DEVELOPMENT OF CORPORATE FRAMEWORK

FOR AVIATION ENGINEERING COMPLEX

BY

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A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENT FOR THE DEGREE OF
MASTER OF SCIENCE
in
Systems Engineering

RESEARCH CENTER FOR MODELING & SIMULATION (RCMS)

NATIONAL UNIVERSITY OF SCIENCES AND TECHNOLOGY (NUST), ISLAMABAD

DECEMBER, 2017

Annex A to NUST Letter No. 0972/102/Exams/Thesis-Cert dated 23 Dec 16.

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I hereby certify that the work embodied in this thesis is the result of original research and has not been submitted for a higher degree to any other University or Institution.

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Murtaza Alam

Dedication

I dedicate this effort to all those who have assisted me in any possible way to become what I am today. Their sacrifices seeded my success especially my parents who showed their devoted attention and to faculty members who inspired me all the way.

Declaration

I hereby declare that the work presented in the following thesis titled as "*Development of Corporate framework for Aviation Engineering Complex"* is my own effort, except where otherwise acknowledged, and that the thesis is my own composition. All the secondary data has been cited properly in dissertation report and accordingly sources have been mentioned in references.

Murtaza Alam

Acknowledgments

First and foremost, I would like to express my gratitude to Allah Almighty who gave me an opportunity to explore my natural abilities and blessing me with the courage to complete this desired task in the required time frame.

Special thanks goes to my supervisor, Dr. Adnan Maqsood, Assistant Professor, RCMS, NUST, who did his level best to guide me with the latest knowledge and encouraged me to move ahead to brighten the future of our country in a friendly and conducive environment specifically in Systems Engineering field. I also owe gratitude to my respected committee members especially, Engr. Tanveer Ahmad who made untiring efforts to make this pioneering thesis possible in said field through his continuous support.

I am highly obliged to Engr. Sikander Hayat Mirza for his overall guidance and Engineer Shakeel Ahmed Jan, Garrison Engineer (Construction) of Pakistan Navy, for his valuable assistance and support. Finally, I would also like to express my gratitude to my respected faculty members for equipping me with knowledge to accomplish this milestone.

Abstract

Systems Engineering (SYSE) is a multidisciplinary field that makes effective insight into complex engineering projects. Realizing the significant contribution that application of SYSE has made in public as well as private sectors in project management fields for developed countries, establishing corporate framework for Aviation Engineering Complex (AEC) in exclusive Aerospace & Defence (A&D) sector is considered in this thesis. Customized "System Engineering Management Plan" (SEMP) for corporate framework of AEC was prepared through application of SYSE approach in conjunction with SYSE tools. This SEMP contains organizational structure to be followed, tasks, interfaces, activities, and objectives of SYSE management required to accomplish and control the project. Establishment of AEC is envisaged to be an international standard, very high quality, private sector infrastructure in A&D sector of Pakistan that will look after the interest of customers and will also contribute to national goals in terms of imports substitution and exports enhancements. House of Quality (HOQ) was prepared for selecting site of AEC. Results of HOQ indicated that preferred site for AEC will be situated close to Kamra to take advantage of huge engineering capabilities of Pakistan Aeronautical Complex (PAC), secure environment, good civic infrastructure and possible access to social facilities of the area. Corporate framework will house Enterprise Resource Planning (ERP), quality, Human Resource (HR), finance & marketing and administration departments. A strong matrix structure is proposed in AEC to support six independent, mutually supporting business units of technical segment. Corporate center will provide administration, quality, ERP, HR and financial support / services to the technical units on as and when required basis. Interface identification and development between system elements is so vital for smooth functioning of any complex system. Same has been addressed by categorizing interfaces between corporate sub-departments into three types for development of system model. Implementation of customized industry standard automation tool such as ERP and its selection using Analytical Hierarchy Process (AHP) based on seven factors criteria is novel part of this work which has never been practiced for A&D sector specifically.

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List of Abbreviations

AEC	Aviation Engineering Complex
A&D	Aerospace & Defence
SEMP	System Engineering Management Plan
ERP	Enterprise Resource Planning
SYSE	System Engineering
CW	Civil Works
MRO	Maintenance, Repair & Overhaul
PMEL	Precision Measuring Equipment Lab
SP & HM	Small Parts & Harness Manufacturing
T & C	Training & Consultancy
I & O	Indenting & Outsourcing
AL	Assembly Line
PAC	Pakistan Aeronautical Complex
CAA	Civil Aviation Authority
FAA	Federal Aviation Administration
EASA	European Aviation Safety Agency
IATA	International Air Transport Association
CPEC	China Pakistan Economic Corridor
QFD	Quality Function Deployment
HOQ	House of Quality
AHP	Analytical Hierarchy Process
PMP	Program Management Plan
SYSML	System Modeling Language
UML	Unified Modeling Language
MBSE	Model Based System Engineering
HRM	Holistic Requirement Model
NMA	Need Mean Analysis
BoDs	Board of Directors
BU	Business Units
PDR	Preliminary Design Review
CDR	Critical Design Review

PMR	Programme Management Review
PEC	Pakistan Engineering Council
QC	Quality Control
QA	Quality Assurance
FFBD	Functional Flow Block Diagram
SoS	System of Systems
TPMs	Technical Performance Measures
R&D	Research and Development
PP	Production Planning
SLA	Service Level Agreement
CI	Consistency Index
CR	Consistency Ratio
PERT	Programme Evaluation and Review Technique
OEM	Original Equipment Manufacturer
STA	System Textual Analysis

CHAPTER 1 – INTRODUCTION

This introductory chapter of subject research covers the purpose, overview, aviation sector and its importance followed by the need for establishing private sector aviation complex in Pakistan.

1.1 PURPOSE

Industrial project selected for following thesis work is "Development of Corporate Framework for International Standard Aviation Engineering Complex" (AEC) in private Aerospace & Defence (A&D) sector of Pakistan. AEC, when established, will provide highest quality of certified aviation products and services to both public and private sector domestic as well as international customers. Keeping in view the diversity, complexity, requirements, areas of applicability and time constraint, AEC is divided into two segments, first one will cover technical facility and second one will deal with corporate cognitions in complex engineering projects. The need for corporate sector to support technical operations is considered paramount in any complex project. This document will serve as a customized System Engineering Management Plan (SEMP) for building corporate framework for AEC and will provide planning guidance for assigning management responsibilities, Enterprise Resource Planning (ERP) system evaluation and selection, equipment procurement and installation, Civil Works (CW) developments and quality certifications. This study will not only encourage future students to opt for industrial related projects but will also raise the stature of RCMS in pioneering role of system engineering (SYSE) field in Pakistan.

1.2 OVERVIEW

The project when operational will be first of its kind in the country. AEC will look after the interest of customers and will also contribute to nation in terms of indigenization. The AEC will house Maintenance Repair & Overhaul (MRO), Precision Measuring Equipment Lab (PMEL), Small Parts & Harness Manufacturing (SP & HM), Training & Consultancy (T & C), Indenting & Outsourcing (I & O), and Assembly Line (AL) units to provide services to local and foreign customers. Major AEC customers will be Pakistan Air Force (PAF), Pakistan Aeronautical Complex (PAC) Kamra, Army Aviation and Naval Aviation for phase-I whereas regional defence forces and local airlines in phase II. PAC's international customers will also be targeted for provisioning of AEC services. AEC will be certified with generic Integrated

Management Standards ISO 9001-2015 Quality Management System (QMS), 14001 Environment Management System (EMS), 18001 Occupational Health and Safety Management (OHSA), Aerospace AS 9100 Rev D, Civil Aviation Authority (CAA) Pakistan, European Aviation Safety Agency (EASA) / Federal Aviation Administration (FAA) and customer specific standards (if required).

It will leverage modern technologies, including Industry standard ERP system, for well-organized operations. Main focus will be on producing quality products that are accompanied with quality services while minimizing delivery cycles and less pricing compared to competitors. AEC will offer these advantages to its customers by relying on strengths to be drawn from its high quality Human Resource (HR) that will comprise of both ex PAC/Military Aviation setup and corporate background professionals. Ex- PAC/Military MRO experienced personnel will form bulk of AEC technical HR that is considered its real asset because of their exposure to high tech environments in developed countries, and discipline.

1.3 IMPORTANCE OF AVIATION SECTOR

Aviation sector is an important part of national economy in providing movement of people and goods throughout the world and contributes a lot towards economic affluence. It is the quickest means of transportation till date. Apart from this, it also creates large number of high-value jobs being from hi-tech environment. Overall aviation industry and its numerous related businesses are growing rapidly fast. Based on economic and demographic growth, International Air Transport Association (IATA) has projected intra Pakistan air traffic to grow at 9.9%, Middle East and Asia-Pacific at 9% and 7.6% respectively over the next 20 years [1]. In Pakistan, large scale induction in PAF, Army, Naval aviation and increase in number of private airlines has upraised new prospects in Pakistan's aviation industry.

This MRO business is growing rapidly worldwide. J M Burger [2] stated in his report that global commercial MRO business has remained US$ 64.3 billion in year 2015 with contribution of US$ 18 billion (28%) from Asia, Middle East US$ 5.2 billion (8%), America US$ 24.4 billion (38%) and Europe US$ 16.7 billion (26%). This commercial MRO market is expected to grow by 4.1% per annum from US$ 64.3 billion to US$ 96 billion by 2025. Global Fleet & MRO Market Forecast Summary [3] predicted that total commercial MRO spending in 2017 are expected to be US$ 75.6 billion in 2017. Deloitte [4] in their report specified that global military aviation MRO market is expected to be US$ 18.5 billion in 2017 & defence

sector revenues are likely to grow by 3.2% in year 2017. This multi-billion dollar MRO market has remained untapped in Pakistan whereas it is operating at less than 0.05% MRO business as stated in civil aviation policy of 2015 [5].

1.4 MAJOR MRO SETUPS IN PAKISTAN

Major enterprises such as Boeing, Lockheed Martin, Monarch Aircraft Engineering (MAEL), Emirates, Etihad and so on have their own MRO setup to provide various engineering services for aircrafts. In Pakistan, local airlines operating aircrafts include Pakistan International Airline (PIA), Shaheen Air, Air Blue Limited and Serene Air whereas major defence sector organizations that operate military aircrafts include Pakistan Air Force, Pakistan Army and Pakistan Navy. The MRO setups available in Pakistan include:

a. Pakistan Aeronautical Complex, Kamra
b. PIA Engineering Complex, Karachi
c. Aviation Base Workshop at Qasim aviation base Rawalpindi for Pak Army
d. Air Engineering Department, PNS Mehran, Karachi for Pak Navy.

Defence organizations have their own MRO setup whereas PAC Kamra and PIA Engg. Complex are the only commercial available sites to undertake MRO activities. These aviation hubs are state owned and are not geared up to undertake these aviation activities effectively due to numerous issues. Some of the prominent are beaurocratic hurdles, lengthy procedures of procurement, procedural delays due long chain of command, late payments / financial transactions and more importantly, underutilization of capabilities & resources. Hence, the local airlines mostly outsource their MRO related work to foreign companies. Thus, establishment of an AEC in private sector will be prolific in generating foreign business and helping us in achieving self-reliance.

1.5 NEED OF PRIVATE SETUP

With the stability being restored in the region and construction of China Pakistan Economic Corridor (CPEC), enhanced economic activity is foreseen especially in aviation sector. Because of almost total absence of any vendor industry in the A&D MRO and After Market Solutions, there is an increasing trend of outsourcing to high cost global markets. Government of Pakistan has also offered incentives for aviation MRO business in CAA policy of 2015 to

promote this sector [5]. For a third world country like Pakistan having huge military and weak economy, it is necessary to have significant contribution especially in MRO business from private sectors but unfortunately this is not the case. A recent example of the catastrophic consequences of a similar situation is the disintegration of the Soviet Union which had a huge military setup and a weak economy.

Thus, establishment of AEC in private sector will not only strengthen aviation industry of Pakistan but will also contribute towards self-reliance and reduce foreign debts being spent on MRO through better utilization of in-house resources. More importantly, it will generate local & foreign business that will support our economy. MRO will be the major component of AEC that will characterize itself with such essential elements as efficiency, quality certifications, automation, committed human resource, and enabling environment. Products & Services provided by the AEC are appended below:

a. MRO of Aircraft's and Helicopter's accessories, avionics and instruments from OEM certified facilities.
b. Provisioning and MRO of ground handling and support equipment.
c. Spares And Logistic Support (SLS) for assemblies, sub-assemblies and components along-with provisioning of aviation standard raw material and manufacturing consumables.
d. Calibration and repair of Test Measurement and Diagnostic Equipment (TMDE), Precision Measuring Equipment's (PME), instruments and testers through renowned setup and facilities.
e. Manufacturing, Upgrades and Modification (MUM) of Line Replaceable Units (LRUs), Shop Replaceable Units (SRUs) and components of aircrafts.
f. Training in fields related to aviation manufacturing and auxiliary systems.
g. Consultancy in ERP and QFD for aviation related setups.

1.6 PROBLEM STATEMENT

Execution of complex projects faces numerous constraints especially in developing countries like Pakistan, which have significant negative impact on overall project performance. Either the project requirements are not understood well or adequate systematic thinking process is not applied resulting in delay of project activities or increase in cost during its execution. Solution to overcome these difficulties is to develop life cycle based conceptual planning document for

projects based on SYSE approach. This thesis work contains customized SEMP for development of corporate framework of Aviation Engineering Complex.

1.7 THEME OF STUDY

The theme of study is application of SYSE process in conjunction with SYSE tools to develop corporate framework for AEC in Pakistan. This research will be useful for aviation sector organizations, whether in private or public sector of Pakistan and can also be used as benchmark for developing aviation engineering related setups in third world countries. Industry standard ERP solution will also be implemented in AEC which will be the first of its kind in Pakistan where business process will be managed through automation. ERP selection criteria has also been developed using Analytical Hierarchy Approach (AHP) method considering AEC requirements and business process flow.

1.8 RELATIONSHIP WITH OTHER PROJECTS

This project is part of Project Management Plan (PMP) of AEC. The technical and corporate infrastructure will form the AEC. The plan will be interacting with technical area SEMP, PMP and other plans that are working under AEC. Such projects need a healthy interaction with other associated plans for smooth operations.

CHAPTER 2 - LITERATURE REVIEW

This chapter consists of summary of different research publications related to the research question and literature gaps that current research study will try to address.

2.1 RELEVANT STUDIES

Systems Engineering is an interdisciplinary approach that integrates different disciplines with complete focus on life cycle management. Origin of SYSE stems after World War II due to development of complex systems based on advanced technologies and competitions. Kossiakoff et al [6] highlighted that the role of SYSE is increasing in projects day by day to achieve a balance among conflicting objectives. Developing countries like Pakistan, face numerous constraints during execution of complex projects. These constraints can be identified and managed through top down process of decomposition and bottom up process of integration as followed in the VEE model. Blanchard [7] defined the importance of SEMP as a fully integrated engineering and management effort. He emphasized that SEMP should define the project scope, organizational structure and responsibilities of key team members followed by SYSE processes, value engineering, maintenance and operational concepts, functional analysis, interfaces, system model and System Retirement / Disposal. MITRE corporation [8] expressed that system building block covers requirement elicitation, development and analysis prior developing system architecture. Guide to System Engineering Body of Knowledge (SEBOK) [9] also considers planning through SEMP an important aspect of SYSE Management in controlling cost, risk and schedule.

Aviation is the art of aeronautics in developing the design of aircrafts. It is an important means of transportation for passengers and cargo. Civil and military aviation together is known as Aerospace & Defence sector. IATA [10] described the impacts of Sep 9/11 incident on aviation sector. This industry is growing fast nowadays which was not expected after such incident. Commercial MRO market is expected to grow by 4.1% per annum till 2025 whereas global military aviation MRO market is likely to grow by 3.2% in year 2017. This multi-billion dollar MRO market has remained unexploited in Pakistan because Aviation sector related MRO activities entails massive technical infrastructure, high tech equipment and supporting facilities. Development of vast infrastructure and facilities necessitates enormous planning for facility design.

Petrossi [11] described importance of facility planning layout in reducing manufacturing process waste and decreasing lead time for customers by controlling material handling cost and efficient planning. Krishnan [12] highlighted that material handling expense can be further reduced by 10-30% through efficient facility layout design. John V. Farr [13] also analyzed life cycles cost considerations of a complex project based on parametric cost consideration and cost estimating relationship to overwhelm the complexity and advance technology issues over lifecycle of product.

Facility planning can be achieved effectively through development of a system model. Models use different languages as their syntax and semantics to express information between system elements [14]. Grönniger et al [15] described that modeling languages were primarily used in software development of projects. Subsequently, System Modeling Language (SYSML) derived from Unified Modeling Language (UML) was adapted by Sanfard et al [16] for system modeling. Forder [17] presented goals of Model Based System Engineering (MBSE) approach in 2012 on the basis of improved communication, quality, increased productivity and reduced risk. He compared traditional document centric SE approach with model based approach and concluded that system architecture based on MBSE approach better manages the complexities of program and reduces requirement error. Piaszczyk [18] described that MBSE focuses SYSE process and promotes communication between stakeholders. He further added that SYSE activities in MBSE approach are centered on the system model.

Different SYSE tools are available that use system modeling languages in developing a system model. System balance can best be achieved through utilization of these tools and techniques during system analysis process. SYSE tools are also input activities for experimentation, modeling and simulation that are used in conjunction with traditional available tools [19]. These modern tools can perform system integration and configuration management very easily. Basarke et al [20] stated that explicit actions and training is needed in utilizing management support in a disciplined manner. Burge [21] developed system engineering tool box for modeling diverse SYSE activities. These tools are helpful in determining efficacy and fruitfulness of the project in covering all aspects of a balanced system design. Quality Function Deployment tool provides system requirements based on system thinking and provide requirement traceability. It is also a powerful tool for converting vague customer requirements into consistent, unambiguous technical requirements which was used for site selection and

support plan formulation in this thesis. AHP is a decision making technique that aids in developing selection criteria of products. These criteria are developed for a particular project based on subjective judgments and customer requirements. Criteria is evaluated based on weighting factors [22]. Context Diagram is a functional modelling approach to develop high level model for a system. A single picture is developed for all entities covering system and interacting elements [23]. Holistic Requirement Model (HRM) is a requirement analysis technique to classify requirements into operational, functional and non-functional requirements. It uses System Textual Analysis (STA) form for requirement categorization [24]. Need Mean Analysis (NMA) is a system thinking tool for exploring available alternative options for completion of task [25]. Utilization of these tools enhances the efficacy and productivity of a project. Apart from this, productivity and effectiveness of engineering setup can further be elevated through implementation of industry standard capable ERP system.

ERP is business process software that manages all business activities starting from purchasing of raw materials till delivery to customers. F. Salimi et al [26] defined success or failure of a ERP implementation project via critical success factors. Lichtblau [27] provided a comparison of various ERP solution providers on the basis of cost, implementation time, functionality and payback period. Bari [28] highlighted that main reasons for ERP implementation failure are lack of understanding of corporate goals and top management misalignment. Wei et al [29] described systematic framework for selecting objectives of ERP system. Lin et al [30] provided supplier selection criteria amongst several manufactures based on system thinking process to save time and money. Shih [31] used Fuzzy AHP approach for ERP selection based on six factors and determined weightage of each factor through fuzzy matrix. This approach was also used by Ayhan [32] in 2013 for supplier selection of gear motor company. Yemm [33] provided ten best steps for ERP selection for an entrepreneur. George et al [34] modeled business process requirements for ERP implementation in large scale public sectors as baseline for configuration management repository.

Salimi [35] discussed implementation of ERP in aviation industry and described possible ways of achieving reduction in cost, increase of flexibility and efficiency of MRO activities of firm through ERP. He also discussed differences between four approaches of top-down, bottom-up, technology-oriented and process-oriented for implementing ERP in manufacturing and service industries [36]. An ERP program is successful if it delivers substantial portion of benefits to

company. AEC business plan [37] and different case studies of project failure [38] were also studied. These case studies presented main reasons of project failure as poor corporate management, lack of vision, communication gap and inappropriate planning.

2.2 MISSING LINKS IN LITERATURE

Project execution in developed countries stems from development of SEMP for any complex project and has yielded significant results in achieving project goals and objectives within estimated time and resources. In developing countries like Pakistan, project execution always suffers numerous issues due to lack of planning, lack of vision and non-application of SYSE approach that results in cost and time overruns. SEMP has been prepared for different engineering projects worldwide and has yielded substantial results but no comprehensive study has been conducted using SYSE tools in application of each SYSE activity to corroborate the subjective judgments particularly in Pakistan. Evaluation and selection of ERP based on project goal and criteria is a new concept introduced in A&D sector of Pakistan that will be helpful for decision makers in evaluating proposals.

CHAPTER 3 - METHODOLOGY AND PROGRAMME PLANNING

Technical program planning and control covers main areas to be implemented in project. It covers feasibility study of project using SCOPE analysis, site selection process and project organization to be implemented in conjunction with their responsibilities and authorities.

3.1 FEASIBILITY STUDY

Feasibility study is carried out to determine the efficacy, strength and potential impacts of economical, technological and political factors on development of a project. Wimmer [39] suggested that situation analysis should be conducted to examine sustainability of setup at corporate level. This situational analysis encompasses present, past and future perspectives of the project. **SCOPE** analysis created by John Webb is the most logical and novel approach for corporate analysis as it helps management in defining project scope and covers both internal and external environment assessment.

3.1.1 SCOPE

In **SCOPE**, **S** stand for situation, **C** for core competencies, **O** for obstacles, **P** for prospects and **E** for expectations.

a. Situation: It pertains to conditions that can influence planning decisions with regards to internal or external environmental factors. AEC is a unique project envisaged to be international standard, high quality setup in private sector. Induction of 1900 new commercial aircraft worldwide, expected high growth in air traffic as stated in IATA report, increase in number of private airlines in Pakistan, large scale induction in PAF, Army and Naval aviation, substantial rise in passenger travel, cargo activities and flights has opened new business prospects. Being no other private sector setup in Pakistan, AEC will be fruitful in generating foreign business and help in achieving self-sufficiency.

b. Core Competencies: These are unique abilities of the business which will give AEC substantial advantage over its competitors.

i. The biggest problem faced in aviation industry is shortage of trained manpower and their high salaries. In Pakistan, hundreds of experienced technicians / engineers, with almost 25 years of MRO experience, retire every year from well-reputed organizations like PAF, PAC Kamra, Army and Navy. Most of them have acquaintance with quality maintenance environment. Services of these experienced individuals can be employed at rather less monthly salaries in comparison to their equally trained and qualified counterparts of developed countries. Professionally competent, highly experienced HR, at relatively low salaries will offer the biggest competitive advantage.

ii. Necessary industry standards and customer specific quality accreditations will be achieved by AEC. These internationally accepted standards include ISO 9001-2015 QMS, 14001 EMS, 18001 OHSA, AS 9100 Rev D, CAA (Pak), ICAO / FAA certifications (if required). These certification have not been achieved by any A&D industry in Pakistan.

iii. Oracle / SAP based ERP system will be deployed for efficient operation and optimal utilization of resources.

iv. AEC will be functioning more proficiently being in private sector as compared to public sector MRO set ups in Pakistan.

c. Obstacles: Obstacles are potential issues that can jeopardize the core competencies. Obstacles can be either internal or external, and highlights specific issues needed to be addressed. Major obstacles in setting up quality engineering setup are given below:

i. Negative perception about Pakistan regarding political instability, business environment, and security conditions may deter foreign investors and foreign customers.

ii. Tariff structure, procedural deferrals, bureaucratic hurdles and lengthy procedures related to import and re-export of components, assemblies for MRO

and assembly work (from kits) can also pose serious challenges to the success of AEC.

iii. Aviation is high tech industry that not only demands huge investment but also differs in its characteristics as compared to all other sectors. Thus, attaining these quality certifications is vital for successful accomplishment of MRO business and same will be challenging task.

d. Prospects & Expectations: Prospects are opportunities that exist internally / externally to business in enhancing sales / profits. Expectations reflect expected developments and predictions of conditions that are likely to impact. Networking with right people and open / sincere communication with decision makers have created lot of goodwill for AEC in the relevant circles. Apart from this, it will also provide:

i. Job opportunities will be created in A&D Sector.

ii. Availability of skilled manpower will contribute significantly in successful accomplishment of plan.

iii. Foreign Direct Investment (FDI) will be attracted to boost up local aviation industry.

iv. Services facility will be established only for those items not held in-house/with Kamra which will contribute towards self-reliance and will also save lot of foreign exchequer.

Any engineering setup in aviation sector has to undergo important generic, industry standard, and customer specific quality standards to meet products conformity and customer requirements. Quality Certificated AEC will attract the local & foreign customers to get quality work done at cheap rates compared to developed countries.

3.2 SITE SELECTION

First important step is selection of appropriate site for AEC. Choosing site is not a simple task because selected site shall be secure, accessible and linked though modern communication means, preferably in close locality of an airport. Cardon [40] stated that selected site shall satisfy the needs of customers for foreseeable future and cater for all potential risk areas.

Criteria for site selection by a company varies significantly in terms of their manufacturing strategy, work force organization, management styles, in-house inventory controls and local laws. Thus keeping all these aspects in mind, site selection factors were classically brainstormed.

3.2.1 SITE SELECTION FACTORS

Following factors were considered while selecting site for AEC in Pakistan:

a. Safe and secure environment
b. Connectivity
c. Economical consideration
d. Availability of quality HR in vicinity
e. Availability of raw material
f. Civic development
g. Availability of utilities
h. Demographic profile
i. Proximity to CPEC

House of Quality (HOQ) was prepared to select the most appropriate site keeping all important factors in mind. It is a planning matrix that relates customer requirements (What the customer wants) to technical requirements (How a firm that produces products is going to meet those wants). The body of matrix is a comparison of Whats vs Hows and roof of matrix is a comparison of "Hows vs. Hows". All the information is documented and analyzed.

3.2.2 QUALITY FUNCTION DEPLOYMENT FOR SITE SELECTION

In developing HOQ, the first step is to gather requirements from the customers. It is quite possible that customer may not know all requirements of product / services so we must document the requirement. In our case, site selection shall be based on above stated factors. Importance of each factor on scale of 1-5 is determined. It is also good idea to ask customers how your product or service rates in relation to the competition. The relationship matrix was prepared where the team determines the relationship between customer needs and the company's ability to meet those needs. Technical analysis of competitors is also conducted.

Thus for AEC, the major competitors are PAC and Air Weapons Complex (AWC). HOQ was prepared considering all possible factors as shown below:

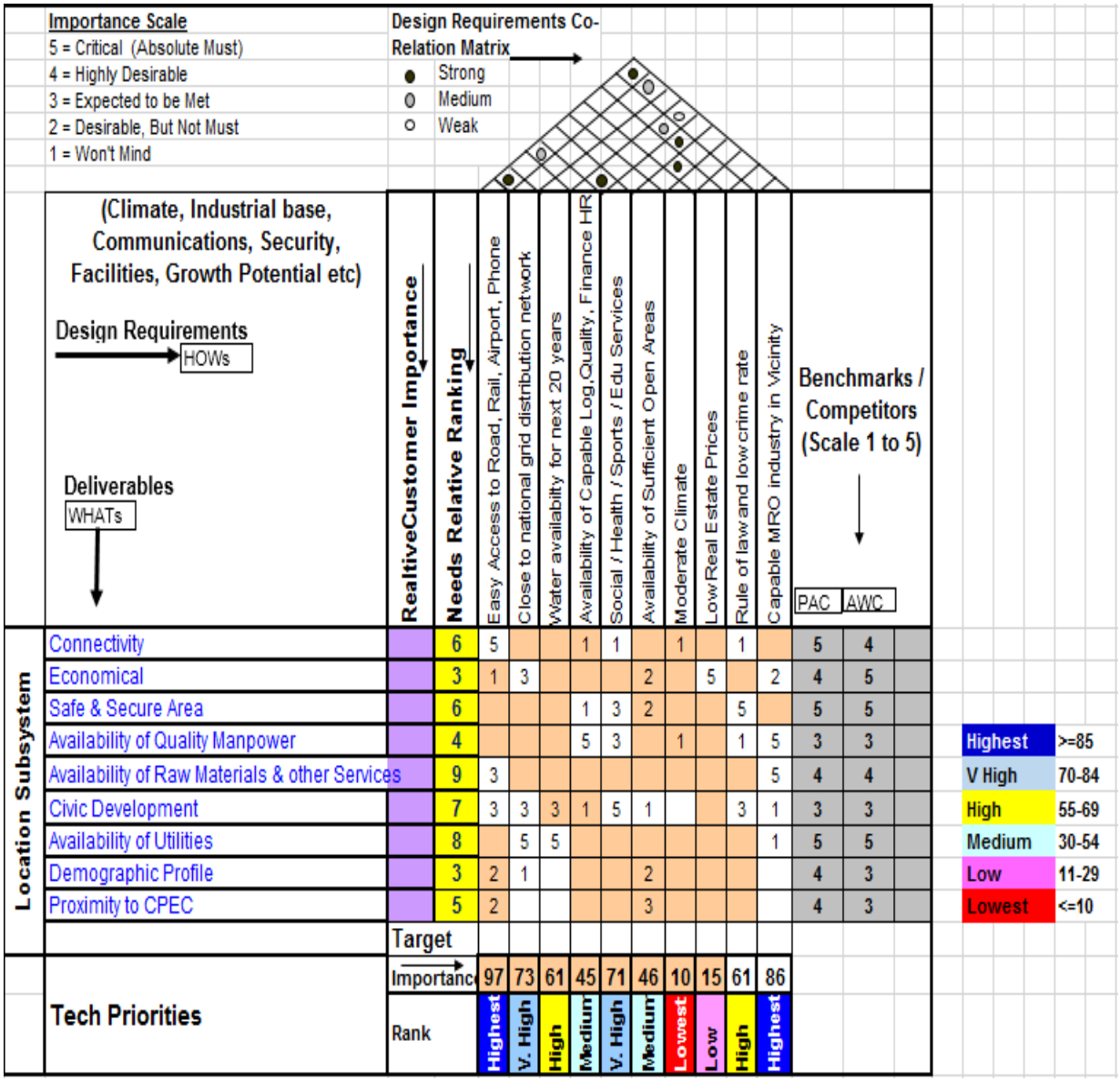

Figure 3.1: Site Selection HOQ

We can see that technical descriptors easy access to rail, road network, capable MRO industry in vicinity, close to national grid and social facilities in area seek more weightage in site selection. Thus, Kamra is the most ideal location for AEC because it not only meets technical descriptors but also has basic facilities of life, sufficient open space and clean environment. It has gained high popularity because of huge capabilities in A&D sector.

3.3 PROJECT ORGANIZATION

Organizational structure can be centralized or decentralized. In centralized model, the top management generally makes decisions whereas in decentralized, decision making process is spread to managers / individual business units. AEC business units include MRO, PMEL, SP & HM, T & C, I & O and AL. All of these units have complex processes, diversified scope of work, unique specialties, different fields of training, development and business environment, which necessitates involvement of managers in decisions making process on regular basis. Thus decentralized structure is more prudent for AEC due to efficient decision-making process, relieving the burden of top management and better interpretation of the customer needs and expectations.

Organizational chart of the project is unique in which decentralized strong matrix structure will be followed. Chief Executive Officers (CEOs) supported by 5 directors having specialty in their respective areas of concern will form the AEC. In addition to this organization, 8 member board of directors (BoDs) comprising of 6 CEOs of independent Business Units (BU), CEO of corporate center, and a non-executive member with no financial interest in the company, but with extensive and credible experience of A&D Sector in Pakistan will supervise AEC affairs. An advisory board will also be formulated to assist CEOs in existing practices and developing new business streaks.

3.3.1 STRONG MATRIX STRUCTURE

A strong matrix structure will be followed in AEC as most of the authority and responsibility will lie with the product managers / BU CEOs while functional managers / corporate directors will have limited control. Both managers will initially develop program oriented objectives to avoid conflict issues and better utilization of resources. Thus, organogram of AEC will be:

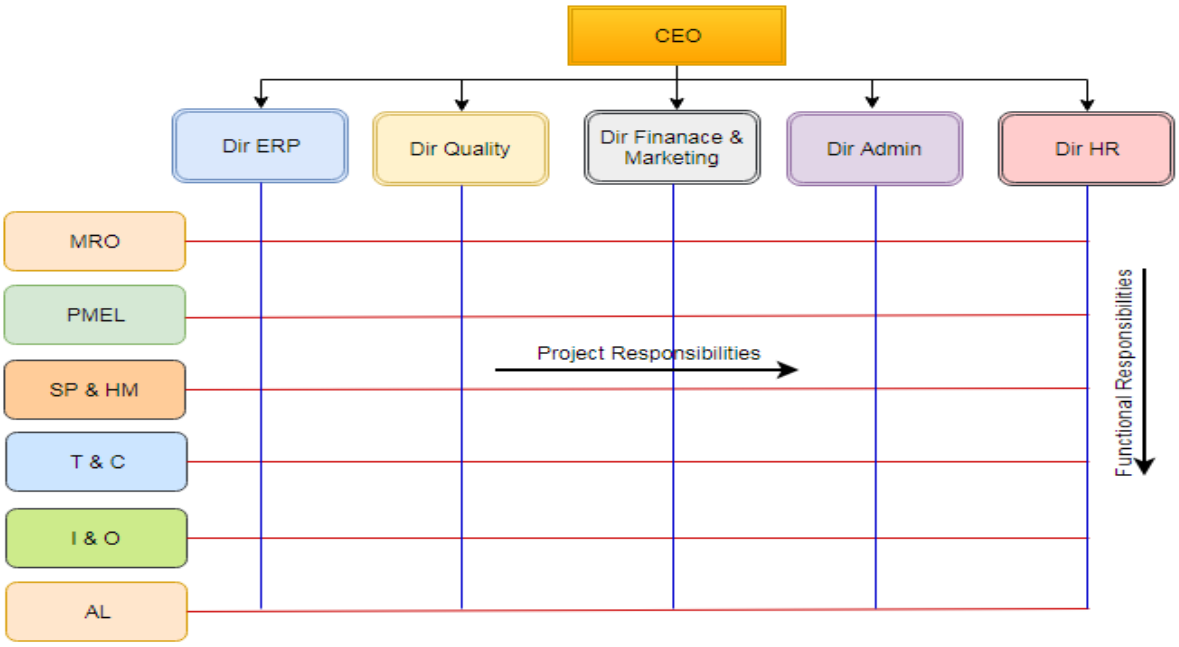

Figure 3.2: AEC Corporate Sector Organization

Management cadre qualification requirements will be:

MANAGEMENT CADRE QUALIFICATION REQUIREMENTS	
CEOs	MS/BE Aerospace/Avionics Engg. with at least 20 years of field experience with minimum of 5 years in respective MRO, manufacturing, assembly line, indenting areas.
Director ERP	MS/BE Electronics/Avionics/Computer Science Engg. with at least 15 years of field experience including minimum of 3 years related to large networks/ database management.
Director Quality	MS/BE Aerospace/Avionics Engg. with at least 15 years of field experience including minimum of 3 years' experience related to Quality Control (QC) / Quality Assurance (QA). Moreover, he/she should have been personally involved in at least 2 quality standards that AEC will implement.
Director Finance	Chartered Accountant with 10 years of experience in corporate sector.
Director Admin	Bachelor/Master degree in business administration with 15 years of

	admin experience in reputed organizations with good computer knowledge.
Director HR	MS/MBA HR with 15 years' experience in reputable organization with min of 5 year's involvement in recruitment & training.

Table 3.1: Management Cadre Qualification Requirements

For creation of corporate framework for AEC, selection of all directors is not defensible as early system engineering activities entail few experienced key personnel. Thus, preliminary organization during project execution phase will be:

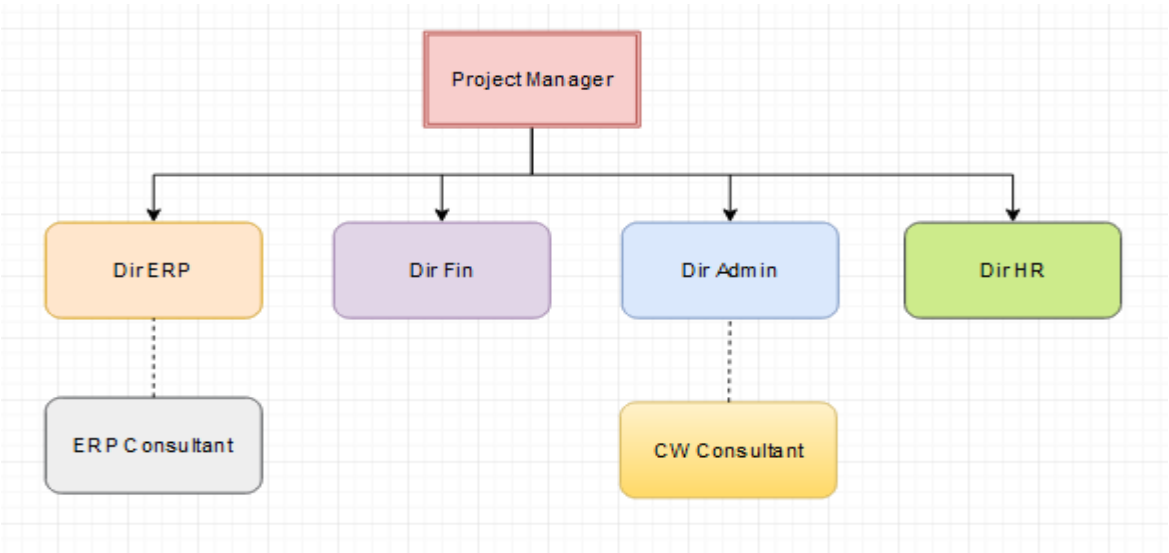

Figure 3.3: Project Organization

3.4 AUTHORITIES AND RESPONSIBILITIES

The authorities and responsibilities of the main players involved in this project are narrated below:

a. Project Manager:

Project Manager (PM), assisted by the senior management staff will be overall responsible for execution of project, estimating budget and time, resolution of disputes, interface definition & management, and risk management. His/her other tasks include:

i. Formulation of project execution team for managing AEC development activities.

ii. Consolidation of user requirements.

iii. Resource planning and documentation of project activities.

iv. Signing of contracts for civil works and ERP service provider.

v. Identification and selection of AEC potential customers.

vi. Overseeing design, marketing, facilities management, human resource management and public relations.

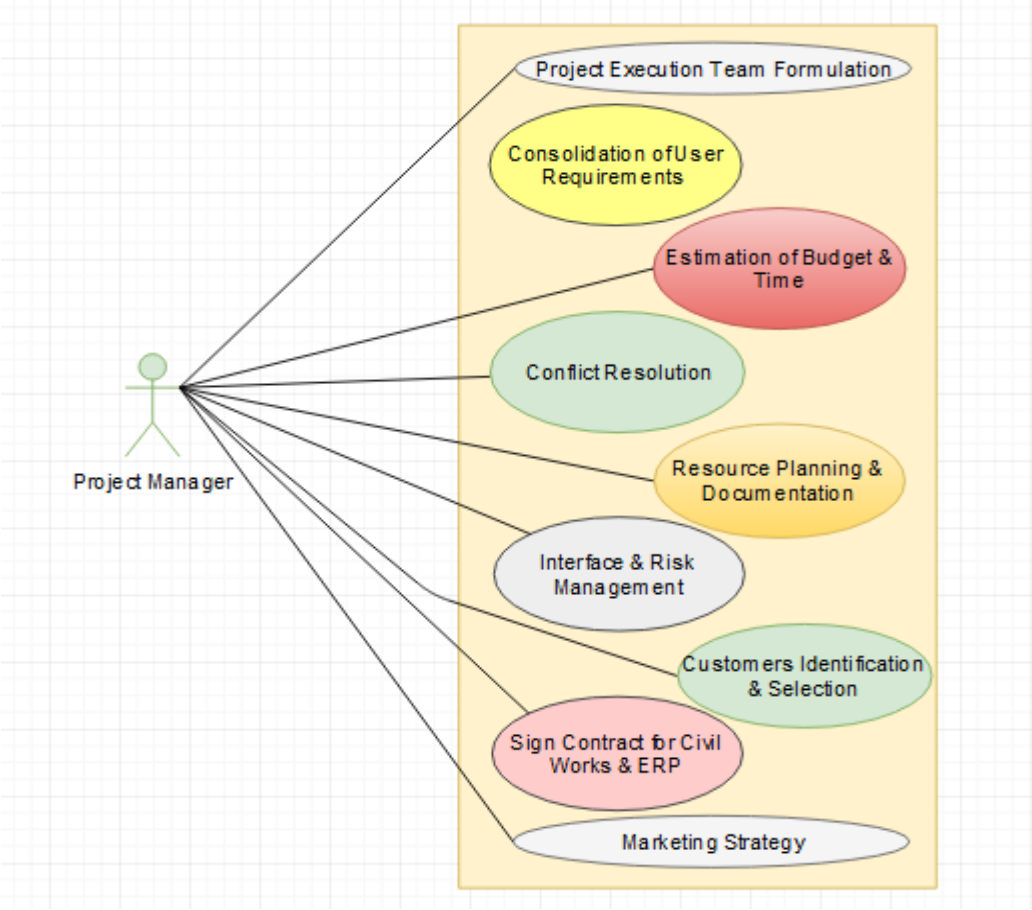

Figure 3.4: Usecase for Project Manager Responsibilities

b. Director Administration:

Director is responsible for:

i. Acquisition of land for AEC and preparation of architectural design, construction alongwith CW consultants and maintenance of AEC infrastructure (technical, corporate and residential sectors)

ii. Identification and arrangements for security needs of AEC.

iii. Arrangement and provision of utilities that is electricity, gas, water and transport for AEC.

iv. Identification and central purchasing of generic equipment/machinery, tools, office furniture's, IT assets for AEC.

v. Ensure availability of emergency services such as Fire Fighting equipment, medical services, disaster management plan for all business units.

vi. Assist project manager in administrative matters and have liaison with civil agencies for such matters.

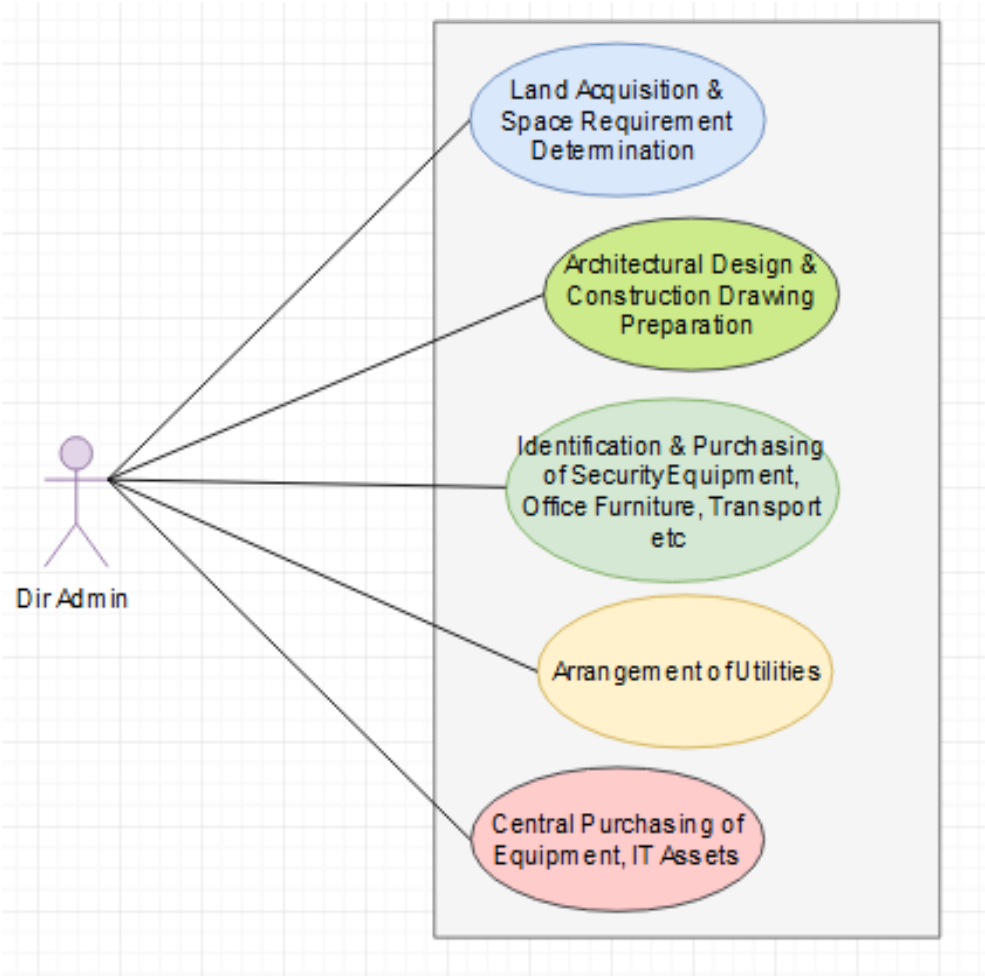

Figure 3.5: Usecase for Dir Admin Responsibilities

c. Director Finance:

The role of the finance director is to:

i. Manage funds for AEC development in coordination with project manager.

ii. Prepare company's overall accounts, budgetary forecasts for AEC units.

iii. Conduct capital need analysis and implement recommendations based on findings, with the most profitable outcomes.

iv. Manage finance requirements of admin, quality, ERP & HR department.

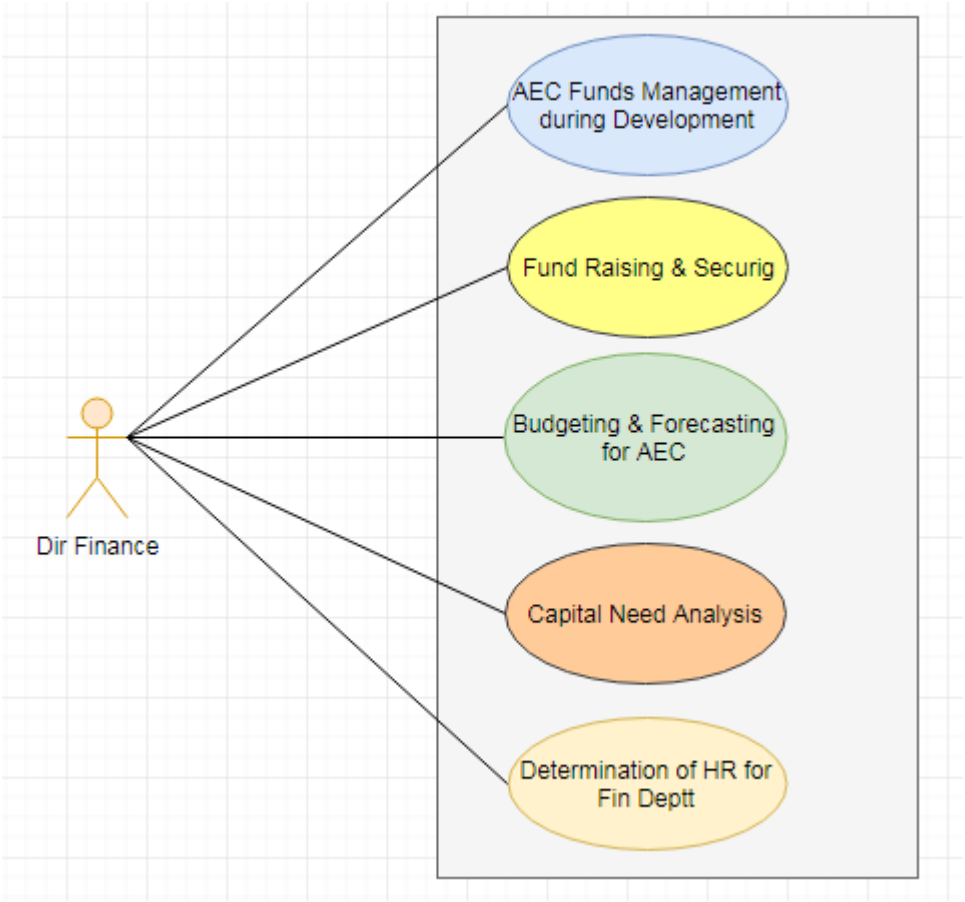

Figure 3.6: Usecase for Dir Finance Responsibilities

d. Director ERP:

The ERP Director is responsible for:

i. Development of an effective planning process, for the creation of an integrated project schedule that encompasses all aspects for the ERP program.

ii. Assessment of available industry standard ERP systems in A&D sector and selection of most feasible system for AEC in concurrence with ERP consultant.

iii. Ensure smooth implementation of industry standard ERP system. He is also responsible to set deadlines, assigns responsibilities, and monitor progress for the ERP system.

iv. Determine requirements for ERP and other IT related equipment/assets for AEC.

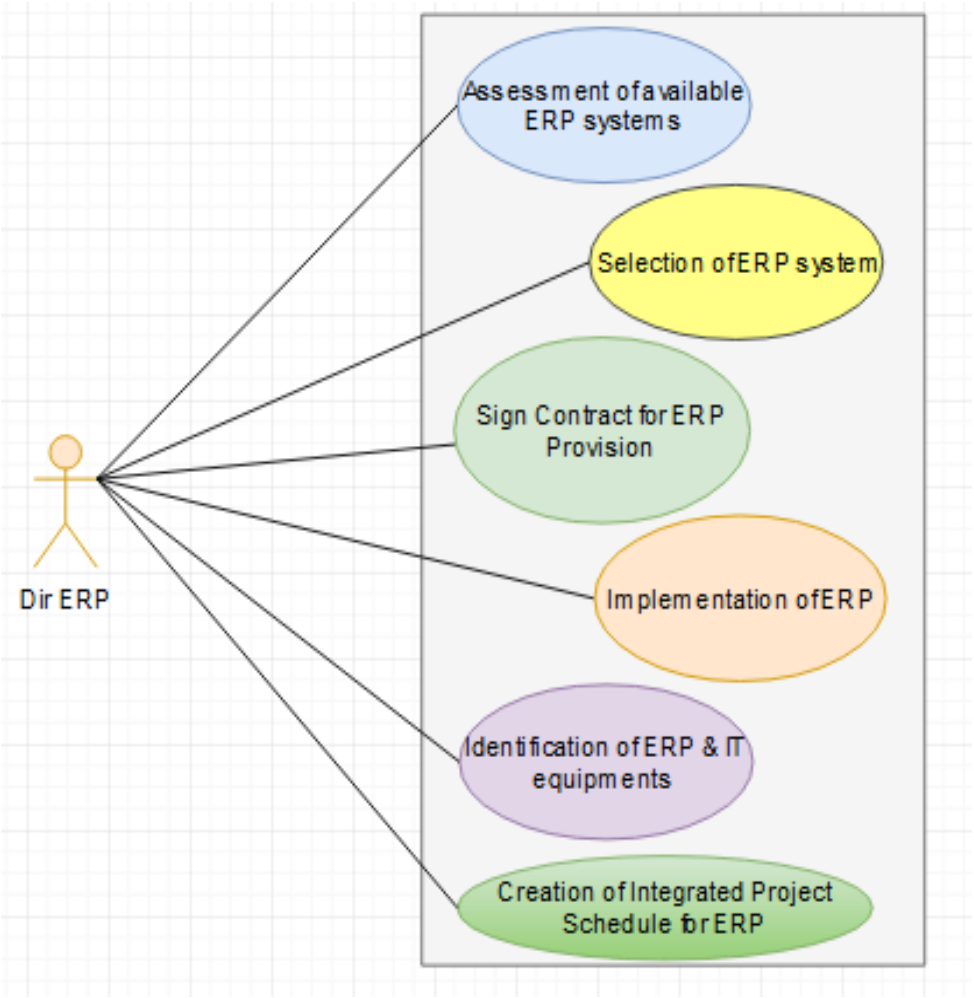

Figure 3.7: Usecase for Dir ERP Responsibilities

Director HR:

The Director HR is responsible for:

i. Determination of HR requirements for AEC in liaison with BU CEOs.
ii. Recruitment of company's HR in line with business unit CEOs requirements & company policies.
iii. Identification of training needs & training of company's HR in consultation with CEOs/Managers.
iv. Maintaining company's overall HR picture and develop skill matrix of employees.
v. Create policies & procedures regarding welfare, compensation and disciplinary cases.

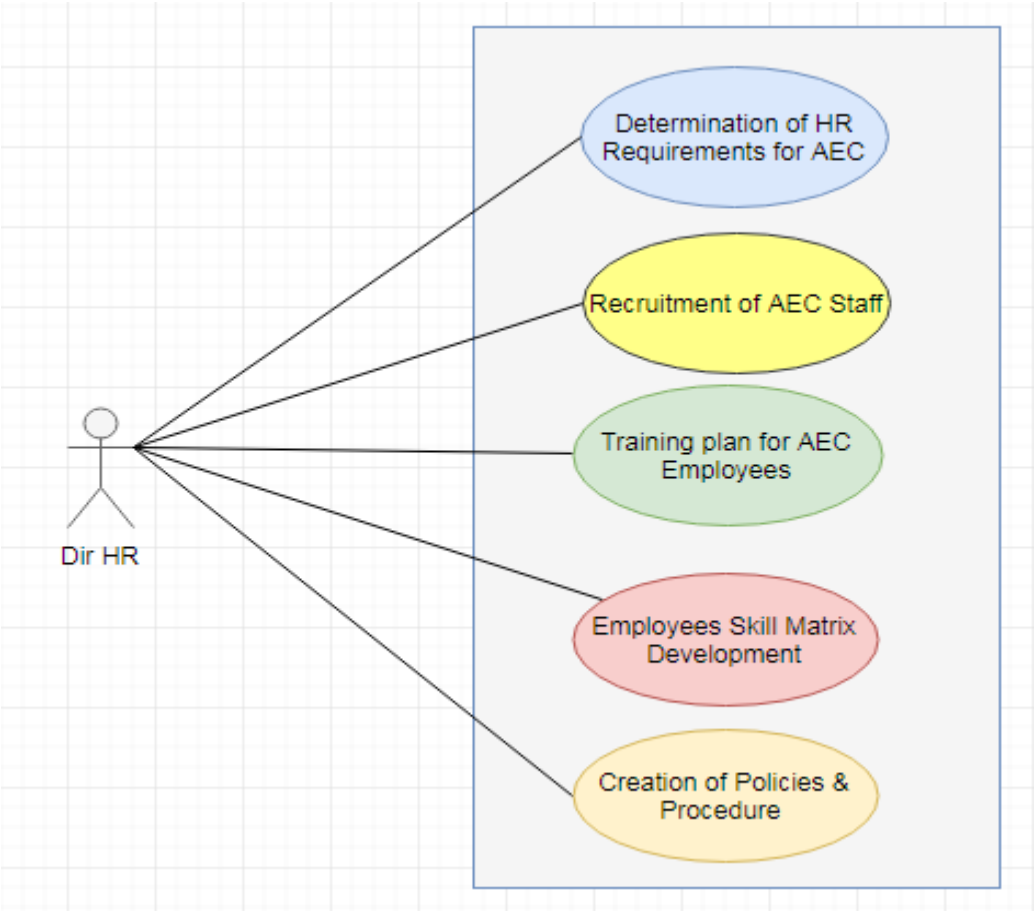

Figure 3.8: Usecase for Dir HR Responsibilities

ERP Consultant: ERP consultant is responsible for exploration of all available industry standard ERP systems, selecting best feasible system for AEC and advising ERP manager in signing of contract with ERP solution provider. He/she is to create integrated project schedule for implementation of ERP at AEC with ERP solution provider. He/she is also responsible to determine ERP/IT equipment requirements for AEC business units and corporate setup in liaison with ERP manager and monitor progress of ERP system.

CW Consultant: CW consultant is responsible for determining land requirements for AEC, preparation of general layout plan for infrastructure, facilities, architectural drawings and construction plans with contracting firms. He/she is also responsible to monitor/assist director admin during infrastructure development.

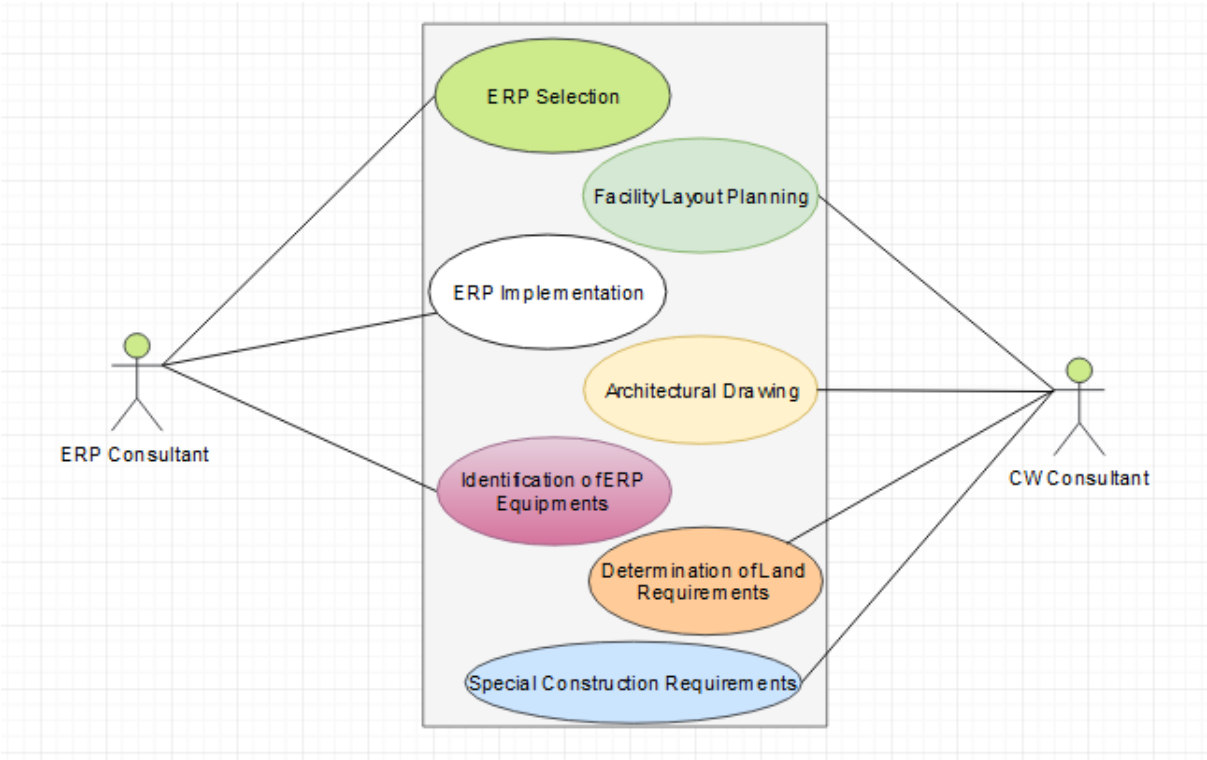

Figure 3.9: Usecase for ERP and CW Consultant

The overall responsibility usecase will be:

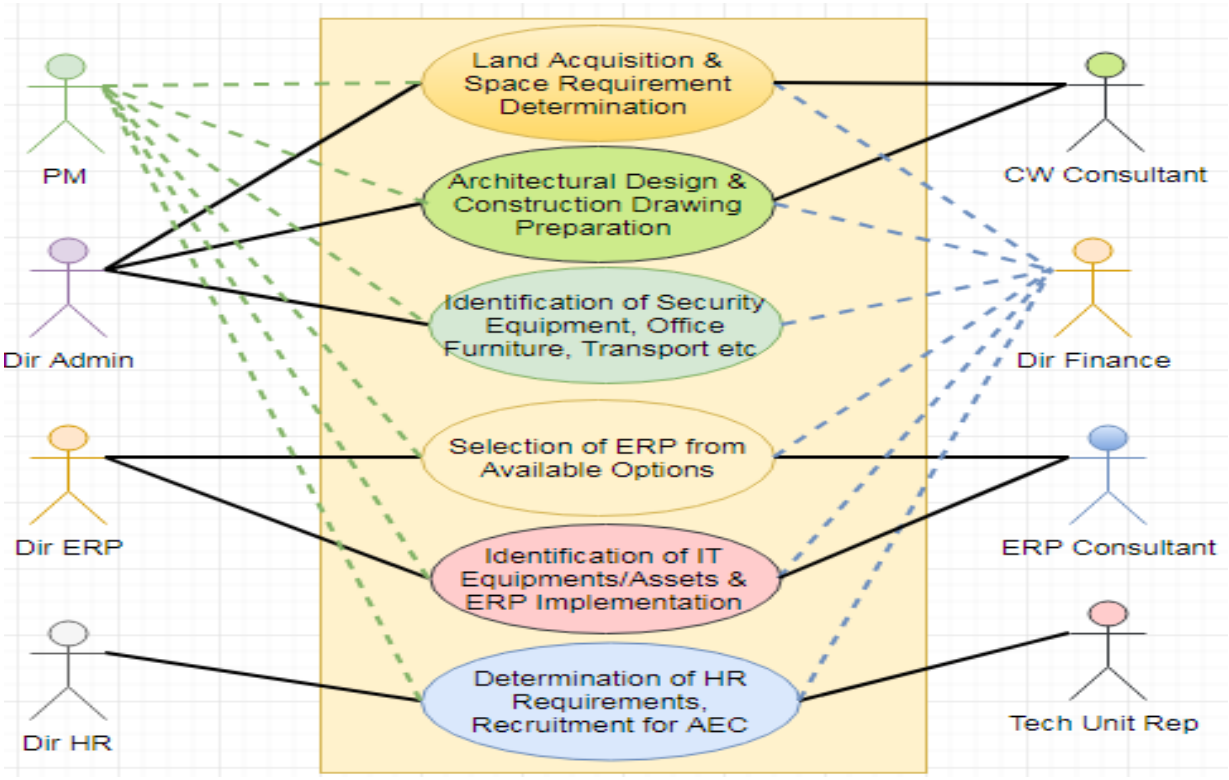

Figure 3.10: Usecase for Project Responsibilities

Services of director logistic can also be hired during procurement process on as and when required basis.

3.5 PROGRAMME REVIEWS

Two types of program reviews are conducted to evaluate the standard and quality of a programme. These are formal and informal reviews. Informal reviews will be conducted by respective directors on regular basis whereas formal design reviews are conducted during the design and execution phases of project and are classified into three categories:

a. Preliminary Design Review (PDR)
b. Critical Design Review (CDR)
c. Programme Management Review (PMR)

PDR will be conducted after completion of conceptual planning and development of functional baselines alongwith system level specification (Type A specs) whereas CDR will be conducted just prior to approval of the project implementation and finalization of development plan. PDR & CDR will be chaired by PM and are totally an in house affair. PDR will focus on facility layout plans, subsystem interfaces, potential risk areas and system level tradeoffs whereas CDR is usually more extensive and will focus on development level specifications, process to be followed during creation, material requirements & their quality, logistic plan, interface drawings, data flow diagram.

Regular monthly PMRs will also be conducted during the execution phase of the project. These meetings will provide project execution team, AEC advisory body and the contractor, the opportunity to discuss any questions or issues identified in the program implementation or any recent changes to the program or configuration. All of these PMRs will be chaired by the PM in the presence of directors, representatives of advisory body and contractors. Any anomaly identified during PMR will be incorporated after necessary change and formal/informal approval through PMR board.

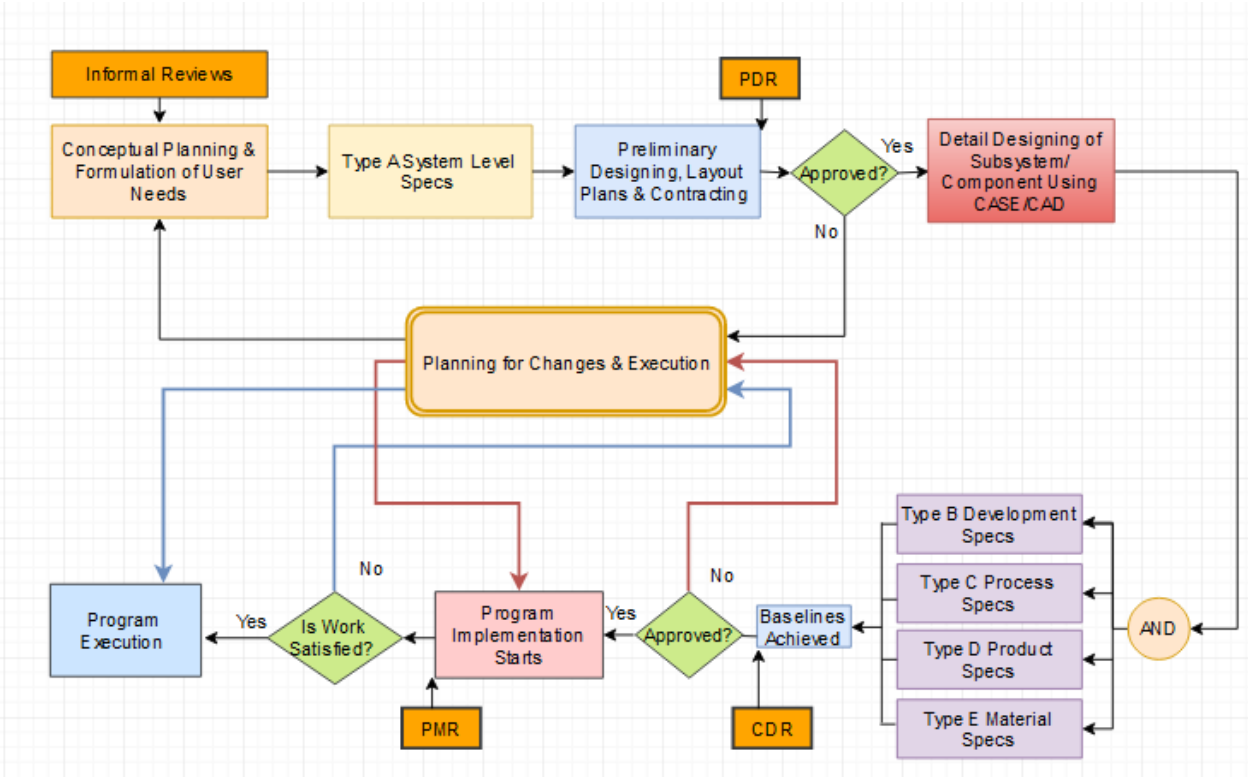

Figure 3.11: Programme Reviews

CHAPTER 4 – SYSTEM ENGINEERING PROCESS

SYSE process transforms user needs and requirements into life cycle based balanced system solution. Overall scenario in which system is expected to operate must be understood to find out unambiguous and well-defined requirements. Context Diagram helps in understanding the complete picture alongwith identification of all major stakeholders involved in the project. The context diagram was prepared to depict overall scenario of AEC operation. Main body of the system i.e. corporate sector is in the center of the diagram whereas the rectangle boxes on the sides of main body reflect interacting elements involved in the project. These interacting elements are technical sector, residential complex, potential customers, AEC management, service providers and suppliers. Arrows depict the information flow within the interacting elements and between interacting elements and main body. Context diagram of AEC is shown below:

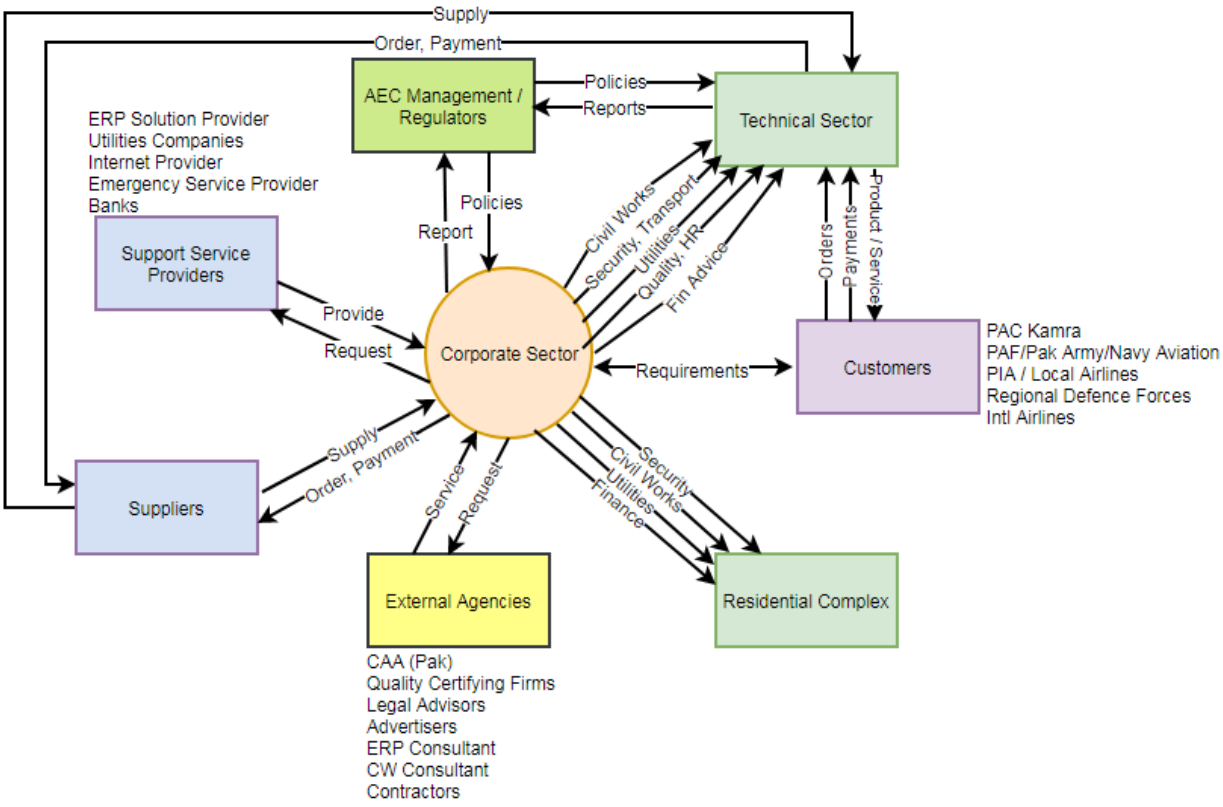

Figure 4.1: Context Diagram of Corporate Sector

From context diagram, requirement analysis process was performed to determine mandatory and preferential requirements of corporate sector.

4.1 MISSION REQUIREMENTS ANALYSIS

Mission requirement analysis are those performance requirement measures indispensable for conduct of mission. Impacts of the stated system operational characteristics, minimum acceptable system functional requirements, mission objectives, technical performance are analyzed during the conduct of the contract.

4.1.1 NEED ANALYSIS

Establishment of exact system needs is often a difficult process and same was the case with this particular project as well. It took several meetings with AEC management, IT experts, civil engineers and with the vendors in the local market to work out these system needs. Extensive web browsing, interviews and e-mail exchanges is also part of this process. The very nature of this project was also a crucial factor as not much data & expertise are available and being a maiden attempt in private sector in Pakistan. Furthermore, infrastructure development related projects are one-time activity that requires vigilant infrastructure need assessment and analysis of influencing factors.

4.1.2 CUSTOMER NEEDS

In many cases, the acquirer may not be fully aware of his needs. It is therefore essential that the systems engineering experts should express needs as definitive requirements so that the professed needs are transformed into realistic requirements.

a. Mandatory Requirements:

Mandatory requirements are those minimum necessary and effective conditions that a system shall have in order to be acceptable with no trade-offs between requirements. System as a whole cannot qualify until every single mandatory requirement is not met. These requirements were determined on the basis of major corporate activities such as project site selection, quality management process, HR management, finance & marketing, supply chain & logistics activities, ERP and administration. Mandatory requirements for each of above areas are given below:

Site Selection

a. Site selected for AEC shall be based on following considerations: Economical, well connected, secure, availability of quality manpower, timely availability for raw materials, demographic profile, availability of utilities, MRO industry in close proximity, civic developments and environmental considerations.

b. Construction at site shall follow Ministry of Housing & Works Building Codes 2007, Pakistan Engineering Council (PEC) industrial standards, CAA (Pak) requirements during planning and implementing design codes.

c. It shall have sufficient space to house corporate offices for 7 CEOs, quality department, ERP system, administration office, human resource, finance and marketing departments alongwith technical and residential complexes.

Quality

d. AEC shall have all necessary generic, industry standard certifications. These standards include CAA (Pak), ISO 9001-2015 QMS, AS 9100 Rev D.

e. Ensure timely delivery of quality products and services through streamlined QC and QA processes of AEC business units.

f. Maximize customer satisfaction (>= 90%) through consistent provision of conformed products, continuous improvement and prevention of non-conformities due streamlined business processes.

g. AEC shall deliver high quality products, services at economical cost (less than 15-20%) compared to other competitors alongwith documented configuration management.

HR

h. Selected HR shall be experienced, high quality and up-to-date with existing technologies in respective domains.

i. Top level HR such as Directors/Managers shall have MS/BE Aerospace / Avionics degree with at least 15 years of field experience and minimum of 3 years of experience in respective fields.

j. Lower level HR such as Supervisors/Trade Assistants shall have B.Tech/DAE degree with at least 15 years of experience in respective trade work.

k. Conduct recruitment and training of HR in consultation with business unit CEOs to boost up individual's knowledge and to enhance skill level.

l. Performance assessment of HR must be conducted on regular scheduled (yearly) basis and informal communication/assessment on as and when required basis by individual business unit CEO. Feedback / counseling on scheduled assessment shall be provided to employees.

Finance & Marketing

m. Maintain business balance sheet of company's assets and liabilities depicting overall business financial health.

n. Financial planning of all independent, mutually supporting units shall be conducted through budgeting and forecasting for AEC BoDs.

o. Finance department shall timely meet tax filing deadlines and payments of all business units to avoid fines / penalties and shall maintain record of all such payments.

p. Ensure marketing of company's deliverable products and services through participation in different exhibitions & association with potential firms

Supply Chain & Logistics

q. Supply Chain shall remain robust through effective management and better relationship with local and foreign suppliers to support company business units.

r. Procurement of goods, raw materials, products, COTS items by respective CEOs of business units must be in accordance with governmental directives and regulations.

s. Ensure centralized procurement of all generic equipment such as computers, printers, other IT related equipment alongwith standardized forms, abbreviations to be used within AEC.

ERP

t. AEC must house industry standard ERP system to gain additional advantage over competitors through efficient resource planning and management.

u. Industry standard ERP system shall have Accounting & Finance, Human Resource, Supply Chain Management, MRO, Quality, Production Planning and Manufacturing modules.

v. The ERP system based on cloud computing shall have atleast 95% reliability.

Administration

w. Administration department shall arrange land for AEC.

x. Arrange security, transportation & utilities for business units through admin staff and equipment.

y. Ensure infrastructure development/construction, maintenance for AEC in accordance with applicable building codes stated above.

b. Preferential Requirements

The preferential requirements are those conditions that would make the purchaser happier and tradeoffs in these requirements are possible. Preferential requirements are given below:

Site

a. Site may be in close vicinity of airport.

Quality

b. Internationally accepted standards of 14001 EMS, 18001 OHSA, ICAO, FAA (USA) certifications may be obtained.

HR

c. HR manager may encourage self-reporting culture / Just Culture for employees to provide wellness, employee assistance programs.

d. Record of performance assessment may be kept with Manager HR for all business units.

e. CEO may conduct review of organizational structure of individual business units on required basis focused on workload and future needs to meet operational strategy.

Administration

f. Recreation facilities, park, mosque for AEC may also be included.

g. Facilities may be equipped with RFID and Biometric systems to ensure safety measures.

h. Facilities may be equipped with surveillance cameras for security.

Finance & Marketing

i. They should participate in seminars, conferences to promote company products.

ERP

j. Online help & Mail Tracking Facility for ERP can be made available.

After formulation of mandatory and preferential requirements, next step is requirement analysis. Holistic Requirement Model (HRM) was used for requirement analysis.

4.1.3 Holistic Requirement Model

HRM is requirement analysis tool used in SYSE to interpret, analyze and classify system requirements. It is an effective method that helps us in identification of deficiencies/missing requirements. Often the customer requirements are incomplete, vague & inconsistent and to make them clear, unambiguous and measurable, it is necessary to analyze these requirements. Thus, HRM applies system thinking process for proper identification by classifying requirements into operational, functional and non-functional requirements so that all requirements are properly identified [24]. The non-functional requirements are further sub classified into non-functional system requirements, non-functional performance requirements & non-functional implementations requirements. A model of same is shown below:

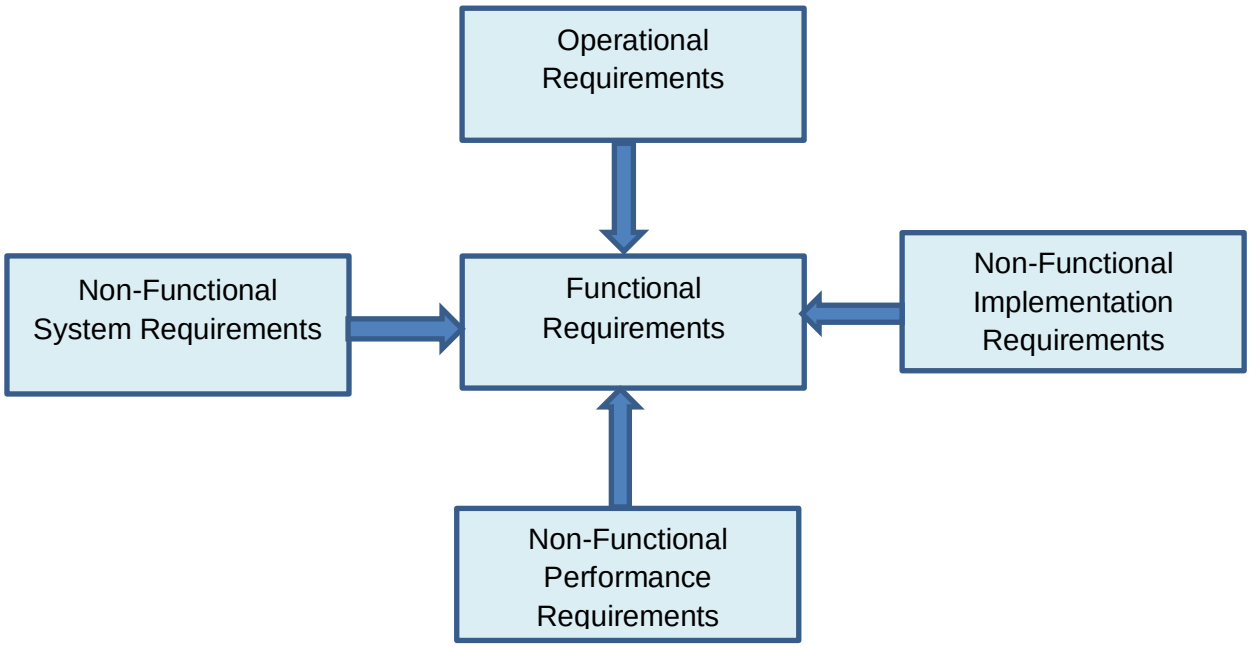

Figure 4.2: Holistic Requirement Model [24]

Keeping in view corporate functions, these requirements were derived using STA form and same is placed as appendix A.

4.2 FUNCTIONAL ANALYSIS

The system capabilities that are used as guidelines to perform the functional analysis include the mission, test, deployment, and support functions. The top-level functions identified from the mission analysis include the actions, and sequence of actions, required for the system (user, hardware, software) to complete each mission phase. NASA space system engineers developed functional analysis module to prepare Functional Flow Block Diagrams (FFBDs) and cultivate functional architecture in system development context [41]. John Leonard also emphasized on functional analysis importance to transform performance, functional and interface requirements into system functions [42].

The main function would be creation of corporate framework to support technical operations of AEC. AEC is divided into three parts which are technical, corporate and residential sector. Corporate setup consists of five subsystems which are administration, quality, Finance & marketing, ERP, HR as shown below:

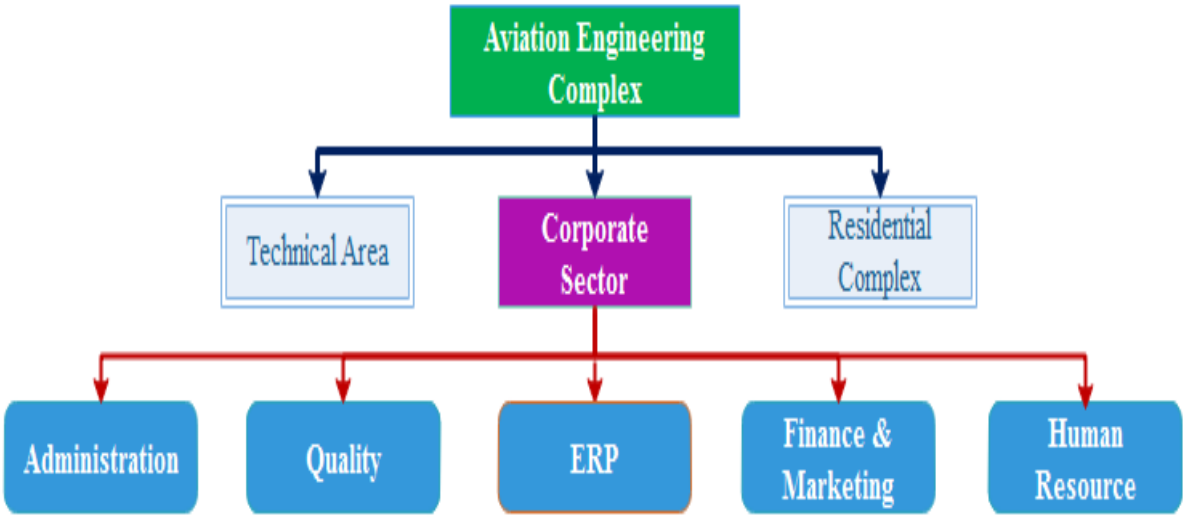

Figure 4.3: AEC Divisions

4.2.1 FUNCTIONAL TREE

A functional tree was formulated depicting all major functions to be performed related to corporate framework. These functions were further decomposed into low level functions. Functional tree is appended below:

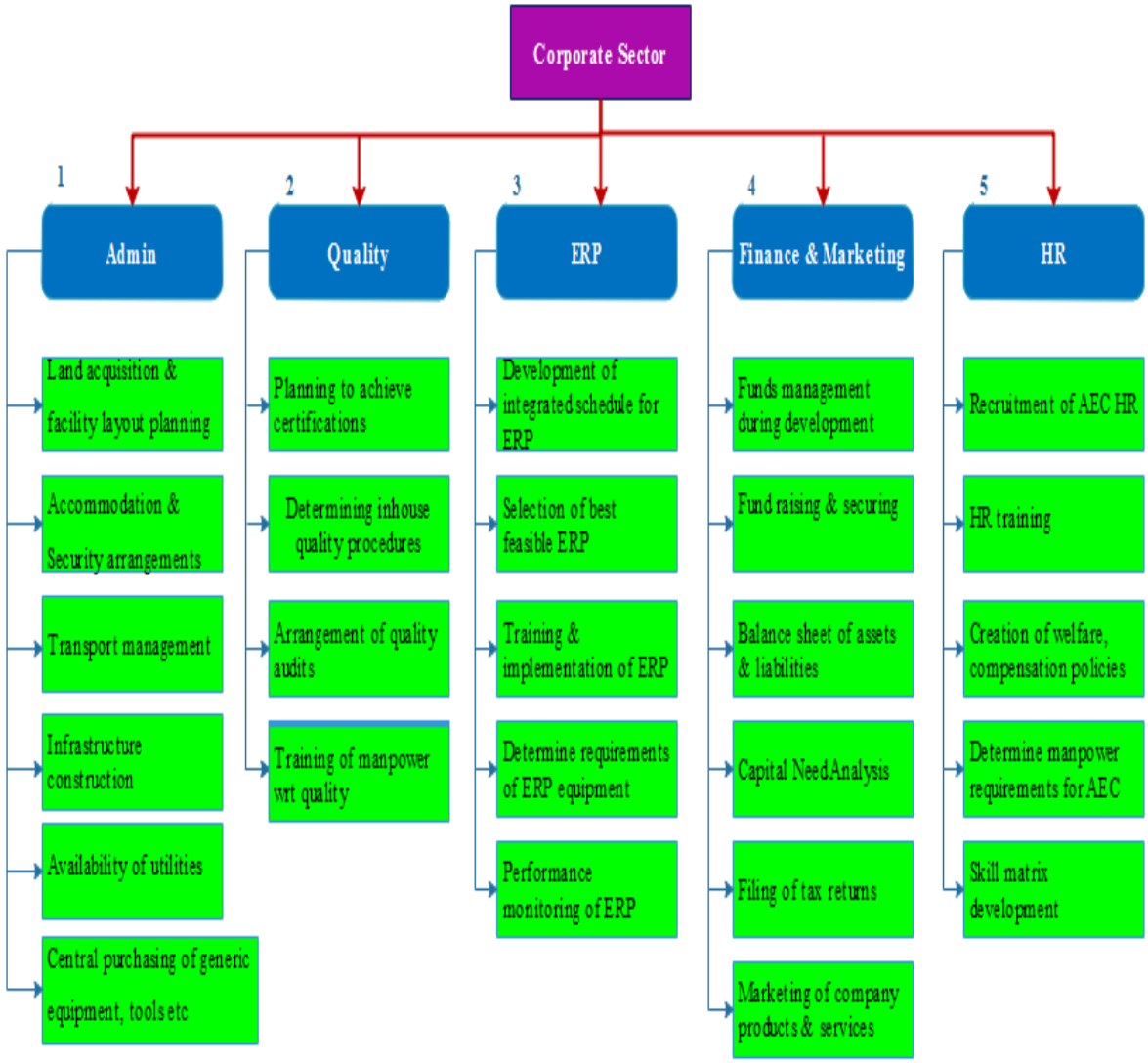

Figure 4.4: Functional Tree of Corporate Sector

4.2.2 FUNCTIONAL FLOW BLOCK DIAGRAM OF CORPORATE FUNCTIONS

After identification of all major functions, functional analysis of each sub department from viewpoint of different functions to be executed within corporate center was performed. FFBDs were used in development of AEC for functional analysis. FFBDs are based on logical architecture that helps in representing stepwise flow of functions. FFBDs of each sub-department alongwith resource requirements are shown below:

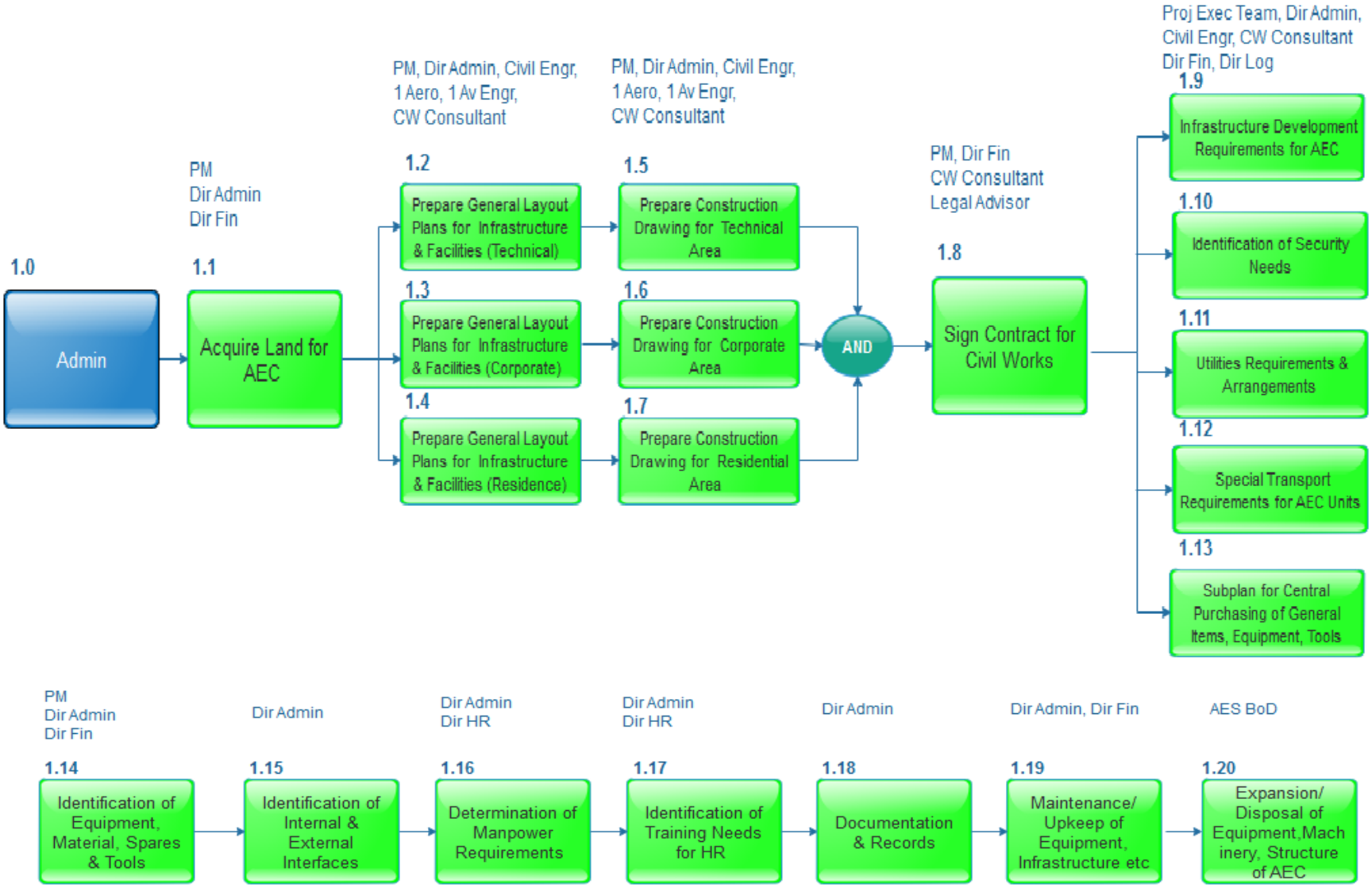

Figure 4.5: Administration Department FFBD

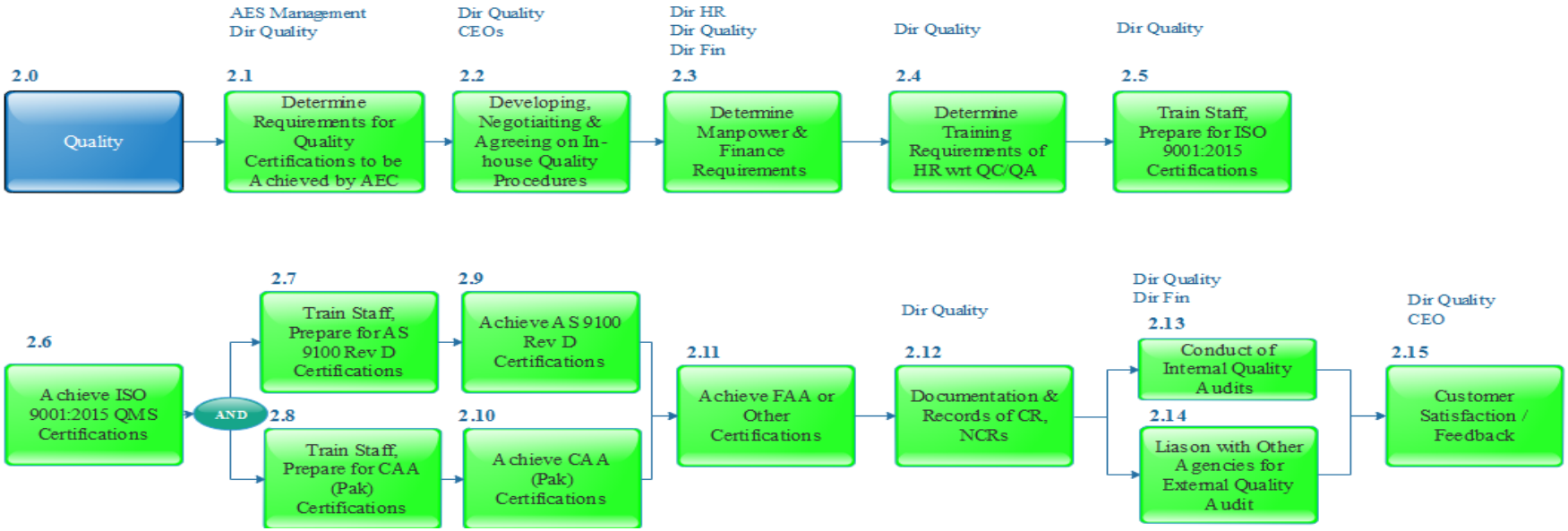

Figure 4.6: Quality Department FFBD

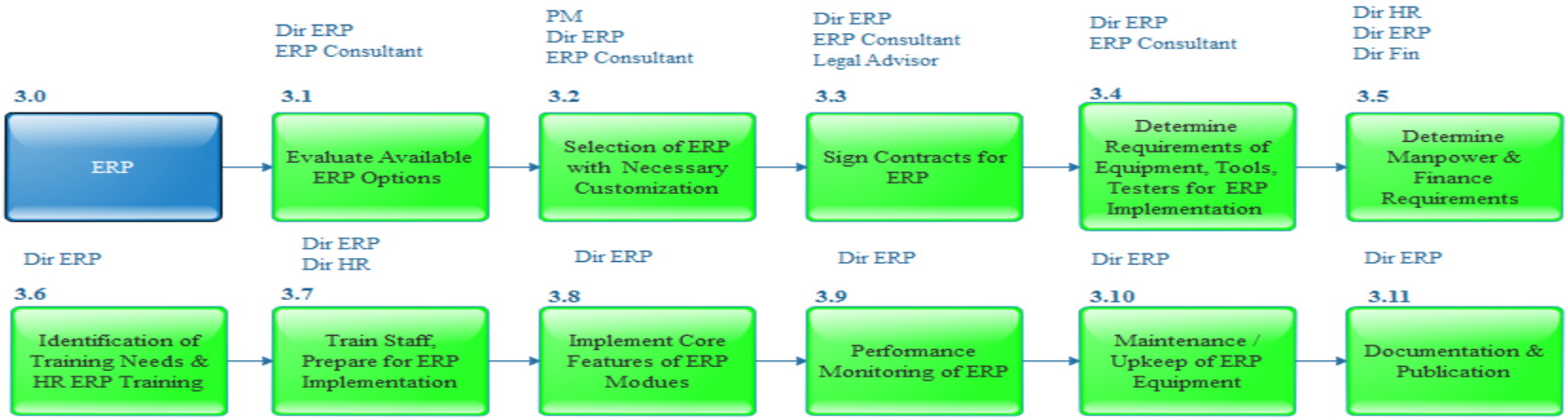

Figure 4.7: ERP Department FFBD

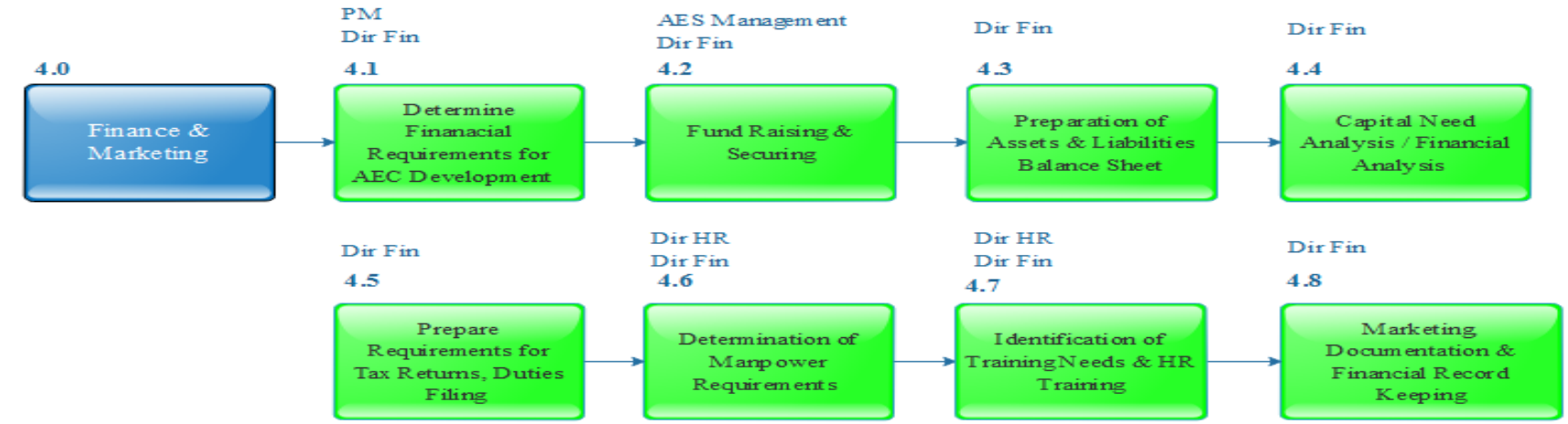

Figure 4.8: Finance Department FFBD

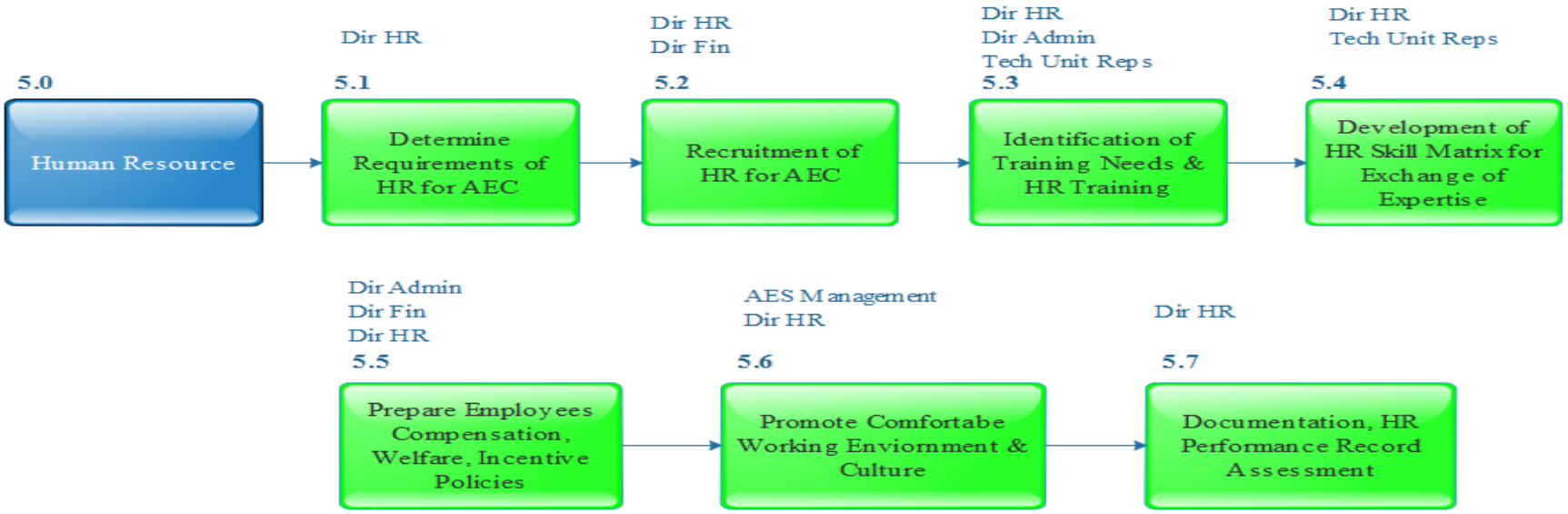

Figure 4.9: HR Department FFBD

4.3 INTERFACE MANAGEMENT

Interfaces are connections representing system elements. Interface management is a structured process that encourages communication between participants in identifying constraints as stated by Josh Caglar et al [43]. These interfaces are categorized into three types:

a. Interfaces within subsystems
b. Interfaces with other systems in Systems of System (SoS) context
c. External interfaces outside AEC

4.3.1 INTERFACES WITHIN SUBSYSTEMS:

In development of a corporate framework for AEC, major subsystems identified were Administration, Finance & Marketing, Quality, ERP and HR departments. Each of these subsystems are interdependent on each other working under single CEO through respective departmental heads. Their interface diagram is shown below:

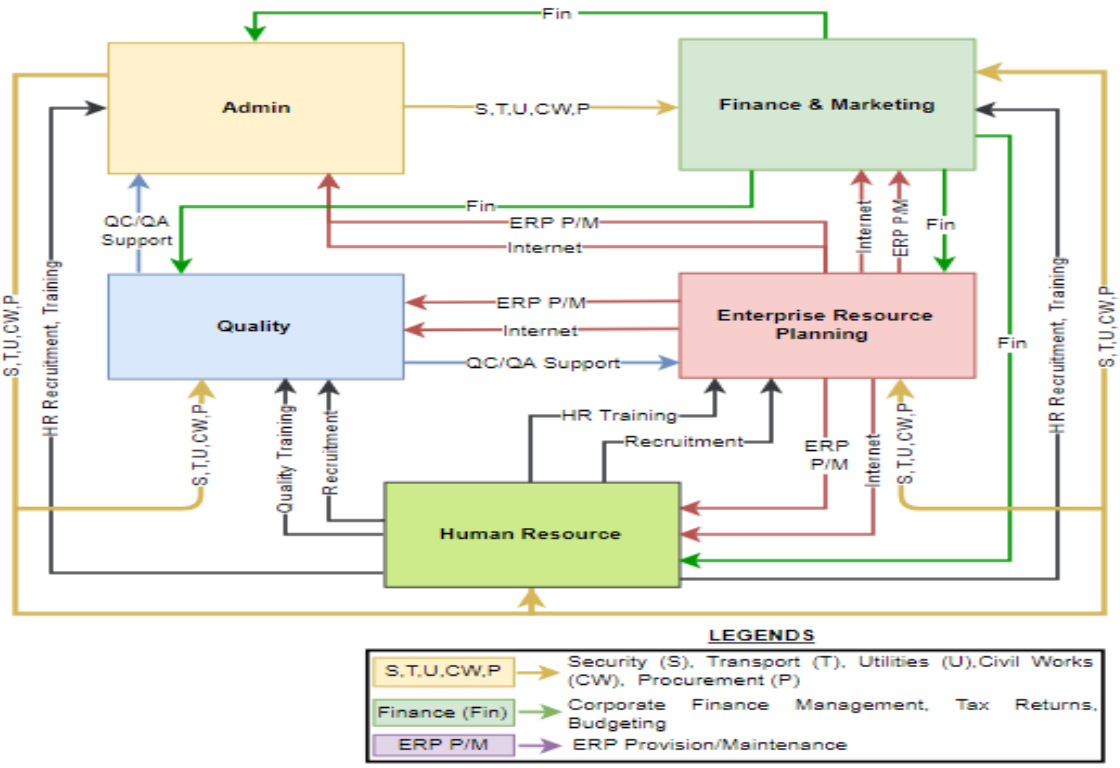

Figure 4.10: Internal Interface Diagram

4.3.2 INTERFACES WITH OTHER SYSTEMS

AEC is divided into three parts which are technical, residential and corporate. Each of these requires support from corporate sector in initial development, construction, maintenance and other administrative activities. As we can see that major contribution of corporate sector subsystems in initial phases will be from admin and finance department. Thus, interfaces of corporate sector with technical and residential part is presented below:

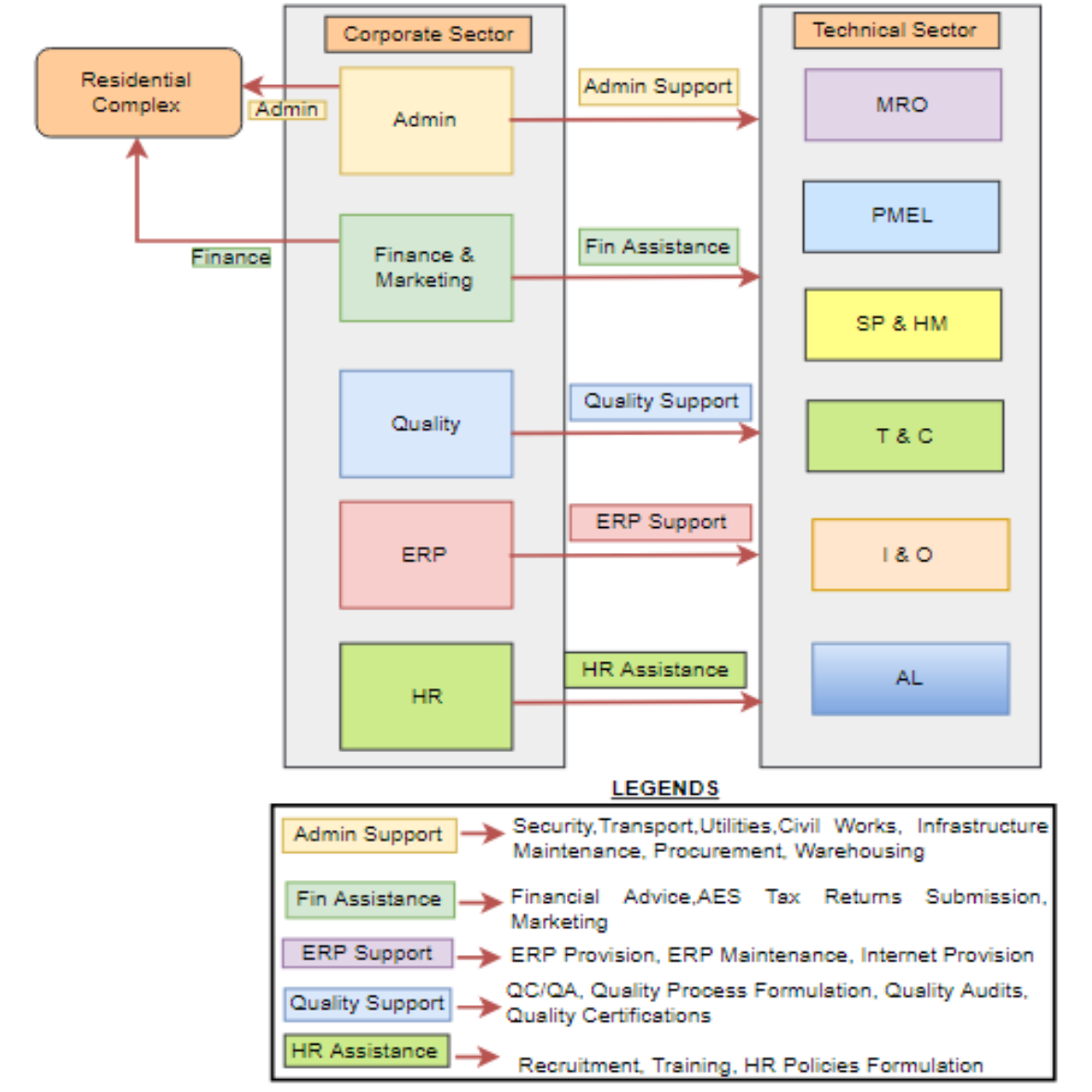

Figure 4.11: Other Systems Interface Diagram

4.3.3 EXTERNAL INTERFACES OUTSIDE AEC

These interfaces include all external players who will be involved in making system successful but will not be part of our system. Admin department has to arrange security, special transport, utilities, civil works, central procurement of generic items, warehousing and accommodation arrangement for AEC employees. ERP department has to arrange ERP solution for technical and corporate sector whereas quality department has to formulate quality control / quality assurance processes, obtain quality certifications and arrange quality audits. Human resource department has to perform HR recruitment and training of AEC. Finance department will perform financial management during development phase and liaison with FBR, customs for tax issues. As it is evident that, several interfaces with external agencies are required in AEC development to make it successful. Thus, interface diagram for the same will be:

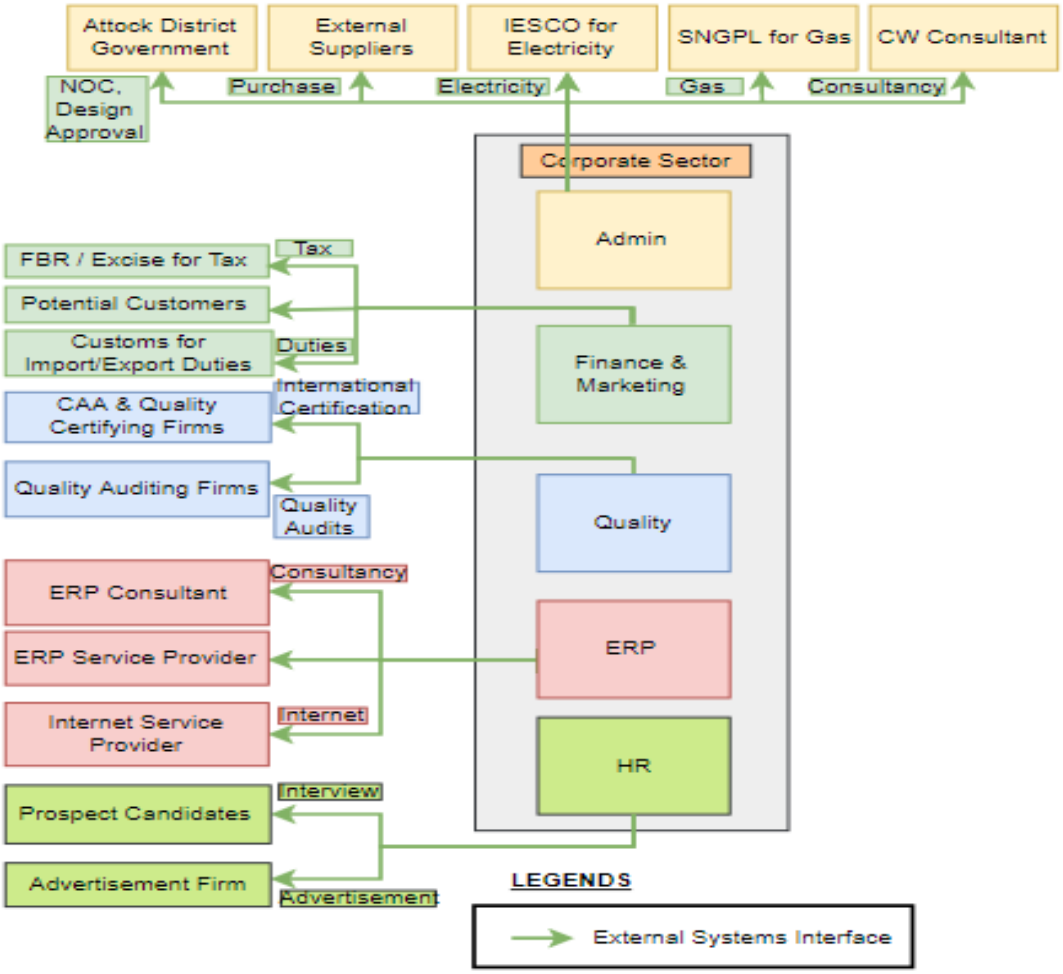

Figure 4.12: External Interface Diagram

4.3.4 OVERALL INTERFACE DIAGRAM

The overall interface diagram covering all three type of interfaces is appended below:

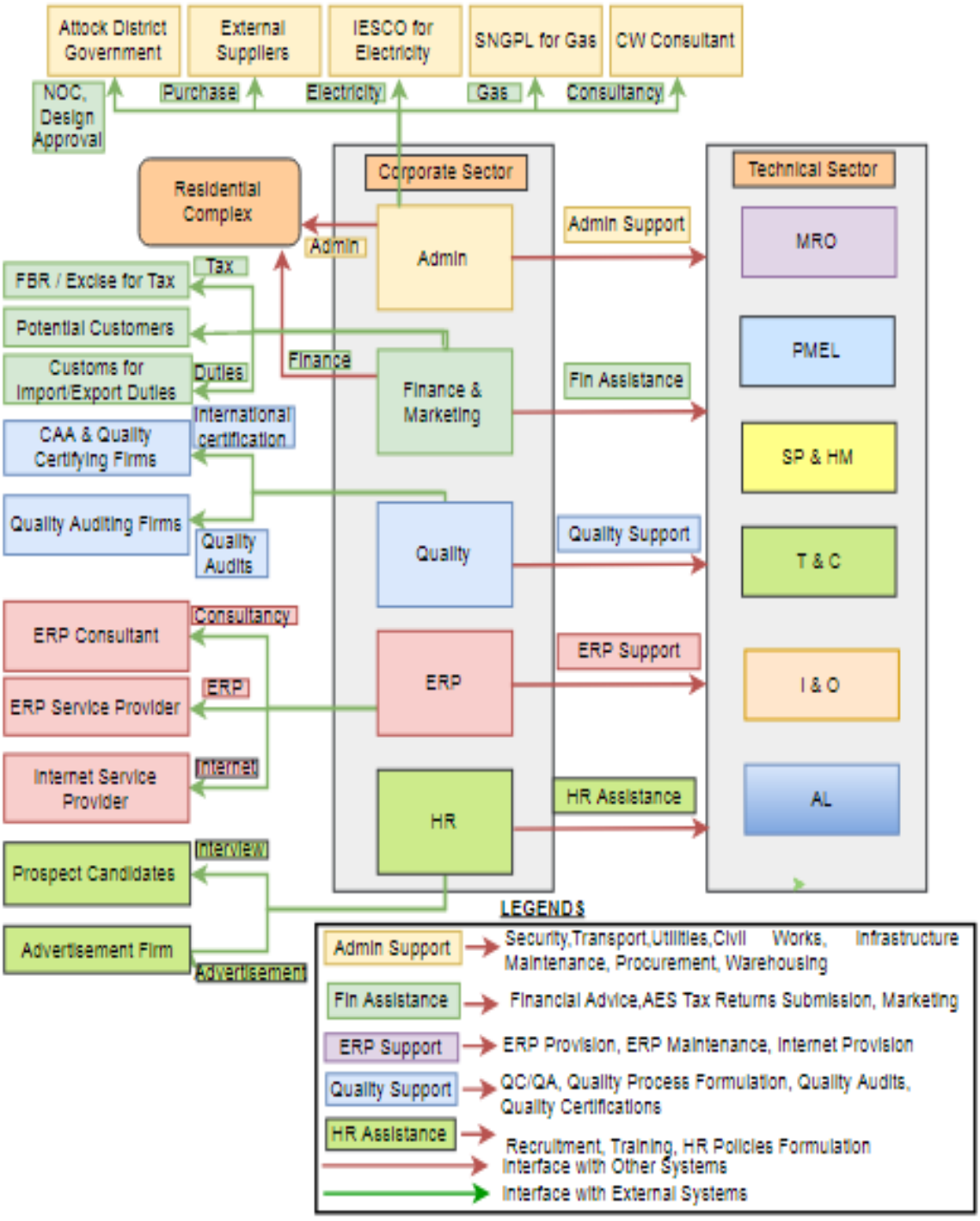

Figure 4.13: Overall Interface Diagram

4.4 SYSTEM MODEL

System model for corporate sector was developed using system modeling language. It covers different sections inside each functional area for performing multiple activities to support technical operations and to run the corporate center.

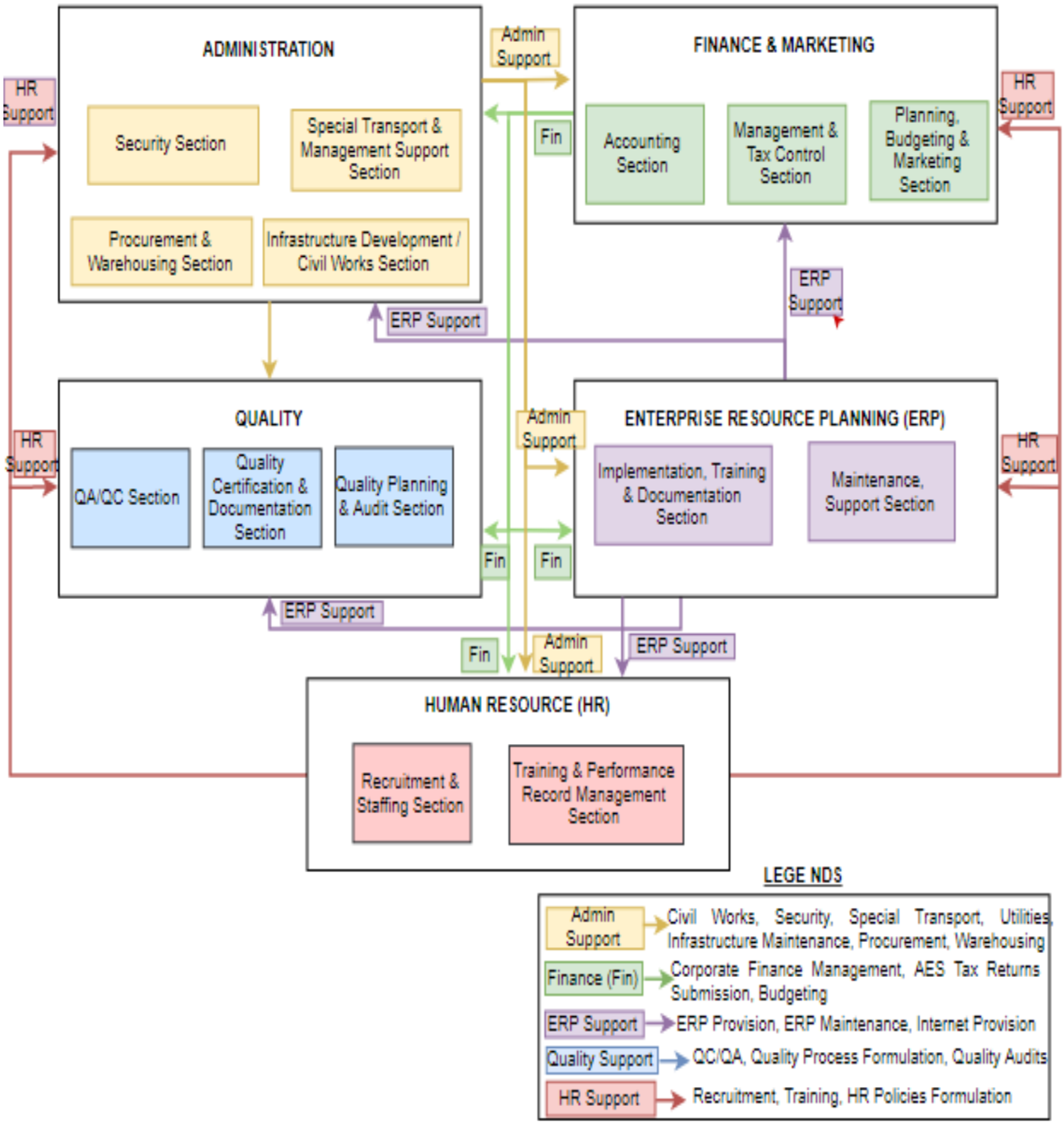

Figure 4.14: System Model

4.4.1 DEVELOPMENT OF ALTERNATIVES

The required functions can be completed in two different ways:

(a) Horizontal Structure Model: First option is to follow horizontal construction model and build only single floor for every corporate sector sub department. Major drawback with this model is that departments are separated which requires more space and is expensive. Difficulty in prompt communication within a department will also be observed.

(b) Vertical Structure Model: In this option we can develop infrastructure on basis of vertical structure having multiple floors. For corporate sector, a single building with 2 floors will suffice the job. Same model will also be followed for developing technical infrastructure as it requires less space and is more cost effective. The problem in this choice is that we have to consider soil type and the amount of load it can bear, results of which will decide the type of foundation to be laid. Average load bearing capacity of KAMRA region is 0.75-1 ton. Thus, vertical structure model is more prudent for AEC.

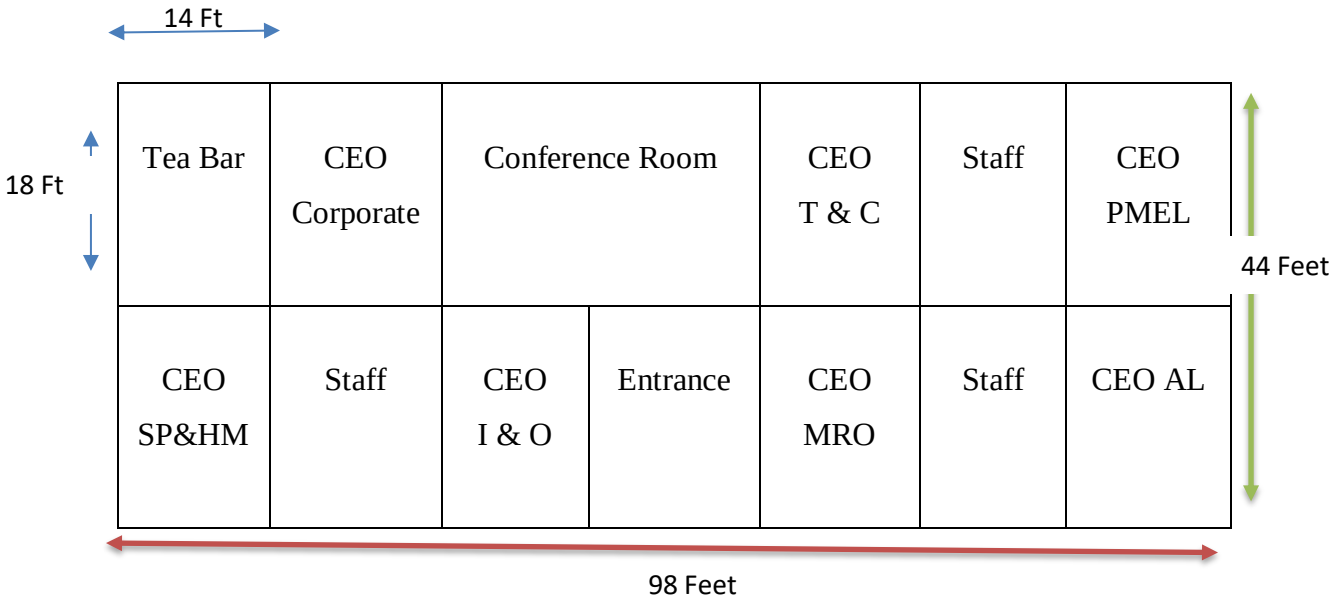

Figure 4.15: CEO Offices Diagram

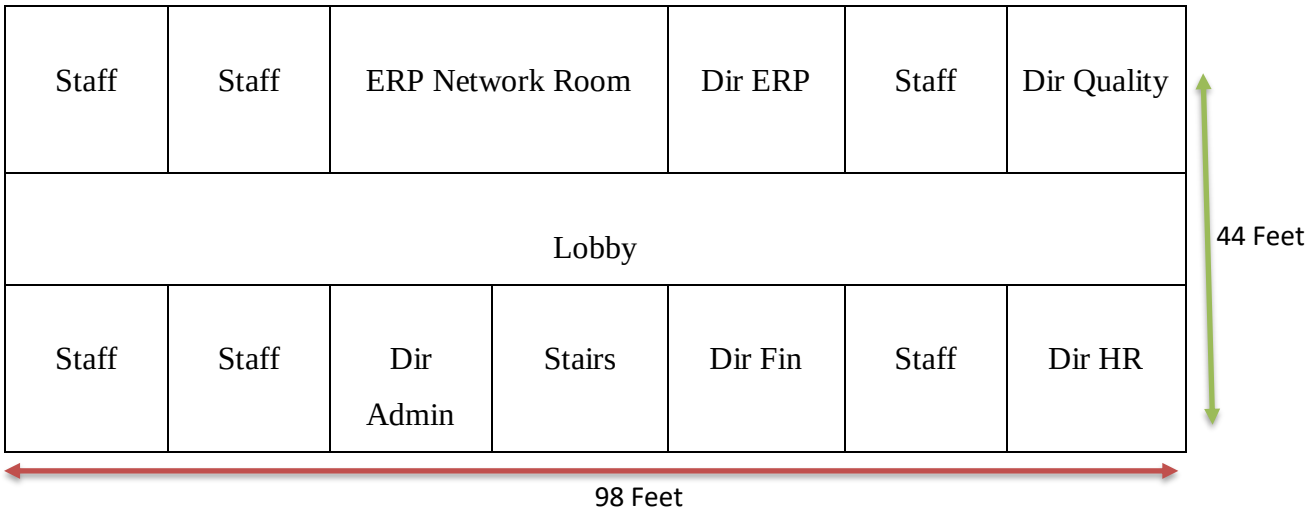

Figure 4.16: Dir Offices Diagram

Space Requirements

a.	HQ & Corporate Offices	6000 Sq Ft
b.	Warehouse	1500 Sq Ft
c.	Cafeteria and Guard Room	1000 Sq Ft
d.	Employees Hostel	1500 Sq Ft
e.	Miscellaneous (Parking, Reception)	2000 Sq Ft
	Total Area	**12000 Sq Ft**

4.5 LIFE-CYCLE COST ANALYSIS

Life cycle cost analyses are performed periodically to update and include the cost of acquisition and ownership. This effort is an ongoing process that results in identification of the economic consequences of the project. The life cycle cost of every project can be divided into two main categories of fixed cost and recurring cost. Funds from one head can also be utilized in other head during development phase.

4.5.1 FIXED AND RECURRING COST

Fixed Cost are one time expenditure on project activities whereas recurring cost are expenditure occurring on regular basis. Cost estimates have been obtained from AEC business plan, budgetary quotes of different firms and exhaustive market survey. Activity wise cost breakdown of fixed and recurring cost is shown below:

Cost Category	Qty	Unit Cost (US$)	Fixed Cost (US$)	Recurring Cost (US$)
Civil Works/Infrastructure Development				
Preparation of AEC Master Plan	1	28,571	28,571	
Preparation of Construction Drawings	3 (1 for each)	25,000	75,000	
Contracts for Construction / Development			28,571	
Contracts for Utilities			1,429	
Consultancy Services (Civil Engg)	For AEC		71,429	
Construction of Boundary Wall			21,500	10,000 per annum
Construction of Furnished Corporate Offices Block with Conference Room			250,000	
Construction of Tech Area			630,000	
Construction of Roads and Pavements			107,143	
Construction of Guard Room			7,143	
Ware House Construction			85,714	
Employees Hostel Construction			20,000	
Utility Services Arrangements			100,000	200 per annum
Furniture for W/Shops - Tech Area			100,000	200 per annum
Cafeteria			10,000	
General Development (Parks, Plantation)			35,714	1,000 per annum
Mosque			35,714	300 per annum
Take Formal Possession of AEC Civil Infrastructure			1,714	
			1,609,642	

ERP				
Contracts for ERP and Networking			2,857	
ERP User Fee Per Month	15	250	3,750 per month	45,000 per annum
ERP & IT Hardware			10,000	500 per annum
Train Staff on Basic Features of ERP Modules			24,000	
Train Key Staff on Adv Features of Core ERP Modules			5,000	
Train AEC Key Staff on Adv Features of A&D Engines			12,000	
Other Software License fee			1,429	
			59,036	
Quality				
ISO 9001-2015 Contract, Trg, Prep, Implementation			10,714	
ISO 9001-2015 Audit	1	2,143	2,143	
AS 9100 Rev D Contract, Trg, Prep, Implementation			22,143	
As 9100 Rev D Audit	1	4,286	4,286	
CAA (Pak) Contract, Trg, Prep, Implementation			10,714	
CAA (Pak) Audit	1	1,429	1,429	
ICAO/FAA/EASA Contracts, Trg, Prep, Implementation			45,714	
FAA /EASA / ICAO Audit	1	7,143	7,143	
Preparation of SOPs and Business Processes			7,000	
			111,286	
Human Resource				
HR Selection & Induction			4,857	300 per annum
Development of Core Values, Principles, Rules, Logo			1,450	

Proj Manager Salary	1	3,000 x 21	63,000	
Salary for director	4	2,000 x 21	168,000	
Salary of Lower Staff	4	300 x 21	25,200	
			262,507	
Misc				
Transport / Machinery			196,900	2,000 per annum
D/Cabin	1	38,990		
APV	1	23,110		
Shahzore	1	32,000		
Portable Crane with Truck (8 ton)	1	45,000		
Fork Lifter (1.5 ton)	1	78,00		
Portable Elevated Work Platform (12m)	1	15,000		
Portable Diesel Generator (150KVA)	1	35,000		
Security Equipment Purchase			15,000	500 per annum
AEC website Development			2,000	100 per annum
Travelling Expenses			8,000	
Project Development Phase Marketing, Promotion, Souvenirs			50,000	
Stationary / Office Supplies			10,000	1,500 per annum
			281,900	
Total			**2,324,371**	
Risk Factor (20%)			464,874	
Unforeseen (10%)			232,437	
Total Amount			**3,021,682**	
Note: ERP software customization cost to be included				

Table 4.1: Activity wise Cost Breakdown

4.6 OPTIMIZATION

Optimization using SYSE approach takes into consideration the uncertainties in achieving project objectives and technical goals. The uncertainties are risks associated with a project whereas technical goals are measurable attributes of system defined as Technical Performance Measures (TPMs). The aim of this exercise is to achieve a balance in performance and cost between system elements.

4.6.1 RISK MANAGEMENT

Risk Management is one of the most important area to be focused during any project. Risk management process covers identification of risk areas related to the project, then assessing the impacts of these risk factors on success of project during its lifecycle and finally developing a risk response strategy to abate or minimize these risks to keep projects on track and to ensure its completion within resources. Once these potential issues / uncertainties becomes reality, these must be addressed from project management context. Risk factors mainly affect program from schedule, performance, functionality and cost perspectives. So, a proactive approach to manage risks at earlier stage will aid in developing contingency plan instead of reacting to the crisis that can be costly and will hamper the project performance. In developing AEC, a lot of functions are to be performed with regards to corporate sector, thus, recognition of potential risks, evaluating and devising a strategy to overcome these uncertainties will be the responsibility of the project manager. Most of construction related work will also be carried out apart from other corporate functions. It is pertinent to mention that these construction projects are unique and built only once so focused attention will be required in identifying risks.

a. Risk Identification

It is not possible to identify all risk factors that may arise in project in planning stage. So classical brainstorming and judgments is required in identifying major risk areas related to corporate sector development and proposing necessary remedial action. There will be many unforeseen that may arise during project execution. Potential risk areas for AEC corporate development are appended below:

i. Project Cost Overruns

ii. Project Schedule Exceeds
iii. Stakeholders Risk
iv. Ineffective method of Consultant & Contractor Selection
v. ERP Implementation Failure
vi. HR Risks
vii. Environmental Risks
viii. Delay in Funds Availability & Payment
ix. Change in Master Planning by Regulating Bodies

b. Risk Assessment & Response

Risk assessment is an important technique to find out the likelihood / main causes of risk occurrence on proposed project. Risk areas identified are assessed from the perspective of main sources that causes them to occur, their risk level is determined and appropriate risk response to mitigate or abate the risk are considered. Risk areas mainly impact the project from cost, time, performance and quality perspective, and are categorized into three levels i.e. high, medium and low. Risk levels categorized as high will have a severe impact on project execution, medium risk level will hamper project efficiency and will disturb project timelines whereas lower level risks will have minimal effect on the program. A risk assessment sheet covering all these factors was prepared and risk response was indicated against each uncertainty that can be faced by project execution team and is placed as appendix B. A risk chart depicting these risk factors along with their potential impact and probability of occurrence with regard to AEC development project is shown below:

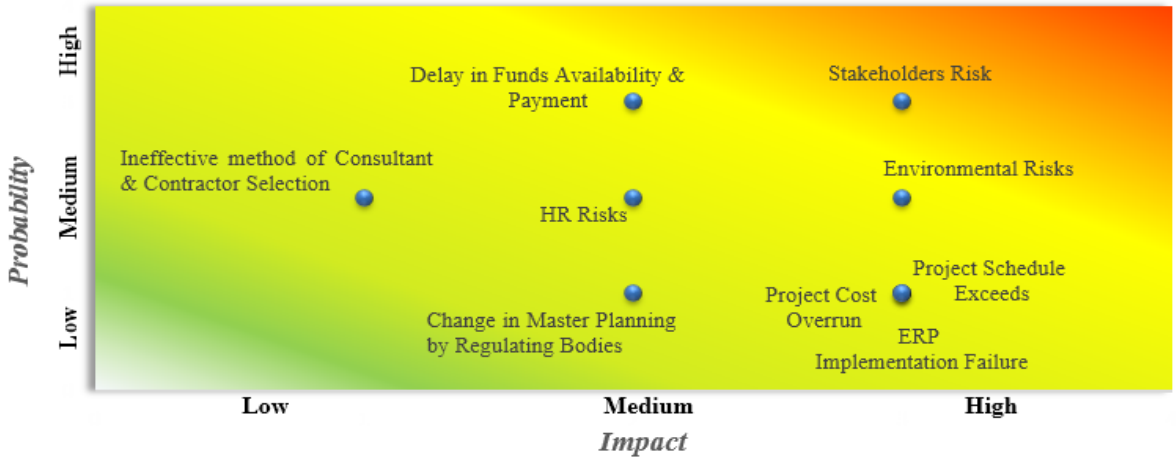

Figure 4.17: Risk Chart

4.6.2 TECHNICAL PERFORMANCE MEASURES

TPMs are the parameters to measure outcome of specific goal and help program managers to monitor progress and take necessary remedial actions. The success of this project will be measured against the following TPMs:

a. Project should be completed within an estimated cost of US$ 3.02 Million excluding ERP customization cost. Additional cost of 20% as risk factor and 10% for unforeseen contingencies has also been included in cost estimates.

b. Project should be completed within 14 months.

c. Project should cover area of 6 kanals for corporate sector excluding area for pavements, technical and residential portion.

Construction

d. The AEC construction shall comply with Facility Requirements Standards AFRCH 32-1001 for aviation setups [44], CAA (Pak), Ministry of Housing & Works building codes 2007.

e. Construction in technical area shall support demountable walls, moveable partitions to allow flexibility for the projected and future needs.

f. Building designs of technical & corporate infrastructure should cater earth quake and bear shocks up to 7.5 Richter scale.

g. Installation of safety/support equipment inside AEC facilities & their serviceability in accordance with international health, safety & environmental standards.

Quality

h. AEC shall achieve ISO 9001:2015 QMS, AS 9100 Rev D, CAA (Pak) certifications.

i. AEC shall attain customer satisfaction (>90%) with respect to (wrt) quality of work and services being hired/offered with less rework.

j. Determination of QC/QA procedures & establishment of internal organizational process for MRO, manufacturing, assembling, calibrations work must conform to OEM technical publications or International aviation / EASA standards.

ERP

k. ERP planning, selection and implementation in AEC shall be completed within 6 months alongwith Service Level Agreement (SLA).

l. ERP usability should be 24/7 with less maintenance cost, complexity & High MTBF. A minimum of 95% reliability should be set as achievable target.

HR

m. Core HR selected for AEC must have at least 10 years of experience at PAC/Military aviation setup in their respective fields with sound grip on latest technologies & professional excellence.

n. Inducted HR capability growth and HR value addition will be established based on profit margins (around 15%) and increase in revenue.

o. Efficient resource utilization, employee's commitment & timely completion within budget will alleviate AEC productivity.

4.7 SUPPORT PLAN

Support plan was prepared using QFD. This support plan covers support for external and internal customers, on time deliveries alongwith economical cost for products & services offered by AEC.

4.7.1 FACTORS CONSIDERED DURING SUPPORT PLAN

Factors considered during support plan are given below:

a. Timely support to external customers
b. High support for internal customers
c. Economical cost

d. Flexibility

e. On time delivery

f. Quality product

4.7.2 QUALITY FUNCTION DEPLOYMENT (QFD) FOR SUPPORT PLAN

HOQ of support plan was prepared. These six factors were translated into technical requirements to calculate the weightage of each technical descriptor. HOQ of support plan is shown below:

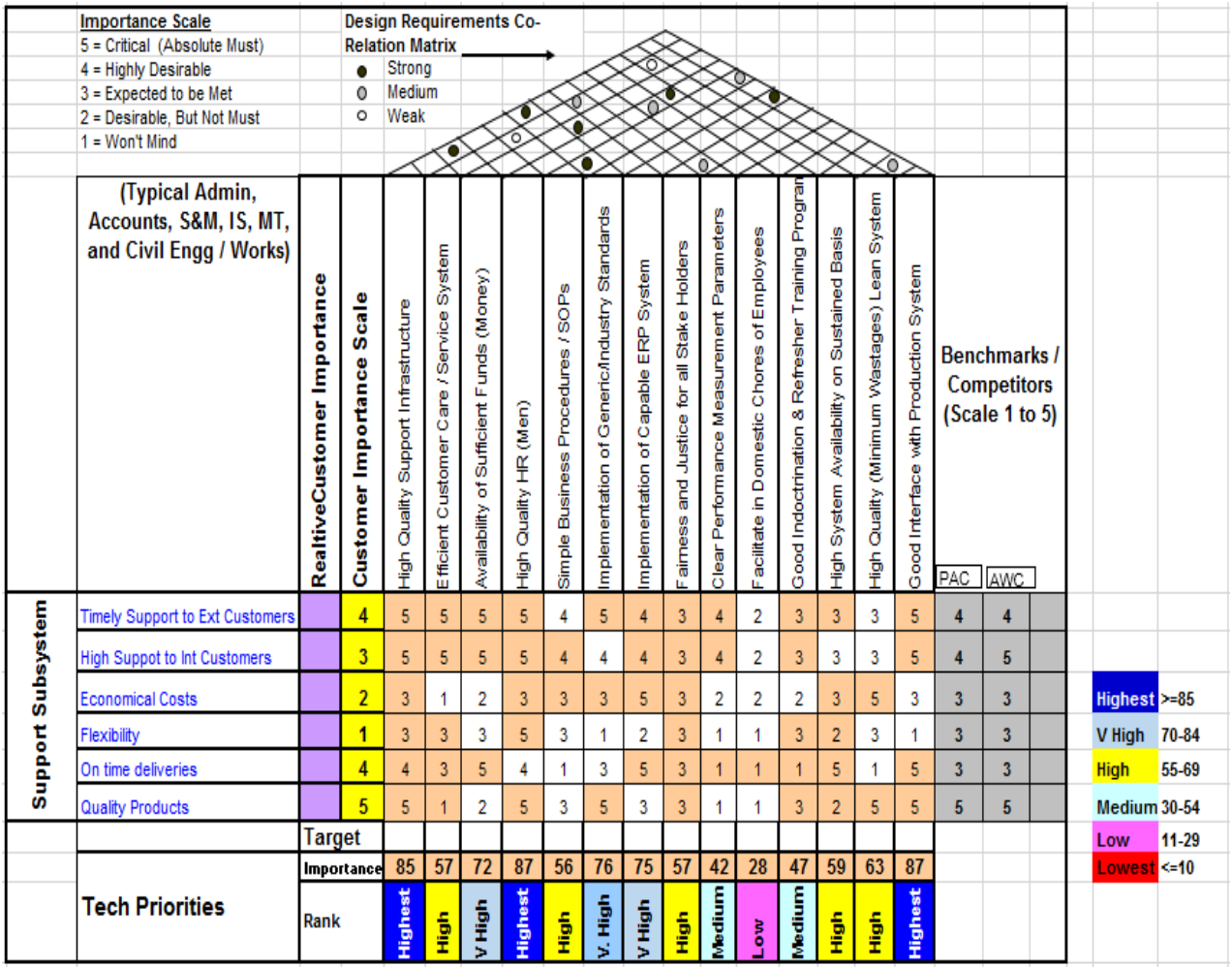

Figure 4.18: Support Plan HOQ

We can see that, high quality infrastructure, good interface with production system, high quality HR, implementation of capable ERP system and availability of sufficient funds are indispensable for AEC to successfully accomplish support plan.

4.8 FINAL DISPOSAL OF EQUIPMENT

A very unfortunate and rather sad part of every system is that it only has a limited life. A day would, therefore, always come when somebody will have to make the difficult decision of disposing it off. This has to be catered for right in the beginning so that the process is smooth and orderly. The operational life of corporate infrastructure is 50 years, if maintained well and same will be disposed off as scrap. Life of infrastructure can be increased to some extent through effective maintenance. In case of equipment, life of a system will be governed by the principal manufacturer's ability to support and maintain the system at an affordable cost to the user. It is, therefore, suggested that a firm commitment be taken from the supplier for cost effective support for the desired period. If required, and practical, the provision of buy-back may be incorporated in the contract and cost effects be worked out e.g. in some percentage of the cost of new equipment. An understanding with the supplier that the existing system will be replaced with another system manufactured by them will make the incorporation of this provision easier. This will also mean a long-term relationship between the supplier and user, a factor that will have a strong influence on the quality of after sales service.

In case of any dispute between shareholders / management, individual may decide to sell his portion to other shareholders but same will not be dejected for initial 05 years from project's formal launch date. In the most unfortunate situation, BoDs may sell AEC to another party as an exit strategy for proportionate dissemination of sale proceeds amongst the partners. Adherence to customary norms of justice and mutual determination to succeed must guide BoDs in such an eventuality.

CHAPTER 5 – ENTERPRISE RESOURCE PLANNING

AEC is planned to be involved in diversified operations like MRO, PMEL, manufacturing, indenting and so on. There is no denying the fact that effective management of such broad areas is not possible without an effective ERP solution. It not only allows software integration of processes and sub processes to manage a business and automate functions but also provides vital remunerations to manufacturers in reducing costs, managing growth, streamlining processes, improving productivity and efficiency by preventing duplication of efforts / work. An industry standard ERP system having Accounting & Finance, Human Resource, Administration, Supply Chain Management, MRO, Manufacturing, Quality Management and Production Planning modules with necessary customization will be deployed in AEC. ERP must be flexible enough to integrate additional modules in future and shall be helpful in improving visibility through planning and scheduling.

5.1 ERP DEVELOPMENT OPTIONS

Number of ERP solution providers are available. All of these provide customized business processes with requisite modules. The available options for acquiring ERP applications are:

a. In-house development or development of ERP through a vendor (in-country or foreign)
b. Off-the shelf applications like SAP or Oracle based solutions

As far as development by an in-country vendor is concerned, none of the software developer has an experience of handling a system of this magnitude. The databases developed in-house are limited in scope and specific to certain work areas. To get an ERP developed from any vendor requires a thorough understanding of the development process, solid foundation of business flow, long implementation time, higher development cost, high implementation failure risk along with management challenges. The best option for AEC is to acquire off the shelf industry standard applications like SAP or Oracle. Purchasing industry standard applications will reduce the development time and implementation failure risk but requires a dedicated server room for installation of application and databases and backup servers. As AEC is in startup phase, so developing a dedicated server room will be quite expensive due hardware equipment

requirements, application and database software's & licensing fees and IT experts. Server room equipment requirements are given below:

a. Raised flooring
b. Storage Area Network (SAN) for data backup
c. 4 x Xeon Servers (for live application, database & their backups)
d. Rack for servers
e. 2 x Racks for server and switches
f. 2 x Core Switch for network management
g. Cable trays
h. 2 x ACs
i. 2 x Hygrometers
j. 1 x Dehumidifier
k. 1 x Domain Controller server
l. Linux based OS being more secure
m. 1 x Tool Box
n. 2 x 10KVA UPS

Thus, a cloud computing option is considered more prudent, and the requirement for a dedicated server room can be reviewed after five years of AEC operation through formal approval of BoDs. A block diagram of the same is shown below:

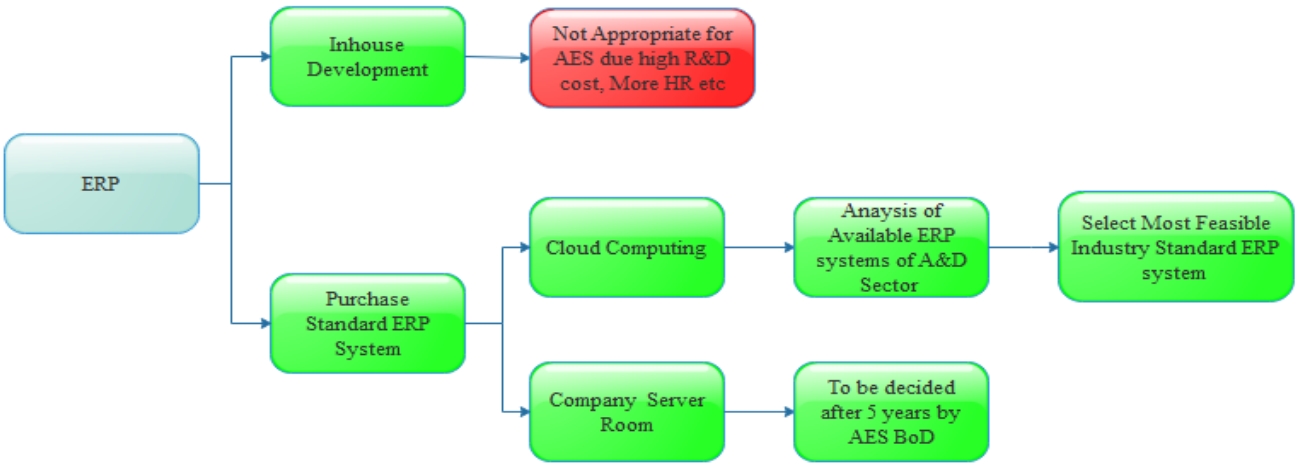

Figure 5.1: ERP Alternatives Options

5.2 CHARACTERISTICS OF ERP SYSTEM

In selection of ERP system for AEC, following characteristics must be considered:

a. Modular design comprising of many distinct business modules such as Accounting & Finance, Human Resource, Administration, Supply Chain Management, MRO, Manufacturing, Quality Management and Production Planning modules.

b. The modules shall provide seamless data flow among each other, increasing operational transparency, efficiency through standard data interfaces.

c. ERP system must include an option to integrate additional modules of business redundancy, business reengineering modules and so on in future.

d. ERP shall provide traceability of parts, components and task responsibilities with accurate anticipation of functions.

e. It should be highly secured distributed network that provides total overview of available information to management.

f. The modules shall work in real time with batch processing capabilities without delay and without periodic updates.

g. ERP system should have 15 nodes with extendable option up to hundred nodes.

5.3 ERP BUSINESS PROCESS FLOW DIAGRAM

Business process followed in ERP will be based on the concept of independent, mutually supporting BU in which each CEO will be independent to run his BU and services provided by the corporate center will be charged from the respective unit at less rates compared to open market to corroborate the concept of less pricing for products and services being offered by AEC. Each unit will also charge other units for services being offered / hired and all this will be managed through ERP. The business process for ERP will be:

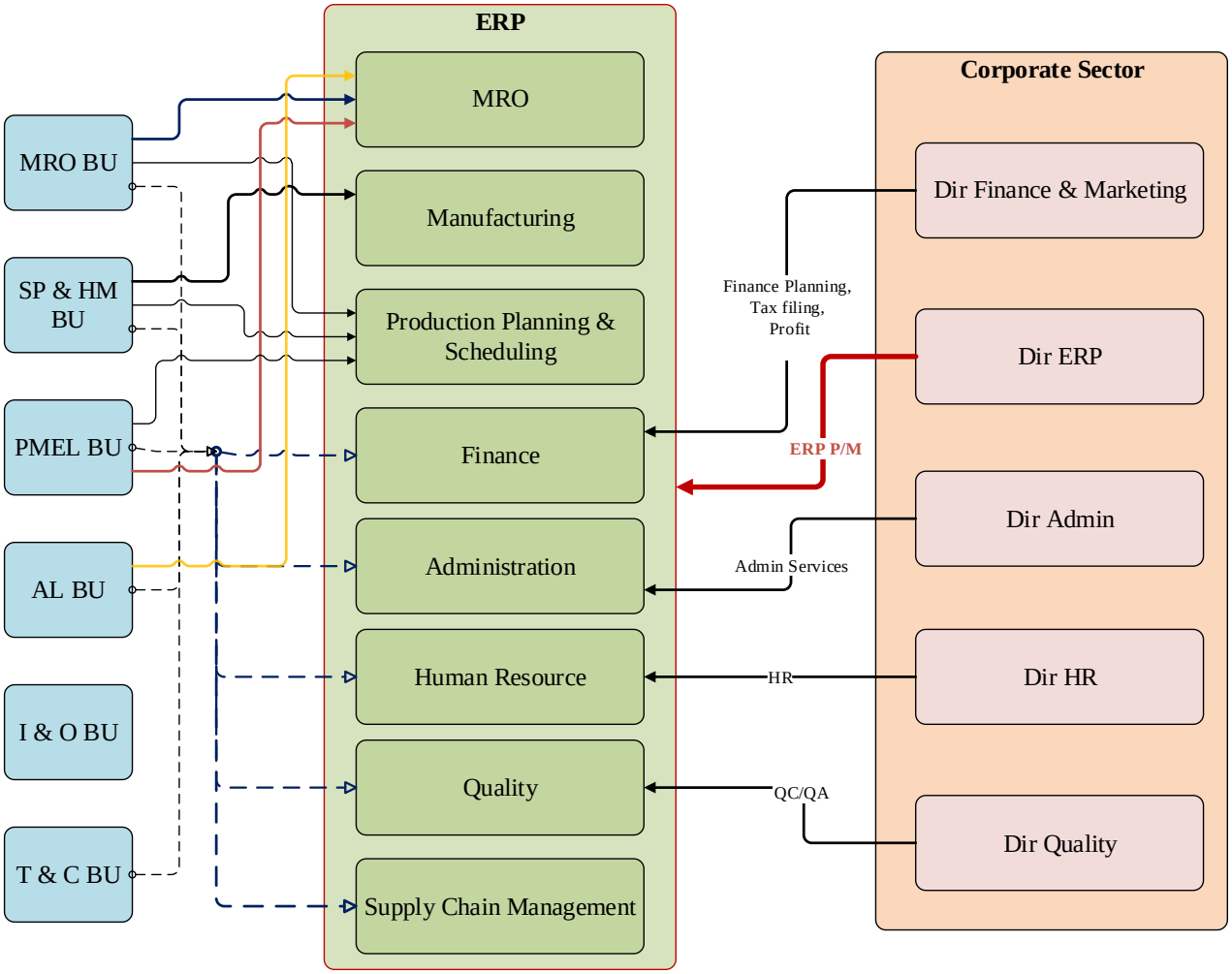

Figure 5.2: ERP Model for AEC BUs

For AL, I & O, T &C units, their business process will be modeled with slight customization of their workflow.

5.4 ERP SELECTION CRITERIA USING ANALYTICAL HIERARCHY PROCESS

Different ERP systems from renowned companies are available in local market that suit our business framework with slight customization. Selection of the most feasible option for AEC out of these can be determined based on a set of selection criteria developed using Analytical Hierarchy Process. AHP was developed by Prof. Thomas L. Saaty [22] and is a structured technique for decision making process that helps in selection of most feasible option for company / organization based on a given set of criteria. Weightage factors are assigned for each attribute

and their cumulative sum is calculated and compared. To calculate the weighting factor, first step is to list down the criteria factors to be considered during selection of ERP solution for AEC. Same is appended below:

Goal	**Factors to be Considered**
To select the best ERP System for AEC	Cost
	Implementation time
	Implementation risk
	Functionality
	Lifespan
	Scalability
	Cloud adaptation

Table 5.1: Factors to be Considered for AEC ERP Selection

All these criteria factors can also be further subdivided into sub-criteria's depending on requirements. Priority matrix for pairwise comparison of these seven factors was developed. For priority matrix of order 7x7, the number of areas to be filled for priority matrix are calculated using the following formula:

$$No\ of\ Areas\ to\ be\ filled = n\,(n-1)/2 \quad (1)$$

where n = number of factors considered during ERP selection. For seven factors, n=7

$$No\ of\ Areas\ to\ be\ filled = 7\,(7-1)/2 = 21 \quad (2)$$

As we know that these factors are independent. Thus, pairwise comparison of these factors will also be performed independently. A relative importance of each factor on a scale of 1 to 9 based on subjective judgments was used for this pairwise comparison. The priority matrix deduced using above comparison scale is given below:

Priority Matrix of AHP							
	COST	CLOUD ADOPTATION	IMPLEMENTATION TIME	FLEXIBILITY	IMPLEMENTATION RISK	LIFESPAN	FUNCTIONALITY
COST	1	5	5	2	1	2	2
CLOUD ADOPTATION	1/5	1	1/3	1/5	1/5	1/3	1/5
IMPLEMENTATION TIME	1/5	3	1	1	1/4	1/3	1/2
FLEXIBILITY	1/2	5	1	1	1/5	1/3	1
IMPLEMENTATION RISK	1	5	4	2	1	2	1/2
LIFESPAN	1/2	3	3	1	1/2	1	1/3
FUNCTIONALITY	1/2	5	2	1	2	3	1
SUM	3.90	27	16.33	8.2	5.15	9.00	5.53

Table 5.2: Priority Matrix for ERP Selection using AHP

Then determinant of this priority matrix was taken by dividing individual score of each filled area by sum of respective column score.

	Determinant of Priority Matrix						
	C1	C2	C3	C4	C5	C6	C7
COST	0.2564	0.1852	0.3061	0.2439	0.1942	0.2222	0.3614
CLOUD ADOPTATION	0.0513	0.0370	0.0204	0.0244	0.0388	0.0370	0.0361
IMPLEMENTATION TIME	0.0513	0.1111	0.0612	0.1220	0.0485	0.0370	0.0904
FLEXIBILITY	0.1282	0.1852	0.0612	0.1220	0.0388	0.0370	0.1807
IMPLEMENTATION RISK	0.2564	0.1852	0.2449	0.2439	0.1942	0.2222	0.0904
LIFESPAN	0.1282	0.1111	0.1837	0.1220	0.0971	0.1111	0.0602
FUNCTIONALITY	0.1282	0.1852	0.1224	0.1220	0.3883	0.3333	0.1807
	1	1	1	1	1	1	1

Table 5.3: Determinant of Priority Matrix

We sum the individual row score and take average to determine the priority vector. This priority vector is also known as eigen vector.

$$x = \begin{bmatrix} \frac{\sum row1}{n} \\ \frac{\sum row2}{n} \\ \frac{\sum row3}{n} \\ \frac{\sum row4}{n} \\ \frac{\sum row5}{n} \\ \frac{\sum row6}{n} \\ \frac{\sum row7}{n} \end{bmatrix} \quad (3)$$

Square of this determinant / normalized matrix was taken to perform the second iteration and subsequently results were compared with the first one. It is pertinent to mention that, if the difference between the results of two iterations is negligible, then Eigenvalue λmax can be calculated by multiplying each column sum of priority matrix with the priority vector and if the difference is significant, we will repeat this squaring process until negligible difference is achieved. Thus, Eigenvector values will be multiplied with 100 to find out weightage of each factor. The largest Eigenvalue λmax was 7.2879 in first iteration. Square of this matrix was obtained for next iteration

	Square of Determinant							Sum of Rows	Priority Vector	Priority
	C1	C2	C3	C4	C5	C6	C7			
COST	0.2468	0.2611	0.2485	0.2527	0.2809	0.2725	0.2673	1.8299	0.2614	1
CLOUD ADOPTATION	0.0385	0.0356	0.0399	0.0373	0.0385	0.0392	0.0384	0.2674	0.0382	7
IMPLEMENTATION TIME	0.0664	0.0728	0.0589	0.0649	0.0701	0.0673	0.0731	0.4736	0.0677	6
FLEXIBILITY	0.0990	0.1048	0.0926	0.0942	0.1211	0.1151	0.1190	0.7457	0.1065	5
IMPLEMENTATION RISK	0.2089	0.2041	0.2116	0.2122	0.1727	0.1799	0.2128	1.4023	0.2003	3
LIFESPAN	0.1105	0.1123	0.1118	0.1159	0.0959	0.0979	0.1153	0.7596	0.1085	4
FUNCTIONALITY	0.2297	0.2092	0.2364	0.2230	0.2207	0.2279	0.1739	1.5209	0.2173	2
	1.0195	1.0314	1.1055	0.8733	1.0315	0.9765	1.2017			
Eigen Value (λmax)	7.2394									

Table 5.4: Priority Vector Values of AHP

Thus, λmax of next iteration was:

$$\lambda \max = 1.0195 + 1.0314 + 1.1055 + 0.8733 + 1.0315 + 0.9765 + 1.2017 = 7.2394 \quad (4)$$

Difference between these two values are negligible, so this λmax value was taken to measure the consistency of subjective judgments made during the development of priority matrix. The consistency can be validated by determining consistency index (CI) and consistency ratio (CR). If the values of CI and CR are less than 0.1 (10%), judgments are considered to be reliable and trustworthy. Thus, CI was calculated from the formula:

$$CI = \frac{\lambda max - n}{n-1} \quad (5)$$

$$CI = \frac{7.2394-7}{7-1} = 0.04 \quad (6)$$

Next step is to verify consistency ratio. It is computed using formula given below:

$$CR = {}^{CI}/_{RI} \quad (7)$$

Random Consistency Index (RI) followed is:

N	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

So in our case, CR will be

$$CR = {}^{0.04}/_{1.32} = 0.03 \quad (8)$$

As we can see that, CI & CR < 0.1 that corresponds to almost perfect fit for judgments to be trustworthy. Thus, criteria followed while selecting ERP for AEC from different alternatives should be based on weighting factors given below:

Criteria Factors	**Weightage**
COST	*26%*
FUNCTIONALITY	*22%*
IMPLEMENTATION RISK	*20%*
LIFESPAN	*11%*
FLEXIBILITY	*11%*
IMPLEMENTATION TIME	*6%*
CLOUD ADAPTATION	*4%*
Total	***100%***

Table 5.5: Weightage of ERP Factors

Pie chart for these factors contribution was also prepared as shown below:

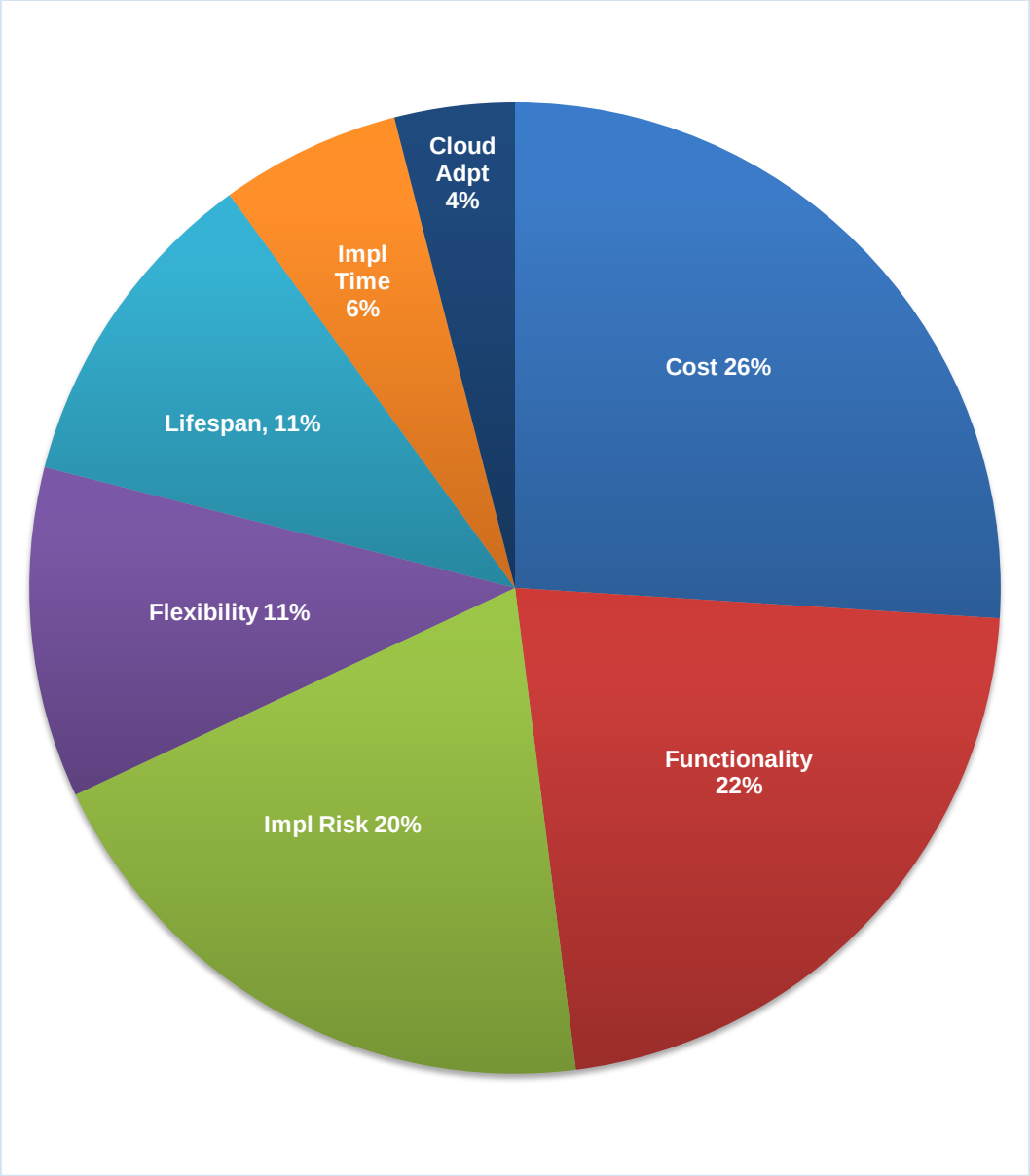

Figure 5.3: Pie Chart of ERP Factors

ERP network diagram for AEC will be:

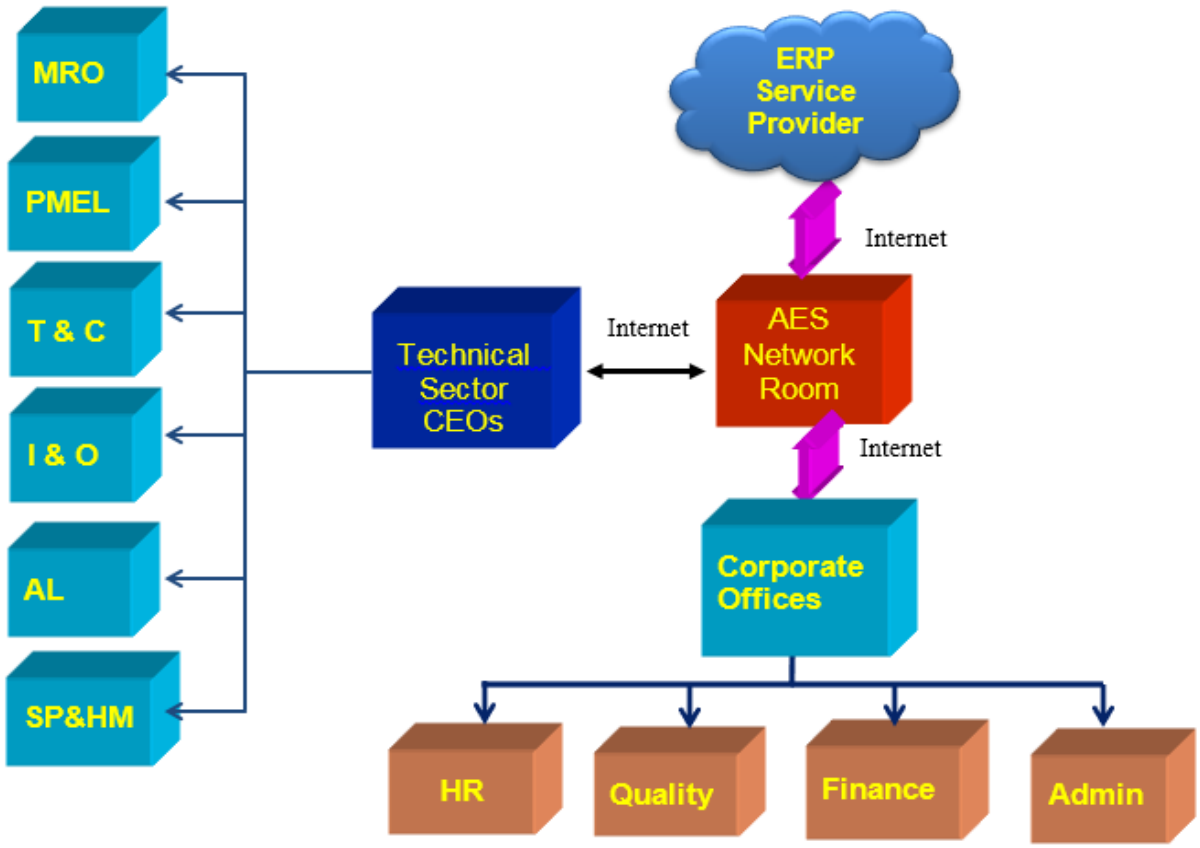

Figure 5.4: ERP Network Diagram

Suppliers repute, market share, implementation success rate and history of failed / delayed implementations shall also be considered while finalizing ERP solution. After selection of ERP, necessary negotiation with ERP supplier should be initiated regarding cost and time.

5.5 ENGINEERING SPECIALTY INTEGRATION

Specialty Engineering is part of system engineering that includes specialty area disciplines such as maintainability, reliability, availability, testability. It is the system engineer who has to decide what specialty engineering disciplines are required to compliment project activities apart from traditional engineering fields. Specialty engineering supports project activities and integration of these specialty engineering disciplines with traditional engineering fields is necessary in developing project infrastructure that meets stakeholder requirements.

5.5.1 RELIABILITY PROGRAM PLAN

'Reliability program plan' provides basis for measuring the system reliability. A minimum of 90 percent reliability should be set as an achievable target. This would, of course, mainly depend on the reliability of equipment, machines, communication medium, infrastructure development process and work quality material. ERP selection and implementation in corporate sector shall also gratify reliability aspects. System capability maturity level, recoverability of data, fault tolerances wrt specific level of performance achievable after any fault, operability and adaptability conditions must be considered in determining ERP system reliability whereas expertise of system administrator and operators, if any, would also affect the overall system reliability. As far as other hardware, software, machines reliability is concerned, focused attention will be required by decision makers / AEC management during procurement of all such items.

5.5.2 MAINTAINABILITY PROGRAM PLAN

A 'Maintainability program' is prepared for every project to improve overall readiness, reduce maintenance manpower needs, reduce life cycle cost and to provide data essential for management. The vendor, under a separate contract, should handle intermediate level maintenance, service level agreements and spares support provisioning. The AEC staff should, however, carry out all O-level maintenance of equipment whereas infrastructure and ERP maintenance will be performed by contractor / service provider through respective departmental heads. It is suggested that a target of 90 percent serviceability be set for the system. Analyzability, changeability wrt easy future modifications, testability for validation after any change and efficient resource utilization to be focused from maintainability aspects especially in procurement of technical equipment.

5.5.3 SYSTEM TEST PLAN

This plan is prepared to establish strategy for qualifying the system and provides testing strategy to ensure what executable functions are required with minimum acceptable range. The vendors will prepare this plan after necessary coordination with AEC managements, lead consultants and all the users at the respective sites. Testing strategy shall cover functional requirement testing at

customer site, test case specifications and results, acceptance criteria. Testing team must have experts of that particular system alongwith a lead consultant.

5.5.4 ENGINEERING PROJECT PLAN

This data is described graphically in the form of PERT charts. It identifies the major milestones and events required by the 'Statement of Work'. This plan shall be revised prior to a formal progress review. Activity framework of AEC corporate sector was developed and shown below:

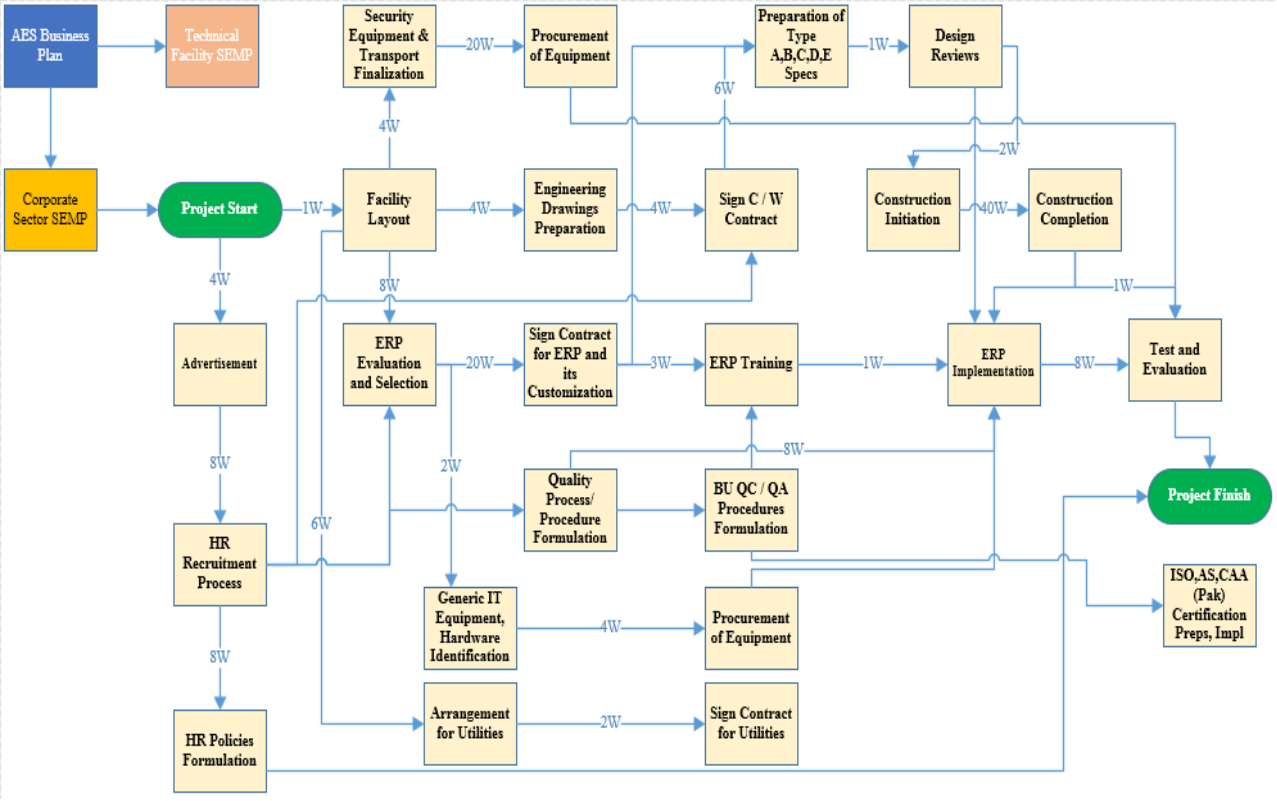

Figure 5.5: Activity Framework Chart

As we can see that infrastructure development part is most critical in all of these activities. Any delay in this activity will affect the project timelines. All remaining activities have slack time that can be managed. So careful attention shall be given on infrastructure development to avoid any delay in project activities.

CHAPTER 6 – CONCLUSION, RECOMMENDATIONS/ IMPLICATIONS

6.1 CONCLUSION OF RESEARCH STUDY

Customized SEMP, covering the systematic approach for development of AEC corporate framework is the backbone for this thesis work. This research is applicable to both public and private sector aviation engineering setups. Thesis work covers system and subsystem level activities tangled in creation of corporate framework of AEC.

AEC will endeavor to become high-quality private sector MRO vendor for A&D organizations particularly in the SAARC countries and the Gulf region mainly because of experienced AEC technical HR having a military background. MRO business can only be undertaken in a legally accredited and licensed basis so AEC will subsequently achieve certifications of ISO & CAA (Pak). OEM agreed spares will be used during MRO operations of assemblies and engines along with comprehensive traceability records. OEM instructions will be strictly adhered to A&D standard for innumerable processes. AEC will also abide by all occupational health, environmental and safety regulations applicable in Pakistan to meet its legal and social obligations.

It will be situated in vicinity of Kamra to take benefit of PAC's huge engineering capabilities, clean environment, civic developments, quality manpower and possible access to social facilities of the area. This preferred site was selected based on deployment of quality function. AEC will also leverage latest technologies such as Industry standard ERP system, for efficient operations and effective utilization of resources. ERP selection will be based on criteria factors developed using AHP approach that will save a lot of resources, time and effort during proposal evaluation process.

AEC will be producing high quality products complemented with quality services while minimizing delivery cycles. Support plan was prepared using QFD to achieve high support to external and internal customers alongwith economical costs and on-time deliveries. Successful accomplishment of support plan will require high quality support infrastructure, good interface with production department, high quality HR, implementation of capable ERP system and

sufficient funds as translated through HOQ. Thus high quality, well equipped AEC in the private sector will be idyllically placed to entice significant business and to fill the gaps in industry. By doing this, AEC will not only help us to achieve self-sufficiency but also save a lot of foreign exchequer through in-country MRO activities.

6.2 ADDITION TO BODY OF KNOWLEDGE / FILLED LITERATURE GAP

It is a pioneering research study based on system engineering approach for development of an Aviation Engineering Complex in Pakistan utilizing SYSE tools and techniques. Being novel research that conglomerates SYSE process via SYSE tools to corroborate the concept of independent mutually supporting business unit supported by single corporate center. Author also determined ERP selection criteria using AHP approach based on seven factors for AEC, which has never been accomplished in A&D sector.

6.3 IMPLICATIONS FOR FUTURE WORK

This study covers activities at system and subsystem level due to limitations of a single researcher, component level activities has not been addressed. Identification of requirements at component level, residential area SEMP preparations, development of sub criteria's for each ERP selection factor for more irrefutable evaluation of ERP proposals ERP proposals evaluations & selection from vendors based on criteria developed using AHP from implementation viewpoint can be worked out in future. Planning, developing quality procedures and achieving international certifications can also be accomplished as part of future work. Furthermore, explicit SEMP covering SYSE activities through SYSE tools can be prepared for both public and private sector projects as master planning documents to complete them within allocated time and resources.

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APPENDIX A: HOLISTIC REQUIREMENT MODEL

STA Form	
Project: **Development of Corporate Framework for Aviation Engineering Setup**	
Requirements	**Comments**
Operational Requirements: To plan and develop corporate framework for establishing very high quality international standard MRO & Manufacturing setup in Aerospace & Defence sector and optimal utilization of PAC Kamra's capabilities and capacity by outsourcing AEC local/international customers' requirements to PAC Kamra at relatively lower prices along with a loyal customer following.	
Non-Functional System Requirements: a. Meet the requirements of Pakistan Aerospace & Defence Sector. b. Qualified & experienced HR with attractive salary package. c. Recruiting and training facility for HR. d. High quality workmanship, timely delivery, high reliability (>90%). e. Conformance to CAA (Pak), ISO, FAA, EASA & other safety standards. f. ERP system installation facility along with power distribution and management. g. ERP should be accessible 7 days a week, 24 hours a day. h. ERP should have useful life of atleast 25 years with 95% reliability. i. Corporate head office, business unit CEOs & Corporate department Offices alongwith ERP network room facility, j. Communication room for data, voice and security services. k. Charging prices approximately 15-20 % less as compared to other A&D organizations.	

Functional Requirements	**Non-Functional Performance Requirements**	**Non-Functional Implementation Requirements**	
Human Resource Management	a. Comfortable working environment b. Cultural bonds c. Skill level d. Prompt response to employee inquiries e. Conformance to performance goals f. Adherence to Company SOPs	a. Effective organizational structure b. Workforce planning (Leave/shift management) c. Salary d. Welfare and compensation policies e. Regular monitoring of employee performance f. ERP HR module knowledge g. ERP node availability & backup UPS h. Resource requirement i. Publications/User manuals	
Quality Management	a. Certification of CAA (Pak), ISO, AS 9100 rev D b. Customer Satisfaction (>90%) c. Conformity of products d. Continuous process Improvement	a. Streamlined work process of company units b. Quality plan of units c. Automation of Quality Management process d. ERP quality module knowledge e. ERP node & UPS f. Publications/User manuals	
ERP	a. ERP system reliability (95 %)	a. Hardware equipment	

	b. Minimum customization from standard business processes c. Analysis of business unit for better performance and expansion	b. Software of applications layers c. Oracle layer database d. ERP operation / maintenance knowledge e. IT systems + UPS f. Software Modification Cell g. Specialized equipment/Tools h. User / Maintenance manuals i. Power Supplies & Standby supplies j. Firefighting arrangements	
Finance & Marketing Management	a. Balance Sheet b. Company assets evaluation c. Warranty coverage d. After sales support e. Recording product configurations	a. Financial planning (Budgeting & Forecasting) b. Cash flow Management (Cash receipt/Paid) c. Tax Files & returns d. Advertisement of company's product/services e. Market research & survey for potential customers f. ERP finance module knowledge g. ERP node availability & backup UPS h. User manuals/Policies	

Logistics & Supply Chain Management	a. Timely provision of resources b. Meet customer satisfaction (> 90%) for delivered products & services c. Customer & supplier relation management d. Timely delivery of product within specified schedule	a. Procurement Management (raw materials, COTS items) b. Inventory Management c. Order management d. Warehousing & FF arrangement e. Transportation f. ERP usage knowledge g. ERP node availability & backup UPS h. Publications/User manuals	
Administration	a. Timely availability of resources b. Infrastructure maintenance & upkeep c. Development plans	a. Accommodation / Hostel for Employees b. Transportation c. Security equipment d. Utilities requirements e. Recreation Facilities f. ERP node availability & backup UPS g. Publications/User manuals	

APPENDIX B: RISK ASSESSMENT SHEET

S No	Risk Area	Main Reasons/Risk Drivers	Effected Area	Risk Level	Risk Response
a.	Project Cost Overrun	a. Wrong cost estimation b. Inflation / fluctuations in prices of equipment & material c. Currency variations	Cost	High	20% of overall cost to be included as risk factor to overcome these issues.
b.	Project Schedule Overshoots	a. Incorrect time assessment b. Changes in design process c. Delays in materials delivery d. Shortage of manpower / labor strike	Time	High	Monthly PMRs to overcome schedule delays.
c.	Stakeholders Risk (Contractor, Designer, Supplier, Service provider, PM)	a. Capacity of contractor/ subcontractor to perform quality wok b. Delay in supply chain activities c. Design deficiencies or anomaly in service d. Changes in requirement or incompetent project team	Cost, Time	High	a. Obligation of contractor to meet contract conditions. Focused attention of experts to b b. Supplier response time & backup suppliers to be identified prior to start of project c. Obligation of designer / service provider. d. Requirement changes to be

					finalized prior to PDR. PM responsibility to keep project on track. Monthly PMR
d.	Ineffective Method for Consultant & Contractors Selection	a. Vague description of Statement/scope of work b. Consultant/Contractor incompetence & lack of experience	Scope, Quality	Low	a. Unambiguous, clear description & documentation of scope of work in presence of legal advisors b. Consultant/Contractor selection based on evaluation of past experience / previous performance data
e.	ERP Selection & Implementation Failure	a. Inadequate business process for AEC b. Difficulty in achieving technical accomplishment c. Insufficient training d. Lack of management involvement	Performance, Cost, Time	High	ERP Consultant and PM to select ERP after thorough understanding & clear documentation of AEC work process framework, contract conditions covering exhaustive training program, and service level agreement (SLA).
f.	HR Risks	a. Shortage of skilled HR b. Labor strike c. Lack of knowledge	Performance, Quality	Medium	a. HR recruitment & training should be based on AEC project goals & backup maintainer

		d. Poor supervision of work			concept. b. Rigorous training and safety regulation adherence alongwith supervision/inspection of work to be ensured. c. HR dispute resolution through negotiations based on incentives/promotion by concerned if situation arises.
g.	Environmental Risks	a. Political Instability b. Bad security condition of country c. Disaster / Climate issues	Cost, Time	High	We may have to defer/restart the project. Situational assessment & necessary remedial actions by AEC Management/PM.
h.	Delay in Funds, payment and unanticipated costs	a. Shortage of funds b. Unexpected cost	Cost, Time	Medium	a. Agreement with bank for soft loan in advance by AEC Management. b. Reserve additional 10 % amount to cater for these unforeseen.
i.	Master Plan Change by Regulating Bodies	a. Non-conformance of standards b. Change of govt. policies	Scope	Medium	PM to incorporate necessary changes with help of consultants.