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

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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 Usmen 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 research 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 Relationship between Quality of Service and Organizational Performance ........ 17

    2.3.2 Service Industry Characteristics vs. Manufacturing ............................................. 18

    2.3.3 Differences in the Evaluation of Product Quality vs. Service Quality ............... 19

    2.3.4 Obstacles Facing Service Quality Improvements .............................................. 20

    2.3.5 Customer Satisfaction vs. Service Quality ......................................................... 21
2.4 Six-Sigma and Service Quality ................................................................. 22
  2.4.1 Six-Sigma in the Service Industry ......................................................... 24
  2.4.2 Tools and Techniques for Service Process Performance Improvement ....... 25
     2.4.2.1 Process Map .................................................................................. 26
     2.4.2.2 Cause and Effect Matrix (C&E) Analysis ......................................... 28
     2.4.2.3 Voice Of Customer (VOC) ............................................................... 29
     2.4.2.4 Failure Mode and Effect Analysis (FMEA) ....................................... 30
  2.4.3 Critical Success Factors of Six-Sigma ................................................. 32
  2.4.4 Differences Between Six-Sigma and Other Quality Initiatives ............... 34
  2.4.5 Challenges for Implementation of Six-Sigma ........................................ 35

2.5 Dimensions and Determinants of Service Quality and Quality Models .......... 37
  2.5.1 Importance of Determinants ................................................................. 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 Service Production Component .......................................................... 49
      3.1.1.1 Management Commitment ............................................................ 49
      3.1.1.2 Service Design ............................................................................. 50
      3.1.1.3 Tools and Equipment to Perform Service ....................................... 50
      3.1.1.4 IT Involvement ............................................................................. 51
   3.1.2 Service Delivery Component .............................................................. 51
      3.1.2.1 Employee’s Role ........................................................................... 51
3.1.2.2 Physical Facilities ............................................................................................................. 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 Rating Scale ....................................................................................................................... 62

3.4 Analysis by using Six-Sigma ................................................................................................ 63

3.4.1. Define Phase ..................................................................................................................... 65

3.4.2. Measure Phase ............................................................................................................... 65

3.4.3. Analyze Phase ............................................................................................................... 66

3.4.4. Improve Phase .............................................................................................................. 66

3.4.5 Control Phase ................................................................................................................... 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 Process Map ..................................................................................................................... 67

3.5.2 Cause and Effect (C&E) Matrix .................................................................................... 68

3.5.3 Failure Mode and Effect Analysis (FMEA) ................................................................... 70

CHAPTER 4 RESULTS AND DISCUSSION .................................................................................. 73

4.1 Quality Modeling ................................................................................................................ 73

4.1.1 Observations from the Survey Results .......................................................................... 74

4.1.1.1 Service Categories Histogram ................................................................................ 75

4.1.1.1.1 Mean Service Category Rating for Services .................................................. 75

4.1.1.2 Histograms of each Service Quality Rating .............................................................. 76

4.1.1.2 Coefficient of Variation Histogram (CV) ................................................................. 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-process
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 flowchart ...... 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-process …………………160

Figure 40: Pareto chart prioritizing the most impact hazardous on the process output for the
cost estimate, design, and bidding (CEPDB) GIRF sub-process …………………169
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 thorough 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 device 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.


10. Parking and transportation services.
Table 1: Common facility services in universities

<table>
<thead>
<tr>
<th>Services</th>
<th>WSU</th>
<th>FPM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Installation and repair services</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Service Category</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>Plumbing</td>
<td>Providing all plumbing works related to building renovations</td>
<td></td>
</tr>
<tr>
<td>Carpentry</td>
<td>All carpentry related works for building renovations</td>
<td></td>
</tr>
<tr>
<td>Painting</td>
<td>They provide the following services: spray painting, furniture refinishing, graffiti removal, electrostatic painting, and exterior and interior painting</td>
<td></td>
</tr>
<tr>
<td>Cabinetry</td>
<td>A shop produces different types of furniture</td>
<td></td>
</tr>
<tr>
<td>Furniture repair</td>
<td>Wood furniture repair, reupholstery services, sports and therapy equipment, transportation materials, auditorium seating</td>
<td></td>
</tr>
<tr>
<td>Signage</td>
<td>Providing signage and window films</td>
<td></td>
</tr>
<tr>
<td>Glass works</td>
<td>Skylight repairs, mirrors, screen replacement, entrance systems/doors, windows replacement</td>
<td></td>
</tr>
<tr>
<td><strong>2. Facilities maintenance services</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HVAC</td>
<td>Heating, Ventilation, Air condition</td>
<td></td>
</tr>
<tr>
<td>Plumbing maintenance</td>
<td>All preventive and corrective plumbing works for buildings maintenance</td>
<td></td>
</tr>
<tr>
<td>Roofing</td>
<td>Installation, maintenance, repair, and seasonal cleaning.</td>
<td></td>
</tr>
<tr>
<td>Elevators</td>
<td>Maintenance and repair of elevators and escalators.</td>
<td></td>
</tr>
<tr>
<td>Metal shops</td>
<td>Heating service, sheetmetal shop, machine shop, welding shop, millwright shop.</td>
<td></td>
</tr>
<tr>
<td>Fire systems</td>
<td>Including all firefighting systems</td>
<td></td>
</tr>
<tr>
<td>Electrical systems</td>
<td>Including preventive and corrective electrical works related to building maintenance</td>
<td></td>
</tr>
<tr>
<td><strong>3. Facilities custodial and ground services</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Custodial services</td>
<td>Involves cleaning, trash removal, bulb changing, and other related works</td>
<td></td>
</tr>
<tr>
<td>Pest control</td>
<td>Preventive and corrective actions regarding extermination of all pests</td>
<td></td>
</tr>
<tr>
<td>Ground services</td>
<td>Street and sidewalk sweeping, snow removal, and trash removal</td>
<td></td>
</tr>
<tr>
<td>Landscape design</td>
<td>Landscape renovations, develop landscape plans, provide project management during installation.</td>
<td></td>
</tr>
<tr>
<td><strong>4. Facilities administrative services</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Financial services</td>
<td>Budget administration and general accounting.</td>
<td></td>
</tr>
<tr>
<td>--------------------</td>
<td>-----------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Information technology services</td>
<td>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</td>
<td></td>
</tr>
<tr>
<td>Preventive maintenance plans</td>
<td>Preparing plans for scheduled preventive maintenance for buildings.</td>
<td></td>
</tr>
<tr>
<td>Quality assurance inspections</td>
<td>Follow up and control all facilities related activities to ensure a quality provided services to customers</td>
<td></td>
</tr>
</tbody>
</table>

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. |
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

<table>
<thead>
<tr>
<th>Principles</th>
<th>Customer focus</th>
<th>Continuous improvement</th>
<th>Teamwork</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer focus</td>
<td>Paramount importance of providing products and services that fulfill customer needs; requires organizationwide focus on customers</td>
<td>Consistent customer satisfaction can be attained only through extreme improvement of processes that create products and services</td>
<td>Customers focus and continuous improvement are best achieved by collaboration throughout an organization as well as with customers and suppliers.</td>
</tr>
<tr>
<td>Techniques</td>
<td>Customer surveys and focus groups. Quality function deployment (translates customer information into product specifications)</td>
<td>Flowcharts. Pareto analysis. Statistical process control. Fishbone diagrams.</td>
<td>Organizational development methods such as the nominal group technique. Team-building methods (e.g., role clarification and group feedback).</td>
</tr>
</tbody>
</table>

(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.

(AI-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. (Hemon 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 (s) 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, Lloyda 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 theses defects, and then to device process improvements to prevent or reduce the occurrence of theses 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 processes 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

(Anthony 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). (Anthony 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

<table>
<thead>
<tr>
<th>Model</th>
<th>Primary focus of the model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical and functional quality model (Gronroos 1993)</td>
<td>Three components of service quality were identified: technical quality; functional quality; and image</td>
</tr>
<tr>
<td>Model</td>
<td>Description</td>
</tr>
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<td>----------------------------------------------------------------------</td>
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</tr>
<tr>
<td>Quality gap analysis (Parasuraman et al. 1985)</td>
<td>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.</td>
</tr>
<tr>
<td>Extended model of service quality (SERVQUAL) (Parasuraman et al. 1988)</td>
<td>The ten dimensions were reduced to five. The SERVQUAL model had modified in 1991 and 1994 with little variation from the 1988 version.</td>
</tr>
<tr>
<td>A conceptual model for service quality (Haywood-Farmer 1988)</td>
<td>This model is based essentially on three service quality components: physical and procedural, behavioral, and judgmental. Each of these components consists of several factors.</td>
</tr>
<tr>
<td>Synthesized model of service quality (Brogowicz et al. 1990)</td>
<td>This model defines three factors affecting technical and functional quality of service; company image, external influences and traditional marketing activities.</td>
</tr>
<tr>
<td>Performance only model (Brady et al. 2002)</td>
<td>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.</td>
</tr>
<tr>
<td>Ideal value model of service quality (Mattsson 1992)</td>
<td>This model argues for a value approach representing customer satisfaction. Two values incorporating satisfaction: ideal standard and experienced outcome.</td>
</tr>
<tr>
<td>Evaluated performance and normed quality model (Teas 1993)</td>
<td>The model proposed the following two frameworks for service quality: evaluated performance (EP) framework, and normed quality model.</td>
</tr>
<tr>
<td>Improving service quality with information technology (Berkley and Gupta 1994)</td>
<td>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.</td>
</tr>
<tr>
<td>Attribute and overall affect models (Dabholkar 1996)</td>
<td>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.</td>
</tr>
<tr>
<td>Model of perceived service quality and satisfaction (Spreng and Mackoy 1996)</td>
<td>This model focused on the distinction between perceived service quality and satisfaction.</td>
</tr>
<tr>
<td>PCP attribute model (Philip and Hazlett 1997)</td>
<td>This model is based on the SERVQUAL model and gives some critics to this model. The PCP model...</td>
</tr>
<tr>
<td>Model/Model Description</td>
<td>Description</td>
</tr>
<tr>
<td>--------------------------------------------------------------------------------------</td>
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<tr>
<td>Retail service quality and perceived value model (Sweeney et al. 1997)</td>
<td>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.</td>
</tr>
<tr>
<td>Service quality, customer satisfaction, and customer value model (Oh 1999)</td>
<td>An integrative model combining service quality, customer value, and customer satisfaction focusing mainly on hotels service industry.</td>
</tr>
<tr>
<td>Antecedents and mediator model (Dabholkar et al. 2000)</td>
<td>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.</td>
</tr>
<tr>
<td>INTSERVQUAL - Internal service quality model (Frost and Kumar 2000)</td>
<td>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.</td>
</tr>
<tr>
<td>Internal service quality Data Envelopment Analysis (DEA) model (Soteriou and Stavrinides 2000)</td>
<td>A DEA model developed for bank services to assess bank branches performance, and how to measure and improve internal customer service quality.</td>
</tr>
<tr>
<td>Service quality in internet banking, Internet banking model (Broderick and Vachirapornpuk 2002)</td>
<td>This model describes service quality of internet banking. It proposes and tests a service quality model of Internet banking.</td>
</tr>
<tr>
<td>IT based services and service quality model in consumer banking (Zhu et al. 2002)</td>
<td>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.</td>
</tr>
<tr>
<td>E-service quality. A model of virtual service quality dimensions (Santos 2003)</td>
<td>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.</td>
</tr>
</tbody>
</table>
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

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

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)

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

\[ RPN = S \times O \times D \]

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

<table>
<thead>
<tr>
<th>Service category</th>
<th>Total count</th>
<th>N</th>
<th>N*</th>
<th>Mean</th>
<th>S.E Mean</th>
<th>St.Dev.</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.Restroom fixtures</td>
<td>205</td>
<td>204</td>
<td>1</td>
<td>6.821</td>
<td>0.154</td>
<td>2.198</td>
<td>4.831</td>
</tr>
<tr>
<td>2.Water fountains</td>
<td>205</td>
<td>204</td>
<td>1</td>
<td>6.850</td>
<td>0.147</td>
<td>2.097</td>
<td>4.397</td>
</tr>
<tr>
<td>3.Internal lighting</td>
<td>205</td>
<td>205</td>
<td>0</td>
<td>7.339</td>
<td>0.131</td>
<td>1.872</td>
<td>3.503</td>
</tr>
<tr>
<td>4.Exterior lighting</td>
<td>205</td>
<td>199</td>
<td>6</td>
<td>7.188</td>
<td>0.134</td>
<td>1.890</td>
<td>3.572</td>
</tr>
<tr>
<td>5.Winter comfort</td>
<td>205</td>
<td>202</td>
<td>3</td>
<td>6.067</td>
<td>0.173</td>
<td>2.465</td>
<td>6.076</td>
</tr>
<tr>
<td>6.Summer comfort</td>
<td>205</td>
<td>203</td>
<td>2</td>
<td>5.934</td>
<td>0.169</td>
<td>2.409</td>
<td>5.805</td>
</tr>
<tr>
<td>7.Elevators</td>
<td>205</td>
<td>201</td>
<td>4</td>
<td>7.286</td>
<td>0.151</td>
<td>2.140</td>
<td>4.579</td>
</tr>
<tr>
<td>8.Door hardware and keys</td>
<td>205</td>
<td>205</td>
<td>0</td>
<td>7.476</td>
<td>0.148</td>
<td>2.121</td>
<td>4.499</td>
</tr>
<tr>
<td>9.Ceilings</td>
<td>205</td>
<td>203</td>
<td>2</td>
<td>6.973</td>
<td>0.140</td>
<td>2.001</td>
<td>4.005</td>
</tr>
<tr>
<td>10.Floors</td>
<td>205</td>
<td>203</td>
<td>2</td>
<td>6.899</td>
<td>0.129</td>
<td>1.832</td>
<td>3.357</td>
</tr>
<tr>
<td>11.Painting</td>
<td>205</td>
<td>202</td>
<td>3</td>
<td>6.874</td>
<td>0.142</td>
<td>2.012</td>
<td>4.050</td>
</tr>
<tr>
<td>12.Maintenance work request</td>
<td>205</td>
<td>185</td>
<td>20</td>
<td>6.346</td>
<td>0.169</td>
<td>2.293</td>
<td>5.260</td>
</tr>
<tr>
<td>13.GIRF work request</td>
<td>205</td>
<td>111</td>
<td>94</td>
<td>5.955</td>
<td>0.240</td>
<td>2.528</td>
<td>6.389</td>
</tr>
<tr>
<td>14. Satisfaction with work processed.</td>
<td>205</td>
<td>186</td>
<td>19</td>
<td>7.078</td>
<td>0.130</td>
<td>1.768</td>
<td>3.125</td>
</tr>
<tr>
<td>Service category</td>
<td>Coef. Var.</td>
<td>Min</td>
<td>Median</td>
<td>Max</td>
<td>Range</td>
<td>Mode</td>
<td>N for mode</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>------------</td>
<td>-----</td>
<td>--------</td>
<td>-----</td>
<td>-------</td>
<td>------</td>
<td>------------</td>
</tr>
<tr>
<td>1. Restroom fixtures</td>
<td>32.22</td>
<td>0</td>
<td>7</td>
<td>10</td>
<td>10</td>
<td>7</td>
<td>40</td>
</tr>
<tr>
<td>2. Water fountains</td>
<td>30.61</td>
<td>0</td>
<td>7</td>
<td>10</td>
<td>10</td>
<td>7</td>
<td>41</td>
</tr>
<tr>
<td>3. Interior lighting</td>
<td>25.5</td>
<td>0</td>
<td>8</td>
<td>10</td>
<td>10</td>
<td>8</td>
<td>45</td>
</tr>
<tr>
<td>4. Exterior lighting</td>
<td>26.29</td>
<td>0</td>
<td>8</td>
<td>10</td>
<td>10</td>
<td>8</td>
<td>55</td>
</tr>
<tr>
<td>5. Winter comfort</td>
<td>40.63</td>
<td>0</td>
<td>6</td>
<td>10</td>
<td>10</td>
<td>8</td>
<td>36</td>
</tr>
<tr>
<td>6. Summer comfort</td>
<td>40.54</td>
<td>0</td>
<td>6</td>
<td>10</td>
<td>10</td>
<td>7</td>
<td>34</td>
</tr>
<tr>
<td>7. Elevators</td>
<td>29.37</td>
<td>0</td>
<td>8</td>
<td>10</td>
<td>10</td>
<td>8</td>
<td>43</td>
</tr>
<tr>
<td>8. Door hardware and keys</td>
<td>28.37</td>
<td>0</td>
<td>8</td>
<td>10</td>
<td>10</td>
<td>8</td>
<td>47</td>
</tr>
<tr>
<td>9. Ceilings</td>
<td>28.7</td>
<td>0</td>
<td>7</td>
<td>10</td>
<td>10</td>
<td>8</td>
<td>44</td>
</tr>
<tr>
<td>10. Floors</td>
<td>26.56</td>
<td>1</td>
<td>7</td>
<td>10</td>
<td>9</td>
<td>7</td>
<td>45</td>
</tr>
<tr>
<td>11. Painting</td>
<td>29.28</td>
<td>0</td>
<td>7</td>
<td>10</td>
<td>10</td>
<td>7,8</td>
<td>42</td>
</tr>
<tr>
<td>12. Maintenance work request</td>
<td>36.14</td>
<td>0</td>
<td>7</td>
<td>10</td>
<td>10</td>
<td>7</td>
<td>41</td>
</tr>
<tr>
<td>13. GIRF work request</td>
<td>42.45</td>
<td>0</td>
<td>6</td>
<td>10</td>
<td>10</td>
<td>7,8</td>
<td>21</td>
</tr>
<tr>
<td>14. Satisfaction with work processed.</td>
<td>24.98</td>
<td>2</td>
<td>7.5</td>
<td>10</td>
<td>8</td>
<td>8</td>
<td>61</td>
</tr>
</tbody>
</table>

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.

![Mean Service Category Rating](chart.png)

**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

![Histogram for individual service quality ratings](image)

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
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.
In Fig. 7, one of the services that customers 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.

![Histogram for individual service quality ratings](image)

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.

![Histogram for individual service quality ratings](image)

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%

![Histogram for individual service quality ratings](image1)

**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%

![Histogram for individual service quality ratings](image2)

**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.

![Histogram for individual service quality ratings](image)

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

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 strengthens and confirms 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. Group 3 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

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

Team building and group dynamic skills training.

Quality related training, including quantitative/statistical TQM methods.

Understanding of service quality goals and objectives.

Degree of participation and enabling and valuing feedback by employees in decision making (e.g. suggestion box)

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

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Factor/sub-factor description</th>
<th>R1</th>
<th>R2</th>
<th>R3</th>
<th>R4</th>
<th>R5</th>
<th>Total R</th>
<th>Mean</th>
<th>St.Dev.</th>
<th>Coeff. of Var.</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>Goal settings, providing resources within available funding, removing obstacles, supporting personnel, employee relation, design&amp; implement improvement processes &amp; plans.</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>12</td>
<td>2.4</td>
<td>1.14</td>
<td>0.48</td>
</tr>
<tr>
<td>F11</td>
<td>Goal setting (long term-quality improvements).</td>
<td>5</td>
<td>9</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>19</td>
<td>3.8</td>
<td>2.49</td>
<td>0.66</td>
</tr>
<tr>
<td>F12</td>
<td>Comprehensiveness and realism of goals.</td>
<td>9</td>
<td>2</td>
<td>7</td>
<td>5</td>
<td>8</td>
<td>31</td>
<td>6.2</td>
<td>2.77</td>
<td>0.45</td>
</tr>
<tr>
<td>Code</td>
<td>Description</td>
<td>Ratings</td>
<td>Scores</td>
<td>Confidence</td>
<td></td>
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</tr>
<tr>
<td>F14</td>
<td>Facilitating work, removing obstacles, supporting personnel.</td>
<td>8 5 6 6 7 32 6.4 1.14 0.18</td>
<td></td>
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</tr>
<tr>
<td>F15</td>
<td>Design and implement efficient cost-effective processes.</td>
<td>4 6 3 1 6 20 4 2.12 0.53</td>
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</tr>
<tr>
<td>F16</td>
<td>Effective management of resources within funding constraints.</td>
<td>2 3 5 7 4 21 4.2 1.92 0.46</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>F17</td>
<td>Commitment to employee training, availing resources.</td>
<td>7 4 8 8 5 32 6.4 1.82 0.28</td>
<td></td>
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</tr>
<tr>
<td>F18</td>
<td>Providing a safe and healthy work environment</td>
<td>6 7 9 9 9 40 8 1.41 0.18</td>
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</tr>
<tr>
<td>F19</td>
<td>Evaluation, control, and verification of results obtained from services</td>
<td>1 8 1 2 1 13 2.6 3.05 1.17</td>
<td></td>
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</tr>
<tr>
<td>F2</td>
<td>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.</td>
<td></td>
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<tr>
<td>F21</td>
<td>Service quality awareness and associated background and skills by people involved in service design</td>
<td>5 5 3 2 3 18 3.6 1.34 0.37</td>
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</tr>
<tr>
<td>F22</td>
<td>Careful review of service design(s) before launching service(s).</td>
<td>3 4 2 5 5 19 3.8 1.30 0.34</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>F23</td>
<td>Service design(s) reflecting analysis of stakeholders input and requirements (e.g. building engineers)</td>
<td>4 2 4 4 2 16 3.2 1.10 0.34</td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>F24</td>
<td>Clarity and practicality of service specifications, including standardization</td>
<td>1 3 5 3 4 16 3.2 1.48 0.46</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>F25</td>
<td>Effectiveness of service contact and service delivery (dispatch) system (timely and satisfactory response).</td>
<td>2 1 1 1 1 6 1.2 0.45 0.37</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>F3</td>
<td>Suitability and sufficiency of tools and equipment used in service delivery including transportation between buildings</td>
<td>4 5 4 5 3 21 4.2 0.84 0.20</td>
<td></td>
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</tr>
</tbody>
</table>

**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.)
- Service quality awareness and associated background and skills by people involved in service design
- Careful review of service design(s) before launching service(s).
- Service design(s) reflecting analysis of stakeholders input and requirements (e.g. building engineers)
- Clarity and practicality of service specifications, including standardization
- Effectiveness of service contact and service delivery (dispatch) system (timely and satisfactory response).

**F3: Physical Facilities**
- Suitability and sufficiency of tools and equipment used in service delivery including transportation between buildings
<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>4</th>
<th>2</th>
<th>18</th>
<th>3.6</th>
<th>1.14</th>
<th>0.32</th>
</tr>
</thead>
<tbody>
<tr>
<td>F32</td>
<td>Quality of maintenance and repairs done on tools and equipment, and quantity, and adequate of tools</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>2</td>
<td>18</td>
<td>3.6</td>
<td>1.14</td>
<td>0.32</td>
</tr>
<tr>
<td>F33</td>
<td>Sufficiency and quality of IT and technology support, and software training</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>5</td>
<td>16</td>
<td>3.2</td>
<td>1.79</td>
<td>0.56</td>
</tr>
<tr>
<td>F34</td>
<td>Degree of comfort and satisfaction with work places at FPM facilities.</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td>1.2</td>
<td>0.45</td>
<td>0.37</td>
</tr>
<tr>
<td>F35</td>
<td>Quality of on-site communications such as pagers, and cellphones</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>14</td>
<td>2.8</td>
<td>0.84</td>
<td>0.30</td>
</tr>
<tr>
<td>F4</td>
<td>Employee roles, skills and contribution</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F41</td>
<td>Continuous improvement and update of skills.</td>
<td>3</td>
<td>1</td>
<td>4</td>
<td>6</td>
<td>4</td>
<td>18</td>
<td>3.6</td>
<td>1.82</td>
<td>0.50</td>
</tr>
<tr>
<td>F42</td>
<td>Specific technical skills training.</td>
<td>4</td>
<td>6</td>
<td>6</td>
<td>4</td>
<td>7</td>
<td>27</td>
<td>5.4</td>
<td>1.34</td>
<td>0.25</td>
</tr>
<tr>
<td>F43</td>
<td>Team building and group dynamic skills training.</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>14</td>
<td>2.8</td>
<td>1.48</td>
<td>0.53</td>
</tr>
<tr>
<td>F44</td>
<td>Quality related training, including quantitative/statistical TQM methods.</td>
<td>5</td>
<td>2</td>
<td>7</td>
<td>2</td>
<td>1</td>
<td>17</td>
<td>3.4</td>
<td>2.51</td>
<td>0.74</td>
</tr>
<tr>
<td>F45</td>
<td>Understanding of service quality goals and objectives.</td>
<td>2</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td>15</td>
<td>3</td>
<td>2.35</td>
<td>0.78</td>
</tr>
<tr>
<td>F46</td>
<td>Degree of participation by employees in decision making; enabling and valuing feedback (e.g. suggestion boxes)</td>
<td>7</td>
<td>7</td>
<td>5</td>
<td>5</td>
<td>2</td>
<td>26</td>
<td>5.2</td>
<td>2.05</td>
<td>0.39</td>
</tr>
<tr>
<td>F47</td>
<td>Employee motivation and job satisfaction including reward system for cost effective services</td>
<td>6</td>
<td>4</td>
<td>3</td>
<td>7</td>
<td>3</td>
<td>23</td>
<td>4.6</td>
<td>1.82</td>
<td>0.39</td>
</tr>
</tbody>
</table>

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

![Total Weighting scores for sub-factors](image)

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
Decision on whether the project includes dorm and/or classrooms

Yes

Go to Fire Marshal

No

Is design required?

Yes

Go to JDI procedure

No

Is the customer approve JDI?

Yes

Go to JDI procedure

No

Does the customer want cost estimate?

Yes

Go to schematic design process

No

Is schematic design required?

Yes

Go to schematic design process

No

Go to cost estimate process

Is bidding required?

Yes

Go to bidding and Long Form Construction Contract approval process and execute the project

No

Is JDI acceptable?

Yes

Go to JDI process

No

Go to Short Form Construction Contract approval process and execute the project

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

![Flowchart Diagram]

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

Customer GIRF request via FPM website

Generate GIRF request number

FPM planning and design team acknowledges the request

Does the project require Fire Marshal process?

No

Decision made by customer to develop a cost estimate

Yes

Go to Fire Marshal process

A cost estimator (CE) is assigned by FPM planning and design director

Decision made on not to do JDI and not to do schematic design

Decision on whether customer accepts cost estimate

Yes

Project dies

A cost estimator (CE) contacts customer to confirm project scope and arranges a site visit if required

CE develops cost estimate with assistance from sub-trades

CE reviews cost estimate with customer

Decision on whether customer accepts cost estimate

Yes

Customer funds project

Decision made on following the “no bidding” procedure

No

PM develops scope for the project and issue a Work Order (WO) to sub-trades

PM develops punchlist with customer and gives it to sub-trades for completion

Decision if PM and customer accept completed work

Yes

Customer accepts completed project

No

Rework

Sub-trades construct work

PM develops punchlist with customer and gives it to sub-trades for completion

Decision if PM and customer accept completed work

Yes

Customer accepts completed project

No
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 stoping it.
Table 10: Input-output-responsibility matrix for a CEP sub-process

<table>
<thead>
<tr>
<th>Process Step</th>
<th>Input</th>
<th>Responsibility</th>
<th>Output</th>
<th>Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Customer GIRF request via FPM website</td>
<td>GIRF request</td>
<td>Customer</td>
<td>The customer request received by FPM</td>
<td>FPM</td>
</tr>
<tr>
<td>2 Generate GIRF request number</td>
<td>GIRF request</td>
<td>Customer</td>
<td>GIRF request number</td>
<td>FPM</td>
</tr>
<tr>
<td>3 FPM Planning and Design Team acknowledges the request</td>
<td>GIRF request</td>
<td>Customer</td>
<td>Confirm and approve GIRF request</td>
<td>FPM</td>
</tr>
<tr>
<td>4 Decision made on not to do JDI and not to do schematic design</td>
<td>Discussion on how to conduct the project</td>
<td>Customer and FPM</td>
<td>A decision of conducting the project with cost estimate, without schematic design, and no bidding</td>
<td>Customer and FPM</td>
</tr>
<tr>
<td>5 Does the project require Fire Marshal process?</td>
<td>If project includes classroom and/or dorm</td>
<td>FPM</td>
<td>Decision to go to Fire Marshal or not</td>
<td>FPM</td>
</tr>
<tr>
<td>6 If yes, go to Fire Marshal process</td>
<td>The project includes classroom and/or dorm</td>
<td>FPM</td>
<td>Fire Marshal procedure is followed</td>
<td>FPM</td>
</tr>
<tr>
<td>7 Decision made by customer to develop a cost estimate</td>
<td>Decision to develop cost estimate</td>
<td>Customer</td>
<td>Start cost estimate process</td>
<td>FPM</td>
</tr>
<tr>
<td>8 A cost estimator (CE) is assigned by FPM Planning and Design</td>
<td>GIRF request</td>
<td>Customer</td>
<td>CE is assigned to the project</td>
<td>FPM</td>
</tr>
<tr>
<td>9 CE contacts customer to confirm project scope and arranges a site visit if required</td>
<td>GIRF request</td>
<td>Customer</td>
<td>Project scope is confirmed</td>
<td>CE and customer</td>
</tr>
<tr>
<td>10 CE develops cost estimate with assistance of sub-trades</td>
<td>Confirmed project scope</td>
<td>CE and customer</td>
<td>Cost estimate for the project is developed</td>
<td>CE</td>
</tr>
<tr>
<td>11 CE reviews cost estimate with customer</td>
<td>Developed cost estimate</td>
<td>CE</td>
<td>A revision on the cost estimate if needed</td>
<td>CE and customer</td>
</tr>
<tr>
<td>Step</td>
<td>Description</td>
<td>Responsible Parties</td>
<td></td>
<td></td>
</tr>
<tr>
<td>------</td>
<td>-----------------------------------------------------------------------------</td>
<td>---------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Decision on whether customer accepts cost estimate</td>
<td>Developed/revised cost estimate, CE and customer, Decision to accept or refuse, Customer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>If no, project dies</td>
<td>Developed/revised cost estimate, CE and customer, Project discontinued (or put on hold pending new funding), FPM and customer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>If yes, decision made on following the “no bidding” procedure</td>
<td>Developed cost estimate, CE, Implement “no bidding procedure”, FPM and customer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Customer funds project; based on decision on how to fund the project (PFA vs. IRB or direct billing)</td>
<td>Developed cost estimate, CE, Decision to fund the project by either PFA, IRB, or direct billing, Customer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Decision on whether customer accepts JDI</td>
<td>Developed cost estimate and decision on how to fund the project, CE and customer, Start the process, FPM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>If yes for step 16, PM develops scope for the project and issue a Work Order (WO) to sub-trades</td>
<td>Go to sub-process JDI steps 6-13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>If no for step 16, Sub-trades develop lumpsum construction proposal and give it to PM for evaluation</td>
<td>A cost estimate, and other project documents, CE and FPM, Lump sum construction proposal is developed and submitted to PM, Sub-trades</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Does PM accept proposal?</td>
<td>Lump sum construction proposal, Sub-trades, Decision to accept or refuse, PM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>If yes, PM prepares Short Form Construction Contract (SFCC) and submits it to sub-trades for execution</td>
<td>Accepted lump sum construction proposal, PM, SFCC is prepared and submitted to sub-trades, PM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>If no, revision of proposal</td>
<td>Lump sum construction proposal, Sub-trades, Revised proposal, Sub-trades</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Step</td>
<td>Activity Description</td>
<td>Responsible Party</td>
<td>Related Activities</td>
<td></td>
</tr>
<tr>
<td>------</td>
<td>--------------------------------------------------------------------------------------</td>
<td>----------------------------</td>
<td>-------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Sub-trades return SFCC to PM after finalizing proposal with insurance certificate</td>
<td>SFCC submitted to sub-trades</td>
<td>PM</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Completed SFCC</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sub-trades</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>PM prepares Redbook for SFCC execution and submits it for approval by different FPM management levels</td>
<td>Completed SFCC</td>
<td>Sub-trades</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>SFCC approvals by different management levels</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Different FPM management levels</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>Administrative actions to ensure funding existence; issue Purchase Order# (PO#); and PM retrieves PO# within Banner</td>
<td>Approved SFCC</td>
<td>Different FPM management levels</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Administrative actions completed and PO# is issued</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Clerks and purchasing department</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>PM submits PO# to sub-trades for project execution</td>
<td>PO# issued within Banner</td>
<td>Purchasing department</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PO# submitted to sub-trades</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PM</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>Sub-trades construct work</td>
<td>PO#</td>
<td>PM</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Work constructed</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sub-trades</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>PM develops punchlist with customer and submits it to sub-trades for completion</td>
<td>Constructed work</td>
<td>Sub-trades</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Punchlist is submitted to sub-trades</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PM and customer</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>Do PM and customer accept completed work?</td>
<td>Completed punchlist</td>
<td>Sub-trades</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Decision to accept or not</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PM and customer</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>If no, rework and go to step 27</td>
<td>Completed punchlist</td>
<td>Sub-trades</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Rework</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sub-trades</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>If yes, Customer occupies completed facility</td>
<td>Completed punchlist</td>
<td>Sub-trades</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Project completed</td>
<td></td>
</tr>
</tbody>
</table>

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

Customer GIRF request via FPM website

Generate GIRF request number

FPM planning and design team acknowledges the request

Does the project require Fire Marshal process?

Decision made on not to do JDI

Decision made to go through schematic design and cost estimate

Director assigns project planner (PP) and/or project engineer (PE) to the project

Does PP/PM accept design proposal?

Architect/Engineer (A/E) develops design proposal upon PM request

Director assigns project planner (PP) and/or project engineer (PE) to the project

Yes

No

Revision

PP/PM prepares Redbook for contract execution and submits it to different management levels for approval

Administrative actions to ensure funding, Purchase Order# (PO#) is issued, and PM retrieves PO# within Banner

A/E executes design contract and returns it to PP/PM with insurance certificate

A/E reviews schematic design with PM and customer

PM instructs A/E to develop schematic design

PM and A/E develop cost estimate

A/E reviews schematic design with PM and customer

Yes

No

Revision

Does customer accept schematic design?

PP/PM prepares Redbook for contract execution and submits it to different management levels for approval

Administrative actions to ensure funding, Purchase Order# (PO#) is issued, and PM retrieves PO# within Banner

A/E executes design contract and returns it to PP/PM with insurance certificate

A/E reviews schematic design with PM and customer

PM instructs A/E to develop schematic design

PM and A/E develop cost estimate

A/E reviews schematic design with PM and customer

Yes

No

Revision

Does customer accept schematic design?

PP/PM prepares Redbook for contract execution and submits it to different management levels for approval

Administrative actions to ensure funding, Purchase Order# (PO#) is issued, and PM retrieves PO# within Banner

A/E executes design contract and returns it to PP/PM with insurance certificate

A/E reviews schematic design with PM and customer

PM instructs A/E to develop schematic design

PM and A/E develop cost estimate

A/E reviews schematic design with PM and customer

Yes

No

Revision

Does customer accept cost estimate?

Project dies

A
PM develops scope for the project and issue a Work Order (WO) to sub-trades

Sub-trades construct work

PM develops punchlist with customer and gives it to sub-trades for completion

Decision if PM and customer accept completed work

Yes

Customer accepts completed project

No

Rework

PM develops punchlist with customer and submits it to sub-trades for completion

Do PM and customer accept completed work?

Yes

Customer occupies completed facility

No

Rework

PM submits PO# to sub-trades for project execution

PM prepares Short Form Construction Contract (SFCC) and submits it to sub-trades

Sub-trades return SFCC to PM after finalizing with insurance

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

Sub-trades develop lumpsum construction proposal and give it to PM for evaluation

Does PM accept proposal?

Yes

PM prepares Short Form Construction Contract (SFCC) and submits it to sub-trades for execution

Sub-trades return SFCC to PM after finalizing with insurance

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

PM submits PO# to sub-trades for project execution

Sub-trades construct work

PM develops punchlist with customer and submits it to sub-trades for completion

Do PM and customer accept completed work?

Yes

Customer occupies completed facility

No

Rework

Decision on whether customer accepts JDI

Yes

Customer funds project

No

Rework

Figure 31: Cost estimate; schematic design, and no bidding (CEPD) sub-process flow chart
Table 11: Input-output-responsibility matrix for CEPD sub-process

<table>
<thead>
<tr>
<th>Process Step</th>
<th>Input</th>
<th>Responsibility</th>
<th>Output</th>
<th>Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Customer GIRF request via FPM website</td>
<td>GIRF request</td>
<td>Customer</td>
<td>The customer request received by FPM</td>
</tr>
<tr>
<td>2</td>
<td>Generate GIRF request number</td>
<td>GIRF request</td>
<td>Customer</td>
<td>GIRF request number</td>
</tr>
<tr>
<td>3</td>
<td>FPM Planning and Design team acknowledges the request</td>
<td>GIRF request</td>
<td>Customer</td>
<td>Confirm and approve GIRF request</td>
</tr>
<tr>
<td>4</td>
<td>Does the project require Fire Marshal process?</td>
<td>If project includes classroom and/or dorm</td>
<td>FPM</td>
<td>Decision to go to Fire Marshal or not</td>
</tr>
<tr>
<td>5</td>
<td>If yes, go to Fire Marshal process</td>
<td>The project includes classroom and/or dorm</td>
<td>FPM</td>
<td>Fire Marshal procedure is followed</td>
</tr>
<tr>
<td>6</td>
<td>Decision made to go to schematic design and cost estimate</td>
<td>Decision made to develop schematic design and cost estimate</td>
<td>FPM and customer</td>
<td>Start schematic design and cost estimate process</td>
</tr>
<tr>
<td>7</td>
<td>Director assigns project planner (PP) and/or project engineer (PE) to the project</td>
<td>Decision to start schematic design and cost estimate</td>
<td>FPM</td>
<td>PP and/or PM is assigned to the project</td>
</tr>
<tr>
<td>8</td>
<td>Decision made to establish PFA for the project</td>
<td>Customer contacted on how the project will be funded</td>
<td>FPM and customer</td>
<td>Decision to fund the project by PFA</td>
</tr>
<tr>
<td>9</td>
<td>Architect/Engineer (A/E) develops design proposal upon PM request</td>
<td>PM request for design proposal</td>
<td>PM</td>
<td>Developed design proposal</td>
</tr>
<tr>
<td>10</td>
<td>Does PP/PM accept design proposal?</td>
<td>Developed design proposal</td>
<td>A/E</td>
<td>Decision to accept or not</td>
</tr>
<tr>
<td>11</td>
<td>If no, rework and go to step 9</td>
<td>Design not accepted</td>
<td>PP/PM</td>
<td>Redevelop design proposal</td>
</tr>
<tr>
<td>Step</td>
<td>Description</td>
<td>Responsible Party</td>
<td>Note</td>
<td></td>
</tr>
<tr>
<td>------</td>
<td>-------------</td>
<td>-------------------</td>
<td>------</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>If yes, PP/PM develops design contract and submits it to A/E for execution</td>
<td>Accepted design proposal</td>
<td>PP/PM</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PP/PM develops design contract and submits it to A/E for execution</td>
<td>Design contract developed and submitted to A/E</td>
<td>PP/PM</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>A/E executes design contract and returns it to PP/PM with insurance certificate</td>
<td>Developed design contract</td>
<td>PP/PM</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Developed design contract</td>
<td>Executed design contract with insurance certificate</td>
<td>A/E</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Decision to start project or not based on verification of funding</td>
<td>Verification of funding</td>
<td>Customer and FPM</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Verification of funding</td>
<td>Funding verified or not verified</td>
<td>Customer and FPM</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>If yes go to step 17</td>
<td>Funding verified</td>
<td>Customer and FPM</td>
<td></td>
</tr>
<tr>
<td></td>
<td>If yes go to step 17</td>
<td>Go to step 17</td>
<td>FPM</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>If no, project stays on hold or die</td>
<td>Funding not verified</td>
<td>Customer and FPM</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Funding not verified</td>
<td>Project stays on hold or die</td>
<td>Customer</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>PP/PM prepares Redbook for contract execution and submits it for approval by different management levels</td>
<td>Executed design contract with insurance certificate</td>
<td>A/E</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Executed design contract with insurance certificate</td>
<td>Redbook for contract execution approved by different management levels</td>
<td>Different FPM management levels</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Administrative actions to ensure funding existence, Purchase Order# (PO#) is issued, and PM retrieves PO# within Banner</td>
<td>Approved design contract</td>
<td>Different FPM management level</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Approved design contract</td>
<td>Administrative actions completed and PO# is issued</td>
<td>Staff and Purchasing Department</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>PM instructs A/E to develop schematic design</td>
<td>Issued PO# within Banner</td>
<td>Purchasing Department</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Issued PO# within Banner</td>
<td>Developed schematic design</td>
<td>A/E</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>A/E reviews schematic design with PM and customer</td>
<td>Developed schematic design</td>
<td>A/E</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Developed schematic design</td>
<td>Reviewed schematic design</td>
<td>PM and customer</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Does customer accept schematic design?</td>
<td>Reviewed schematic design</td>
<td>PM and customer</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reviewed schematic design</td>
<td>Decision to accept or not</td>
<td>PM and customer</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>If no, Rework and go to step 19</td>
<td>Not accepted schematic design</td>
<td>PM and customer</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Not accepted schematic design</td>
<td>Redevelop schematic</td>
<td>A/E</td>
<td></td>
</tr>
<tr>
<td></td>
<td>If yes, PM and A/E develop cost estimate</td>
<td>Accepted schematic design</td>
<td>PM and customer</td>
<td>Developed cost estimate</td>
</tr>
<tr>
<td>---</td>
<td>----------------------------------------</td>
<td>--------------------------</td>
<td>----------------</td>
<td>----------------------------</td>
</tr>
<tr>
<td>24</td>
<td>Does customer accept cost estimate?</td>
<td>Developed cost estimate</td>
<td>PM and A/E</td>
<td>Decision to accept or not</td>
</tr>
<tr>
<td>25</td>
<td>If no, project dies</td>
<td>Developed/revised cost estimate</td>
<td>PM and A/E</td>
<td>Project discontinued (or put on hold)</td>
</tr>
<tr>
<td>26</td>
<td>Customer funds project; based on decision on how to fund the project (PFA vs. IRB or direct billing)</td>
<td>Developed cost estimate</td>
<td>PM and A/E</td>
<td>Decision to fund the project by either PFA, IRB, or direct billing</td>
</tr>
<tr>
<td>27</td>
<td>Decision on whether customer accepts JDI</td>
<td>Developed cost estimate and decision on how to fund the project</td>
<td>PM and customer</td>
<td>Start the process</td>
</tr>
<tr>
<td>28</td>
<td>If yes for step 27, PM develops scope for the project and issue a Work Order (WO) to sub-trades</td>
<td>Go to sub-process JDI steps 6-13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>If no for step 27, Sub-trades develop lump sum construction proposal and give it to PM for evaluation</td>
<td>A cost estimate, and other project documents</td>
<td>PM and A/E</td>
<td>Lump sum construction proposal is developed and submitted to PM</td>
</tr>
<tr>
<td>30</td>
<td>Does PM accept proposal?</td>
<td>Lump sum construction proposal</td>
<td>Sub-trades</td>
<td>Decision to accept or refuse</td>
</tr>
<tr>
<td>31</td>
<td>If yes, PM prepares Short Form Construction Contract (SFCC) and submits it to sub-trades for execution</td>
<td>Accepted lump sum construction proposal</td>
<td>PM</td>
<td>SFCC is prepared and submitted to sub-trades</td>
</tr>
<tr>
<td>32</td>
<td>If no, revision of proposal</td>
<td>Lump sum construction</td>
<td>Sub-trades</td>
<td>Revised proposal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>proposal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>----------</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>33</td>
<td>Sub-trades return SFCC to PM after finalizing proposal with insurance certificate</td>
<td>SFCC submitted to sub-trades</td>
<td>PM</td>
<td>Completed SFCC</td>
</tr>
<tr>
<td>34</td>
<td>PM prepares Redbook for SFCC execution and submits it for approval by different FPM management levels</td>
<td>Completed SFCC</td>
<td>Sub-trades</td>
<td>SFCC approvals by different management levels</td>
</tr>
<tr>
<td>35</td>
<td>Administrative actions to ensure funding existence; issue Purchase Order# (PO#); and PM retrieves PO# within Banner</td>
<td>Approved SFCC</td>
<td>Different FPM management levels</td>
<td>Administrative actions completed and PO# is issued</td>
</tr>
<tr>
<td>36</td>
<td>PM submits PO# to sub-trades for project execution</td>
<td>PO# issued within Banner</td>
<td>Purchasing department</td>
<td>PO# submitted to sub-trades</td>
</tr>
<tr>
<td>37</td>
<td>Sub-trades construct work</td>
<td>PO#</td>
<td>PM</td>
<td>Work constructed</td>
</tr>
<tr>
<td>38</td>
<td>PM develops punchlist with customer and submits it to sub-trades for completion</td>
<td>Constructed work</td>
<td>Sub-trades</td>
<td>Punchlist is submitted to sub-trades</td>
</tr>
<tr>
<td>39</td>
<td>Do PM and customer accept completed work?</td>
<td>Completed punchlist</td>
<td>Sub-trades</td>
<td>Decision to accept or not</td>
</tr>
<tr>
<td>40</td>
<td>If No, Rework and go to step 37</td>
<td>Completed punchlist</td>
<td>Sub-trades</td>
<td>Rework</td>
</tr>
<tr>
<td>41</td>
<td>If yes, Customer occupies completed facility</td>
<td>Completed punchlist</td>
<td>Sub-trades</td>
<td>Project completed</td>
</tr>
</tbody>
</table>

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

Customer GIRF request via FPM

Generate GIRF request number

FPM planning and design team acknowledges the request

Decision made on not to do JDI

Does the project require Fire Marshal process?

Yes

Go to Fire Marshal

No

Decision made to go through schematic design and cost estimate

Director assigns project planner (PP) and/or project engineer (PE) to the project

Architect/Engineer (A/E) develops design proposal upon PM request

Decision made to establish PFA for the project

Does PP/PM accept design proposal?

Yes

PP/PM develops design contract and submits it to A/E for execution

A/E executes design contract and returns it to PP/PM with insurance certificate

Revision

Project put on hold pending verification of PFA

PP/PM prepares Redbook for contract execution and submits it to different management levels for approval

Administrative actions to ensure funding, Purchase Order# (PO#) is issued, and PM retrieves PO# within Banner

Decision made to develop schematic design

PM and A/E develop cost estimate

A/E reviews schematic design with PM and customer

PM instructs A/E to develop schematic design

Does customer accept schematic design?

Yes

Revision

No

Does customer accept cost estimate?

Yes

No

Project dies

A
Fig. 32: Cost estimate, schematic design, and bidding (CEPDB) sub-process flowchart
<table>
<thead>
<tr>
<th>Process Step</th>
<th>Input</th>
<th>Responsibility</th>
<th>Output</th>
<th>Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Customer GIRF request via FPM website</td>
<td>GIRF request</td>
<td>Customer</td>
<td>The customer request received by FPM</td>
<td>FPM</td>
</tr>
<tr>
<td>2 Generate GIRF request number</td>
<td>GIRF request</td>
<td>Customer</td>
<td>GIRF request number</td>
<td>FPM</td>
</tr>
<tr>
<td>3 FPM planning and design team acknowledges the request</td>
<td>GIRF request</td>
<td>Customer</td>
<td>Confirm and approve GIRF request</td>
<td>FPM</td>
</tr>
<tr>
<td>4 Does the project require Fire Marshal process?</td>
<td>If project includes classroom and/or dorm</td>
<td>FPM</td>
<td>Decision to go to Fire Marshal or not</td>
<td>FPM</td>
</tr>
<tr>
<td>5 If yes, go to Fire Marshal process</td>
<td>The project includes classroom and/or dorm</td>
<td>FPM</td>
<td>Fire Marshal procedure is followed</td>
<td>FPM</td>
</tr>
<tr>
<td>6 Decision made to go to schematic design and cost estimate</td>
<td>Decision made to develop schematic design and cost estimate</td>
<td>FPM and customer</td>
<td>Start schematic design and cost estimate process</td>
<td>FPM</td>
</tr>
<tr>
<td>7 Director assigns project planner (PP) and/or project engineer (PE) to the project</td>
<td>Decision to start schematic design and cost estimate</td>
<td>FPM</td>
<td>PP and/or PM is assigned to the project</td>
<td>FPM</td>
</tr>
<tr>
<td>8 Decision made to establish PFA for the project</td>
<td>Customer contacted on how the project will be funded</td>
<td>FPM and customer</td>
<td>Decision to fund the project by PFA</td>
<td>FPM and customer</td>
</tr>
<tr>
<td>9 Architect/Engineer (A/E) develops design proposal upon PM request</td>
<td>PM request for design proposal</td>
<td>PM</td>
<td>Developed design proposal</td>
<td>A/E</td>
</tr>
<tr>
<td>10 Does PP/PM accept design proposal?</td>
<td>Developed design proposal</td>
<td>A/E</td>
<td>Decision to accept or not</td>
<td>PP/PM</td>
</tr>
<tr>
<td>11 If no, rework and go to step 9</td>
<td>Design not accepted</td>
<td>PP/PM</td>
<td>Redevelop design</td>
<td>A/E</td>
</tr>
<tr>
<td>Step</td>
<td>Action</td>
<td>Responsible</td>
<td>Status</td>
<td>Comment</td>
</tr>
<tr>
<td>------</td>
<td>--------</td>
<td>-------------</td>
<td>--------</td>
<td>---------</td>
</tr>
<tr>
<td>12</td>
<td>If yes, PP/PM develops design contract and submits it to A/E for execution</td>
<td>Accepted design proposal</td>
<td>PP/PM</td>
<td>Design contract developed and submitted to A/E</td>
</tr>
<tr>
<td>13</td>
<td>A/E executes design contract and returns it to PP/PM with insurance certificate</td>
<td>Developed design contract</td>
<td>PP/PM</td>
<td>Executed design contract with insurance certificate</td>
</tr>
<tr>
<td>14</td>
<td>Decision to start project or not based on verification of funding</td>
<td>Verification of funding</td>
<td>Customer and FPM</td>
<td>Funding verified or not verified</td>
</tr>
<tr>
<td>15</td>
<td>If yes go to step 17</td>
<td>Funding verified</td>
<td>Customer and FPM</td>
<td>Go to step 17</td>
</tr>
<tr>
<td>16</td>
<td>If no, project stays on hold or die</td>
<td>Funding not verified</td>
<td>Customer and FPM</td>
<td>Project stays on hold or die</td>
</tr>
<tr>
<td>17</td>
<td>PP/PM prepares Redbook for contract execution and submits it for approval by different management levels</td>
<td>Executed design contract with insurance certificate</td>
<td>A/E</td>
<td>Redbook for contract execution approved by different management levels</td>
</tr>
<tr>
<td>18</td>
<td>Administrative actions to ensure funding existence, Purchase Order# (PO#) is issued, and PM retrieves PO# within Banner</td>
<td>Approved design contract</td>
<td>Different FPM management level</td>
<td>Administrative actions completed and PO# is issued</td>
</tr>
<tr>
<td>19</td>
<td>PM instructs A/E to develop schematic design</td>
<td>Issued PO# within Banner</td>
<td>Purchasing Department</td>
<td>Developed schematic design</td>
</tr>
<tr>
<td>20</td>
<td>A/E reviews schematic design with PM and customer</td>
<td>Developed schematic design</td>
<td>A/E</td>
<td>Reviewed schematic design</td>
</tr>
<tr>
<td>21</td>
<td>Does customer accept schematic design?</td>
<td>Reviewed schematic design</td>
<td>PM and customer</td>
<td>Decision to accept or not</td>
</tr>
<tr>
<td>22</td>
<td>If no, rework and go to step 19</td>
<td>Not accepted schematic design</td>
<td>PM and customer</td>
<td>Redvelop schematic design</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>---</td>
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<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>23</td>
<td>If yes, PM and A/E develop cost estimate</td>
<td>Accepted schematic design</td>
<td>PM and customer</td>
<td>Developed cost estimate</td>
</tr>
<tr>
<td>24</td>
<td>Does customer accept cost estimate?</td>
<td>Developed cost estimate</td>
<td>PM and A/E</td>
<td>Accept or not</td>
</tr>
<tr>
<td>25</td>
<td>If no, project dies</td>
<td>Developed/revised cost estimate</td>
<td>PM and A/E</td>
<td>Project discontinued (or put on hold)</td>
</tr>
<tr>
<td>26</td>
<td>If yes, a decision made to go to “bidding”</td>
<td>Accepted cost estimate</td>
<td>Customer</td>
<td>Decision to conduct the project with the “bidding procedure”</td>
</tr>
<tr>
<td>27</td>
<td>Did the design contract include development of construction documents (CD)?</td>
<td>Design contract</td>
<td>PM</td>
<td>Yes or No</td>
</tr>
<tr>
<td>28</td>
<td>If no, there are two options: option 1: PM prepares impact report to continue design phase and submit for logging</td>
<td>Design contract</td>
<td>PM</td>
<td>Impact report prepared</td>
</tr>
<tr>
<td>29</td>
<td>PM submits impact report for approval by different management levels</td>
<td>Prepared impact report</td>
<td>PM</td>
<td>Impact report submitted for approval by different management levels</td>
</tr>
<tr>
<td>30</td>
<td>Impact report returned to PM after authorization</td>
<td>Approved impact report</td>
<td>Different FPM management levels</td>
<td>Approved impact report returned to PM</td>
</tr>
<tr>
<td>31</td>
<td>Option 2: A/E develops change order proposal after PM instruction</td>
<td>Design contract</td>
<td>PM</td>
<td>Change order proposal developed</td>
</tr>
<tr>
<td>32</td>
<td>PM evaluates change order proposal</td>
<td>Developed change order proposal</td>
<td>A/E</td>
<td>Evaluated change order proposal</td>
</tr>
<tr>
<td>33</td>
<td>Does PM accept</td>
<td>Evaluated change</td>
<td>PM</td>
<td>Accept or not</td>
</tr>
<tr>
<td>Step</td>
<td>Description</td>
<td>Action 1</td>
<td>Action 2</td>
<td></td>
</tr>
<tr>
<td>------</td>
<td>------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>If no, Rework and go to step 31</td>
<td>Change order proposal not accepted</td>
<td>PM</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rework</td>
<td>A/E</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>If yes, PM prepares change order, and submits it to A/E for execution</td>
<td>Accepted change order proposal</td>
<td>PM</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Change order proposal prepared and submitted to A/E</td>
<td>PM</td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>A/E returns change order to PM after execution</td>
<td>Submitted change order to A/E</td>
<td>Change order executed and returned back to PM</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>A/E</td>
<td>A/E</td>
<td></td>
</tr>
<tr>
<td>37</td>
<td>PM prepares Redbook for change order execution and submits it for approval by different management levels</td>
<td>Executed change order</td>
<td>Redbook for change order prepared and submitted to different management levels for approval</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>A/E</td>
<td>PM</td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>Administrative actions to activate funding, Purchase Order# (PO#) is issued, and PM retrieves PO# within Banner</td>
<td>Approved Redbook for change order</td>
<td>Administrative actions conducted and PO# issued</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>FPM different management levels</td>
<td>Clerks and purchasing department</td>
<td></td>
</tr>
<tr>
<td>39</td>
<td>If yes for step 27, A/E develops CD’s and conducted required design review with PM and customer</td>
<td>Issued PO# within Banner</td>
<td>CD’s developed, required design reviewed</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Purchasing department</td>
<td>A/E, PM, and customer</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>PM develops project manual for bidding after completing CD’s</td>
<td>Developed CD’s, and reviewed design</td>
<td>Project manual for bidding is developed</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>A/E, PM, and customer</td>
<td>PM</td>
<td></td>
</tr>
<tr>
<td>41</td>
<td>FPM posts notice for bidding and holds a mandatory pre-bid conference with qualified bidders</td>
<td>Developed project manual for bidding</td>
<td>Notice for bidding posted; prebid conference is held</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PM</td>
<td>FPM</td>
<td></td>
</tr>
<tr>
<td>Step</td>
<td>Description</td>
<td>Responsible Parties</td>
<td></td>
<td></td>
</tr>
<tr>
<td>------</td>
<td>-----------------------------------------------------------------------------</td>
<td>------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>Bid Day: Bids received and accepted if “responsive”</td>
<td>Prebid conference conducted</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PM and FPM</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Received bids</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PM and FPM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>43</td>
<td>PM prepares Redbook for Long Form Construction Contract (LFCC) execution and submit it for approval by different management levels</td>
<td>Received bids</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PM and FPM</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Redbook for LFCC prepared and submitted for approval by different management levels</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>44</td>
<td>Administrative actions to ensure funding, Purchase Order# (PO#) is issued, and PM retrieves PO# within Banner</td>
<td>Redbook for LFCC prepared and submitted for approval</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PM</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Administrative actions conducted and PO# issued</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Clerks and purchasing department</td>
<td></td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>PM issues PO# to general contractor (GC)</td>
<td>Administrative actions conducted and PO# issued</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Clerks and purchasing department</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PO# issued to GC</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>46</td>
<td>GC constructs work</td>
<td>PO# issued to GC</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PM</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Work constructed</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>GC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>47</td>
<td>PM develops punchlist with customer and submits it to GC for completion</td>
<td>Constructed work</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>GC</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Punchlist developed and submitted to GC</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>GC completes punchlist</td>
<td>Submitted punchlist to GC</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PM</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Punchlist completed</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>GC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>49</td>
<td>Do PM and customer accept completed work?</td>
<td>Completed punchlist</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>GC</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Decision to accept or not</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PM and customer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>If no, rework and go to step 48</td>
<td>Constructed work not accepted</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PM and customer</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rework</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>GC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>51</td>
<td>If yes, Customer occupies completed facility</td>
<td>Constructed work accepted</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PM and customer</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Project completed</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

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

<table>
<thead>
<tr>
<th>Rating of importance to customers</th>
<th>Process step</th>
<th>Key process input variables (KPIV)</th>
<th>Project duration</th>
<th>Total project cost</th>
<th>Project quality</th>
<th>Project cost estimate reliability</th>
<th>Rank %</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Customer GIRF request via FPM website</td>
<td>Time and effort for customer to request a GIRF process</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>FPM Planning and Design Team acknowledges the request</td>
<td>Knowledge, skill and time availability of FPM Planning and Designing Team</td>
<td>6 (m)</td>
<td>6 (m)</td>
<td>6 (m)</td>
<td>5 (m)</td>
<td>8.2%</td>
<td>99</td>
</tr>
<tr>
<td>3</td>
<td>The project requires Fire Marshal process</td>
<td>Turnaround time with Fire Marshal procedure</td>
<td>8 (h)</td>
<td>6 (m)</td>
<td>6 (m)</td>
<td>0 (vl)</td>
<td>7.6%</td>
<td>92</td>
</tr>
<tr>
<td>4</td>
<td>CE develops cost estimate with assistance from sub-trades and reviews it with customer</td>
<td>Accuracy of project cost estimate</td>
<td>6 (m)</td>
<td>10 (vh)</td>
<td>6 (m)</td>
<td>10 (vh)</td>
<td>11.1%</td>
<td>134</td>
</tr>
<tr>
<td>5</td>
<td>Customer funds project and selects PFA as funding mechanism</td>
<td>The effect of selecting PFA as funding mechanism (complexity)</td>
<td>10 (vh)</td>
<td>8 (h)</td>
<td>6 (m)</td>
<td>7 (h)</td>
<td>10.9%</td>
<td>131</td>
</tr>
<tr>
<td>6</td>
<td>Project put on hold pending verification of PFA</td>
<td>Lack of availability of funds until PFA is verified</td>
<td>10 (vh)</td>
<td>8 (h)</td>
<td>5 (m)</td>
<td>0 (vl)</td>
<td>8.7%</td>
<td>105</td>
</tr>
<tr>
<td>7</td>
<td>Sub-trades develop lumpsum construction proposal and submit it to PM for evaluation</td>
<td>Time required for proposal submission and approval</td>
<td>8 (h)</td>
<td>9 (h)</td>
<td>9 (h)</td>
<td>8 (h)</td>
<td>12.1%</td>
<td>146</td>
</tr>
<tr>
<td>8</td>
<td>PM prepares Short Form Construction Contract (SFCC) and submits it to sub-trades for execution</td>
<td>Timeliness and accuracy of SFCC</td>
<td>6 (m)</td>
<td>7 (h)</td>
<td>9 (h)</td>
<td>0 (vl)</td>
<td>8.6%</td>
<td>104</td>
</tr>
<tr>
<td>9</td>
<td>PM prepares Redbook for SFCC execution and submits it</td>
<td>Time for getting FPM management approval for the</td>
<td>10 (vh)</td>
<td>5 (m)</td>
<td>10 (vh)</td>
<td>5 (m)</td>
<td>10.8%</td>
<td>130</td>
</tr>
<tr>
<td></td>
<td>to different FPM management levels for approval</td>
<td>SFCC execution</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>------------------------------------------------</td>
<td>--------------------------------------------------------------------------------</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Administrative actions to ensure funding, issue Purchase Order# (PO#), and PM retrieves PO# within Banner</td>
<td>Timeliness and efficiency of ensuring funding, issuing PO#, and retrieving it from Banner</td>
<td>9 (h)</td>
<td>8 (h)</td>
<td>5 (m)</td>
<td>6 (m)</td>
<td>9.9%</td>
<td>119</td>
</tr>
<tr>
<td>11</td>
<td>PM and customer do not accept completed work (punchlist)</td>
<td>Time and costs associated with completing punchlist</td>
<td>10 (vh)</td>
<td>8 (h)</td>
<td>9 (h)</td>
<td>7 (h)</td>
<td>12.1%</td>
<td>146</td>
</tr>
</tbody>
</table>
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, CEPI, 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>
<thead>
<tr>
<th>Process step</th>
<th>KPIV</th>
<th>Project duration</th>
<th>Total project cost</th>
<th>Project quality</th>
<th>Project cost estimate reliability</th>
<th>Rank %</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Customer GIRF request via FPM website</td>
<td>Time and effort for customer to request a GIRF process</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>2 FPM Planning and Design Team acknowledges the request</td>
<td>Knowledge and skill; time availability of FPM Planning and Designing Team</td>
<td>6 (m)</td>
<td>6 (m)</td>
<td>6 (m)</td>
<td>5 (m)</td>
<td>5.3%</td>
<td>99</td>
</tr>
<tr>
<td>3 The project requires Fire Marshal process</td>
<td>Turnaround time with Fire Marshal procedure</td>
<td>8 (h)</td>
<td>6 (m)</td>
<td>6 (m)</td>
<td>0 (vl)</td>
<td>4.9%</td>
<td>92</td>
</tr>
<tr>
<td>4 Decision made to establish PFA for the project</td>
<td>The effect of selecting PFA as funding mechanism (complexity)</td>
<td>10 (vh)</td>
<td>8 (h)</td>
<td>6 (m)</td>
<td>7 (h)</td>
<td>7%</td>
<td>131</td>
</tr>
<tr>
<td>5 A/E develops design proposal upon PM’s request</td>
<td>Time spent for and accuracy of developed design proposal</td>
<td>8 (h)</td>
<td>7 (h)</td>
<td>9 (h)</td>
<td>9 (h)</td>
<td>7.5%</td>
<td>139</td>
</tr>
<tr>
<td>6 PP/PM accept design proposal?</td>
<td>Assume no</td>
<td>7 (h)</td>
<td>6 (m)</td>
<td>8 (h)</td>
<td>5 (m)</td>
<td>6%</td>
<td>113</td>
</tr>
<tr>
<td>7 Customer funds project and selects PFA as funding mechanism</td>
<td>The effect of selecting PFA as funding mechanism (complexity)</td>
<td>10 (vh)</td>
<td>8 (h)</td>
<td>6 (m)</td>
<td>7 (h)</td>
<td>7%</td>
<td>131</td>
</tr>
<tr>
<td>8 Project put on hold pending verification of PFA</td>
<td>Lack of availability of funds until PFA is verified</td>
<td>10 (vh)</td>
<td>8 (h)</td>
<td>5 (m)</td>
<td>0 (vl)</td>
<td>5.6%</td>
<td>105</td>
</tr>
<tr>
<td></td>
<td><strong>PP/PM prepares Redbook for design contract execution and submits it to different management levels for approval</strong></td>
<td><strong>Time of getting FPM management approval</strong></td>
<td>10 (vh)</td>
<td>9 (h)</td>
<td>8 (h)</td>
<td>7 (h)</td>
<td>7.8%</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>10</td>
<td>Does customer accept schematic design and cost estimate? Assume no</td>
<td><strong>Rework time and cost of redeveloped schematic design and cost estimate</strong></td>
<td>8 (h)</td>
<td>9 (h)</td>
<td>9 (h)</td>
<td>9 (h)</td>
<td>8%</td>
</tr>
<tr>
<td>11</td>
<td><strong>Sub-trades develop lumpsum construction proposal and submit it to PM for evaluation</strong></td>
<td><strong>Time required for proposal submission and approval.</strong></td>
<td>8 (h)</td>
<td>9 (h)</td>
<td>9 (h)</td>
<td>8 (h)</td>
<td>7.8%</td>
</tr>
<tr>
<td>12</td>
<td><strong>PM prepares Short Form Construction Contract (SFCC) and submits it to sub-trades for execution</strong></td>
<td><strong>Timeliness and accuracy of SFCC</strong></td>
<td>6 (m)</td>
<td>7 (h)</td>
<td>9 (h)</td>
<td>0 (vl)</td>
<td>5.6%</td>
</tr>
<tr>
<td>13</td>
<td><strong>PM prepares Redbook for SFCC execution and submits it to different FPM management levels for approval</strong></td>
<td><strong>Time for getting FPM management approval for the SFCC execution</strong></td>
<td>10 (vh)</td>
<td>5 (m)</td>
<td>10 (vh)</td>
<td>5 (m)</td>
<td>7%</td>
</tr>
<tr>
<td>14</td>
<td><strong>Administrative actions to ensure funding, issue Purchase Order# (PO#), and PM retrieves PO# within Banner</strong></td>
<td><strong>Timeliness and efficiency of ensuring funding, issuing PO#, and retrieving it from Banner</strong></td>
<td>9 (h)</td>
<td>8 (h)</td>
<td>5 (m)</td>
<td>6 (m)</td>
<td>6.4%</td>
</tr>
<tr>
<td>15</td>
<td><strong>Sub-trades construct work</strong></td>
<td><strong>Sub-trades knowledge, training level, experience and motivation</strong></td>
<td>9 (h)</td>
<td>7 (h)</td>
<td>9 (h)</td>
<td>0 (vl)</td>
<td>6.2%</td>
</tr>
<tr>
<td>16</td>
<td><strong>PM and customer do not accept completed work (punchlist)</strong></td>
<td><strong>Time and costs associated with completing punchlist</strong></td>
<td>10 (vh)</td>
<td>8 (h)</td>
<td>9 (h)</td>
<td>7 (h)</td>
<td>7.8%</td>
</tr>
</tbody>
</table>
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>
<thead>
<tr>
<th>Rating of importance to customers</th>
<th>Key process input variables (KPIV)</th>
<th>Project duration</th>
<th>Total project cost</th>
<th>Project quality</th>
<th>Project cost estimate reliability</th>
<th>Rank %</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Customer GIRF request via FPM website</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>FPM Planning and Design Team acknowledges the request</td>
<td>6 (m)</td>
<td>6 (m)</td>
<td>6 (m)</td>
<td>5 (m)</td>
<td>4.7%</td>
<td>99</td>
</tr>
<tr>
<td>3</td>
<td>The project requires Fire Marshal process</td>
<td>8 (h)</td>
<td>6 (m)</td>
<td>6 (m)</td>
<td>0 (vl)</td>
<td>4.4%</td>
<td>92</td>
</tr>
<tr>
<td>4</td>
<td>Decision made to establish PFA for the project</td>
<td>10 (vh)</td>
<td>8 (h)</td>
<td>6 (m)</td>
<td>7 (h)</td>
<td>6.2%</td>
<td>131</td>
</tr>
<tr>
<td>5</td>
<td>A/E develops design proposal upon PM’s request</td>
<td>8 (h)</td>
<td>7 (h)</td>
<td>9 (h)</td>
<td>9 (h)</td>
<td>6.6%</td>
<td>139</td>
</tr>
<tr>
<td>6</td>
<td>PP/PM accept design proposal? Assume no</td>
<td>7 (h)</td>
<td>6 (m)</td>
<td>8 (h)</td>
<td>5 (m)</td>
<td>5.4%</td>
<td>113</td>
</tr>
<tr>
<td>7</td>
<td>Customer funds project and selects PFA as funding mechanism</td>
<td>10 (vh)</td>
<td>8 (h)</td>
<td>6 (m)</td>
<td>7 (h)</td>
<td>6.2%</td>
<td>131</td>
</tr>
<tr>
<td>8</td>
<td>Project put on hold pending verification of PFA</td>
<td>10 (vh)</td>
<td>8 (h)</td>
<td>5 (h)</td>
<td>0 (vl)</td>
<td>5%</td>
<td>105</td>
</tr>
<tr>
<td>9</td>
<td>PP/PM prepares Redbook for design contract execution and submits it for approval by different management levels</td>
<td>10 (vh)</td>
<td>9 (h)</td>
<td>8 (h)</td>
<td>7 (h)</td>
<td>6.9%</td>
<td>146</td>
</tr>
</tbody>
</table>

Table 16: Cause and effect matrix for the cost estimated, schematic design, with bidding project (CEPDB) GIRF sub-process
<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Does customer accept schematic design and cost estimate? Assume no</td>
<td>Rework time and cost of redeveloped schematic design and cost estimate</td>
<td>8 (h)</td>
<td>9 (h)</td>
<td>9 (h)</td>
</tr>
<tr>
<td>11</td>
<td>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 continue with design phase; and submits it for logging.</td>
<td>Time and costs needed to prepare and approve impact report.</td>
<td>8 (h)</td>
<td>8 (h)</td>
<td>7 (h)</td>
</tr>
<tr>
<td></td>
<td>Option 2: A/E develops change order proposal at PM’s direction</td>
<td>Time and costs needed to prepare and accept a change order proposal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>PM prepares Redbook for change order execution and submits it for approval by different management levels</td>
<td>Time of getting FPM management approval for the Redbook for change order execution</td>
<td>7 (h)</td>
<td>8 (h)</td>
<td>7 (h)</td>
</tr>
<tr>
<td>13</td>
<td>Assume yes for step11, A/E develops CD’s and conducts required design review with PM and customer</td>
<td>Time of developing and completing CD’s after design review</td>
<td>8 (h)</td>
<td>5 (m)</td>
<td>8 (h)</td>
</tr>
<tr>
<td>14</td>
<td>PM develops project manual for bidding after completing CD’s</td>
<td>Time spent by PM to develop project manual for bidding</td>
<td>6 (m)</td>
<td>7 (h)</td>
<td>6 (m)</td>
</tr>
<tr>
<td>15</td>
<td>PM prepares Redbook for Long Form Construction Contract (LFCC) execution and submits it to different management levels for approval</td>
<td>Time for getting FPM management approval for preparing LFCC</td>
<td>9 (h)</td>
<td>8 (h)</td>
<td>8 (h)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Knowledge, training level, experience, efficiency, and reliability of general contractor to construct work</td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>16</td>
<td>PM issues PO# to General Contractor (GC) and GC constructs work</td>
<td>Knowledge, training level, experience, efficiency, and reliability of general contractor to construct work</td>
<td>9 (h)</td>
<td>8 (h)</td>
<td>9 (h)</td>
</tr>
<tr>
<td>17</td>
<td>PM develops punchlist with customer and submits it to GC for completion; and GC completes punchlist</td>
<td>Accuracy and completeness of punchlist</td>
<td>9 (h)</td>
<td>6 (m)</td>
<td>9 (h)</td>
</tr>
<tr>
<td>18</td>
<td>Is completed work accepted by FPM and customer? Assume no</td>
<td>Time and costs associated with completing punchlist</td>
<td>10 (vh)</td>
<td>8 (h)</td>
<td>9 (h)</td>
</tr>
<tr>
<td>19</td>
<td>If yes, customer occupies facility</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
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 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 contractor 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>
<thead>
<tr>
<th>Process Step</th>
<th>Key Process Input</th>
<th>Potential Failure Mode(s)</th>
<th>Potential Failure Effects</th>
<th>Potential Causes of Failure</th>
<th>Occurrence</th>
<th>Current Controls for Prevention/Detection</th>
<th>Detection</th>
<th>Risk Priority Number (RPN)</th>
<th>Recommended Actions</th>
<th>Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer GIRF request via FPM website</td>
<td>Time and effort of customer to request a GIRF process</td>
<td>Faulty or incomplete reporting the problem</td>
<td>Delay in correcting errors and/or completing information</td>
<td>Unfocused customer; reporting form lacks clarity</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Design the GIRF form to include all required information, discuss with customer all required information after placing the request</td>
</tr>
<tr>
<td>FPM planning and design team acknowledges the request</td>
<td>Knowledge, skill and time availability of FPM Planning and Design Team (PD)</td>
<td>Improper handling of the request; errors and omissions in design</td>
<td>Project time delay; increased project costs,</td>
<td>Lack of knowledge/skills to handle the request</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Assign knowledgeable and skilled people for planning and design work of the project</td>
</tr>
<tr>
<td>The project requires Fire Marshal process</td>
<td>Turnaround time with Fire Marshal procedure</td>
<td>Faulty determination of if project requires Fire Marshal; incomplete documents required by Fire Marshal process</td>
<td>Project time delay</td>
<td>Lack of knowledge/ skill of FPM PD Team in submitting required documents to submit to Fire Marshal</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Skills training for members of FPM PD Team; double check documents before submitting to Fire Marshal</td>
</tr>
<tr>
<td>Request order (RO) is converted to Work Order (WO) and a Project Manager (PM) is assigned to execute the JDI process</td>
<td>Time and effort involved in converting RO to WO</td>
<td>Faulty and/or incomplete processing converting RO to a WO</td>
<td>Faulty and/or incomplete execution of project (not meeting project/customer requirements); project time delays and cost increase due to rework</td>
<td>Lack of skill for the PM; inadequate communication with customer to confirm his request</td>
<td>6</td>
<td>3</td>
<td>7</td>
<td>126</td>
<td>Double check WO before submitting it to sub-trades for project construction; better communication with customer to fully understand requirements</td>
<td>PM</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Sub-trades construct work</td>
<td>Sub-trades knowledge, skill training level, experience and motivation</td>
<td>Faulty and/or incomplete construction; reworks needed to correct deficiencies</td>
<td>Project time delay and cost increase due to rework</td>
<td>Lack of sub-trades knowledge, skills, training, and motivation of the sub-trades</td>
<td>9</td>
<td>2</td>
<td>6</td>
<td>108</td>
<td>Improve sub-trade selection &amp; oversight</td>
<td>Sub-trades</td>
</tr>
<tr>
<td>PM develops punchlist with customer and submits it to sub-trades for completion</td>
<td>Accuracy and completeness of punchlist (punchlist reflects all project sub-factors)</td>
<td>Faulty or incomplete punchlist</td>
<td>Project time delay and cost increase caused by rework on punchlist and sub-factors not included in original punchlist</td>
<td>Lack of focus and skill</td>
<td>8</td>
<td>2</td>
<td>5</td>
<td>80</td>
<td>Double check the punchlist before submitting it to sub-trades</td>
<td>PM</td>
</tr>
<tr>
<td>Do PM and customer accept completed work? Assume no</td>
<td>Amount of rework needed for completion of punchlist sub-factors by sub-trades</td>
<td>Substantial rework needed for some project tasks</td>
<td>Increasing time and cost of the project</td>
<td>Lack of skill, knowledge, training, and motivation of the sub-trades</td>
<td>8</td>
<td>5</td>
<td>6</td>
<td>240</td>
<td>Improve sub-trade selection &amp; oversight</td>
<td>Sub-trades</td>
</tr>
</tbody>
</table>
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>
<thead>
<tr>
<th>Process Step</th>
<th>Key Process Input</th>
<th>Potential Failure Mode(s)</th>
<th>Potential Failure Effects</th>
<th>Potential Causes of Failure</th>
<th>Current Controls for Prevention/Detection</th>
<th>Detection Risk Priority Number (RPN)</th>
<th>Recommended Actions</th>
<th>Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer GIRF request via FPM website</td>
<td>Time and effort of customer to request a GIRF process</td>
<td>Faulty or incomplete reporting the problem</td>
<td>Delay in correcting errors and/or completing information</td>
<td>Unfocused customer; reporting form lacks clarity</td>
<td>7</td>
<td>2</td>
<td>28</td>
<td>Design the GIRF form to include all required information, discuss with customer all required information after placing the request</td>
</tr>
<tr>
<td>FPM planning and design team acknowledges the request</td>
<td>Knowledge, skill and time availability of FPM Planning and Design Team (PD)</td>
<td>Improper handling of the request; errors and omissions in design</td>
<td>Project time delay; increased project costs,</td>
<td>Lack of knowledge/skills to handle the request</td>
<td>3</td>
<td>7</td>
<td>189</td>
<td>Assign knowledgeable and skilled people for planning and design work of the project</td>
</tr>
<tr>
<td>The project requires Fire Marshal process</td>
<td>Turnaround time with Fire Marshal procedure</td>
<td>Faulty determination of if project requires Fire Marshal; incomplete documents required by Fire Marshal process</td>
<td>Project time delay</td>
<td>5</td>
<td>Lack of knowledge/skill of FPM PD Team in submitting required documents to submit to Fire Marshal</td>
<td>4</td>
<td>5</td>
<td>100</td>
</tr>
<tr>
<td>CE develops cost estimate with assistance from sub-trades and reviews it with customer</td>
<td>Accuracy of project cost estimate</td>
<td>Faulty or incomplete estimation for the project cost</td>
<td>Substantial variation between the initial estimated cost and the Total project cost; customer may not accept the high faultly estimated cost because it will be over his funding capability</td>
<td>9</td>
<td>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</td>
<td>5</td>
<td>6</td>
<td>270</td>
</tr>
<tr>
<td>Customer funds project and selects PFA as funding mechanism</td>
<td>The effect of selecting PFA as funding mechanism (complexity)</td>
<td>Funding resources not available on time, administrative problems regarding the transformation of money to FPM account</td>
<td>Project time delay</td>
<td>7</td>
<td>Customer cannot confirm funding the project on time, unforeseen institutional transactional problems and regulations regarding money transfer</td>
<td>3</td>
<td>4</td>
<td>84</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Project put on hold pending verification of PFA</td>
<td>Lack of availability of funds until PFA is verified</td>
<td>Project time delay (project fund is not confirmed)</td>
<td>Project time delay; increased project costs</td>
<td>6</td>
<td>Customer unable to confirm project funding on time; unforeseen institutional transactional problems/ delays in fund transfer</td>
<td>4</td>
<td>4</td>
<td>96</td>
</tr>
<tr>
<td>Sub-trades develop lumpsum construction proposal and submit it to PM for evaluation</td>
<td>Time required for proposal submission and approval</td>
<td>Faulty and/or incomplete lumpsum construction proposal</td>
<td>Project time delay; increased project costs</td>
<td>4</td>
<td>Lack of skill/ knowledge, training for sub-trades, lack of focus</td>
<td>7</td>
<td>4</td>
<td>112</td>
</tr>
<tr>
<td>PM prepares Short Form Construction Contract (SFCC) and submits it to sub-trades for execution</td>
<td>Timeliness and accuracy of SFCC</td>
<td>Errors and omissions in SFCC</td>
<td>Project time delay</td>
<td>Lack of knowledge, skills, and lack of focus</td>
<td>4</td>
<td>6</td>
<td>120</td>
<td>Assign knowledgeable and skilled PM; more focus, double check prepared SFCC</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>PM prepares Redbook for SFCC execution and submits it to different FPM management levels for approval</td>
<td>Time for getting FPM management approval for the SFCC execution</td>
<td>Errors and omissions in Redbook for SFCC; Redbook approval takes long time</td>
<td>Project time delay</td>
<td>Lack of Knowledge/skills for PM; burocratic procedures in getting approval of different management levels</td>
<td>4</td>
<td>4</td>
<td>80</td>
<td>Assign knowledgeable and skilled PM; more focus; facilitating the higher management procedure for approval</td>
</tr>
<tr>
<td>Administrative actions to ensure funding, issue Purchase Order# (PO#), and PM retrieves PO# within Banner</td>
<td>Timeliness and efficiency of ensuring funding, issuing PO#, and retrieving it from Banner</td>
<td>Administrative actions take long time, Some mistakes and/or missed information in the PO</td>
<td>Project time delay; increased project costs</td>
<td>Burocracy in the administrative actions, lack of focus, lack of knowledge/skills for some administrative employees</td>
<td>6</td>
<td>4</td>
<td>120</td>
<td>Facilitating the administrative procedures, more focus, more training and motivation for the employees</td>
</tr>
<tr>
<td>PM and customer do not accept completed work (punchlist)</td>
<td>Time and costs associated with completing punchlist</td>
<td>Rework needed for some project tasks</td>
<td>Project time delay; increased project costs</td>
<td>lack of knowledge/skills, training, and motivation for sub-trades</td>
<td>5</td>
<td>6</td>
<td>240</td>
<td>More training and motivation for the sub-trades</td>
</tr>
</tbody>
</table>
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>
<thead>
<tr>
<th>Process Step</th>
<th>Key Process Input</th>
<th>Potential Failure Mode(s)</th>
<th>Potential Failure Effects</th>
<th>Severity</th>
<th>Potential Causes of Failure</th>
<th>Occurrence</th>
<th>Current Controls for Prevention/Detection</th>
<th>Detection</th>
<th>Risk Priority Number (RPN)</th>
<th>Recommended Actions</th>
<th>Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer GIRF request via FPM website</td>
<td>Time and effort of customer to request a GIRF process</td>
<td>Faulty or incomplete reporting the problem</td>
<td>Delay in correcting errors and/or completing information</td>
<td>2 (Low)</td>
<td>Unfocused customer; reporting form lacks clarity</td>
<td>7</td>
<td></td>
<td>2</td>
<td>28</td>
<td>Design the GIRF form to include all required information, discuss with customer all required information after placing the request</td>
<td>Customer</td>
</tr>
<tr>
<td>FPM planning and design team acknowledges the request</td>
<td>Knowledge, skill and time availability of FPM Planning and Design Team (PD)</td>
<td>Improper handling of the request; errors and omissions in design</td>
<td>Project time delay; increased project costs,</td>
<td>9</td>
<td>Lack of knowledge/skills to handle the request</td>
<td>3</td>
<td></td>
<td>7</td>
<td>189</td>
<td>Assign knowledgeable and skilled people for planning and design work of the project</td>
<td>FPM Planning and Design (PD) Team</td>
</tr>
<tr>
<td>The project requires Fire Marshal process</td>
<td>Turnaround time with Fire Marshal procedure</td>
<td>Faulty determination of if project requires Fire Marshal; incomplete documents required by Fire Marshal process</td>
<td>Project time delay</td>
<td>5</td>
<td>Lack of knowledge/ skill of FPM PD Team in submitting required documents to submit to Fire Marshal</td>
<td>4</td>
<td></td>
<td>5</td>
<td>100</td>
<td>Skills training for members of FPM PD Team; double check documents before submitting to Fire Marshal</td>
<td>FPM PD Team</td>
</tr>
<tr>
<td><strong>A/E develops design proposal upon PM’s request</strong></td>
<td><strong>Time spent for and accuracy of developed design proposal</strong></td>
<td><strong>Developed design proposal takes longer than scheduled; errors and omissions in design; design developed in a way that doesn’t save costs</strong></td>
<td><strong>Project time delay due to redesign to get customer acceptance</strong></td>
<td><strong>Lack of knowledge/skills for A/E; incomplete information about the project; pile up of designs needed to be developed by A/E</strong></td>
<td><strong>Assign knowledgeable and skilled A/E to prepare designs; do not pile up design jobs by hiring more designers when need</strong></td>
<td><strong>A/E</strong></td>
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</tbody>
</table>

| **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** | **Lack of knowledge/skills and experience for A/E; faulty or incomplete or faulty information about the project** | **Assign knowledgeable, skilled A/E to prepare designs; motivate local designers** | **PM** |

<p>| <strong>Customer funds project and selects PFA as funding mechanism</strong> | <strong>The effect of selecting PFA as funding mechanism (complexity)</strong> | <strong>Funding resources not available on time, administrative problems regarding the transformation of money to FPM account</strong> | <strong>Delay time for project completion, confusing detailed project schedules</strong> | <strong>Customer cannot confirm funding the project on time, unforeseen transactional problems and regulations regarding money transfer</strong> | <strong>Customer should confirm his funding resources, and transactional process should be explained to the customer very clearly in the early stages of the project</strong> | <strong>Customer and FPM</strong> |</p>
<table>
<thead>
<tr>
<th>Issue</th>
<th>Cause</th>
<th>Impact</th>
<th>Resolution</th>
<th>Person Responsible</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project put on hold pending verification of PFA</td>
<td>Lack of availability of funds until PFA is verified</td>
<td>Delaying in project finishing time. project schedules messed up leading to project time delay</td>
<td>Customer cannot confirm funding the project on time, unforeseen transactional problems and regulations regarding money transfer</td>
<td>Customer</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Time of getting FPM management approval</td>
<td>Incomplete or faulty information included in Redbook for design contract execution; Redbook approval takes long time</td>
<td>Project time delay</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Time required for proposal submission and approval</td>
<td>Schematic design and/or cost estimate not accepted</td>
<td>Project time delay; project die</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Developed lumpsum construction proposal is not accurate and/or not completed</td>
<td>Delay time for finishing the project</td>
<td>Lack of skill for sub-trades, lack of focus</td>
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<tr>
<td></td>
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<td>More training and motivation for existing sub-trades, skill should be of the highest priority when hiring new sub-trades</td>
</tr>
<tr>
<td>PM prepares Short Form Construction Contract (SFCC) and submits it to sub-trades for execution</td>
<td>Timeliness and accuracy of SFCC</td>
<td>Prepared SFCC in not accurate, some required information in the contract is not included.</td>
<td>Time delay for the project</td>
<td>5</td>
</tr>
<tr>
<td>PM prepares Redbook for SFCC execution and submits it to different FPM management levels for approval</td>
<td>Time for getting FPM management approval for the SFCC execution</td>
<td>Redbook for SFCC in not well prepared, Redbook approval take long time</td>
<td>Time delay for the project</td>
<td>5</td>
</tr>
<tr>
<td>Administrative actions to ensure funding, issue Purchase Order# (PO#), and PM retrieves PO# within Banner</td>
<td>Timeliness and efficiency of ensuring funding, issuing PO#, and retrieving it from Banner</td>
<td>Administrative actions take long time, Some mistakes and/or missed information in the PO</td>
<td>Time delay for the project, cost increased</td>
<td>5</td>
</tr>
<tr>
<td>PM and customer do not accept completed work (punchlist)</td>
<td>Time and costs associated with completing punchlist</td>
<td>Rework needed for some project tasks</td>
<td>Increasing time and cost of the project</td>
<td>8</td>
</tr>
</tbody>
</table>
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
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<tbody>
<tr>
<td>Customer GIRF request via FPM website</td>
<td>Time and effort of customer to request a GIRF process</td>
<td>Faulty or incomplete reporting the problem</td>
<td>Delay in correcting errors and/or completing information</td>
<td>2 (Low)</td>
<td>Unfocused customer; reporting form lacks clarity</td>
<td>7</td>
<td></td>
<td></td>
<td>2 28</td>
<td>Design the GIRF form to include all required information, discuss with customer all required information after placing the request</td>
<td>Customer</td>
<td></td>
</tr>
<tr>
<td>FPM planning and design team acknowledges the request</td>
<td>Knowledge, skill and time availability of FPM Planning and Design Team (PD)</td>
<td>Improper handling of the request; errors and omissions in design</td>
<td>Project time delay; increased project costs,</td>
<td>9</td>
<td>Lack of knowledge/skills to handle the request</td>
<td>3</td>
<td></td>
<td></td>
<td>7 189</td>
<td>Assign knowledgeable and skilled people for planning and design work of the project</td>
<td>FPM Planning and Design Team (PD)</td>
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</tr>
<tr>
<td>Step</td>
<td>Description</td>
<td>Cause</td>
<td>Impact</td>
<td>Recommended Action</td>
<td>Responsible</td>
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<tr>
<td>1</td>
<td>The project requires Fire Marshal process</td>
<td>Turnaround time with Fire Marshal procedure</td>
<td>Faulty determination of if project requires Fire Marshal; incomplete documents required by Fire Marshal process</td>
<td>Project time delay</td>
<td>5</td>
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<td></td>
<td>Lack of knowledge/skill of FPM PD Team in submitting required documents to submit to Fire Marshal</td>
<td>4</td>
<td>5</td>
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<td>Skills training for members of FPM PD Team; double check documents before submitting to Fire Marshal</td>
<td>FPM PD Team</td>
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<tr>
<td>2</td>
<td>A/E develops design proposal upon PM’s request</td>
<td>Time spent for and accuracy of developed design proposal</td>
<td>Developed design proposal takes longer than scheduled, has mistakes, bad design and doesn't save costs.</td>
<td>will take extra time to redesign and make the proper design accepted by customer</td>
<td>4</td>
<td>5</td>
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<td>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</td>
<td>4</td>
<td>80</td>
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<tr>
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<td></td>
<td>Assign skilled A/E to prepare designs, motivate local designers when need</td>
<td>A/E</td>
<td>4</td>
<td>80</td>
<td></td>
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</tr>
<tr>
<td>3</td>
<td>PP/PM accept design proposal? Assume no</td>
<td>Time spent by PP/PM to review and accept design proposal</td>
<td>Project delayed</td>
<td>will take extra time to redesign and make the proper design accepted by customer</td>
<td>4</td>
<td>5</td>
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<td></td>
<td>Lack of skill and experience for A/E, lack of information about the project</td>
<td>4</td>
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<td></td>
<td>Assign skilled A/E to prepare designs, motivate local designers</td>
<td>PM</td>
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<tr>
<td>Customer funds project and selects PFA as funding mechanism</td>
<td>The effect of selecting PFA as funding mechanism (complexity)</td>
<td>Funding resources not available on time, administrative problems regarding the transformation of money to FPM account</td>
<td>Delay time for project completion, confusing detailed project schedules</td>
<td>Customer cannot confirm funding the project on time, unforeseen transactional problems and regulations regarding money transfer</td>
<td>4</td>
<td>84</td>
<td>Customer should confirm his funding resources, and transactional process should be explained to the customer very clearly in the early stages of the project</td>
<td>Customer and FPM</td>
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<tr>
<td>Project put on hold pending verification of PFA</td>
<td>Lack of availability of funds until PFA is verified</td>
<td>Delaying in project finishing time.</td>
<td>in project schedules leading to project finishing time delay</td>
<td>Customer cannot confirm funding the project on time, unforeseen transactional problems and regulations regarding money transfer</td>
<td>4</td>
<td>96</td>
<td>Customer should confirm his funding resources, and transactional process should be explained to the customer very clearly in the early stages of the project</td>
<td>Customer</td>
<td></td>
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</tr>
<tr>
<td>PP/PM prepares Redbook for design contract execution and submits it to different management levels for approval</td>
<td>Time of getting FPM management approval</td>
<td>Redbook for design contract execution has missed information, long time for higher management approval procedure</td>
<td>Project time delay</td>
<td>PP/PM are not enough skilled or well trained, not enough focus, no double checking before submit the Redbook,</td>
<td>4</td>
<td>80</td>
<td>Double check the Redbook before submitting, facilitate the procedure of higher management approval process</td>
<td>PP/PM, different management levels</td>
<td></td>
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</tr>
<tr>
<td>Does customer accept schematic design and cost estimate? Assume no</td>
<td>Rework time and cost of redesigned schematic design and cost estimate</td>
<td>Project delay waiting for redesign and redo cost estimate, project die or put on hold</td>
<td>project time delay, project die</td>
<td>Customer budget is limited, cost estimation is not reliable or over customer expectation</td>
<td>7</td>
<td>4</td>
<td>3</td>
<td>84</td>
<td>Double check designs and cost estimation before submit it to customer</td>
<td>Customer</td>
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<tr>
<td>Did the design contract include development of construction documents (CD) and (CA) services? Assume no, and consider options 1 and 2</td>
<td>Time and costs needed to prepare and approve impact report. Time and costs needed to prepare and accept a change order proposal</td>
<td>Incomplete impact report information; incomplete change order proposal information</td>
<td>Project time delay</td>
<td>Lack of knowledge and/or skills for the PM, no double check after preparing both impact report or change order proposal</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>100</td>
<td>Skilled and Assign knowledge, and skilled PM for the project, double check after preparing impact report or change order proposal</td>
<td>PM, A/E</td>
<td></td>
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</tr>
<tr>
<td>PM’s direction</td>
<td>Time of getting FPM management approval for the Redbook for change order execution</td>
<td>Incomplete information in the Redbook for change order, long time for higher management approval procedure</td>
<td>Project time delay</td>
<td>PP is not enough skilled or well trained, not enough focus, no double checking before submit the Redbook,</td>
<td>4</td>
<td>80</td>
<td>Skilled and knowledge PM should be assigned for the project, double check after preparing The Redbook for change order execution</td>
<td>PM</td>
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<tr>
<td>Assume yes for step11, A/E develops CD’s and conducts required design review with PM and customer</td>
<td>Time of developing and completing CD’s after design review</td>
<td>CD’s are not completed, PM and/or customer not accepting the design</td>
<td>Project time delay, increasing project costs</td>
<td>Lack of knowledge/ skills; pile up of work need to be done</td>
<td>5</td>
<td>100</td>
<td>Assign knowledgeable, skilled and trained A/E; made actions to do the jobs without piling up</td>
<td>A/E</td>
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<tr>
<td>PM develops project manual for bidding after completing CD’s</td>
<td>Time spent by PM to develop project manual for bidding</td>
<td>Incomplete or confusing information in the project manual for bidding; long time spent for developing the manual</td>
<td>Project time delay; may cause bidders get confused about the project</td>
<td>PM do not aware with all aspects of the bidding, CD’s information is not completed</td>
<td>4</td>
<td>80</td>
<td>PM should be aware of all bidding aspects, PM should have knowledge how to prepare project manual for bidding as simple as possible</td>
<td>PM</td>
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</tr>
<tr>
<td>PM prepares Redbook for Long Form Construction Contract (LFCC) execution and submits it to different management levels for approval</td>
<td>Time for getting FPM management approval for preparing LFCC</td>
<td>Incomplete information in the Redbook for LFCC, long time for higher management approval procedure</td>
<td>Project time delay due to reworking the Redbook</td>
<td>Lack of knowledge/skills, and training for PM; not enough focus; no double check before submit the Redbook</td>
<td>4</td>
<td>100</td>
<td>Assign knowledgeable, skilled and trained PM for the project; double check after preparing The Redbook for LFCC</td>
<td>PM</td>
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<tr>
<td>PM issues PO# to General Contractor (GC) and GC constructs work</td>
<td>Knowledge, training level, experience, efficiency, and reliability of general contractor to construct work</td>
<td>Incomplete or missed information in PO# to make GC construct work; work not constructed according to specifications</td>
<td>Project time delay, increased project costs; disputes with GC</td>
<td>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</td>
<td>5</td>
<td>200</td>
<td>Double check PO# before issuing, carefully select the GC who has the ability to do the job according to specifications</td>
<td>PM</td>
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<tr>
<td>PM develops punchlist with customer and submits it to GC for completion; and GC completes punchlist</td>
<td>Accuracy and completeness of punchlist</td>
<td>Punchlist do not cover all the project tasks; substandard quality in punchlist completion by GC</td>
<td>Project time delay; increased project costs due to reworking</td>
<td>Not enough focusing when preparing punchlist; Lack of GC staff knowledge; skills, and training</td>
<td>5</td>
<td>210</td>
<td>Double check punchlist before submitted to GC; carefully selecting GC according to strict specifications</td>
<td>PM</td>
<td></td>
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</tr>
<tr>
<td>Is completed work accepted by FPM and customer? Assume no</td>
<td>Time and costs associated with completing punchlist</td>
<td>Project completion is not accepted by customer</td>
<td>Project time delay; increased project costs due to reworking</td>
<td>Lack of GC staff knowledge; skills, and training</td>
<td>5</td>
<td>210</td>
<td>carefully selecting GC according to strict specifications</td>
<td>GC</td>
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<tr>
<td>If yes, customer occupies facility</td>
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Figure 40: Pareto chart prioritizing the most impact hazardous on the process output for the cost estimate, design, and bidding (CEPDB) GIRF sub-proces
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.plantops.umich.edu/
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.campusservices.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 (laminate, 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, HVAC 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)

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)

**Professional Judgement**
Diagnosis, competence, Advice, guidance, innovation, Honesty, confidentiality, Flexibility, discretion, Knowledge

<table>
<thead>
<tr>
<th>Physical facilities and processes:</th>
<th>Behavioral aspects:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location, layout, décor, Size, Facility reliability Process flow, capacity Balance, Control of flow Process flexibility, Timeliness, speed Ranges of services offered Communication</td>
<td>Timeliness, speed Communication (verbal, non-verbal), courtesy, warmth, friendliness, tact, attitude, tone of voice, Dress, neatness, politeness, Attentiveness, anticipation, Handling complaints, solving problems</td>
</tr>
</tbody>
</table>

1. Short contact/interaction intensity-low customization, for e.g. Hardware/grocery shop
2. Medium contact/interaction intensity-low customization
3. High contact/interaction intensity-low customization, for e.g. Education
4. Low contact/interaction intensity-high customization, for e.g. Clubs
5. High contact/interaction intensity-high customization, for e.g. Health care services

**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)

Value level

Ideal Standard

Experience outcome

Attitude Level

Negative Disconfirmation

Satisfaction

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

- Expected Speed of Delivery
- Expected Ease of Use
- Expected Reliability
- Expected Enjoyment
- Expected Control

Expected Service

Quality of technology based self-service option

Intention to use Technology based self-service Option

(b) Overall Affect Model

- Attitude toward using Technological Products
- Need for interaction with Service Employee

Expected Service

Quality of technology based self-service option

Intention to use Technology based self-service Option

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

Source: Spreng and Mackoy (1996)
PCP attribute model (Philip and Hazlett, 1997)

Increasing importance of weighing of attributes

The service environment

Peripheral attributes
Incidental extras or frills designed to add a roundness to the service encounter and make the whole experience a complete delight

Core Attribute
The people, process, and organizational structure with which a consumer must interact and/or negotiate in order to achieve and receive the pivotal attributes

Pivotal Attributes
The end product or output from the service encounter, that is, what the consumer expects to achieve and perhaps take away from the service process

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)

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

Source: Frost and Kumar (2000)
Consumable Resources → Branch 1 → Service Quality

Account Structure

Consumable Resources → Branch 2 → Service Quality

Account Structure

Consumable Resources → Branch n → Service Quality

Account Structure

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

**Source:** Zhu et al. (2002)

**Source:** Santos (2003)
21. Organizational service quality model (Moore)

- Identify quality problems
  - Provide staff and financial resources
  - Integrate quality improvement with other corporate programmes
  - Emphasize importance of quality improvement efforts

- Define external and internal customers' expectations

- Assess magnitude of quality problems
  - Identify causes of low quality
  - Estimate cost of low service quality

- Obtain management commitment

- Identify customer expectation

- Evaluate performance

- Develop quality strategy

- Implement strategy

- Monitor performance

- Assess effectiveness of quality improvement
  - Revise standards and plans
  - Identify changes in customers

- Change culture
  - Improve performance
  - Reduce costs

- Commitment statement
  - Quality objectives
  - Quality standards
  - Quality action plans
  - Monitoring systems

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

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Factor/sub-factor Description</th>
<th>R1</th>
<th>R2</th>
<th>R3</th>
<th>R4</th>
<th>R5</th>
<th>Total R</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1 (Factor 1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F11 (Sub-factor1)</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F12 (Sub-factor 2)</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>F13 (Sub-factor 3)</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>F14 (Sub-factor4)</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>F1X (Sub-factor X)</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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 □

<table>
<thead>
<tr>
<th>Service Type</th>
<th>Rating 0-10</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Plumbing and water leaks</td>
<td></td>
</tr>
<tr>
<td>A- Restroom fixtures</td>
<td></td>
</tr>
<tr>
<td>B- Water fountains</td>
<td></td>
</tr>
<tr>
<td>2 Electrical Systems and lighting</td>
<td></td>
</tr>
<tr>
<td>A- Interior lighting</td>
<td></td>
</tr>
<tr>
<td>B- Exterior lighting</td>
<td></td>
</tr>
<tr>
<td>3 Heating, Ventilation, and Air Conditioning (HVAC) including pipe fitting.</td>
<td></td>
</tr>
<tr>
<td>A- Winter comfort</td>
<td></td>
</tr>
<tr>
<td>B- Summer comfort</td>
<td></td>
</tr>
<tr>
<td>4 Elevators</td>
<td></td>
</tr>
<tr>
<td>A- Operations and reliability</td>
<td></td>
</tr>
<tr>
<td>5 Other service</td>
<td></td>
</tr>
<tr>
<td>A- Door hardware and keys</td>
<td></td>
</tr>
<tr>
<td>B- Ceilings</td>
<td></td>
</tr>
<tr>
<td>C- Floors</td>
<td></td>
</tr>
<tr>
<td>D- Painting</td>
<td></td>
</tr>
</tbody>
</table>
The measuring instrument (p2)

<table>
<thead>
<tr>
<th></th>
<th>Response time</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A- Maintenance work requests</td>
</tr>
<tr>
<td></td>
<td>B- GIRF work requests (General Improvement Request Form)</td>
</tr>
<tr>
<td>7</td>
<td>Satisfaction with work performed</td>
</tr>
</tbody>
</table>

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