhai, B., and Neves, J. S. (2009). "The challenges of six sigma in improving service quality." *International Journal of Quality & Reliability Management*, 26(7), 663-684.
- Näslund, D. (2008). "Lean, six sigma and lean sigma: fads or real process improvement methods?" *Business Process Management Journal*, 14(3), 269-287.
- Oh, H. (1999). "Service quality, customer satisfaction, and customer value: A holistic perspective." *International Journal of Hospitality Management*, 18, 67-82.
- Parasuraman, A., Zeithaml, V. A., and Berry, L. (2004). "SERVQUAL: a multiple-item scale for measuring consumer perceptions of service quality." *Retailing: Crit Concepts Bk2*, 64(1), 140.
- Parasuraman, A., Zeithaml, V. A., and Berry, L. L. (1985). "A conceptual model of service quality and its implications for future research." *The Journal of Marketing*, 41-50.
- Parasuraman, A., Zeithaml, V. A., and Berry, L. L. (1988). "Servqual." *Journal of retailing*, 64(1), 12-40.
- Parasuraman, A., Zeithaml, V. A., and Berry, L. L. (1990). "Delivering quality service: Balancing customer perceptions and expectations." *Delivering quality service: Balancing customer perceptions and expectations*.
- Philip, G., and Hazlett, S.-A. (1997). "The measurement of service quality: a new PCP attributes model." *International Journal of Quality & Reliability Management*, 14(3), 260-286.
- Raisinghani, M. S., Ette, H., Pierce, R., Cannon, G., and Daripaly, P. (2005). "Six Sigma: concepts, tools, and applications." *Industrial Management & Data Systems*, 105(4), 491-505.
- Rotondaro, R. G., and De Oliveira, C. L. (2001). "Using failure mode effect analysis (FMEA) to improve service quality service operations management."

- Samson, D., and Parker, R. (1994). "Service quality: the gap in the Australian consulting engineering industry." *International Journal of Quality & Reliability Management*, 11(7), 60-76.
- Santos, J. (2003). "E-service quality: a model of virtual service quality dimensions." *Managing Service Quality*, 13(3), 233-246.
- Saraph, J. V., Benson, P. G., and Schroeder, R. G. (1989). "An instrument for measuring the critical factors of quality management." *Decision sciences*, 20(4), 810-829.
- Schroeder, R. G., Linderman, K., Liedtke, C., and Choo, A. S. (2008). "Six Sigma: Definition and underlying theory." *Journal of Operations Management*, 26(4), 536-554.
- Seth, N., Deshmukh, S., and Vrat, P. (2005). "Service quality models: a review." *International Journal of Quality & Reliability Management*, 22(9), 913-949.
- Sitkin, S. B., Sutcliffe, K. M., and Schroeder, R. G. (1994). "Distinguishing control from learning in total quality management: a contingency perspective." *Academy of management review*, 537-564.
- Sokovic, M., Pavletic, D., and Fakin, S. (2005). "Application of Six Sigma methodology for process design." *Journal of Materials Processing Technology*, 162, 777-783.
- Soteriou, A. C., and Stavrinides, Y. (2000). "An internal customer service quality data envelopment analysis model for bank branches." *International Journal of Bank Marketing*, 18(5), 246-252.
- Spath, P. L. (2003). "Using failure mode and effects analysis to improve patient safety." *AoRn*, 78(1), 15-37.
- Spreng, R. A., and Mackoy, R. D. (1996). "An empirical examination of a model of perceived service quality and satisfaction." *Journal of retailing*, 72(2), 201-214.
- Stamatis, D. H. (2003). "Six Sigma And Beyond " *Design for Six Sigma*, St. Lucie Press.

- Su, C. T., Chiang, T. L., and Chang, C. M. (2006). "Improving service quality by capitalising on an integrated Lean Six Sigma methodology." *International Journal of Six Sigma and Competitive Advantage*, 2(1), 1-22.
- Sweeney, J. C., Soutar, G. N., and Johnson, L. W. (1997). "Retail service quality and perceived value: A comparison of two models." *Journal of Retailing and Consumer Services*, 4(1), 39-48.
- Teas, R. K. (1993). "Expectations, performance evaluation, and consumers' perceptions of quality." *The Journal of Marketing*, 18-34.
- Thomas Pyzdek, P. K. (2010). *The Six Sigma Handbook*, McGraw-Hill.
- Usilaner, B. "What's the bottom line payback for TQM?".
- Vermilion, D. (2007). "Improving Customer Satisfaction in the Service Industry using Failure Mode & Effects Analysis."
- Wong, Y. P. (2007). "Facility management benchmarking: measuring performances using multi-attribute decision tools."
- Zeithaml, V. A., Berry, L. L., and Parasuraman, A. (1988). "Communication and control processes in the delivery of service quality." *The Journal of Marketing*, 35-48.
- Zeithaml, V. A., Berry, L. L., and Parasuraman, A. (1993). "The nature and determinants of customer expectations of service." *Journal of the academy of Marketing Science*, 21(1), 1-12.
- Zeithaml, V. A., Parasuraman, A., and Berry, L. L. (1985). "Problems and strategies in services marketing." *The Journal of Marketing*, 33-46.
- Zhu, F. X., Wymer, W., and Chen, I. (2002). "IT-based services and service quality in consumer banking." *International Journal of Service Industry Management*, 13(1), 69-90.

ABSTRACT**QUALITY MODELING AND IMPROVEMENT OF UNIVERSITY FACILITIES SERVICES USING SIX-SIGMA – A CASE STUDY ON WAYNE STATE UNIVERSITY FPM SERVICES**

by

MOHSEN FARAG MOHAMED ISA**August 2013****Advisor:** Mumtaz A. Usmen, PhD, PE**Major:** Civil Engineering**Degree:** Doctor of Philosophy

Literature survey shows that there is no published information concerning the investigation and/or evaluation (by the customer) of the services provided by universities facilities management units, and no previous research was done to measure and evaluate such services to address, identify, and model the critical factors affecting quality.

This research work proposed a service quality model relating factors affecting quality of services provided by facility management units at higher educational institutions to the customer perception of service quality. It also examined the use of the Six-Sigma DMAIC methodology as an improvement strategy for services provided by facility management units at higher education institutions. Based on the service quality model developed and using a tool box of Six-Sigma methods, a case study at Wayne State University (WSU) was performed to examine and improve the facilities services provided by WSU facility planning and management department. A large scale

survey was used as an instrument to measure customer satisfaction with the services delivered. The customer ratings for services showed that some service categories needed improvement. The initial service quality model was devised by surveying the literature, as well as conducting in depth interviews with people in the FM field at different levels of management hierarchy. The model was reviewed, refined, modified, and validated by conducting a Nominal Group Technique session, which led to a final proposed service quality model for higher education institutions.

A set of Six-Sigma tools and techniques were utilized through different phases of the service process improvement, and to conduct an improvement process for the selected service category of General Improvement Request Form (GIRF). These tools and techniques included process map, Pareto charts, cause and effect matrix, and Failure Mode and Effect Analysis (FMEA). A modified process map was developed to avoid bottlenecks, and eliminate non-value adding activities. Critical tasks affecting process outputs were identified through Cause and Effect Matrix, and all Key Process Input Variables (KPIVs) were rank ordered with respect to the importance of the output variable. Potential failure modes, failure effects, and causes of failure were identified through FMEA. A risk Priority Number (RPN) was assigned for each potential failure mode, and recommended actions to eliminate and control failure modes were developed in this process.

AUTOBIOGRAPHICAL STATEMENT

Mohsen Farag Mohamed Isa is a Libyan citizen who lived in Tripoli-Libya. He got his B.Sc in Materials and Metallurgical Engineering Department from Tripoli University (1990). He worked in the field of materials engineering in Tripoli-Libya from 1991-2003. He got his Master degree in Engineering Management from Tripoli University (2000). His master thesis title was “Solving Problems in Libyan Manufacturing Companies by the Application of Quality Management System According to the ISO 9000 Standard and Improvement Journey”. Then he transferred to work as a lecturer at the Mechanical Engineering Department – Faculty of Engineering, Tripoli University on 2003. He got a scholarship to get a PhD, and he started his PhD career in 2007 at Wayne State University- College of Engineering, Civil Engineering Department (USA). He is scheduled to graduate in 2013, his PhD dissertation title is: “Quality Modeling and Improvement of University Facilities Services Using Six-Sigma – A Case Study on Wayne State University FPM Services”. He married to Hunida Husain “an ophthalmologist” in October 2010.