THE SUPERVISING DISCIPLINE ENGINEER'S (SDE) ROLE

IN THE FRONT END PLANNING PROCESS

by

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A THESIS

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ABSTRACT

The Supervising Discipline Engineer's (SDE) role in the Front End Planning (FEP) Process is thought to be an important one by engineering managers at an Engineering, Procurement and Construction (EPC) firm. Although FEP and the role of the SDE have been defined independently, the roles of the SDE in the FEP process lack proper definition and understanding to achieve the much needed alignment of the two. It has been assumed that the SDE has higher levels of involvement in technical roles, based on their job description, but it was important to reinforce this through the research. The information contributed to the FEP process by the SDE is needed in a timely manner and crucial to project success. Therefore, it is important to define these roles and the level of involvement the SDE takes part.

The research addresses this issue. It identifies the roles in which the SDE participates in the three phases of Front End Planning as defined by the Construction Industry Institute. The CII model was chosen based on industry "best practice" as adopted by URS Washington Division, the EPC firm evaluated in this research. Six core engineering disciplines were evaluated, as determined by URS Washington Division, and are as follows: (1) Architectural, Civil, Environmental, and Structural (ACES); (2) Electrical; (3) Instrumentation and Controls (I&C); (4) Mechanical; (5) Piping; and (6) Process. A group of SDEs, from a variety of disciplines, participated in a skills development program defining the activities involved in FEP. Once concluded, the SDE was to rate their level of involvement on a survey questionnaire developed by the research team for each activity. Based on the results, the

research found conclusive evidence to define the level of involvement of the SDE in the FEP process.

Furthermore, conclusions drawn from these respondents reinforced the high levels of involvement in those technically driven activities and elaborated on the role of the SDE in relation to the less technical activities. Last, from the analysis of the data collected, a matrix was developed outlining the roles of the SDE in general, and the roles of the SDE according to discipline.

DEDICATION

This thesis is dedicated to all of my friends and family who have supported me in a variety of ways throughout my life. I would especially like to recognize, my Mom, Dad, Quincy, Bruce, Sam, and Steven for their faith in me. Moreover, the support from the McAbee Construction family, particularly Leroy and Wendell, has been invaluable to my education and development of my character. I owe a wealth of gratitude to all my friends and family for contributing a large part to all of my accomplishments.

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CHAPTER 1

INTRODUCTION

Background

The Front End Planning (FEP) Process is the initial phase of the project life cycle and arguably the most important phase of all involved. According to CII Research Summary 213-1 (2007), the Front End Planning Process is focused on a strong early link between the business and the mission need, project strategy, scope, cost, and schedule and maintaining that link throughout the project life cycle. Given the importance of the phase, it is imperative that the engineering role be defined and aligned with all other aspects of the Front End Planning Process. Within the engineering contribution to the process, the Supervising Discipline Engineer (SDE) provides key information, especially in technical areas, to make those initial planning decisions sound.

The SDE is typically the first level of engineering management within an Engineering, Procurement and Construction (EPC) firm. It is the level at which technical knowledge, management, and communication skills are essential tools to effectively complete project roles. The SDE is focused on one engineering discipline area within a specific project and is tasked with managing a group of engineers in the same discipline. Items such as meeting budget, schedule, and quality targets are each large components of the SDE's profession. Moreover, the SDE provides management, coordination, leadership, and strategic direction for respective discipline activities on assigned projects. The SDE must complete all activities with high regard

to cost, innovative engineering service, safety standards, and schedule to meet the goals and objectives of the company.

Although definitions for the SDE and the FEP process are known, it has been recognized by engineering managers and practitioners that the alignment of the two lack definition. Historically, the SDE learns his or her project roles through the course of his or her career. It has been the shown to take between 10 and 20 years to develop a sufficient understanding of these roles. In looking at the project life cycle, it consists of three distinct areas: Front End Planning, Executing the Project, and Operating the Facility. The role of the SDE in the Front End Planning portion of the project life cycle, or what is sometimes referred to as Pre-Project Planning or Front End Loading, was the focus of this study. Moreover, the Front End Planning portion of the project life cycle is composed of three phases of which this research will focus attention: feasibility, concept, and detailed scope.

To understand the lack of definition concerning the role of the SDE in the Front End Planning Process, a research team was formed. The research team was made of members from The University of Alabama and an EPC firm, URS Washington Division. Based on the lack of alignment between the SDE and the Front End Planning Process, the research team established a need for facilitating a development program to bring definition and understanding to the role of the SDE.

SDE Development Program

The Supervising Discipline Engineer (SDE) Development Program was created as a multipart series of modules to facilitate the learning process needed to standardize the role of the SDE throughout the project life cycle. The modules of the training presented to the SDE were:

Module 1: Front End Planning, Module 2: Project Execution, and Module 3: Project Completion and Team Dynamics. For the purpose of this research the SDEs role, as defined in Module 1: Front End Planning, was examined and conclusions were drawn.

A list of course objectives were to be met once the Front End Planning training Module was completed. They are given as follows:

- Understand the role of the SDE in the Front End Planning Process and the functions that must be performed.
- Understand the project life cycle and particularly Front End Planning and the impact on, and relationship with, project success.
- Understand the importance of the owner's business case for a project and the process of developing project objectives that align with the success criterion.
- Understand the financial implications of Front End Planning or capital projects from the perspective of the major participants including the owner, design professionals, constructors, and financial institutions.
- Know how to develop a risk management plan to address preliminary design and project execution issues.
- Know how to perform Front End Planning with a structured approach that ensures adequate definition of project scope.
- Understand basic owner-contractor types, contract terminology, important contract clauses, and the contract's importance to Front End Planning and the project execution.

- Know how to perform multi-office engineering execution including interface with International Technical Resource Centers (ITRCs) in the overall delivery of engineering services and solutions.
- Know how to support the process of proposal development and the creation of early estimates in support of URS Washington Division Business Development initiatives.

A list of course outcomes was developed as well. The goal was to allow the SDE participant to demonstrate professional competency in the following ways:

- Apply techniques and modern engineering tools to identify, formulate, and solve basic planning problems to different project types including commercial, industrial, infrastructure, and heavy civil work.
- Develop a preliminary design of a system or process to meet desired needs with realistic constraints such as economic, environmental, social, political, ethical, health and safety, constructability and sustainability.
- Predict possible global, economic, environmental, and societal impacts of a specific, relatively constrained engineering solution, including a risk management plan.
- Function effectively as a member of a multi-disciplinary project planning team.
- Analyze a planning situation involving multiple conflicting professional and ethical interests, to determine an appropriate course of action.
- Organize and deliver effective written, verbal, graphical, and virtual communications based on a team process or effort.
- Demonstrate the ability to incorporate contemporary issues into the identification, formulation, and solution of an engineering problem as they apply to a project planning initiative.

- Explain basic concepts in engineering management, business, public policy, and leadership in the context of Front End Planning.

Although the development course objectives and course outcomes were defined, the individual role of the SDE in the FEP process was left for interpretation. Moreover, the structure of the FEP process was provided, but the individual role was not distinguished. Therefore, it was the purpose of the research to define the role in respect to the skills development program presented to the research sample.

Problem Statement

The Supervising Discipline Engineer's (SDE) role within the Front End Planning Process lacks sufficient definition to understand the function in which the SDE must operate for project planning success. To understand the problem and to develop the role of the SDE in Front End Planning (FEP), a skills development program module was implemented to define the role. However, to understand the role from the prospective of the SDE, it is necessary to categorize which disciplines should be emphasized in each activity within the Front End Planning Process.

Previous research considered the need for Front End Planning Process as well as the budget and schedule savings associated with an effectively planned project. The CII Research Summary 213-1, "Front End Planning: Break the Rules, Pay the Price" (2007), outlines many of the needs associated with an effective FEP process. In addition, the previous research identified a need for the alignment of parties and stakeholders, but the role of the SDE was not detailed. While it was generally understood that the SDE has a role in this process, it is not defined when, or for what responsibilities they are to be held accountable. The need for the role of the SDE relates to efficiency in the information flow and alignment. Furthermore, alignment of the SDEs

by discipline is important in that each has specific roles that are fundamental to the flow of consistent and accurate information that support the success of the project.

It is important to note that The Front End Planning Process was well understood by the research team because of past individual research efforts, training, and implementation. Moreover, the extensive research efforts of the Construction Industry Institute (CII) were also of great reference for resource material and gaining definition for phases and terminology associated with Front End Planning. One of the main sources of information was The Front End Planning Toolkit. It served as a basis to measure in what responsibility the SDE would play based on the definitions created by CII Research Team 213 in 2006.

Given the need to define the role, the research team identified a way to quantify data to take a statistical approach to the problem. A tool was then required to gather the data and the information that would allow for interpretation as to what capacities each individual SDE discipline takes part in. A surveying tool was decided upon to gather statistics from the recently trained Module 1: Front End Planning course participants.

Research Objectives

The overall goal of the research was to define the role of the Supervising Discipline Engineer in the Front End Planning Process. Furthermore, the research's aim was to determine the role of each individual SDE discipline and how they align with each other and the overall process of Front End Planning. Based on the known role of the SDE, the research team made the following assumptions:

- The SDE, in general, will likely be more involved in the technical activities associated with Front End Planning.

- Each individual SDE discipline will likely be “much” to “very much” involved in the technical activities associated with their individual disciplines.

The objective is to aid future planning efforts by defining when and where each individual SDE discipline most likely appears in the process. A list of research objects to meet the goal is defined as follows:

- Determine the role and responsibility the Supervising Discipline Engineer, independent of discipline, participates in the Front End Planning Process upon completion of the Module 1: Front End Planning course.
- Determine the role and responsibility of the six individual Supervising Discipline Engineering disciplines and how their discipline aligns with the remaining disciplines. The six individual disciplines include (1) Architectural, Civil, Environmental, and Structural (ACES); (2) Electrical; (3) Instrumentation and Controls (I&C); (4) Mechanical; (5) Piping; and (6) Process.
- Determine the alignment of each individual discipline’s role in relation to the general role defined by all disciplines.
- Develop a list of activities within the Front End Planning Process where the group indicated a unique level of involvement: high or low.
- Develop a list of activities within the Front End Planning Process where the individual SDE has a unique level of involvement: high or low.

To meet the above objectives, it was decided to perform statistical analysis based on the responses given by each participant in the study.

Methodology

The methodology for the research project was composed of six phases: literature review; survey questionnaire development; data collection; analysis; findings; and the summary, conclusions, and recommendations based on the research.

The first phase, literature review, consisted of an extensive review effort that focused on the Front End Planning Process, Engineering Management, and Alignment. Upon reviewing the topics, the majority of research identified on Front End Planning and Alignment were conducted in association with the Construction Industry Institute (CII). Engineering Management topics researched included reviewing journals such as the "Engineering Management Journal," the American Society of Civil Engineer's extensive library of journals, and other engineering journal databases. Chapter 2 of this document focuses on the literature review for these topics.

The second phase, survey questionnaire development, consisted of the research team identifying a need to quantify data and implementing a tool that would do so. The tool identified was a surveying questionnaire that would be implemented post-Module One training. The process of developing the tool relied heavily on the Front End Planning Toolkit's (CII 2006) outline. The development of the survey questionnaire is located in chapter 3.

The third phase, data collection, consisted of distributing the surveying tool outline in chapter 3 to the course participants after completing the Front End Planning training module. The tool surveyed 75 Supervising Discipline Engineers from three separate classes of 25 participants each. The survey was completed following the delivery of Module One: Front End Planning, which consisted of 3 days of extensive skills development education. Each class consisted of a balanced range of engineering disciplines. The disciplines represented included Architectural, Civil, Environmental, and Structural (ACES); Electrical; Instrumentation and

Controls (I&C); Mechanical; Piping; and Process. A total of 47 SDEs out of the original 75 returned the completed survey. These 47 were the sample from which the statistical qualitative analysis was based upon to define the role of the SDE in the Front End Planning Process. Upon receiving data, the analysis and findings portion of the research took place.

The fourth and fifth phases, analysis and findings, focused on the database developed from the 47 SDEs surveyed. The analysis focused on the trend the simple statistics brought forth. The data set was analyzed as a whole and in respect to the individual discipline. The findings revealed where the unlikely and likely roles of involvement the Supervising Discipline Engineer takes on in the Front End Planning Process. Moreover, a list of activities and the level of involvement is looked at in relation to the SDE. An outline of the Front End Planning Process is given and each level of involvement by discipline in relation to the subject matter is presented in matrix form. The research for this portion of work is detailed in chapter 5 and chapter 6.

The trends of the data set yielded conclusions, recommendations, and an overall summary of work. The conclusions were based upon the training received, the participant, and the prospective of an active Supervising Discipline Engineer. The recommendations outline the areas where emphasis of future research may benefit the role of the SDE. The overall summary concludes the research with an examination of the research and the findings.

CHAPTER 2

LITERATURE REVIEW

Background

The role of the Supervising Discipline Engineer (SDE) is thought to be important throughout the project life cycle by practitioners and managers. Moreover, it is assumed that the SDE supplies significant information within the Front End Planning (FEP) process. A research team composed of URS Washington Division (URS WD) and The University of Alabama set out to determine the role of the SDE within the FEP process. In this chapter, a literature review was performed to find any information defining the role of the SDE in the FEP process and to define the key elements of the process. The key elements looked at were as follows: (1) Front End Planning, (2) Alignment, and (3) the Supervising Discipline Engineer (SDE). The following sections outline these key elements.

Front End Planning

URS Washington Division (URS WD), as an organization, determined that the Construction Industry Institute (CII) model for FEP would be adopted as the organization's system to perform the Front End Planning (FEP) process. URS WD chose this model based on CII's identification as an industry "best practice" based on extensive research and reinforcement of the need for a FEP model (CII 2009). Therefore, the research focused on defining the role of the SDE in the FEP process according to CII. It is important to note that the research team did

not determine or define the Front End Planning process, alignment, or the definition of the SDE, but adopted the descriptions as URS WD had defined them.

CII (2006) defines the Front End Planning (FEP) as "the process of developing sufficient strategic information with which owners can address risk and decide to commit resources to maximize the chance for a successful project" (p. 1). Furthermore, Front End Planning helps to alleviate cost and schedule risk, which are two areas of critical concern in any project. In terms of cost benefit alone, research has shown that effective FEP can reduce overall project cost up to 20% (CII 1995). Various research teams inside CII have developed valuable technical reports and tools that aid in the FEP decision-making process. Figure 1 illustrates the influence on the project verse expenditures (CII 2005). The graph helps to illustrate the importance of effective Front End Planning early on in the project life cycle. Once a project is underway, changes often impede project execution and are materialized in a multitude of direct and indirect costs.

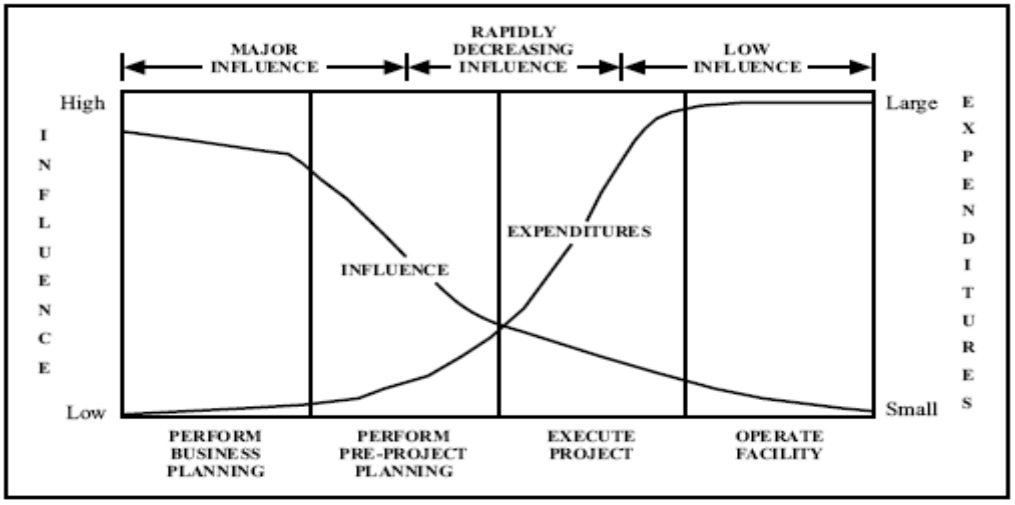


Figure 1. The Dynamics of Influence and Expenditures.

The Front End Planning Tool Kit, Implementation Resource 213-2 (2006), outlines the FEP process in three phases, feasibility, concept, and detailed scope, and provides definition for activities of the phases implemented in this research. The description of items for all activities as defined by the FEP Tool Kit can be found in Appendix H. The toolkit is a comprehensive guide to the planning of capital projects. Additionally, it provides links, references, and deliverable lists to aid in the process. Although it does not give a detailed overview for every organization, it can be used as a basis for creating a program in a variety of applications. For the purpose of this research, the activities outlined by this tool kit were used to create Module 1: Front End Planning skills development program and the survey questionnaire to serve as the standard of Front End Planning. The SDEs were asked to rate their experience based on this process.

Upon researching tools that assist the process of Front End Planning, two tools were discovered relevant to this research. The first tool, the Project Definition Rating Index (PDRI), is a tool that facilitates a method to define a capital project's scope for completeness. There are two versions of the PDRI: an industrial version and a building version. The industrial version focuses on plant type projects (i.e., refineries, pulp and paper mills, power plants, etc.), and the building version focuses on institutional facilities (i.e., universities, healthcare, government, etc.). Key stakeholders (i.e., business units, engineering, project management, owner representatives, etc.) are to address the scope definition within a proposed project. The industrial version focuses on 70 scope definition elements and the building version focuses on 64. The purpose of these elements was to allow a project team to rate the understanding of key components of the project throughout the phases of the Front End Planning Process. Upon completion of the rating, a score is summed to better understand how well-defined the project is at points within the planning stage to better assess project risk (CII 2008).

The second tool, Advance Planning Risk Analysis (APRA) tool for Transportation Projects, is a computer program based and used on heavy infrastructure project types (i.e., bridges, highways, etc.). The purpose, much like the PDRI in implementation, is for key stakeholders to analyze the risk associated with transportation projects. The program allows the user to assess risk based on three sections of elements that define project risk. The score is summed at the end of each implementation session and it allows for the risk of the project to be evaluated (Caldas, Gibson, & Le, 2007).

The previous research and tools provide for a good measurement of assessing project risk and defining the process by addressing the level of definition associated at phases within the FEP process. However, they did not address the roles of the participants within the process. Key stakeholders are identified as participants, but it is not clearly defined as to what the role of the Supervising Discipline Engineer is during the process of Front End Planning.

Alignment

URS Washington Division has defined alignment, as an organization, according to the Construction Industry Institute's (CII, 2005) as "The condition where appropriate project participants are working within acceptable tolerances to develop and meet a uniformly defined and understood set of project objectives" (p. 1). Alignment of all the project team members is of great importance because members represent a variety of disciplines within operations, project management, and business. Each brings a distinct and necessary role in planning. Additionally, these members are oftentimes not from within a single organization but from a conglomerate of companies. Therefore, it has been identified by CII as a "best practice" (CII 2009), to achieve alignment of the project team. The alignment issues identified by CII need to be addressed

because business requirements and overall corporate strategy for an individual project are determined early on and have a critical impact on the outcome of the project (CII 2005).

Alignment During Pre-Project Planning, 2nd Edition, Implementation Resource 113-3 (CII, 2005), focuses on the critical activities to maintain alignment throughout the Front End Planning process. The resource outlines the importance of gaining and maintaining alignment for project teams. The article further describes the importance of alignment for a detailed engineer to be in alignment within the process. Although the resource defines the need, it does not give specific activities in which the SDE participates. Furthermore, the resource offers the Pre-Project Planning (PPP) Alignment Thermometer tool and its implementation to facilitate alignment.

The Pre-Project Planning (PPP) Alignment Thermometer is a tool that outlines the level of agreement among project stakeholders. The tool outlines 10 issues that contribute to project success:

1. Stakeholders are appropriately represented on the project team.
2. Project leadership is defined, effective, and accountable.
3. The priority between cost, schedule, and required project quality features is clear.
4. Communication within the team and with stakeholders is open and effective.
5. Team meetings are timely and productive.
6. Our team culture fosters trust, honesty, and shared values.
7. The Pre-Project Planning process includes sufficient funding, schedule, and scope to meet objectives.
8. Reward and recognition systems promote meeting project objectives.
9. Teamwork and team building programs are effective.

10. Planning tools (e.g., checklists, simulations, and work flow diagrams) are effectively used.

By assessing these issues and determining the alignment, the project team can assess their risk and agreement among one another. Again it is important to address that this resource and tool may be useful to the SDE to understand the project alignment, but they do not offer a definition of alignment for the SDE.

Supervising Discipline Engineer (SDE)

The Supervising Discipline Engineer (SDE) was defined by URS Washington Division as the role of the first level of engineering management within their organization of engineering. It is the level at which technical knowledge, management, and communication skills are essential tools to effectively carry out essential roles. The SDE is focused on one discipline area within a specific project and leads a group of the same discipline engineers. Items such as meeting budget, schedule, and quality targets are all large component of the SDE's profession. Moreover, the SDE provides management, coordination, leadership and strategic direction for respective discipline activities on assigned projects. The SDE must complete all activities with high regard to cost, innovative engineering service, and schedule to meet the goals and objectives of the company (Washington Group International, 2006). After extensive research of outside resources, there were no publications defining the first engineering level manager's role in Front End Planning for EPC firms.

Concluding Remarks

Upon extensive research of the topic, it was determined that previous research, in the form of organizational or technological, had not outlined or determined the responsibility the SDE takes part in the process of Front End Planning for an EPC firm. The goal of the literature review was to provide a basis industry understanding and to find relevant information to build upon. The research was conducted to add to the existing body of knowledge by determining the role of the SDE in the Front End Planning Process for EPC firms.

CHAPTER 3

SURVEY QUESTIONNAIRE DEVELOPMENT

The Supervising Discipline Engineer's (SDE) role in the Front End Planning process research was supported by a board of URS Washington Division professionals and a team of professors and graduate students of The University of Alabama. The board at URS Washington Division consisted of professionals representing different levels of management and departments within the organization. Members of the board included the following backgrounds:

- the Executive Vice President of Engineering,
- a variety of Manager of Discipline Engineering (MDE),
- a variety of Project Controls and Management Professionals,
- an exemplary Supervising Discipline Engineer (SDE), and
- a variety of Principle Engineers.

The goal of the board was to facilitate an engineering and management skills development program that would enable a SDE the ability to exercise the FEP skill sets that in the past were only gathered through years of "on-the-job experience." The team from The University of Alabama provided the definition and outline for the skills development program from the input given by the URS Washington Division board. The combined research team from The University of Alabama and URS Washington Division provided the path of the research throughout the skills development process. Key driving members of the team included the following:

- W. Edward Back, Ph.D., University of Alabama,

- Al Ebner, Ph.D., URS Washington Division,
- G. Edward Gibson, Jr., Ph.D., University of Alabama,
- Clayton B. Ingram, University of Alabama,
- Philip W. Johnson, Ph.D., University of Alabama,
- Don Kalenits, URS Washington Division,
- Calvin Kinsel, URS Washington Division, and
- Robert C. Morriss, University of Alabama.

In order to achieve the research objectives set forth by the team, it was determined that a significant number of participants from a variety of disciplines was required to make the data collection valuable. Moreover, to have a quantifiable data set, a surveying tool was developed to obtain the information from the SDE participants. The purpose of the survey was to yield discrete numbers that would lend themselves to statistical understanding and computation. It was then determined that a number of Module 1: Front End Planning training sessions must pass in order to compile the suitable number of completed surveys from the participants.

The CII "model" for FEP was adopted corporately by URS Washington Division and is now required as one of their Project Execution Procedures (PEP). The PEPs define general rules that URS Washington Division utilizes companywide to achieve uniformity in procedure throughout the organization. As presented in the Front End Planning Toolkit, CII Research Team 213, "Support for Pre-Planning Projects" (2006), three main phases were detailed: feasibility, concept, and detailed scope. Each phase was detailed within the survey and the participants were asked to rate their agreement in terms of SDE involvement. This type question, the agreement scale, allows the SDE to rate the likelihood of their involvement from *very little* to *very much* in each of the questions.

The first phase of the Front End Planning process and the survey, feasibility, outlines the business objectives, identifies potential alternatives, and the steps and resources necessary to continue to the concept phase development. The primary output is a decision about whether the potential project is economically and technically feasible for the organization. The second phase of the Front End Planning process and the survey, concept, deals with defining, evaluating, and selecting the best alternative(s) for site, technology, and acquisition strategy. The third phase of the Front End Planning process and the survey, detailed scope, deals with defining the technical scope of the project, further development of project execution plans, developing a definitive cost estimate, and schedule suitable for project authorization for detailed design and/or construction. The primary output is the design basis for the facility. Tables 1 and 2 provide an outline of the Front End Planning process.

Table 1

Front End Planning: Feasibility Phase

Phase	Activity	Detailed Activity
Feasibility		
	F.1 - Initiate Phase	
		1. Understand Alignment
		2. Understand Business Objectives
		3. Understand project assumptions
		4. Generate early design basis and parameters
	F.2 - Generate Options	
		1. Generate Assumptions/Drivers
		2. Generate Alternatives for Site(s)
		3. Generate Alternatives for Technology
		4. Generate Reliability, Maintainability, and Operability Guidelines
		5. Generate Intellectual Property
		6. Prepare Initial Feasibility Scope
		7. Develop Order of Magnitude (OOM) Estimate/Schedule
	F.3 - Filtering Options	
		1. Develop Economic Model
		2. Develop Funding Strategies
		3. Consider Significant Risks
		4. Develop Initial Roles and Permit Analysis
		5. Develop EHS Considerations
		6. Develop Go/ No-Go Analysis
		7. Develop Sensitivity Analysis
	F.4 - Develop Recommendation Report	

Table 2

Front End Planning: Concept and Detailed Scope Phases

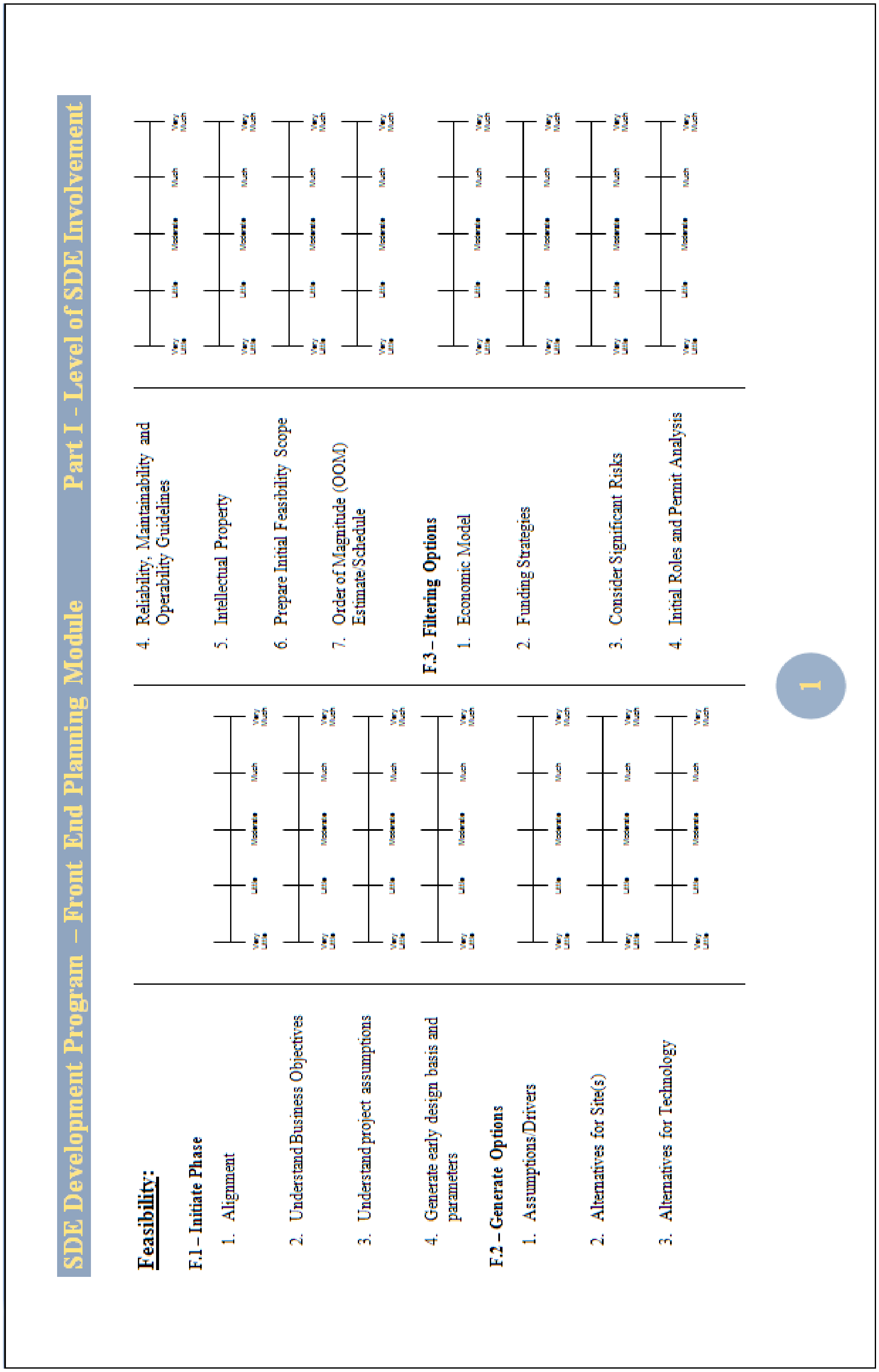
Phase	Activity	Detailed Activity
Concept		
	C.1 - Initiate Phase	
		1. Understand Team Alignment
		2. Review and Understand Business Objectives
		3. Validate project assumptions
		4. Review design basis
	C.2 - Analyze Alternatives	
		1. Review and Identify Alternatives
		2. Analyze Site Alternatives
		3. Analyze Acquisition strategies
		4. Analyze Technology
		5. Identify Short List of Alternative(s):
	C.3 - Develop Conceptual Scopes and Estimates	
		1. Develop Conceptual Scopes
		2. Develop Conceptual Estimates
	C.4 - Evaluate and Select Best Alternatives	
	C.5 - Develop Concept Phase Report	
Detailed Scope		
	S.1 - Initiate Phase	
		1. Understand Team Alignment
		2. Review and Understand Business Objectives
		3. Validate project assumptions
		4. Review conceptual design basis
	S.2 - Develop Preliminary Design/Engineering	
	S.3 - Develop Preliminary Design/Engineering Review	
	S.4 - Finalize Scope Definition Package	
	S.5 - Develop Cost and Schedule Control Estimate	
	S.6 - Compile Project Definition Package	
		1. Compile Project Definition Package
		2. Compile Authorization Package
		3. Prepare Oral presentation

Once the survey was generated, a simple set of directions for the SDE to complete the survey was provided to the respondents. The instructions stated the following:

> Please give careful thought to level of involvement (or effort) of the SDE for each of the steps in Front End Planning. Identify the level of involvement by placing an (X) on the associated scale bar. Note the bar allows you to rate the level of SDE involvement from *very little* to *very much*.

The SDE was to base their determination of *very little* to *very much* involvement based on Module One: Front End Planning, of the SDE Development Program. Within the skills development program, each of the activities was defined and explained a responsibility in which

the SDE was involved. It was the role of the SDE to determine which individual discipline participated in this process upon receiving the definition of each phase. A sample of the survey distributed to the SDE is located in Figure 2. The complete survey distributed to participants can be viewed in Appendix C. In addition to the survey, a glossary of terms associated with Front End Planning is located in Appendix A. These terms were taken from The Front End Planning Toolkit to aid in the understanding of the vocabulary associated with the Front End Planning process.



SDE Development Program – Front End Planning Module **Part I - Level of SDE Involvement**

Feasibility:

F.1 – Initiate Phase

1. Alignment
2. Understand Business Objectives
3. Understand project assumptions
4. Generate early design basis and parameters

F.2 – Generate Options

1. Assumptions/Drivers
2. Alternatives for Site(s)
3. Alternatives for Technology
4. Reliability, Maintainability and Operability Guidelines
5. Intellectual Property
6. Prepare Initial Feasibility Scope
7. Order of Magnitude (OOM) Estimate/Schedule

F.3 – Filtering Options

1. Economic Model
2. Funding Strategies
3. Consider Significant Risks
4. Initial Roles and Permit Analysis

Very Little — Little — Moderate — Much — Very Much

1

Figure 2. Sample of SDE Development Post-Module Survey Questionnaire.

CHAPTER 4

DATA COLLECTION

The SDEs were given 3 days of formal skills development in Module 1: Front End Planning. Each SDE was exposed to a series of lectures outlining Front End Planning, as well as workshops, periodically throughout the development sessions. The workshops were analyzed and commented on giving the SDE's feedback on their responses to the problem statements within the workshop. Upon completion of the skill development program, the surveying tool was distributed to the SDEs and instructions were given to complete the survey. Three total classes were exposed to identical material and then surveyed. As stated in the previous chapter, the purpose of the survey and how to fill the survey out were relayed by the instructor to the SDE participant in the final skills development session of the Front End Planning Module.

A total of 75 participants were surveyed and a total of 47 surveys were returned, giving a 63% response rate for the research analysis. The participants represented six core engineering disciplines with a range of experience from 4 to 35 years. The engineering disciplines represented include Architectural, Civil, Environmental, and Structural (ACES); Electrical; Instrumentation and Controls (I&C); Mechanical; Piping; and Process. The surveyed professionals represented five different regional offices within the United States including Birmingham, Alabama; Cleveland, Ohio; Denver, Colorado; Houston, Texas; and Princeton, New Jersey. The participants' breakdown by discipline can be seen in Figure 3.

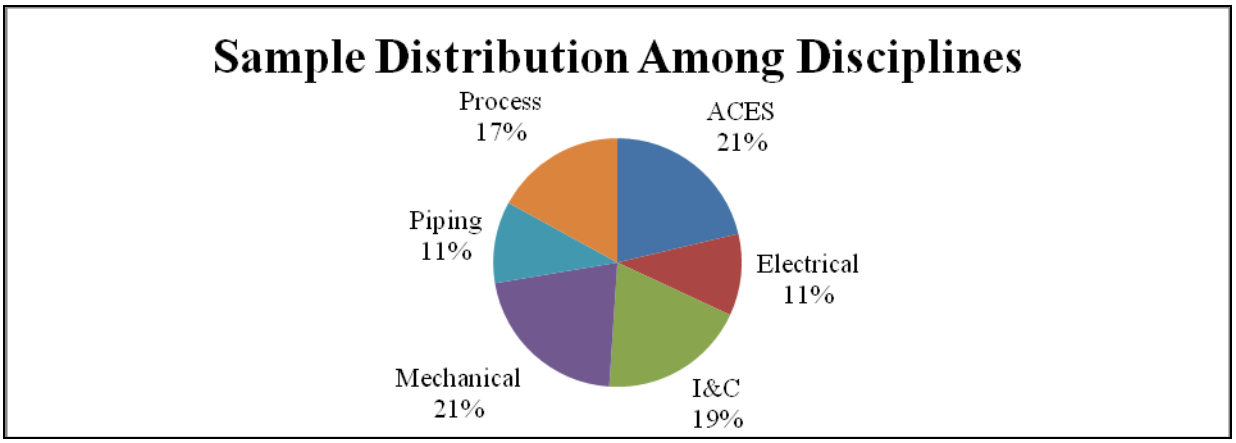


Figure 3. Complete Sample Distribution by Discipline.

The distribution method for the first class of participants consisted of emailed copies of the survey for each participant to complete, and surveys were returned back via email or standard mail. The class consisted of 25 participants from a variety of disciplines. The number of surveys returned was 12 out of the 25 surveyed. This gave a response rate of 48% following the first training session. Figure 4 illustrates the distribution of surveys and the returned surveys by discipline.

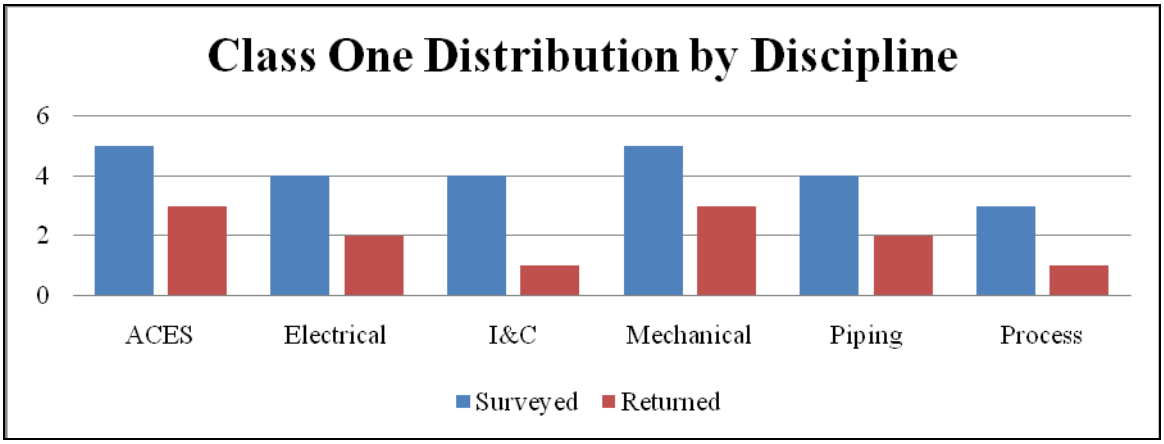


Figure 4. Class One Distribution by Discipline.

The second class of participants was also emailed copies of the survey to complete and return via email or standard mail. The class also consisted of 25 participants from a variety of disciplines. The number of surveys returned was 10 out of the 25 surveyed. This gave a response rate of 40% following the second training session. Figure 5 illustrates the distribution of surveys and the returned surveys by discipline for the second class of participants.

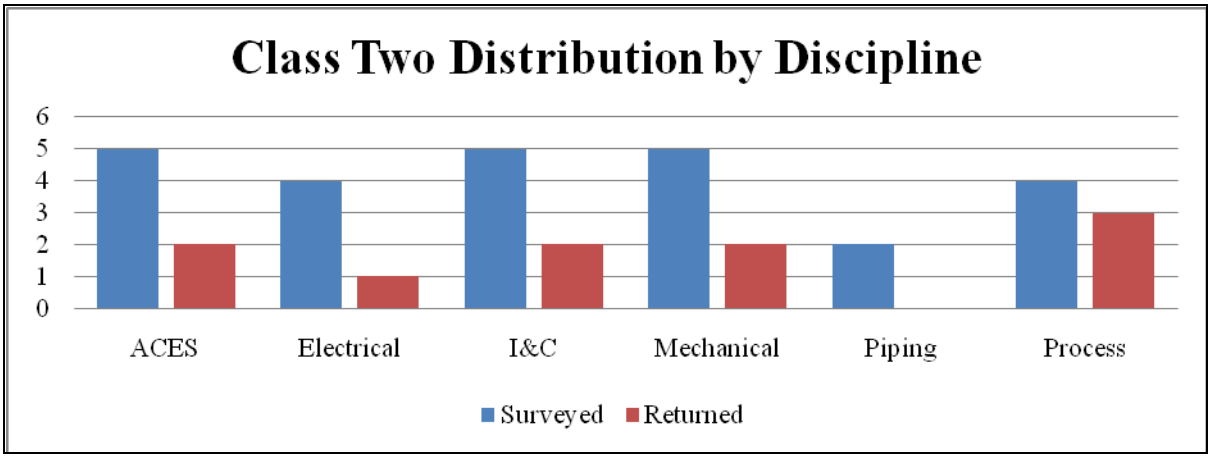


Figure 5. Class Two Distribution by Discipline.

As a result of the decline of surveys returned through distribution by email from the first class participants to the second class, the third class was distributed a hard copy survey and asked to complete the survey and return it the same day. This worked well because all of the surveys were completed and returned, giving 25 more participants input into the study. Figure 6 illustrates the distribution of surveys and the returned surveys by discipline.

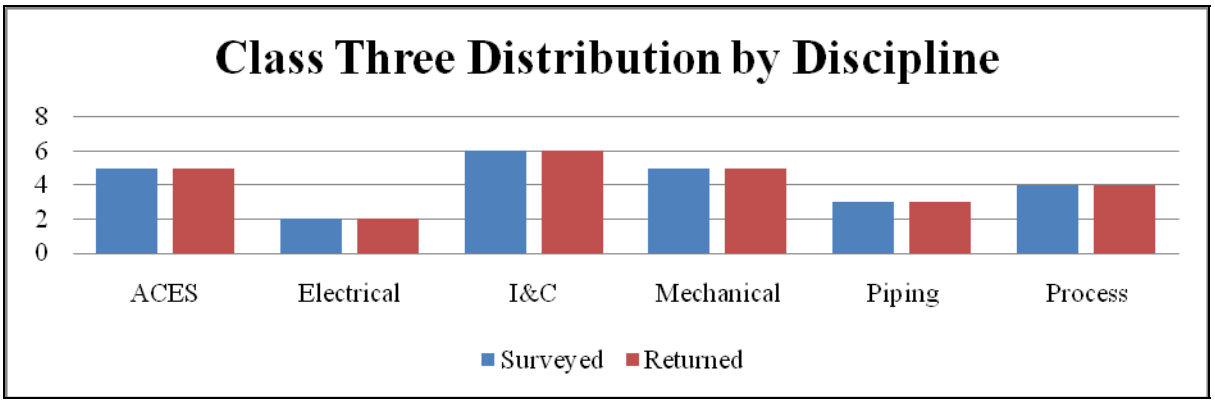


Figure 6. Class Three Distribution by Discipline.

CHAPTER 5

ANALYSIS

General Analysis

This chapter represents the process that was conducted for the group, the SDE in general, and each of the individual SDE disciplines. The results of the analysis are detailed in chapter 6. Within this chapter are discussed the analysis procedure for the statistical calculations, graphics, alignment, determining the list of SDE unique activities, and how the levels of involvement were determined. The trends drawn from the data sets and resulting graphics allowed the research team to make conclusions as to what role the SDE participates in the Front End Planning Process. All data analyzed was gathered once the Module 1: Front End Planning of the SDE Development Program was complete. It is important to note that the SDEs were not exposed to this survey tool before the training took place. The SDE determined their level of involvement based on the Front End Planning phases and activities. There are three phases and they consist of the feasibility, concept, and detailed scope. The feasibility phase is the first phase of the front end planning process. The primary objectives of this phase are to define business objectives, identify potential alternatives, and to outline steps and resources necessary to continue concept phase development. Its primary output is a decision about whether the potential project is economically and technically feasible for the organization. It is also known as business planning, and strategic planning (CII, 2006). The concept phase is the second phase of the front end planning process. It is primarily concerned with defining, evaluating, and selecting the best alternative(s) for site, technology, and acquisition strategy. It is also known as alternative

selection, conceptual design, and programming (CII, 2006). The detailed scope phase is the third phase of the project front end planning process. The primary objectives of this phase is to define the technical scope of the project, further develop project execution plans, and develop a definitive cost estimate and schedule suitable for project authorization for detailed design and/or construction. Its primary output is the design basis for the facility. It is also known as schematic design and design development, scope finalization, preliminary engineering, definition phase, and sanctioning process (CII, 2006). These three phases are outlined by CII and given in Table 3 and Table 4.

Table 3

Front End Planning Outline: Feasibility Phase and Activities

Phase	Activity	Detailed Activity
Feasibility		
	F.1 - Initiate Phase	
		1. Understand Alignment
		2. Understand Business Objectives
		3. Understand project assumptions
		4. Generate early design basis and parameters
	F.2 - Generate Options	
		1. Generate Assumptions/Drivers
		2. Generate Alternatives for Site(s)
		3. Generate Alternatives for Technology
		4. Generate Reliability, Maintainability, and Operability Guidelines
		5. Generate Intellectual Property
		6. Prepare Initial Feasibility Scope
		7. Develop Order of Magnitude (OOM) Estimate/Schedule
	F.3 - Filtering Options	
		1. Develop Economic Model
		2. Develop Funding Strategies
		3. Consider Significant Risks
		4. Develop Initial Roles and Permit Analysis
		5. Develop EHS Considerations
		6. Develop Go/ No-Go Analysis
		7. Develop Sensitivity Analysis
	F.4 - Develop Recommendation Report	

Table 4

Front End Planning Outline: Concept and Detailed Scope Phases and Activities

Phase	Activity	Detailed Activity
Concept		
	C.1 - Initiate Phase	
		1. Understand Team Alignment
		2. Review and Understand Business Objectives
		3. Validate project assumptions
		4. Review design basis
	C.2 - Analyze Alternatives	
		1. Review and Identify Alternatives
		2. Analyze Site Alternatives
		3. Analyze Acquisition strategies
		4. Analyze Technology
		5. Identify Short List of Alternative(s):
	C.3 - Develop Conceptual Scopes and Estimates	
		1. Develop Conceptual Scopes
		2. Develop Conceptual Estimates
	C.4 - Evaluate and Select Best Alternatives	
	C.5 - Develop Concept Phase Report	
Detailed Scope		
	S.1 - Initiate Phase	
		1. Understand Team Alignment
		2. Review and Understand Business Objectives
		3. Validate project assumptions
		4. Review conceptual design basis
	S.2 - Develop Preliminary Design/Engineering	
	S.3 - Develop Preliminary Design/Engineering Review	
	S.4 - Finalize Scope Definition Package	
	S.5 - Develop Cost and Schedule Control Estimate	
	S.6 - Compile Project Definition Package	
		1. Compile Project Definition Package
		2. Compile Authorization Package
		3. Prepare Oral presentation

Statistical Calculations

To understand the role of the Supervising Discipline Engineer (SDE) in the Front End Planning (FEP) process, the data set compiled from the 47 respondents was analyzed statistically. Each phase was broken up into activities by the Front End Planning Toolkit and the respondents were to judge the level of involvement within each activity. The responses across all participants were analyzed to determine level of involvement as a group, to make conclusions about the role of the SDE, independent of discipline, and by individual discipline in terms of the

following: mean, median, mode, lower quartile, upper quartile, and minimum and maximum statistical values. With these statistical values, profiles were constructed for the group of respondents as well as the individual SDE discipline and they included a central tendency distribution profile and box whisker plots of the FEP activities. In addition, a profile of the relationship between each individual SDE discipline versus the group was constructed based on conclusions drawn from the data sets and graphical analysis with respect to level of involvement. An example of the statistical values data set can be found in Table 5.

Table 5

Example of Statistical Values Calculated

Example Statistical Analysis Category/Statistical Method	Mean	Median	Mode	Std. Dev.	Lower Quartile	Min	Max	Upper Quartile
Feasibility								
F.1 - Initiate Phase								
1. Understand Alignment	3.90	4	4	1.20	4	1	5	4.75
2. Understand Business Objectives	3.90	4.5	5	1.45	3.25	1	5	5
3. Understand project assumptions	4.20	5	5	1.40	3.5	1	5	5
4. Generate early design basis and parameters	3.90	4	5	1.29	3.25	1	5	5

Central Tendency Distribution

Central tendency analysis involves a parameter of only looking at the values of mean, median, and mode values to develop trends in a data set. The central tendency distribution profile was used to illustrate the mean, median, and mode values for the data set in relation to each Front End Planning activity. In order to view the data graphically, the respondents' levels of involvement were then translated into numerical data to develop a set of statistics. The potential responses and corresponding numeric value for the original survey are as follows: 1 = *Very Little*, 2 = *Little*, 3 = *Moderate*, 4 = *Much*, 5 = *Very Much*. The mean, median, and mode values were then calculated from these numeric values for the SDE in general as well as each individual

SDE discipline. The mean, median, and mode values, based on the numeric calculations, were graphed, and then grouped and analyzed to determine at what level of involvement the SDE participates in the FEP process. An example of the central tendency distribution can be found in Figure 7.

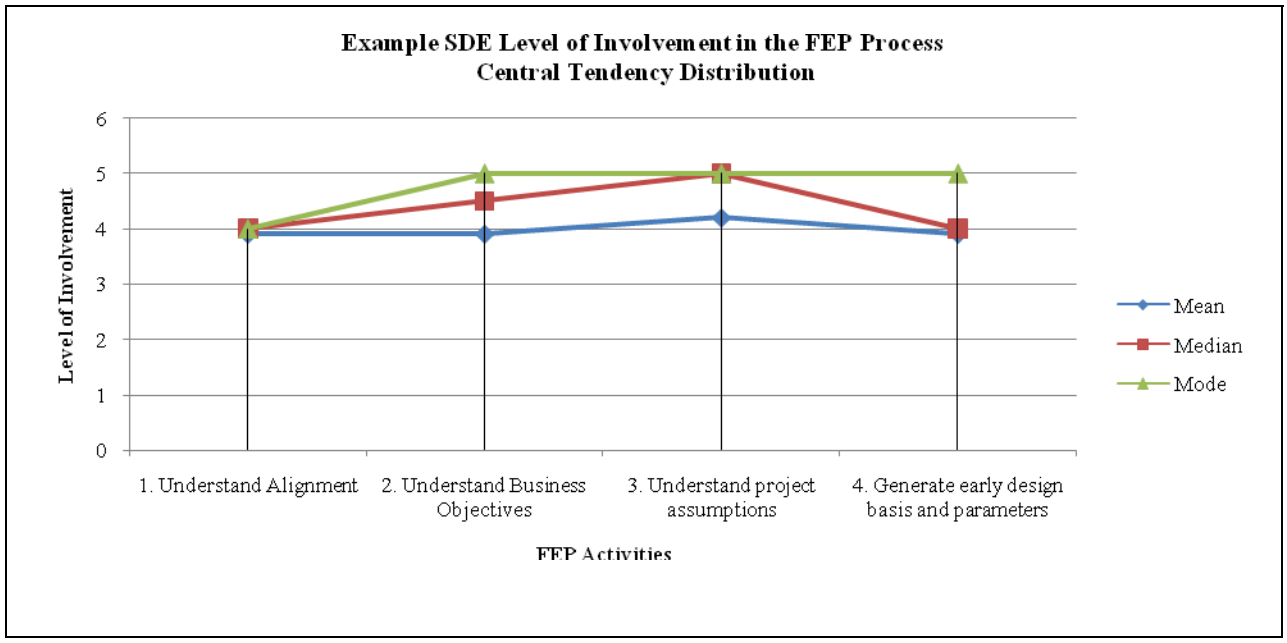


Figure 7. Example of the Central Tendency Distribution of the SDE.

In order to analyze the distribution profile of the mean, median, and mode for each activity within each data set, a standard to determine level of involvement was developed. Therefore, a set of values was determined to rank in relation to the mean, median, and mode values. The conclusions drawn from the trends of the mean, median, and mode values took the following standard ranges for determining the level of involvement: 4.5-5.0 = *Very Much*, 3.5-4.5 = *Much*, 2.5-3.5 = *Moderate*, 1.5-2.5 = *Little*, and 1.0-1.5 = *Very Little*. This standard was

developed based on the original survey's potential values for level of involvement that the SDE was to base their answer upon.

By analyzing the central tendency for each data set, the research was able to base a level of involvement for the group and individual SDE disciplines for all FEP activities. The consequent values were later used for the relationship determination between the group response and the individual SDE discipline.

Box Whisker Plot Analysis

Through the statistics calculated, box whisker plots were developed using the lower quartile, minimum, median, maximum, and upper quartile values. The box whisker plots were used to graphically represent the groups of data in terms of skewness and dispersion of data. The box whisker plot can also be used to determine the outliers present within the data set. For the purpose of this study, the outliers were left in the data set. Through analysis of this graphical representation, trends were determined by evaluating the response range dispersion and skewness. An example of the box whisker plots can be found in Figure 8.

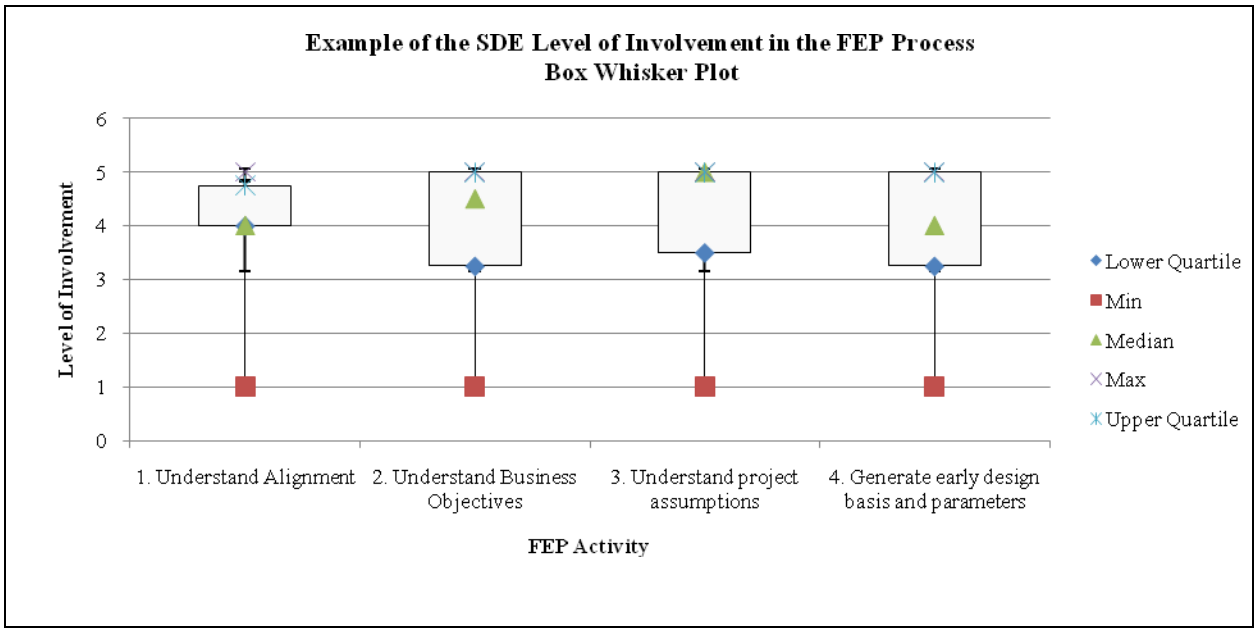


Figure 8. Example of the SDE Level of Involvement in the FEP Process--Box Whisker Plot.

As with the mean, median, and mode, the box whisker plot determination for level of involvement in the Front End Planning process took the following standard ranges for determining the level of involvement: 4.5-5.0 = *Very Much*, 3.5-4.5 = *Much*, 2.5-3.5 = *Moderate*, 1.5-2.5 = *Little*, and 1.0-1.5 = *Very Little*. This standard was developed based on the original survey's potential values for level of involvement that the SDE was to base their answer upon. Moreover, the ranges from the box whisker plots were used to reinforce the levels of involvement, to be used in the alignment analysis, determined from the central tendency analysis. Last, from the standard deviation calculation, the range in values was determined and compared to the box plot to find the alignment of the group data and the individual SDEs within their respective discipline.

Relationship Analysis of the General SDE vs. the Individual SDE Discipline

The analysis of the level of involvement, of the SDE in general and the individual SDE disciplines, determined from the central tendency distribution, and the box whisker plots were used in the relationship analysis. The relationship analysis's purpose was to determine the correlation between the SDE in general, independent of discipline, and the individual discipline. Table 6 outlines an example set of data used to determine the relationship. Moreover, the general SDE data included all disciplines in the relationship analysis. For example, the ACES discipline was compared against all disciplines including the ACES data.

Table 6

Example Values for Group Response vs. Individual SDE Discipline

SDE Level of Involvement Matrix		
Category/Statistical Method	Group SDE	Individual SDE Discipline
Feasibility		
F.1 - Initiate Phase		
1. Understand Alignment	Much	Much
2. Understand Business Objectives	Moderate	Much
3. Understand project assumptions	Much	Very Much
4. Generate early design basis and parameters	Very Much	Much

To display this data set graphically, a set of potential levels of involvement and corresponding numeric values were developed and are as follows: 1 =*Very Little*, 2 = *Little*, 3 = *Moderate*, 4 = *Much*, and 5 = Very *Much*. This standard to distribute the levels of involvement numerically was based on the initial data input from the respondent's potential response and corresponding numeric value. Figure 9 is a graphical representation of Table 6 after the numeric values were determined.

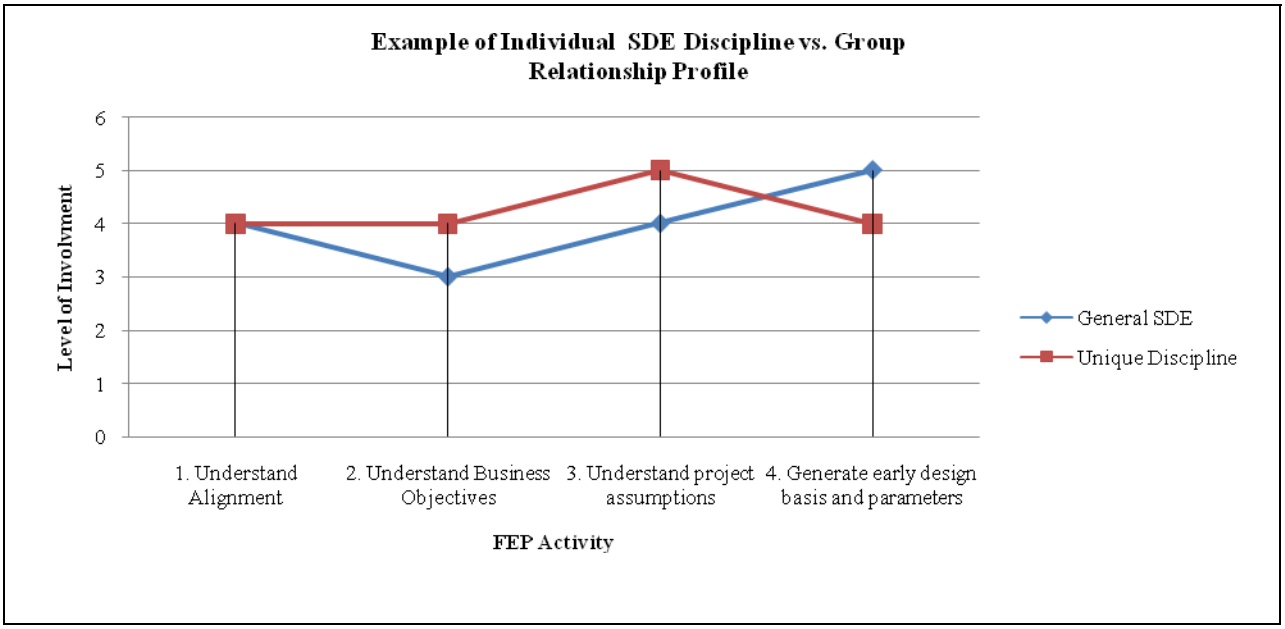


Figure 9. Example of the Unique SDE vs. Group--Relationship Profile.

In performing the analysis of the relationship between the disciplines, the research team focused on the areas where there were more than two levels of involvement difference and distinguished those as areas where the individual SDE discipline and the general SDE discipline were not in agreement. For example, if the individual SDE discipline was determined to have *moderate* involvement and the group was determined to have *very much* involvement, then it was concluded they were not in agreement on the FEP activity. This analysis was not used to determine whether one area was correct over another, but was used to distinguish the differences in disciplines versus the SDE in general.

List of Activities

The last research objective was to develop a list of activities in which the SDE had indicated a significant role. The lists for the group response and for each individual SDE discipline were generated based on the evaluations made from the distribution profiles and box

whisker plots. It is the purpose of these lists to highlight the unique roles of involvement: high or low. The high level was determined by those activities that returned the level of involvement as *much* or *very much.* Similarly, the low level of involvement was determined based on the data analysis revealing *little* or *very little* involvement.

Uncertainty

Although the analysis indicates more or less the levels of involvement in which the SDE is a part, there is a level of uncertainty. This is because of the sample size of 47 respondents and the range of answers selected by each participant. Given the roles defined in the next section, it is important to state this and to analyze the sample accordingly.

CHAPTER 6

FINDINGS

General Findings

What is the role of the Supervising Discipline Engineer (SDE) in the Front End Planning (FEP) process? The three phases of FEP, feasibility, concept, and detailed scope, along with each phase's respective activities in Table 3 and Table 4 were evaluated by each of the 47 survey participants according to the level of involvement of the SDE. Upon analysis and interpretation of each activity's statistical values, important insight was gained in understanding the Supervising Discipline Engineer's role in the Front End Planning process. It was important because the prospective of the SDE was captured. Moreover, it provided the view of an industry professional and allowed them to assess their levels of involvement based on a given definition of the subject matter and relate their experience as practitioners. After completing the calculations, the statistical values yielded trends across disciplines and trends unique to individual disciplines. Once the level of involvement was determined, a matrix of involvement by discipline was developed and is located in Table 15 and Table 16. Furthermore, the matrix is a representation of the level of involvement in each phase of the Front End Planning process and allowed the team to assess how the disciplines related to each other and the group in each activity.

Group SDE Involvement

The group of all participating SDEs consisted of the 47 participants' data to determine the level of involvement of the SDE in general. By looking at the levels of involvement, the research team was able to establish the role where the SDE is likely to be involved in each phase of the process. Moreover, the group data revealed the levels of involvement as indicated by all Supervising Discipline Engineers surveyed that allowed the research to highlight the roles and responsibilities. As indicated by Table 15 and Table 16, the SDE has a higher level of involvement in the technical roles of design and scope. This was seen in the detailed scope phase where corresponding percentage of high involvement areas is much greater than those of the feasibility and concept phases. The general activities with lower levels of involvement were those less technical roles as seen in the data. These activities were primarily based on economics and general business in which the SDE would not be likely to participate in the decision-making process. As with the largest portion of *very much* likely level of involvement in activities in the detailed scope phase, it can be seen that the larger percentage of *little* to *moderate* involvement can be seen in the feasibility phase. Moreover, it can be seen that the largest portion of *much* involvement is in the concept phase.

All activities of the FEP phase were analyzed by phase in accordance with the SDE's level of involvement. The feasibility phase had 19 activities, the concept phase had 13 activities, and the detailed scope phase had 11 activities. The following table outlines the involvement level of the SDE within each phase of the FEP process based on the percentage of total responses aligned out of the total number of questions within the phase. A seen by the responses, the nature and path forward of the project becomes more detailed as the Front End Planning process progresses and the SDE begins to take on a more engaging role. The higher levels of

involvement of the SDE, as seen in Table 7, illustrate the increasing involvement as the Front End Planning Process progresses.

Table 7

Percentage of Question Alignment Response in the FEP Phases

Feasibility	% of Responses Aligned	Concept	% of Responses Aligned	Detailed Scope	% of Responses Aligned
Very Little	0.00%	Very Little	0.00%	Very Little	0.00%
Little	10.53%	Little	7.69%	Little	0.00%
Moderate	42.11%	Moderate	7.69%	Moderate	18.18%
Much	42.11%	Much	76.92%	Much	27.27%
Very Much	5.26%	Very Much	7.69%	Very Much	54.55%

There were definite levels of low and high involvement for the SDE in general as indicated by the data analysis of the box whisker plots and the central tendency distributions. Table 8 represents the areas of high and low involvement for the group.

Table 8

Levels of High and Low Involvement According to the SDE Group Data

Activities of High Involvement	Activities of Low Involvement
Feasibility Phase • Understand Alignment • Understand Project Assumptions • Generate early design basis and parameters • Generate Assumptions/Drivers • Generate Alternatives for Technology • Generate Reliability, Maintainability, and Operability Guidelines • Prepare Initial Feasibility Scope • Develop Order of Magnitude (OOM) Estimate/Schedule • Consider Significant Risks	Feasibility Phase • Develop Economic Model • Develop Funding Strategies

(*table continues*)

Activities of High Involvement	Activities of Low Involvement
Concept Phase • Understand Alignment • Review and Understand Business Objectives • Validate project assumptions • Review design basis • Review and identify alternatives • Analyze Technology • Identify Short List of Alternatives • Develop Conceptual Scopes • Develop Conceptual Estimates • Evaluate and Select Best Alternatives • Develop Concept Phase Report	Concept Phase • N/A
Detailed Scope Phase • Understand Team Alignment • Review and Understand Business Objectives • Validate project assumptions • Review conceptual design basis • Develop Preliminary Design/Engineering • Develop Preliminary Design/Engineering Review • Finalize Scope Definition Package • Develop Cost and Schedule Control Estimate • Compile Project Definition Package	Detailed Scope Phase • N/A

In order to determine the alignment of the Group data, Figure 10 and Figure 11 highlight the roles of the SDE in general and show the dispersion of data and skewness determined by the research analysis. The skewness reflected the high or low levels of involvement as indicated in the previous sections. The dispersion represented the ranges of values given by the SDE respondent according to activity. The following outlines the activities that had a wide range of responses within the lower and upper quartiles:

Feasibility Phase

- Understand Business Objectives
- Generate Assumptions/Drivers
- Generate Alternatives for Technology
- Generate Intellectual Property
- Prepare Initial Feasibility Scope
- Develop Order of Magnitude (OOM) Estimate/Schedule
- Develop Initial Roles and Permit Analysis
- Develop Go/No-Go Analysis

Concept Phase

- Review and Understand Business Objectives
- Validate Project Assumptions

Detailed Scope Phase

- Prepare Oral Presentation

One reason for the misalignment is due to the role differences according to discipline. It was not expected that the SDE as a group would be in complete agreement based on the differences in the technical roles and responsibilities associated with each discipline. In the following sections, the roles of each SDE discipline are expanded on to highlight the responsibilities in relation to discipline and how they differ from the group.

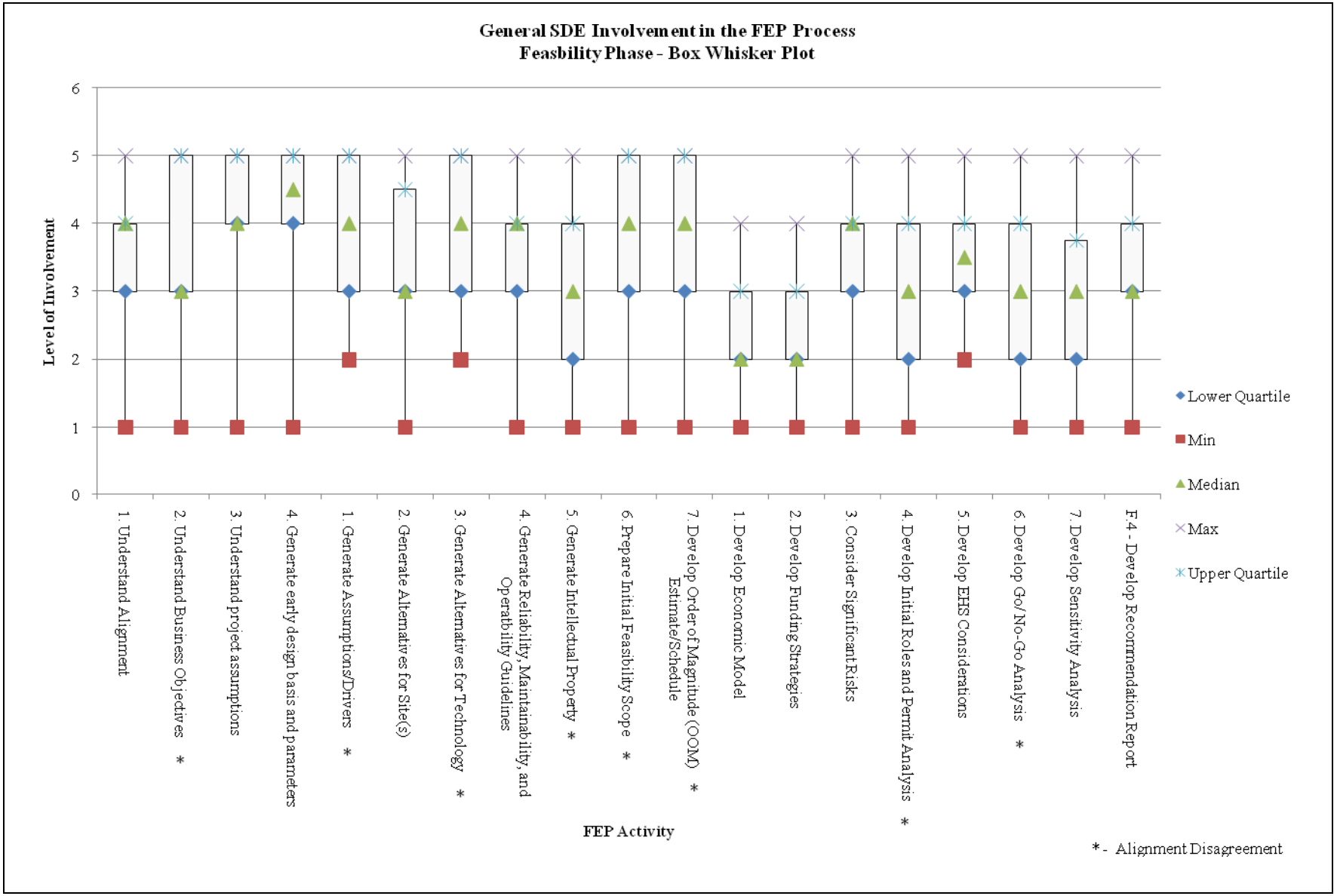


Figure 10. Group Involvement in the Front End Planning Process--Feasibility Phase Box Whisker Plot.

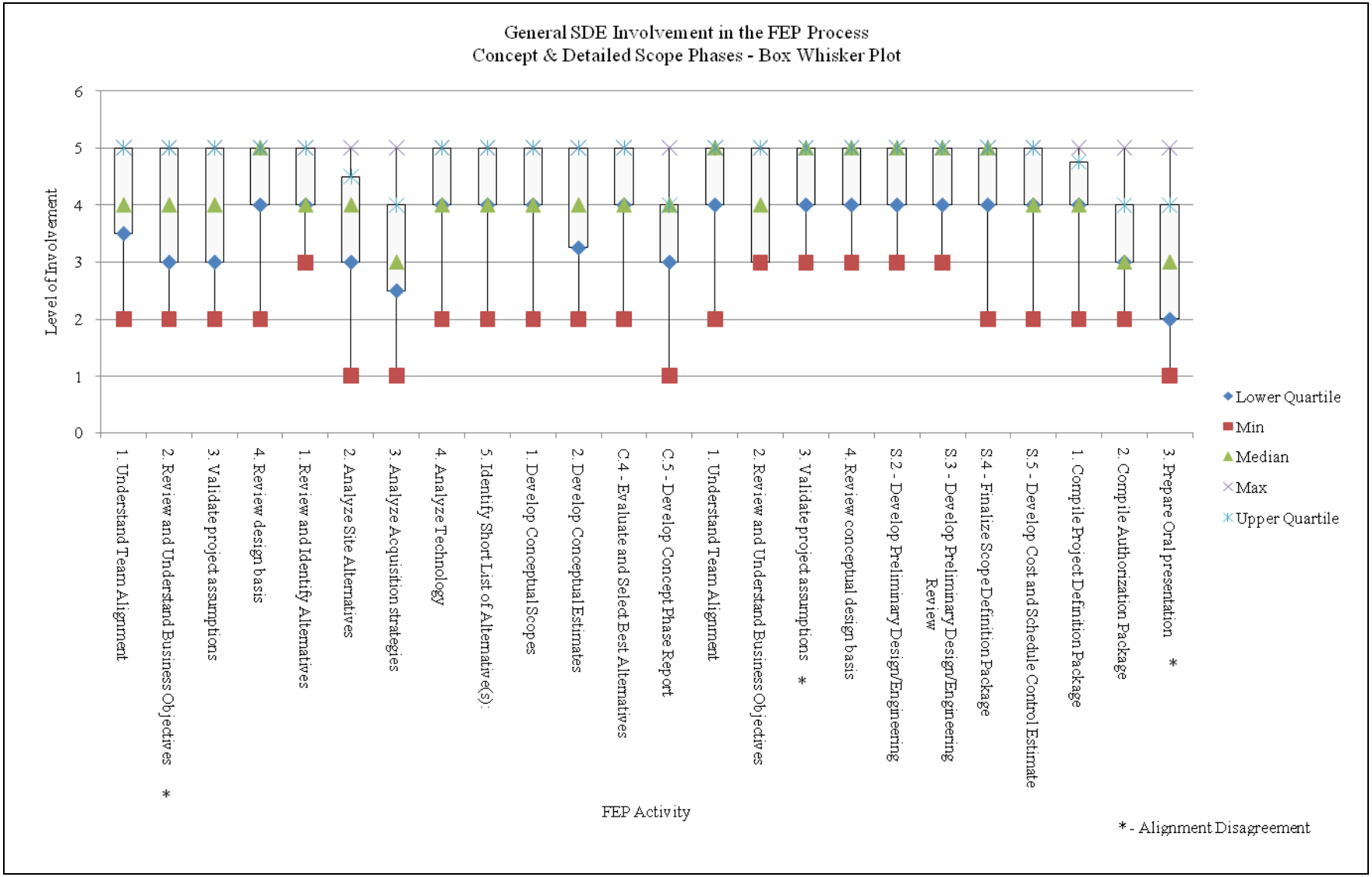


Figure 11. Group Involvement in the Front End Planning Process--Concept and Detailed Scope Phases Box Whisker Plot

SDE by Discipline

The Supervising Discipline Engineer (SDE) is responsible for the general management roles as well as their project specific engineering discipline skill sets. Across disciplines, each has a responsibility to ensure completion of all activities with high regard to cost, innovative engineering service, safety standards, and schedule to meet the goals and objectives of the company. This requires management skills, experienced technical skills, and good communication skills. The skills development program, used as the basis for SDE understanding to complete the survey, focused on improving the management of the technical skills and communication to superiors and subordinates. The program did so by providing definition and introducing terminology. Although many of the roles of the first line engineering manager are common to all disciplines, the technical roles can vary. The research focused on six different discipline engineering types to determine how this role was affected accordingly. The disciplines researched are as follows: Architectural, Civil, Environmental, and Structural (ACES); Electrical; Instrumentation and Controls (I&C); Mechanical; Piping; and Process. In the following sections, the roles and responsibilities of the SDE disciplines will be outlined to focus on the technical role's influence on the role of the SDE in the Front End Planning Process.

ACES Involvement

The first evaluated discipline determined the specific roles of the Architectural, Civil, Environmental, and Structural (ACES) SDE in the FEP process. The ACES SDE's technical role focuses on items such as the preliminary building code, site plan, geotechnical plan, building design and conceptual analysis, building code review, site grading, sewerage and drainage, and defining the ACES scope of work. In analyzing the data, the ACES discipline returned 10

completed surveys, which represented 21% of the total sample. From these respondents, the levels of involvement were determined. In many of the activities, the ACES SDEs maintained a close correlation with the values determined by the group data. However, there were two activities that were not in agreement and they were as follows:

Feasibility Phase

- Generate Alternatives for Site(s)

Concept Phase

- Analyze Site Alternatives

These two activities were understandable and driven by the technical roles and responsibilities of the ACES SDE. Moreover, the ACES SDE is concerned a great deal with the site work in an Engineering, Procurement, and Construction (EPC) firm.

From the ACES SDE data analysis, the high and low levels of involvement were determined. The ACES SDE's higher levels of involvement were concentrated on the technical roles and more specifically the site selection roles. The low involvement roles, similar to the group data determination, focused on the development of the economic model and business strategies. Table 9 outlines the levels of high and low involvement as indicated by the ACES SDE respondents. A complete evaluation and resulting level of involvement can be found in Tables 15 and 16.

Table 9

Levels of High and Low Involvement According to the ACES SDE

Activities of High Involvement	Activities of Low Involvement
Feasibility Phase • Understand Alignment • Understand Business Objectives • Understand Project Assumptions • Generate early design basis and parameters • Generate Assumptions/Drivers • Generate Alternatives for Site(s) • Prepare Initial Feasibility Scope • Develop Order of Magnitude (OOM) Estimate/Schedule • Consider Significant Risks • Develop Initial Roles and Permit Analysis • Develop Go/No-Go Analysis	Feasibility Phase • Develop Economic Model • Develop Funding Strategies
Concept Phase • Understand Team Alignment • Review and Understand Business Objectives • Validate Project Assumptions • Review Design Basis • Review and Identify Alternatives • Analyze Site Alternatives • Analyze Technology • Identify Short List of Alternative(s) • Develop Conceptual Scopes • Develop Conceptual Estimates • Evaluate and Select Best Alternatives	Concept Phase • N/A
Detailed Scope Phase • Understand Team Alignment • Review and Understand Business Objectives • Validate project assumptions • Review conceptual design basis • Develop Preliminary Design/Engineering • Develop Preliminary Design/Engineering Review • Finalize Scope Definition Package • Develop Cost and Schedule Control Estimate • Compile Project Definition Package	Detailed Scope Phase • N/A

Moreover, to reinforce these levels of high and low involvement, Figure 12 and Figure 13 were used to illustrate the dispersion of data and skewness of the responses made by the ACES respondents. The dispersion of data allowed the research to determine the alignment of the ACES SDEs in relation to one another. Furthermore, the skewness helped to determine the level of involvement for the roles and responsibilities. The following list represents the areas were the ACES SDEs were not in close alignment among one another:

Feasibility Phase

- Understand Business Objectives
- Generate Early Design Basis and Parameters
- Develop Economic Model
- Develop EHS Considerations
- Develop Sensitivity Analysis

Concept Phase

- Review and Understand Business Objectives
- Develop Conceptual Scopes
- Develop Conceptual Estimates
- Develop Concept Phase Report

Detailed Scope Phase

- Prepare Oral Presentation

These areas may need further attention to allow the ACES SDE to understand their role within these subject matters. However, the ACES SDE covers a few sub-disciplines; therefore, there may need to be a further breakdown in these disciplines to distinguish their alignment. For example, the “Developing EHS Considerations” may have been out of alignment based on the role of the Environmental sub-discipline in this activity. It is recommended to evaluate the sub-disciplines once more to have a more detailed understanding of the roles and responsibilities in the FEP process.

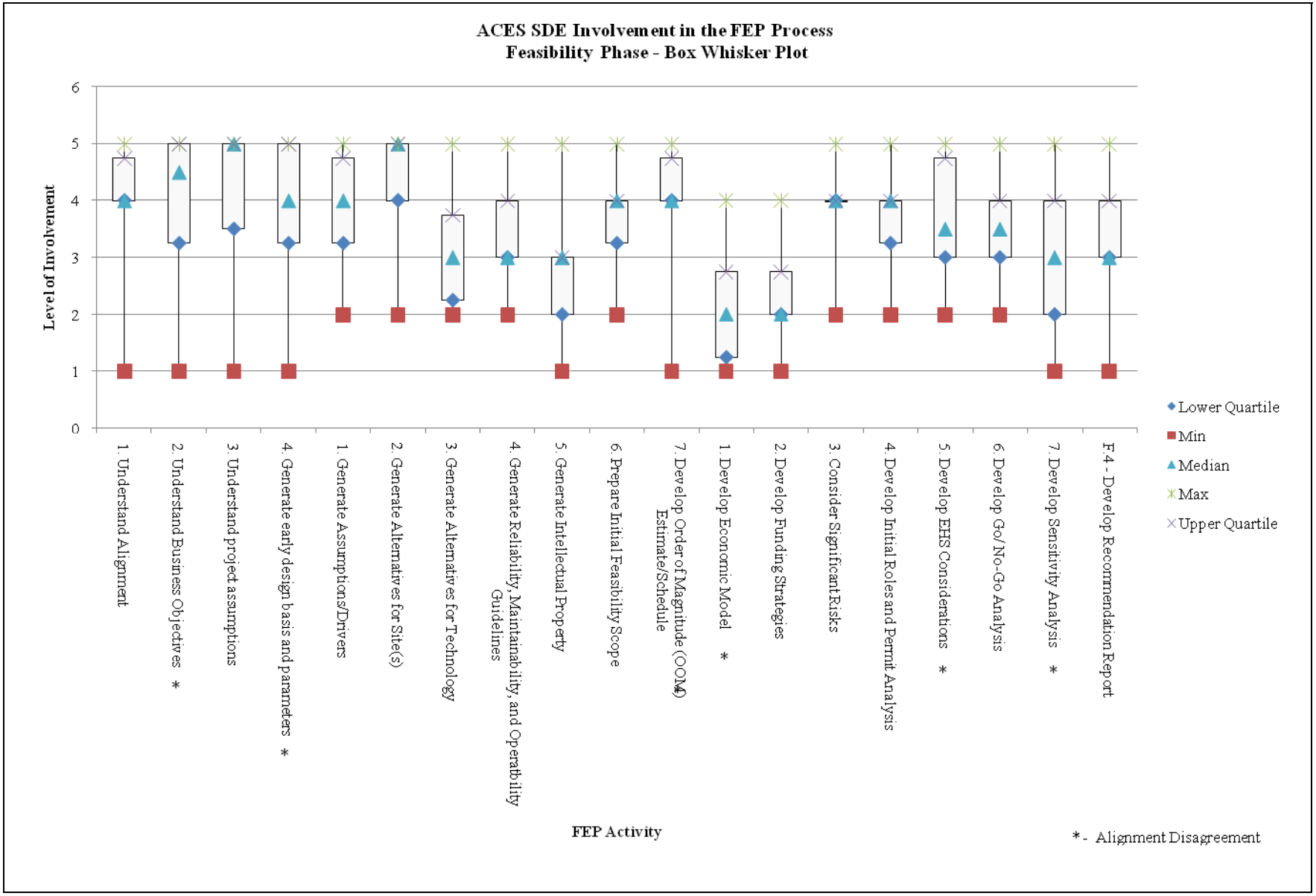


Figure 12. ACES SDE Involvement in the FEP Process Feasibility Phase--Box Whisker Plot.

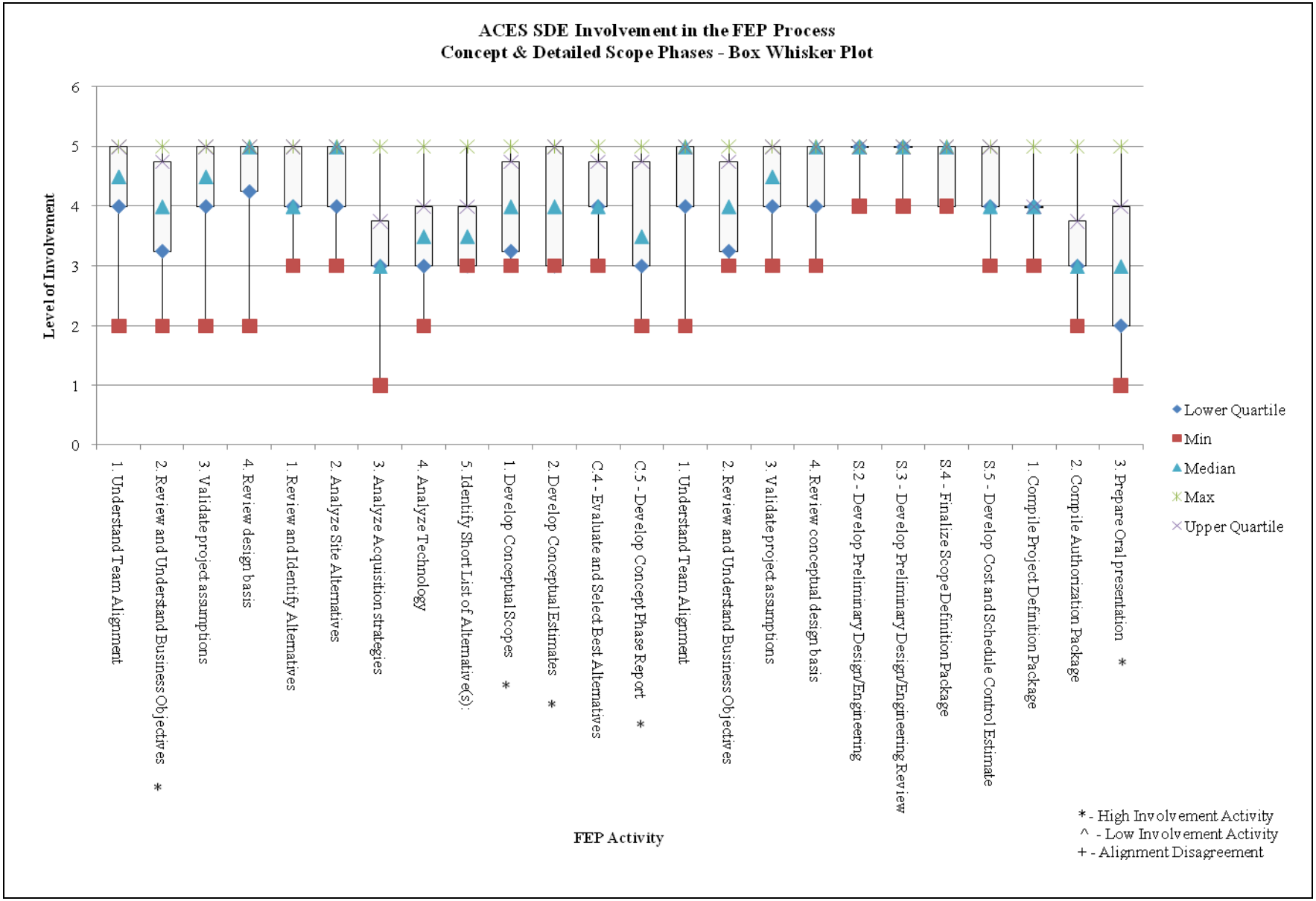


Figure 13. ACES SDE Involvement in the FEP Process Concept & Detailed Scope Phases--Box Whisker Plot.

Electrical Involvement

In assessing the technical roles of the Electrical SDE, the primary focuses are on electrical hazard classification, electrical criteria, single-line diagrams, power substation arrangement, and electrical equipment room (EER) arrangement, and defining the electrical scope of work. Within the group, the Electrical SDE's represented 11% of the sample with 5 returned surveys. These 5 Electrical SDE participants were closely aligned in the majority of the responses. Tables 15 and 16 outline the level of involvement based on the research findings. The respondents indicated a close agreement with the group data findings throughout the subject matter of the Front End Planning process.

In assessing the survey responses, the Electrical SDEs indicated either *moderately* or *much* involvement in many of the Front End Planning activities. The Electrical SDEs indicated many high levels of involvement, but again this was based on the 5 respondents' data and there is some uncertainty involved. In addition, the Electrical SDEs did not indicate a low level of involvement in any of the activities of the Front End Planning process. This is interesting because the other disciplines all indicated a low level of involvement, especially in the business driven activities. Based on this finding, it is a recommendation to provide a more comprehensive definition, especially those business specific activities, to the Electrical SDE and then ask them to evaluate their roles and responsibilities. The following table, Table 10, indicates the levels of Electrical SDE unique involvement as indicated by the respondents.

Table 10

Levels of High and Low Involvement According to the Electrical SDEs

Activities of High Involvement	Activities of Low Involvement
Feasibility Phase • Understand Alignment • Understand Project Assumptions • Generate early design basis and parameters • Generate Assumptions/Drivers • Generate Alternatives for Site(s) • Generate Alternatives for Technology • Generate Reliability, Maintainability, and Operability Guidelines • Generate Intellectual Property • Prepare Initial Feasibility Scope • Develop Order of Magnitude (OOM) Estimate/Schedule • Consider Significant Risks • Develop Initial Roles and Permit Analysis • Develop EHS Considerations	Feasibility Phase • N/A
Concept Phase • Understand Team Alignment • Validate Project Assumptions • Review Design Basis • Review and Identify Alternatives • Analyze Site Alternatives • Analyze Acquisition Strategies • Analyze Technology • Identify Short List of Alternative(s) • Develop Conceptual Scopes • Develop Conceptual Estimates • Evaluate and Select Best Alternatives • Develop Concept Phase Report	Concept Phase • N/A
Detailed Scope Phase • Understand Team Alignment • Review and Understand Business Objectives • Validate project assumptions • Review conceptual design basis • Develop Preliminary Design/Engineering • Develop Preliminary Design/Engineering Review • Finalize Scope Definition Package • Develop Cost and Schedule Control Estimate • Compile Project Definition Package	Detailed Scope Phase • N/A

In order to show the alignment of the Electrical SDE the discipline, Figures 14 and 15 highlight the roles and responsibilities as well as illustrate the dispersion of data and skewness of the results concluded by the research. The Electrical SDEs had a large range of responses in the feasibility phase activities of “Understanding of Team Alignment” and “Understanding Business Objectives” activities. In the concept phase, the activity of “Reviewing and Understanding Business Objectives” had a large dispersion of data. In order to alleviate these misalignments, the Electrical SDE may need to receive further definition to determine their appropriate role and responsibility in the stated activities. The remaining activities, although there were some outliers, were in close alignment as far as the range of data. The skewness reflected the high or low levels of involvement as indicated in the previous sections. Overall, with the few areas of misalignment within the Electrical SDEs’ responses and the high levels of involvement compared to the group data, it is recommended that more definition be provided to the Electrical SDEs and then revaluate the responses.

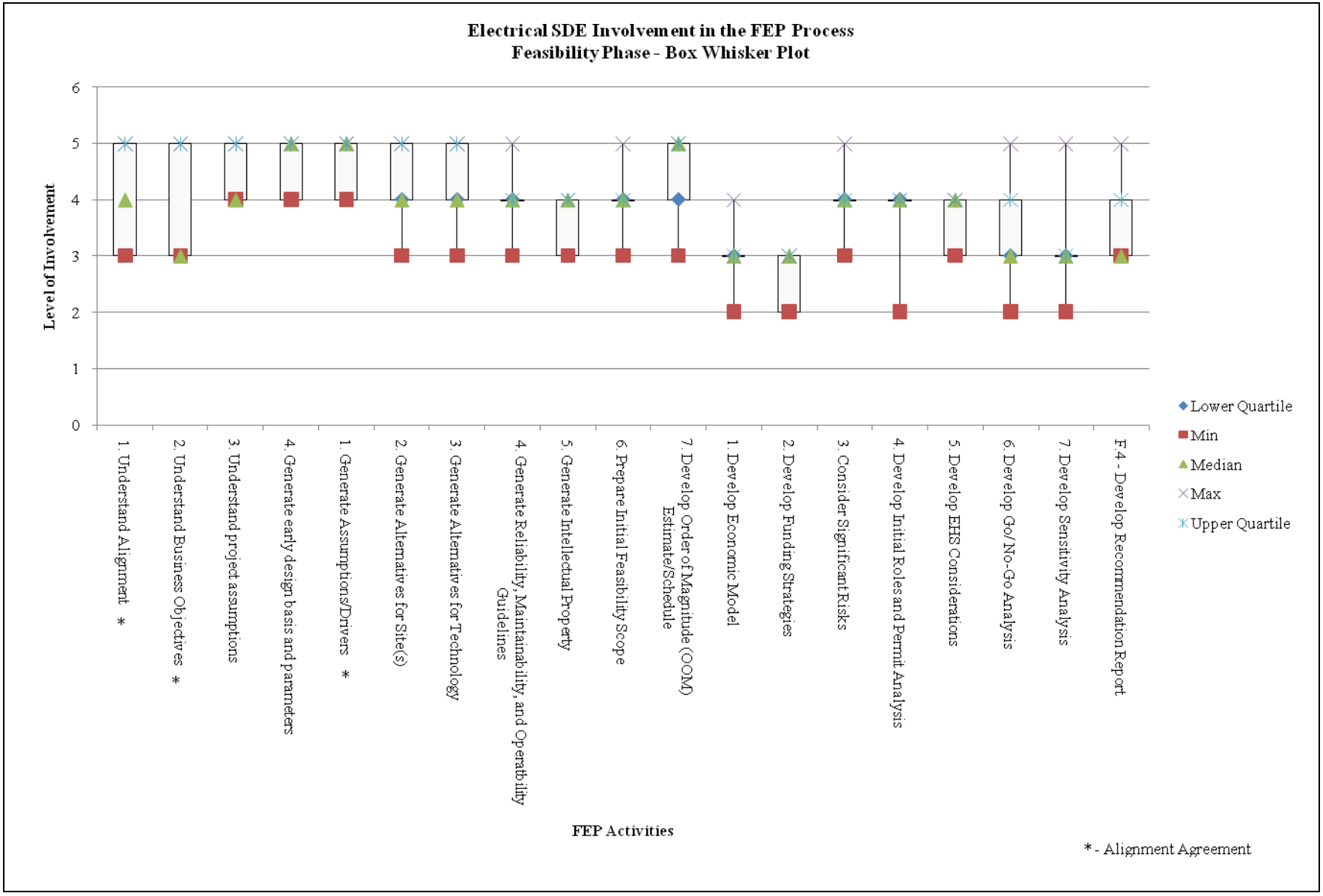


Figure 14. Electrical SDE Involvement in the FEP Process Feasibility Phase--Box Whisker Plot.

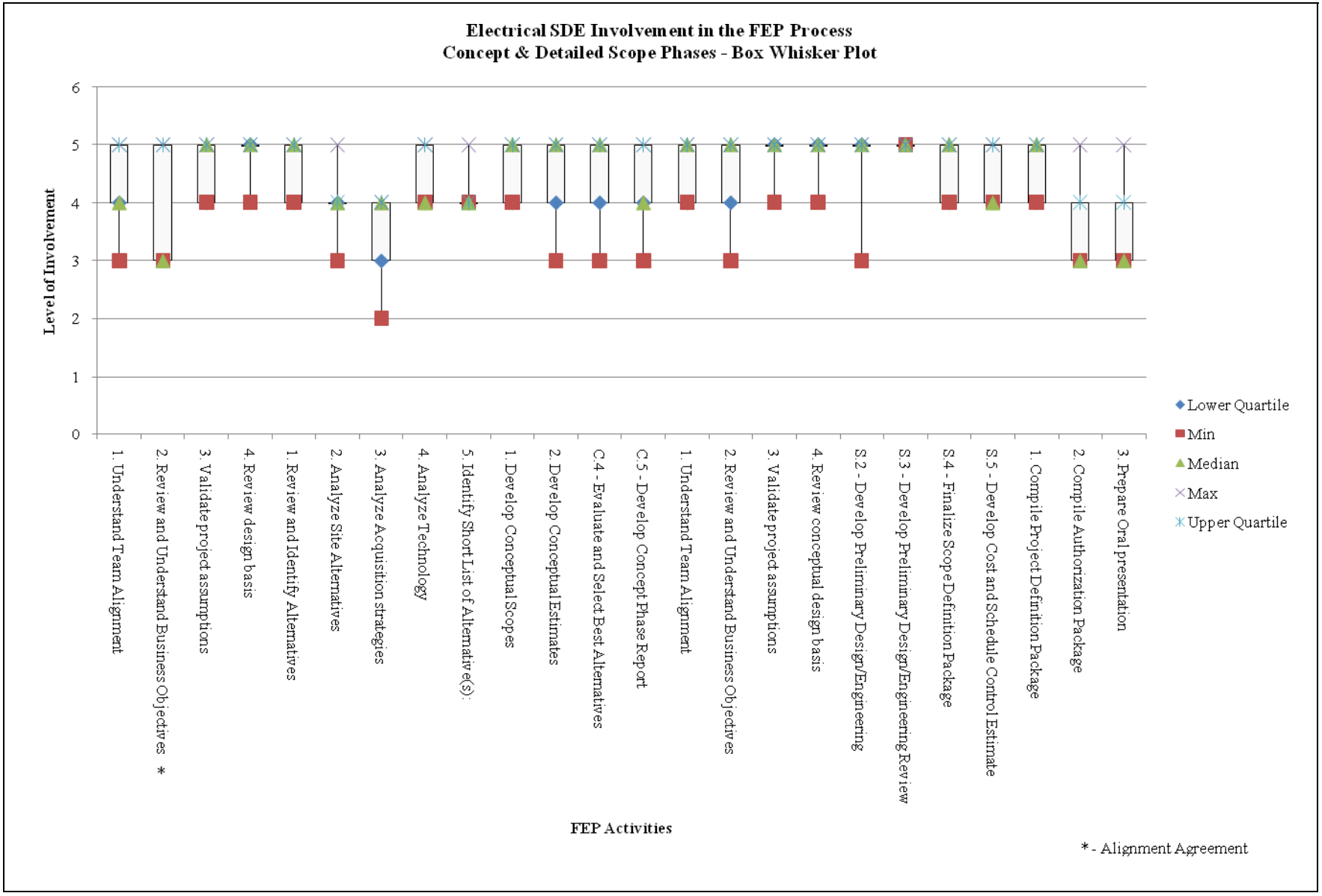


Figure 15. Electrical SDE Involvement in the FEP Process Concept and Detailed Scope Phases--Box Whisker Plot.

Instrumentation and Controls Involvement

The technical roles of the Instrumentation and Controls (I&C) SDE focus on items such as instrument criteria, control scheme, instrument control room arrangement, and the control systems scope of work. Within the data set, the I&C SDEs represented 19% of the sample with 9 returned surveys. The respondents indicated close agreement with the group SDE data. Therefore, the relationship of the I&C SDEs to group is very similar based on the data set. Upon evaluating the data of the 9 I&C respondents, they were either *moderately* or *muc*h involved in all the aspects of the Front End Planning process. Similarly to the other disciplines, the I&C SDEs indicated a higher level of involvement in the technical activities associated with the Front End Planning process. In respect to the low levels of involvement, this was understandable given the technical roles associated with the I&C SDEs and their need for other disciplines to establish their design criteria. Moreover, it is not necessary for the I&C SDEs to provide the lead for the reports and deliverables, but it is important for them to support the SDEs who have a greater role in determining the design basis for the project. Table 11 outlines the levels of high and low involvement according to the I&C respondents.

Table 11

Activities of High and Low Involvement for the I&C SDE

Activities of High Involvement	Activities of Low Involvement
Feasibility Phase • Understand Project Assumptions • Generate early design basis and parameters • Prepare Initial Feasibility Scope • Develop Order of Magnitude (OOM) Estimate/Schedule Concept Phase • Understand Team Alignment • Validate Project Assumptions • Review Design Basis • Review and Identify Alternatives • Analyze Technology • Identify Short List of Alternative(s) • Develop Conceptual Scopes • Develop Conceptual Estimates • Evaluate and Select Best Alternatives • Develop Concept Phase Report Detailed Scope Phase • Understand Team Alignment • Review and Understand Business Objectives • Validate project assumptions • Review conceptual design basis • Develop Preliminary Design/Engineering • Develop Preliminary Design/Engineering Review • Finalize Scope Definition Package • Develop Cost and Schedule Control Estimate • Compile Project Definition Package • Compile Authorization Package	Feasibility Phase • Develop Economic Model • Develop Funding Strategies • Develop Go/No-Go Analysis • Develop Sensitivity Analysis • Develop Recommendation Report Concept Phase • N/A Detailed Scope Phase • N/A

Figures 16 and 17 highlight the roles of the Instrumentation and Controls SDE. The box whisker plots for each activity within the Front End Planning process highlight the levels of involvement as indicated above. Moreover, the range of answers given by the I&C SDEs are apparent in the illustrations. The skewness of the involvement in the activities can be seen as well. By evaluating these figures, it was determined where the I&C SDE was not in alignment within the discipline. The following activities were determined to be misaligned:

Feasibility Phase

- Understand Alignment
- Understand Business Objectives
- Generate Reliability, Maintainability, and Operability Guidelines
- Prepare Initial Feasibility Scope
- Develop Funding Strategies
- Consider Significant Risks
- Develop Go/No-Go Analysis
- Develop Recommendation Report

Concept Phase

- Review and Understand Business Objectives
- Validate project assumptions
- Analyze Site Alternatives

Detailed Scope Phase

- Review and Understand Business Objectives
- Compile Authorization Package
- Prepare Oral Presentation

These areas may need further attention to allow the I&C SDEs to understand their role within these activities. Moreover, the "Development of the Feasibility Phase Report" and "Preparation of the Oral Presentation" activities had a wide range of values from *very little* to *very much*. This was important to note because most of the respondents were not in alignment. Overall, the I&C SDE is more involved in the concept and detailed scope phases. This is

understandable because the I&C SDE's design basis generally relies on parameters established by other disciplines.

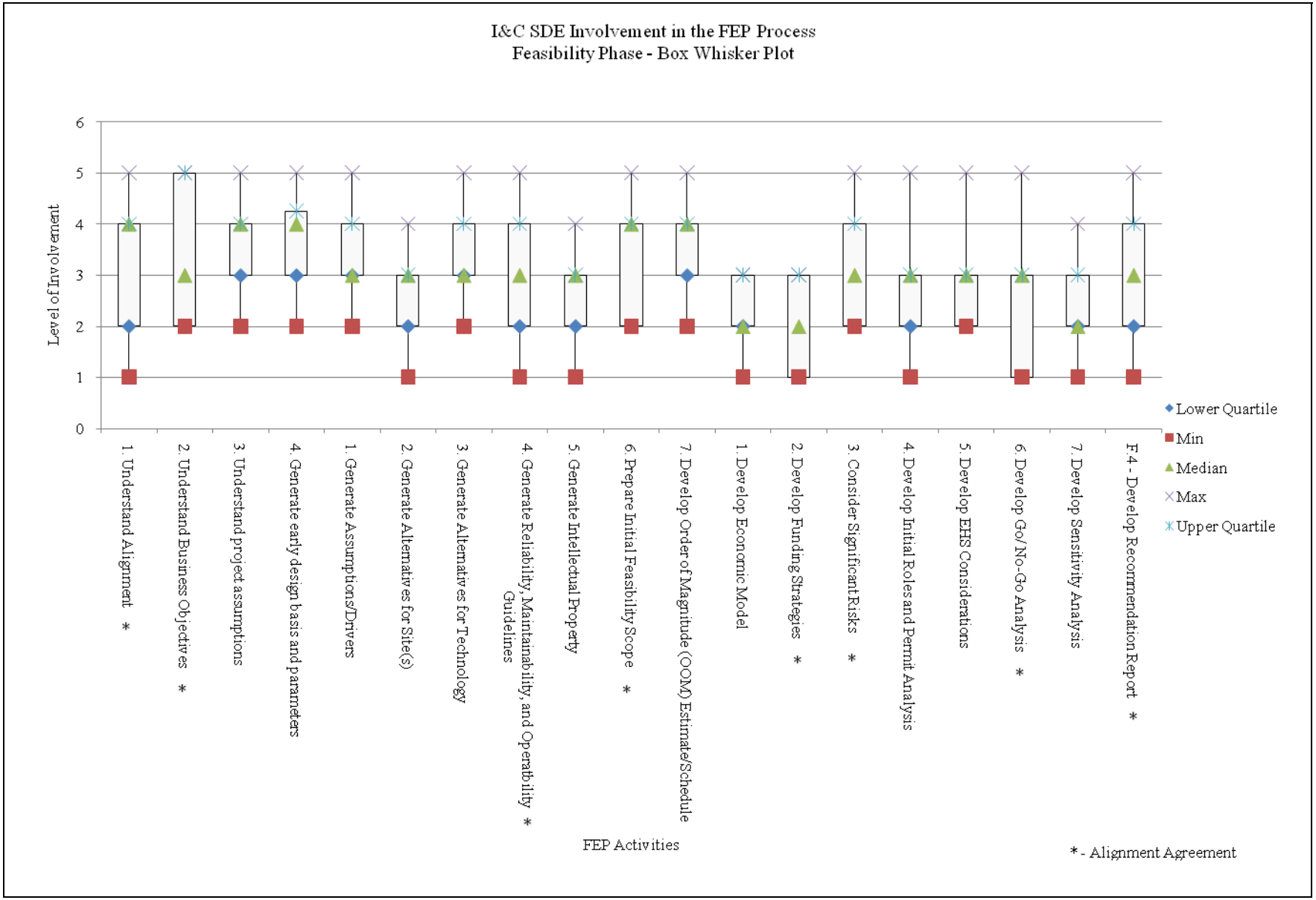


Figure 16. I&C SDE Involvement in the FEP Process Feasibility Phase--Box Whisker Plot.

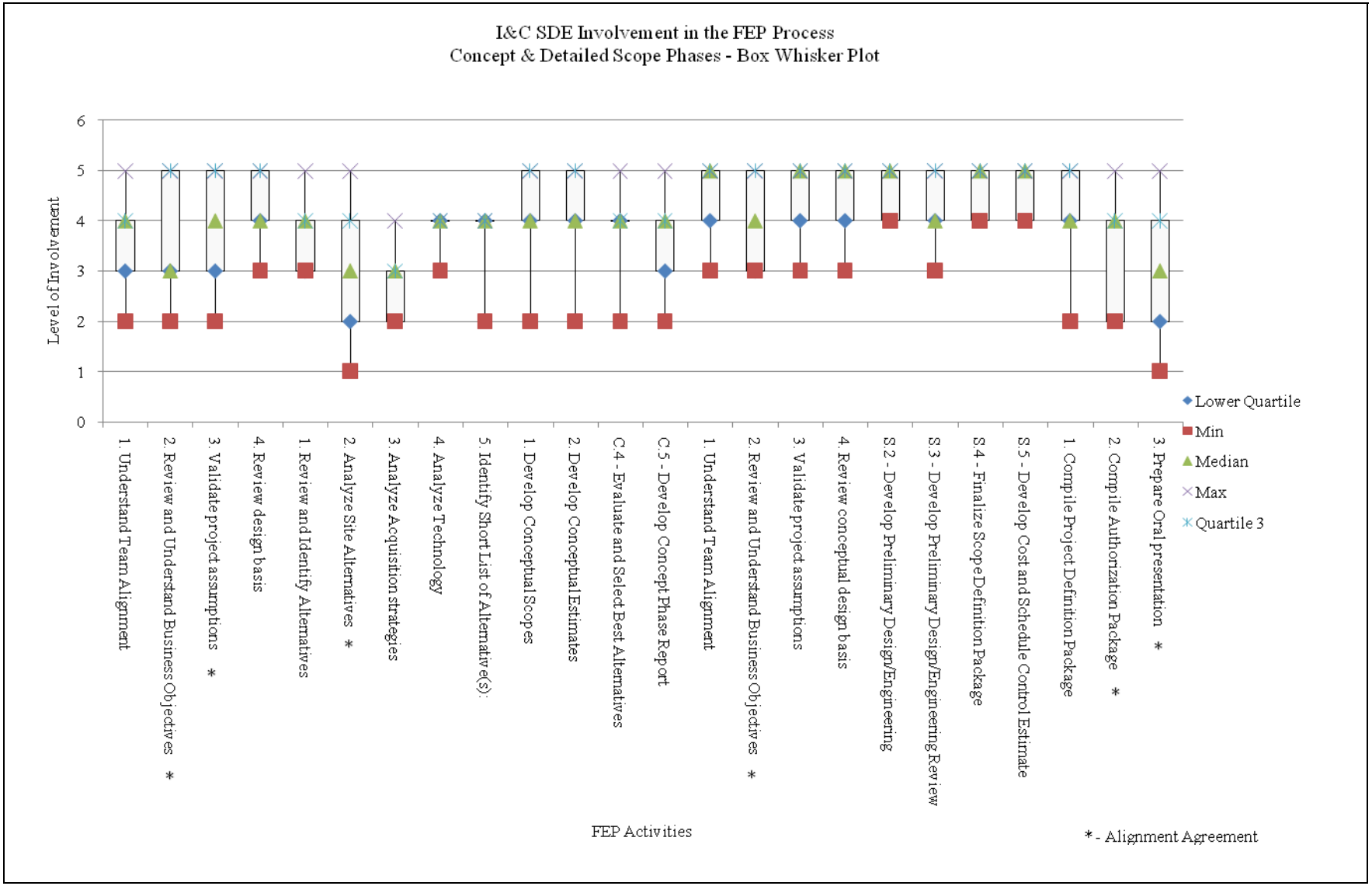


Figure 17. I&C SDE Involvement in the FEP Process Concept & Detailed Scope Phases--Box Whisker Plot.

Mechanical SDE Involvement

In addition to the SDE management and communication skill sets, the Mechanical SDE focuses on the technical items such as the safety and fire review, equipment list development, identifying limiting equipment, major equipment drawing and specifications, spare parts/extra machinery, and the mechanical scope of work. The Mechanical SDEs represented 21% of the sample with 10 returned surveys. These 10 Mechanical SDE participants were closely aligned in most all of the subject matter. Moreover, in assessing how these Mechanical participants responded versus the group, they were in close or complete agreement. Tables 15 and 16 detail the levels of involvement of all activities within the Front End Planning process for the Mechanical SDEs and their relationship to group and remaining disciplines.

Based on the respondents' indications of involvement, the Mechanical SDE was either *moderately* or *much* involved in all the aspects of the Front End Planning process. Furthermore, the Mechanical SDE was involved at a high level in many of the activities. There were not many levels of low involvement for the Mechanical SDE. In Table 12, the areas of high and low involvement are outlined. The higher levels of involvement, as with the other disciplines, were associated with the Front End Planning activities with technical substance. The business driven objectives reflected lower levels of involvement for the Mechanical SDE.

Table 12

Activities of High and Low Involvement for the Mechanical SDE

Activities of High Involvement	Activities of Low Involvement
Feasibility Phase • Understand Alignment • Understand Project Assumptions • Generate early design basis and parameters • Generate Assumptions/Drivers • Generate Alternatives for Technology • Generate Reliability, Maintainability, and Operability Guidelines • Generate Intellectual Property • Prepare Initial Feasibility Scope • Develop Order of Magnitude (OOM) Estimate/Schedule • Consider Significant Risks • Develop EHS Considerations Concept Phase • Understand Team Alignment • Review and Understand Business Objectives • Validate Project Assumptions • Review Design Basis • Review and Identify Alternatives • Analyze Technology • Identify Short List of Alternative(s) • Develop Conceptual Scopes • Develop Conceptual Estimates • Evaluate and Select Best Alternatives • Develop Concept Phase Report Detailed Scope Phase • Understand Team Alignment • Review and Understand Business Objectives • Validate project assumptions • Review conceptual design basis • Develop Preliminary Design/Engineering • Develop Preliminary Design/Engineering Review • Finalize Scope Definition Package • Develop Cost and Schedule Control Estimate • Compile Project Definition Package	Feasibility Phase • Develop Economic Model • Develop Funding Strategies Concept Phase • N/A Detailed Scope Phase • N/A

The alignment of all Mechanical SDEs is important so that the understanding of the roles and responsibilities is uniform and standard across the discipline. The range of values was evaluated to determine the alignment of the Mechanical SDEs within the discipline. Furthermore, the skewness helped to reinforce the levels of involvement. A range and skewness of the Mechanical SDE's responses can be found in Figures 18 and 19. The following are the areas that were misaligned within the Mechanical SDE:

Feasibility Phase

- Generate Assumptions/Drivers
- Generate Alternatives for Technology
- Generate Reliability, Maintainability, and Operability Guidelines
- Generate Intellectual Property
- Develop Order of Magnitude (OOM) Estimate/Schedule
- Develop Economic Model
- Consider Significant Risks
- Develop Initial Role and Permit Analysis
- Develop Go/No-Go Analysis

Concept Phase

- Identify Short List of Alternative(s):

Detailed Scope Phase

- Prepare Oral Presentation

Definition of these activities may be needed to allow the Mechanical SDEs to understand their role within these activities. However, similar to the ACES discipline, the Mechanical SDEs may have different sub-disciplines or specialties within their core competencies. These may need to be evaluated separately in future research to have a more specific role defined. Overall, the Mechanical SDE is generally considered to be an important part of the design process and a primary driver in many EPC firms. This assumption was reflected positively and reinforced in the analysis and findings of the Mechanical SDE participants' responses.

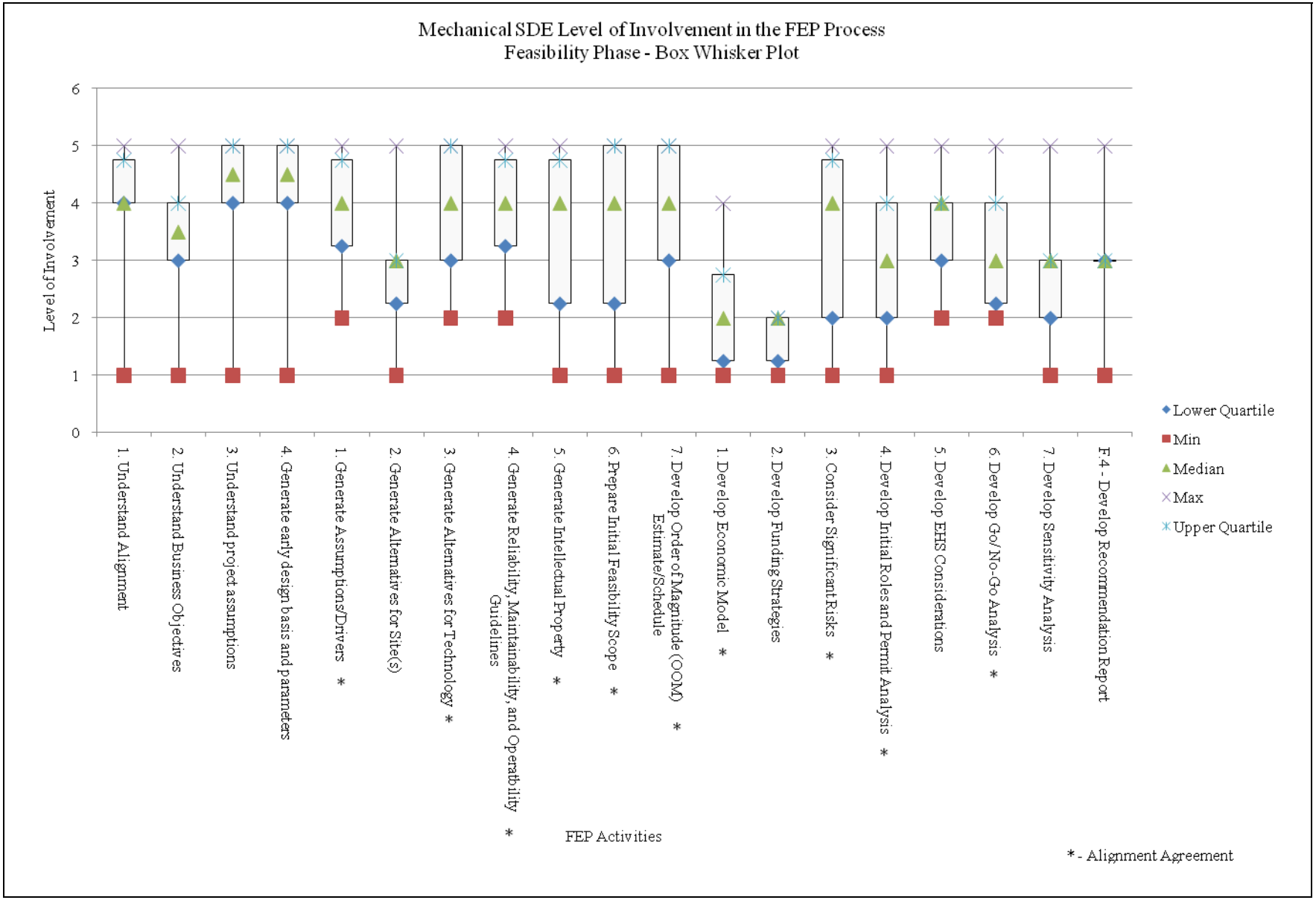


Figure 18. Mechanical SDE Level of Involvement in the FEP Process Feasibility Phase--Box Whisker Plot.

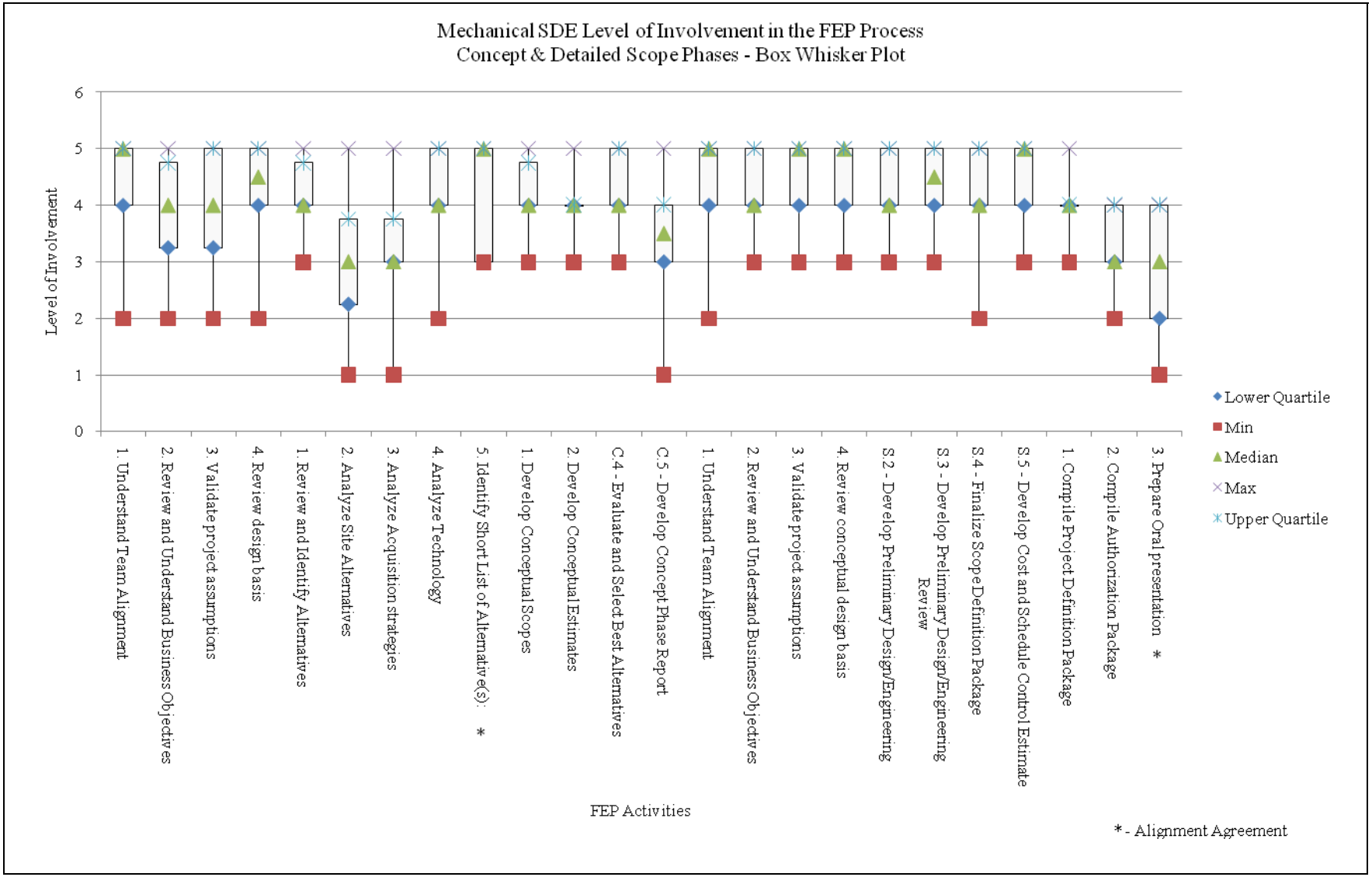


Figure 19. Mechanical SDE Level of Involvement in the FEP Process Concept & Detailed Scope Phases--Box Whisker Plot.

Piping Involvement

The Piping SDE focuses on technical items such as valves and fitting criteria, pipe and valve specifications, insulation specifications, protective coating specifications, plot plans, P&ID completeness evaluation, pipe stress analysis, preliminary line list, preliminary piping routing diagrams, preliminary pipe stress isometrics, preliminary support locations, pipe stress analysis for priority lines, preliminary loads for priority systems and racks, nozzle load tables, equipment arrangement, and the piping scope of work. The Piping SDEs represented 11% of the sample with 5 returned surveys. Furthermore, the Piping SDE was closely or completely in agreement with the group with the exception of one activity. The activity in which the Piping SDEs were not in agreement with the group was "Generate early design basis and parameters," in the Feasibility Phase. This was understandable since the design objectives of the Piping SDE rely heavily on the design selections made by other disciplines.

Upon analysis of the responses, the Piping SDE was either *moderately* or *much* involved in all aspects of the Front End Planning process. However, there were a few areas of the process that had *very much* or *little* involvement. Table 13 highlights the areas of high and low involvement as indicated by the Piping SDE. Like the other disciplines, the Piping SDE was involved to a greater extent in the technical activities and less involved in the business driven activities.

Table 13

Activities of High and Low Involvement for the Piping SDE

Activities of High Involvement	Activities of Low Involvement
Feasibility Phase • Understand Project Assumptions • Generate Assumptions/Drivers • Generate Alternatives for Technology • Generate Reliability, Maintainability, and Operability Guidelines • Prepare Initial Feasibility Scope • Develop Order of Magnitude (OOM) Estimate/Schedule • Develop Recommendation Report Concept Phase • Understand Team Alignment • Review and Understand Business Objectives • Validate Project Assumptions • Review Design Basis • Review and Identify Alternatives • Analyze Site Alternatives • Analyze Acquisition Strategies • Analyze Technology • Identify Short List of Alternative(s) • Develop Conceptual Scopes • Develop Conceptual Estimates • Evaluate and Select Best Alternatives • Develop Concept Phase Report Detailed Scope Phase • Understand Team Alignment • Review and Understand Business Objectives • Validate project assumptions • Review conceptual design basis • Develop Preliminary Design/Engineering • Develop Preliminary Design/Engineering Review • Finalize Scope Definition Package • Develop Cost and Schedule Control Estimate • Compile Project Definition Package	Feasibility Phase • Generate Intellectual Property • Develop Economic Model • Develop Funding Strategies • Develop Initial Roles and Permit Analysis • Develop Go/No-Go Analysis • Develop Sensitivity Analysis Concept Phase • N/A Detailed Scope Phase • N/A

To assess the alignment of the Piping SDE, Figures 20 and 21 were constructed to represent the dispersion and skewness of responses by the 5 Piping SDEs. For the most part, the Piping SDEs were in close alignment based on the range of responses throughout all activities. The standard deviations of all activities were close to 1 or far less. In a few areas, all of the respondents were not in alignment and they are as follow:

Feasibility Phase

- Understand Business Objectives
- Understand project assumptions
- Generate early design basis and parameters
- Generate Alternatives for Technology
- Prepare Initial Feasibility Scope
- Develop Funding Strategies
- Consider Significant Risks
- Develop Recommendation Report

Concept Phase

- Validate project assumptions

Detailed Scope Phase

- Develop Cost and Schedule Control Estimate

To improve alignment of these issues, further definition may need to be provided in order to allow the Piping SDEs to understand their role within these subject matters. The Piping SDE overall needs the most attention in the feasibility phase to improve agreement within the discipline. Moreover, based on only 5 respondents, there was a level of uncertainty that needs to be addressed. It is recommended that the Piping SDE receive further definition and then to revaluate the roles and responsibilities within the FEP process. Overall, the Piping SDE depends on design created by other disciplines. Therefore it is expected that this discipline would act as a supporting role to more of the project driving disciplines.

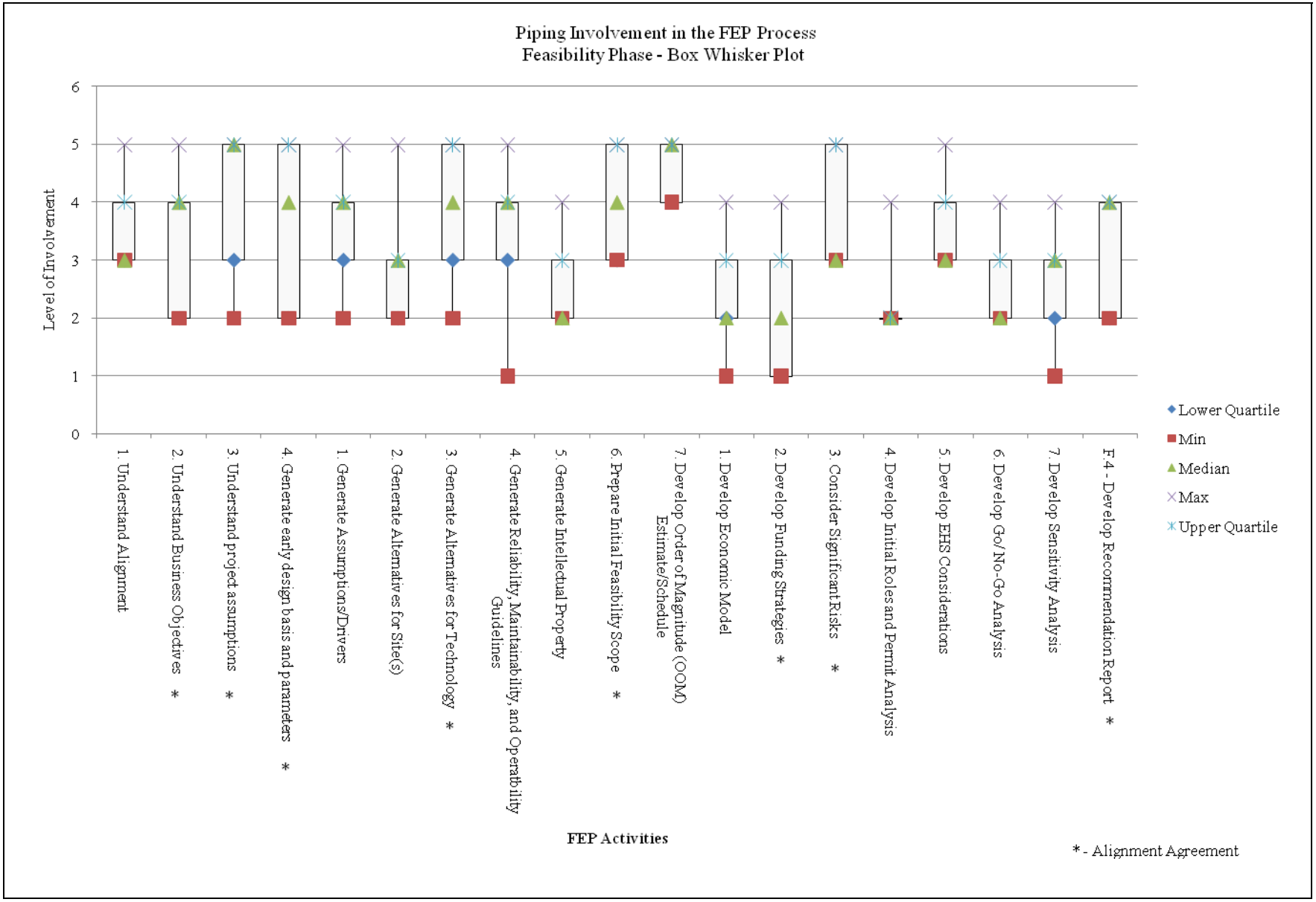


Figure 20. Piping Involvement in the FEP Process Feasibility Phase--Box Whisker Plot.

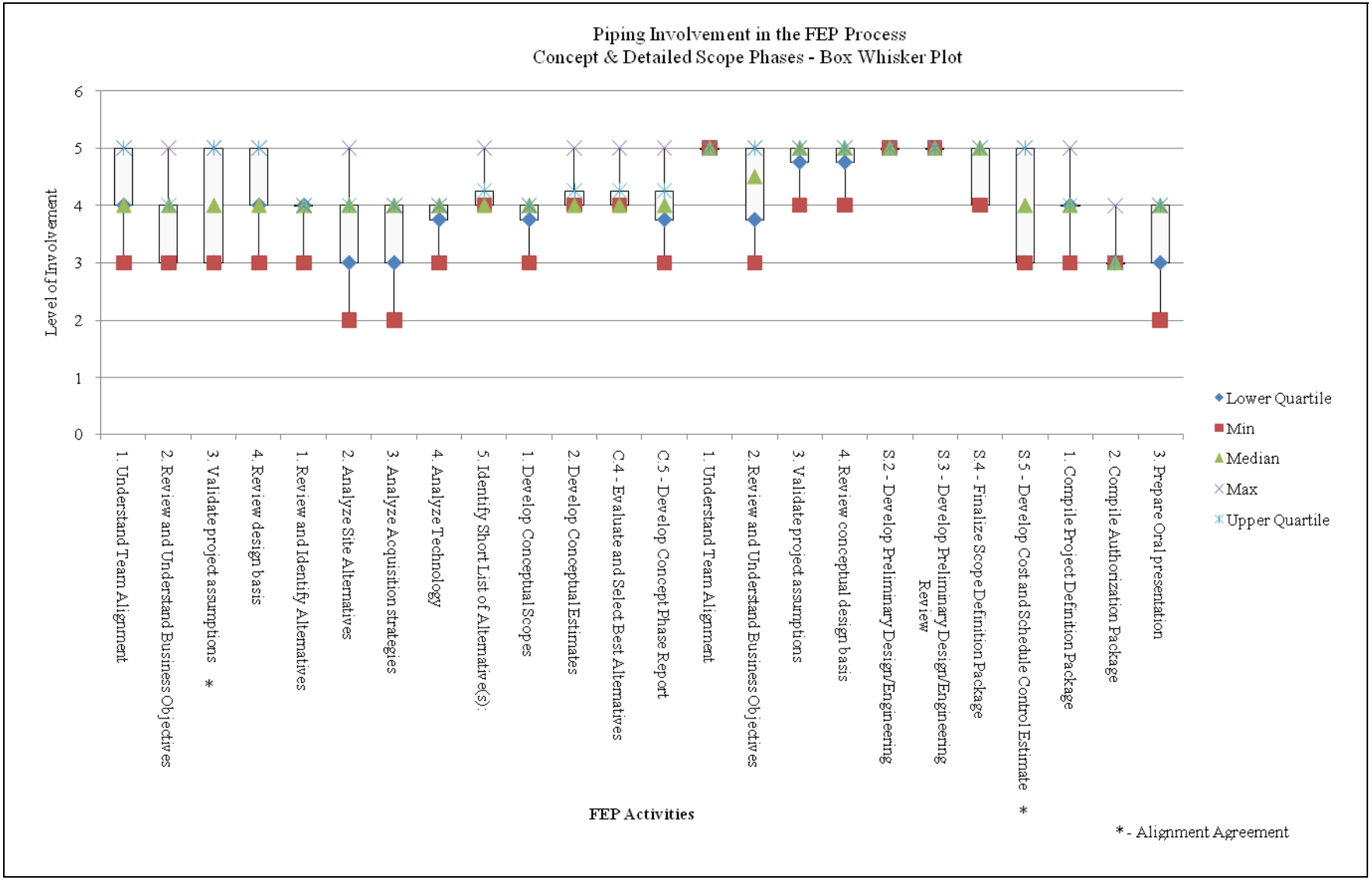


Figure 21. Piping Involvement in the FEP Process Concept & Detailed Scope Phases--Box Whisker Plot.

Process Involvement

To state the technical focus of the Process SDE, the discipline is involved in activities such as the development of process flow diagrams, preliminary hydraulics and relief calculations, utility/energy requirements and site impact, process simplification, equipment sizing, written process description, energy conservation review, materials of construction, system diagram, preliminary process hazards analysis, preliminary P&I Diagrams, process design release (DR) P&I Diagrams, set abnormal design conditions, set preliminary normal design conditions, and the process scope of work. In relation to the number of respondents, the Process SDEs represented 17% of the sample with 8 returned surveys. Based on the statistics performed from these indications on level of involvement by the Process SDE, Tables 15 and 16 were developed to outline the level of involvement in relation to the remaining disciplines and the group. Upon assessing the Process SDE's agreement with the group, there were no significant deviations from the group and therefore they were close or complete in agreement.

In assessing the values represented, the Process SDE was either *moderately* or *much* involved in all the aspects of the Front End Planning process. However, there were a few areas of the process that had high and low involvement and they are presented in Table 14. Like, the previous disciplines evaluated in the research, the Process SDE was involved in technically driven activities of the Front End Planning Process. Moreover, the Process SDE is typically a lead engineer in all phases of the process in an EPC firm. This is reinforced with the levels of involvement indicated by the Process SDE respondents.

Table 14

Activities of High and Low Involvement for the Process SDE

Activities of High Involvement	Activities of Low Involvement
Feasibility Phase • Understand Project Assumptions • Generate early design basis and parameters • Generate Assumptions/Drivers • Generate Alternatives for Site(s) • Generate Alternatives for Technology • Generate Reliability, Maintainability, and Operability Guidelines • Prepare Initial Feasibility Scope • Consider Significant Risks • Develop EHS Considerations • Develop Sensitivity Analysis • Develop Recommendation Report Concept Phase • Understand Team Alignment • Validate Project Assumptions • Review Design Basis • Review and Identify Alternatives • Analyze Technology • Identify Short List of Alternative(s) • Develop Conceptual Scopes • Evaluate and Select Best Alternatives • Develop Concept Phase Report Detailed Scope Phase • Understand Team Alignment • Validate project assumptions • Review conceptual design basis • Develop Preliminary Design/Engineering • Develop Preliminary Design/Engineering Review • Finalize Scope Definition Package • Compile Project Definition Package	Feasibility Phase • Develop Funding Strategies Concept Phase • N/A Detailed Scope Phase • N/A

Figures 22 and 23 represent the box whisker plots developed to graphically represent the data gathered from the Process SDE participants. Once the data was evaluated, it was determined that these 8 participants were closely aligned in most all of the subject matter. Furthermore, the standard deviation was the smallest overall compared to other disciplines therefore making the Process SDE the closest aligned with each of all other disciplines. The small ranges of responses in most of the activities reinforced this point as well. There were two areas however where the range of data reflected misalignment of the respondents. These activities were in the detailed scope phase and were “Understand Team Alignment” and “Validate Project Assumptions.” It may be necessary to provide additional definition to the Process SDE in order to achieve better alignment. Overall, the Process SDE reflected a high level of involvement throughout the FEP process and especially in the technical roles.

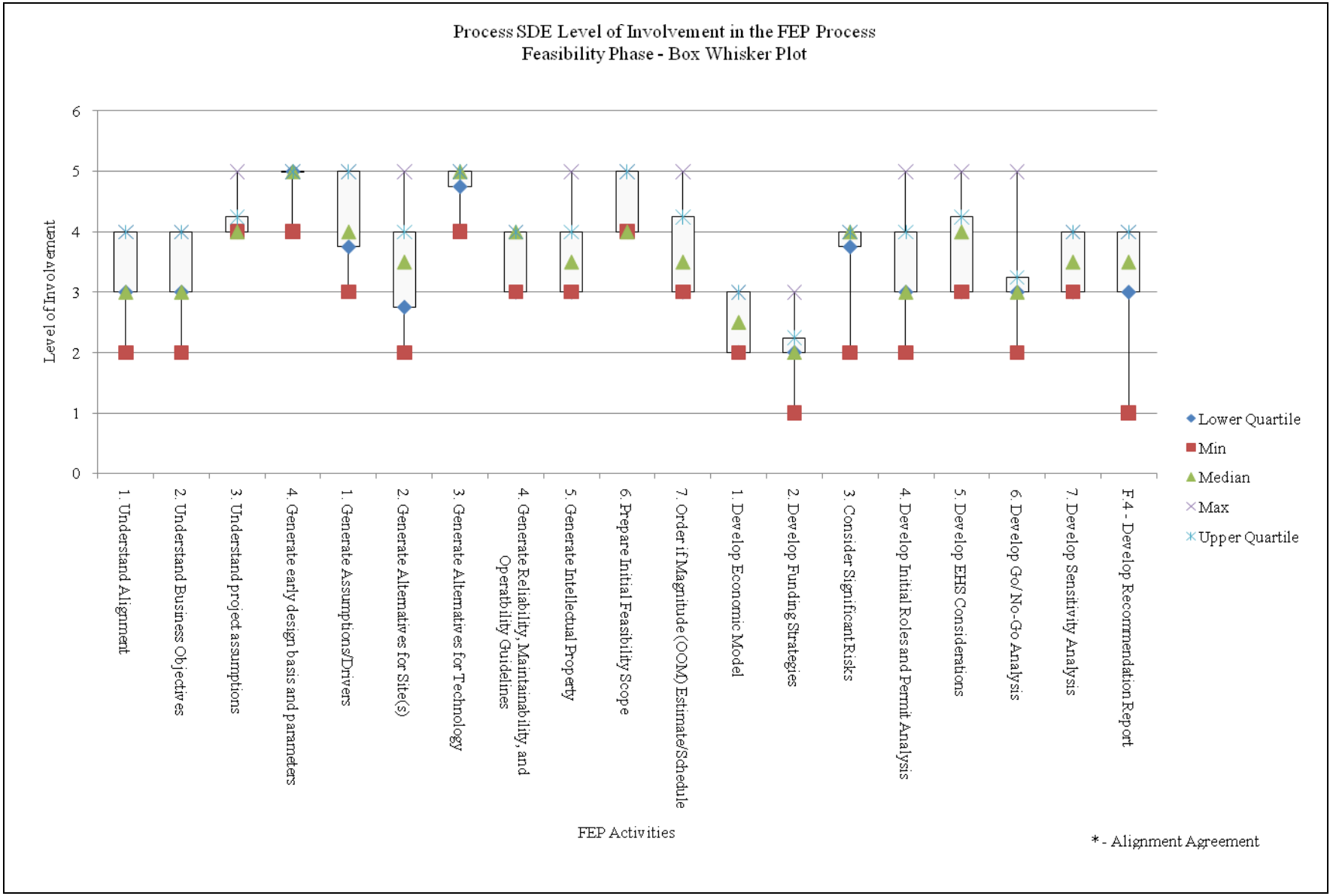


Figure 22. Process SDE Level of Involvement in the FEP Process Feasibility Phase--Box Whisker Plot.

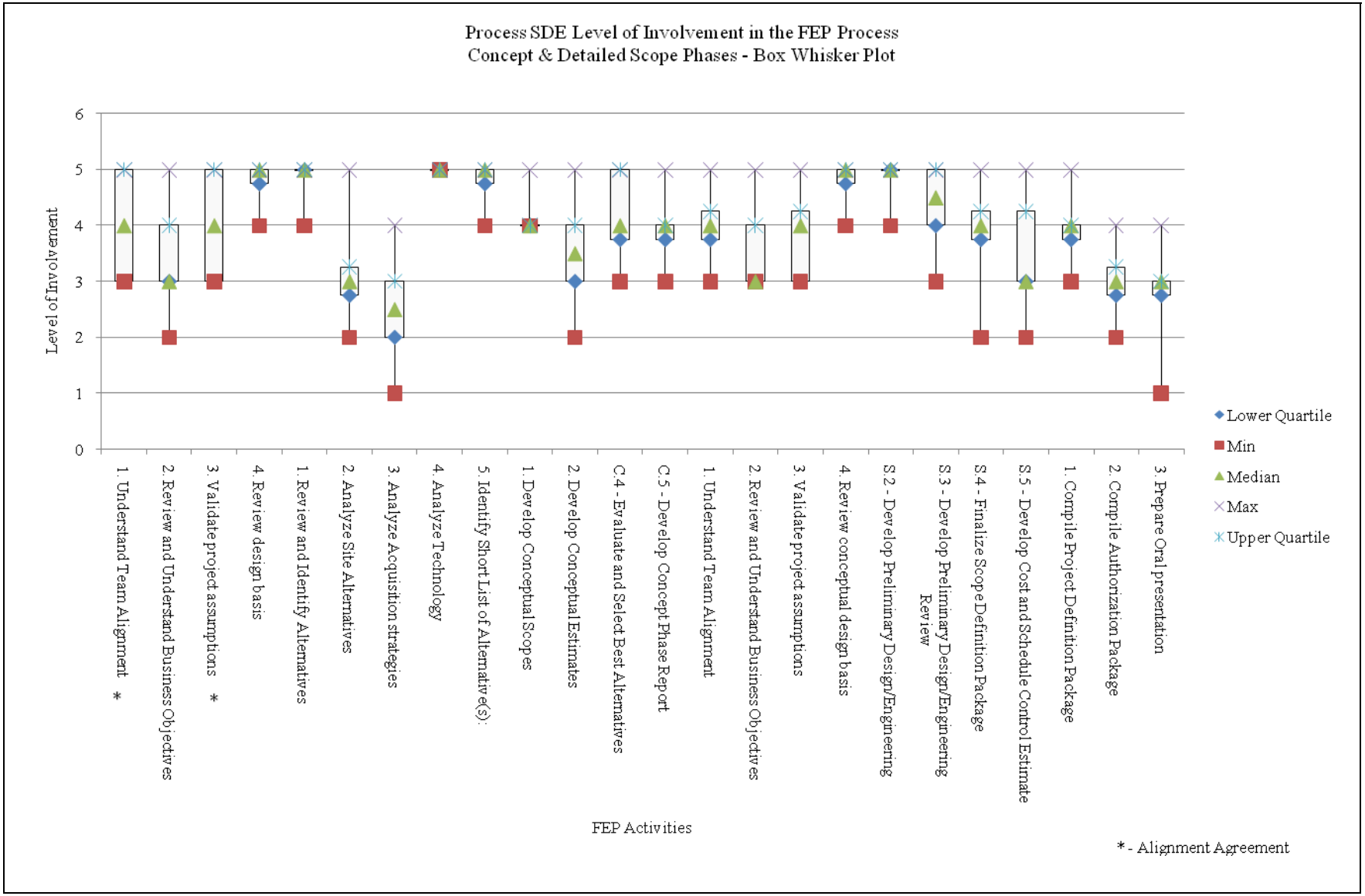


Figure 23. Process SDE Level of Involvement in the FEP Process Concept & Detailed Scope Phases--Box Whisker Plot.

Conclusions

As stated above a matrix outlining the individual SDE disciplines can be found in Tables 15 and 16. The findings in these tables summarize the findings of the 47 respondents who participated in the survey according to discipline and the group. The determinations represented in the matrix reinforced the assumptions made about the SDE taking a more significant level of involvement in the technical driven Front End Planning activities. Moreover, the business driven activities saw the least amount of involvement from the prospective of the SDE. To give more detail for the basis of the evaluations, the following items are available in the Appendices:

- A glossary of terms used within the research can be found in Appendix A.
- The complete central tendency distribution profiles for the group and each individual SDE discipline can be found in Appendix B.
- The complete statistical value data sets for the group as well as the individual SDE discipline can be found in Appendix D.
- The box whisker plots for the group and each individual SDE discipline can be found in Appendix E.
- A complete set of the Relationship Profiles can be found in Appendix G.

Table 15

SDE Level of Involvement Matrix--Feasibility Phase

Category/Statistical Method	Group	ACES	Electrical	I&C	Mechanical	Piping	Process
Feasibility							
F.1 - Initiate Phase							
1. Understand Alignment	Much	Much	Much	Moderate	Much	Moderate	Moderate
2. Understand Business Objectives	Moderate	Much	Moderate	Moderate	Moderate	Moderate	Moderate
3. Understand project assumptions	Much	Very Much	Much	Much	Very Much	Much	Much
4. Generate early design basis and parameters	Very Much	Much	Very Much	Much	Very Much	Moderate	Very Much
F.2 - Generate Options							
1. Generate Assumptions/Drivers	Much	Much	Very Much	Moderate	Much	Much	Much
2. Generate Alternatives for Site(s)	Moderate	Very Much	Much	Moderate	Moderate	Moderate	Much
3. Generate Alternatives for Technology	Much	Moderate	Much	Moderate	Much	Much	Very Much
4. Generate Reliability, Maintainability, and Operability Guidelines	Much	Moderate	Much	Moderate	Much	Much	Much
5. Generate Intellectual Property	Moderate	Moderate	Much	Moderate	Much	Little	Moderate
6. Prepare Initial Feasibility Scope	Much	Much	Much	Much	Much	Much	Much
7. Order of Magnitude (OOM) Estimate/Schedule	Much	Much	Very Much	Much	Much	Very Much	Moderate
F.3 - Filtering Options							
1. Develop Economic Model	Little	Little	Moderate	Little	Little	Little	Moderate
2. Develop Funding Strategies	Little	Little	Moderate	Little	Little	Little	Little
3. Consider Significant Risks	Much	Much	Much	Moderate	Much	Moderate	Much
4. Develop Initial Roles and Permit Analysis	Moderate	Much	Much	Moderate	Moderate	Little	Moderate
5. Develop EHS Considerations	Moderate	Moderate	Much	Moderate	Much	Moderate	Much
6. Develop Go/ No-Go Analysis	Moderate	Much	Moderate	Little	Moderate	Little	Moderate
7. Develop Sensitivity Analysis	Moderate	Moderate	Moderate	Little	Moderate	Little	Much
F.4 - Develop Recommendation Report	Moderate	Moderate	Moderate	Little	Moderate	Much	Much

Table 16

SDE Level of Involvement Matrix--Concept & Detailed Scope Phases

Category/Statistical Method	Group	ACES	Electrical	I&C	Mechanical	Piping	Process
Concept							
C.1 - Initiate Phase							
1. Understand Team Alignment	Much	Very Much	Much	Much	Very Much	Much	Much
2. Review and Understand Business Objectives	Much	Much	Moderate	Moderate	Much	Much	Moderate
3. Validate project assumptions	Much	Very Much	Very Much	Much	Much	Much	Much
4. Review design basis	Very Much	Very Much	Very Much	Much	Very Much	Much	Very Much
C.2 - Analyze Alternatives							
1. Review and Identify Alternatives	Much	Much	Very Much	Much	Much	Much	Very Much
2. Analyze Site Alternatives	Moderate	Very Much	Much	Moderate	Moderate	Much	Moderate
3. Analyze Acquisition strategies	Moderate	Moderate	Much	Moderate	Moderate	Much	Moderate
4. Analyze Technology	Much	Very Much	Much	Much	Much	Much	Very Much
5. Identify Short List of Alternative(s):	Much	Much	Much	Much	Very Much	Much	Very Much
C.3 - Develop Conceptual Scopes and Estimates							
1. Develop Conceptual Scopes	Much	Much	Very Much	Much	Much	Much	Much
2. Develop Conceptual Estimates	Much	Much	Very Much	Much	Much	Much	Moderate
C.4 - Evaluate and Select Best Alternatives	Much	Much	Very Much	Much	Much	Much	Much
C.5 - Develop Concept Phase Report	Much	Moderate	Much	Much	Much	Much	Much
Detailed Scope							
S.1 - Initiate Phase							
1. Understand Team Alignment	Very Much	Very Much	Very Much	Very Much	Very Much	Very Much	Much
2. Review and Understand Business Objectives	Much	Much	Very Much	Much	Much	Very Much	Moderate
3. Validate project assumptions	Very Much	Very Much	Very Much	Very Much	Very Much	Very Much	Much
4. Review conceptual design basis	Very Much	Very Much	Very Much	Very Much	Very Much	Very Much	Very Much
S.2 - Develop Preliminary Design/Engineering	Very Much	Very Much	Very Much	Very Much	Much	Very Much	Very Much
S.3 - Develop Preliminary Design/Engineering Review	Very Much	Very Much	Very Much	Much	Very Much	Very Much	Very Much
S.4 - Develop Finalize Scope Definition Package	Very Much	Very Much	Very Much	Very Much	Much	Very Much	Much
S.5 - Develop Cost and Schedule Control Estimate	Much	Much	Much	Very Much	Very Much	Much	Moderate
S.6 - Compile Project Definition Package							
1. Compile Project Definition Package	Much	Much	Very Much	Much	Much	Much	Much
2. Compile Authorization Package	Moderate	Moderate	Moderate	Much	Moderate	Moderate	Moderate
3. Prepare Oral presentation	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate

CHAPTER 7

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The Front End Planning (FEP) process has been recognized as a “best practice” by the Construction Industry Institute (CII) and therefore implemented into the URS Washington Division framework to achieve project success. However, lack of definition exists pertaining to the Supervising Discipline Engineer’s (SDE) role and alignment in the FEP process. As a result, two questions resulting from the lack definition and alignment were brought forth and answered in this research:

- What is the role of the Supervising Discipline Engineer (SDE) in the Front End Planning (FEP) Process?
- How do the different Supervising Discipline Engineer (SDE) disciplines align in the Front End Planning (FEP) Process?

In order to maintain direction in answering these questions, a set of research objectives was determined. The objectives were derived by the research team based on the need to develop sound conclusions about the SDE’s role in the FEP process. The research objectives were as follows:

- Determine the role and responsibility the Supervising Discipline Engineer, independent of discipline, participates in the Front End Planning Process upon completion of the Module 1: Front End Planning course.

- Determine the role and responsibility of the six individual Supervising Discipline Engineering disciplines and how their discipline aligns with the remaining disciplines. The six individual disciplines include (1) Architectural, Civil, Environmental, and Structural (ACES); (2) Electrical; (3) Instrumentation and Controls (I&C); (4) Mechanical; (5) Piping; and (6) Process.
- Determine the alignment of each individual discipline's role in relation to the general role defined by all disciplines.
- Develop a list of activities within the Front End Planning Process where the group indicated a unique level of involvement: high or low.
- Develop a list of activities within the Front End Planning Process where the individual SDE has a unique level of involvement: high or low.

In order to meet the research objectives, a surveying tool was developed to facilitate the data collection and to determine level of involvement of Supervising Engineering Discipline (SDE) participants' post-formal skills development in the area of Front End Planning. The survey was constructed based on the CII model for the Front End Planning (FEP) process and included the phases of feasibility, concept, and detailed scope. A total of 75 participants were surveyed and a total of 47 surveys were returned, giving a 63% response rate for the research analysis. The participants represented six core engineering disciplines with a range of experience from 4 to 35 years. The six engineering disciplines represented include (1) Architectural, Civil, Environmental, and Structural (ACES); (2) Electrical; (3) Instrumentation and Controls (I&C); (4) Mechanical; (5) Piping; and (6) Process. Furthermore, the surveyed professionals represented five different regional offices within the United States including Birmingham, Alabama; Cleveland, Ohio; Denver, Colorado; Houston, Texas; and Princeton, New Jersey.

The research evaluated the levels of involvement based on the 47 participants' survey responses. The analysis allowed the identification of activities within FEP to be identified where the SDE, independent of discipline, as well as the individual SDE disciplines had *very little*, *little*, *moderate*, *much*, or *very much* involvement. Furthermore, the conclusions based on the data sets facilitated trends that allowed for the role of SDE to be determined through statistical analysis. This analysis met the objectives, through the use of central tendency profile of the mean, median, and mode, and the box whisker plot distributions, by determining

- the role of the SDE in the FEP process independent of discipline.
- the role of the individual SDE discipline in the FEP process.
- a list of FEP activities in respect to the SDE's level of involvement.
- a list of FEP activities in respect to the individual SDE discipline's level of involvement.

To analyze the alignment of the SDE disciplines, the information yielded from the central tendency profile of the mean, median, and mode, and the box whisker plots was used. The group levels of involvement for each activity, independent of discipline, were used as a baseline to compare the individual SDE discipline's levels of involvement. This allowed the remaining objectives set forth by the research to be met and are listed as follows:

- The relationship of the six individual disciplines to the overall SDE data.
- The relationship of the six individual disciplines in relation to one another.

By meeting the objectives, the results give a basis to develop an implementation schedule tool, of the FEP process, to effectively utilize limited SDE resources, based on their level of involvement in regard to the FEP activities. It is recommended that additional research be performed to determine an implementation strategy of the role of the Supervising Discipline

Engineer's role in the Front End Planning Process. Other recommendations include (1) obtain and analyze data with respect to individual markets (i.e., power, oil and gas, consumer products, infrastructure, etc.), (2) obtain and analyze data with respect to geographic region (i.e., domestic, international, regional, etc.), and (3) develop a definition base for each individual SDE discipline to allow better alignment analysis with each activity with the Front End Planning Process.

Based on the results drawn from the levels of involvement and alignment, the research met all objectives set by the research team. Furthermore, the research assumptions were validated by proving that the SDE's focus rests heavily on the technical activities. Additionally, the SDE was found to be less focused on the business aspects of the Front End Planning process. With the activities of high level of involvement, the alignment of the Supervising Discipline Engineer, as with all parties, is important in the Front End Planning process and especially those that are technologically driven. Therefore, by defining the role of the SDE in the FEP process, the research is valuable and contributes to the overall body of knowledge. Given the extent and value of the data found in this research, the research team considered building a quick reference tool that would facilitate a checklist for engineering managers to understand what disciplines take levels of high involvement during the Front End Planning Process. Furthermore, this tool would help facilitate the allocating of SDE resources to more efficiently plan projects for EPC firms.

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APPENDIX A

GLOSSARY OF TERMS

Acquisition Strategy	The contracting strategy for procurement and delivery of consulting, design, equipment, materials, and construction services.
Alignment	The condition where appropriate project participants are working within acceptable tolerances to develop and meet a uniformly defined and understood set of project objectives. These project objectives must meet business requirements and the overall corporate strategy. They are formed in the early stages of project development and have a critical impact on the success of the project delivery process.
Alternatives	Viable options for accomplishing the project objectives.
Alternatives Evaluation	The process to determine risk and assess the relative strengths and weaknesses of each project alternative to facilitate selection of the most favorable option, consistent with project objectives.
Alternative Selection	To determine the best combination of physical, technological, cost, and schedule criteria to use such that the project will meet objectives.
Authorization Package	Document(s) required by the owner, the approval of which will provide funds for the project. Typical requirements include justification for the project, cost of the project, benefits expected from the project, schedule, cash flow, people, material and utility resources, environmental impact, risk analysis with alternates considered, scope of project, and method of project execution.
Barriers	The obstacles to creating and maintaining alignment, or completing the project.
Best Practice	A process or method, which when applied to a project will lead to improved project performance in terms of cost, schedule or quality.
Business Model	The way or ways in which a company generates revenue (and profit).
Business Opportunities	Situations that have the potential to satisfy one or more business objectives.
Business Objectives	The reason or purpose for funding a business venture.

Business Planning	Strategic planning involving the goals and objectives of a business entity.
Charter	A document defining the Pre-Project Planning team, its mission, and its responsibilities, accountability, and authority.
Completed Project	A facility that has no missing or deficient systems or components.
Communication	Two-way effort, involving the transmission of information and understanding from one person or group to another through the use of common symbols.
Concept	The second phase of the front end planning process. It is primarily concerned with defining, evaluating and selecting best alternative(s) for site, technology and acquisition strategy. It is also known as alternative selection, conceptual design, programming, FEL II, etc.
Conceptual Scopes and Estimates	The process of developing and assembling the required information on various alternatives in a format which allows valid comparisons.
Control Guidelines	The method to identify, collect, process, and disseminate that information which is needed to successfully execute the project, including planning and scheduling, cost information, management information systems, change management, etc.
Control Plan	The method to identify, collect, process, and disseminate that information which is needed to successfully execute the project, including planning and scheduling, cost information, management information systems, change management, etc.
Corporate Guidelines for Capital Projects	Guidelines and targets set by the corporation for the construction of capital projects. These may include methods for selecting contractors, types of contracts, relationships with organized labor, methods of exchanging data, percentage of new technology, etc.
Critical Path Method (CPM)	A network analysis scheduling technique used to predict project duration by analyzing which sequences of activities has the least amount of scheduling flexibility.
Culture	The attitudes, values, behavior, and environment of the company and the pre-project planning team.

Decision	A formal determination as to whether or not to provide the resources necessary to proceed with the execution of a project.
Decision Maker	The entity that has the authority to make a decision to commit resources to an undertaking.
Design Parameters	The variables given to develop the Scope of Work and/or Process.
Design Team	Those members of the front end planning team who are specialists in design, including engineers and designers, construction planners, technological consultants, etc.
Detailed Scope	The third phase of the project front end planning process. The primary objectives of this phase are to define the technical scope of the project, further develop project execution plans and develop a definitive cost estimate and schedule suitable for project authorization for detailed design and/or construction. Its primary output is the design basis for the facility. It is also known as schematic design and design development, scope finalization, preliminary engineering, definition phase, FEL III, sanctioning process, Schedule A package, etc.
Economic Model	This model takes in to consideration the entire project life cycle and the time value of money. Typically it uses net present value, internal rate of return or benefit to cost ratio analysis methods.
Execution Approach	The methods that will be used to complete the engineering and design, procurement, construction, and start-up of the project including management of the project. These include identification of project participants, the roles and interrelationships of the participants, contracting strategy, etc.
Execution Processes	Project systems, processes, and procedures.
Existing Technology	Proven methods of producing intermediate or finished products.
Expertise	The aptitudes, qualifications, and experience of people required for pre-project planning.
Feasibility	The first phase of the front end planning process. The primary objectives of this phase are to define business objectives, identify potential alternatives and to outline steps and resources necessary to continue concept phase development. Its primary output is a

	decision whether the potential project is economically and technically feasible for the organization. It is also known as business planning, strategic planning, FEL I, etc.
Front End Loading	see Front End Planning
Front End Planning	The process of developing sufficient strategic information with which owners can address risk and decide to commit resources to maximize the chance for a successful project. This process provides a comprehensive framework for detailed project planning.
Front End Planning Team	Personnel involved in and responsible for front end planning. These personnel may include owners, users, planners, and consultants united in the planning process.
Gate or Phase Gate	A timeline milestone used during planning to insure resources, information and Scope agreement is understood prior to proceeding.
Gate Owner	This person or committee has the ultimate authority to either stop the project or approve continued work.
Index	Measurement based on responses to more than one question or measurement regarding the same general topic.
Information	The data elements, including business objectives, used to define the scope of the project.
Intellectual Property	Defined as a product of the intellect that has commercial value, including copyrighted property such trade names or icons, and ideational property, such as patents, business methods, and industrial processes.
Leadership	The process that provides direction and guidance toward a specific goal or objective. It includes influencing the task objectives and strategies of a group or organization, influencing people in the organization to implement the strategies to achieve the objectives, and influencing the culture of the organization.
Manufacturing Philosophy	A general understanding of the approach to the manufacturing of process.
Make Decision	Process for finalizing whether to provide the resources necessary to

	proceed with the execution of a project.
Objectives	A series of key measurable targets, the fulfillment of which satisfies owner's expectations.
Operate Facility	The use of a facility for its intended purpose.
Organizational Behavior	The study of human behavior in the workplace, the interaction between people and the organization, and the organization itself.
Phase Gate	See Gate
Pre-Project Planning	See Front End Planning
Process Simplification	A disciplined analytical method for reducing capital investment or operating costs by combining or making unnecessary one or more chemical or processing steps.
Product	The output of the facility
Project Definition Package	The detailed formulation of a continuous and systematic strategy to be used during the execution phase of the project to accomplish the project objectives. This package includes sufficient supplemental information to permit effective and efficient detailed engineering to proceed.
Project Definition Rating Index (PDRI)	A tool designed to measure project scope definition for completeness. It is a comprehensive, weighted checklist of scope definition elements.
Project Driver	The reason or justification for the project.
Project Execution	To perform the detailed engineering, procurement and construction, and start-up for a facility (after phase gate 3).
Project Execution Plan or Approach	Documents used to define basis of estimate, basis of schedule, WBS, plans for engineering, procurement and construction, owner/client objectives, etc.
Project Initiator	The originator of the idea or concept.
Project Life Cycle	The duration from Project initiation through Customer acceptance.

Project Objectives	A series of key measurable targets, the fulfillment of which satisfy owner's expectations and leads to project success.
Project Planning Tools	Tools such as software programs, checklists, and aide-memoirs that are typically used to develop and manage projects.
Required Features	Characteristic of the project that define the project quality in the sense of the features incorporated into the project. Issues related to required features include redundancy, operability, durability, and tolerances.
Reward and Recognition System	Processes that provide special recognition and rewards to individuals and/or teams as they accomplish predetermined project goals, milestones, and objectives.
Risk Assessment	The results of identifying and assessing risks associated with the project and of proactively seeking to minimize their impact on its success.
Schedule Milestones	Major events on the Project timeline identified to track progress.
Security	All measures taken to guard against malevolent, intentional acts, both internal and external (e.g., sabotage, crime, and attack), that result in adverse impacts such as project cost growth, schedule extension, operability degradation, safety concerns, transportation delays, emergency responses, and off-site effects (consequences).
Sensitivity Analysis	Varying key project drivers such as market forecast, cost of capital, construction cost estimate, or operations and maintenance cost versus the nominal estimates for each, in order to determine which have the most affect on the project business outcome.
Site Characteristics	Aspects of a location that make it more or less suitable for a project.
Site(s) Evaluation	To assess the relative strengths and weaknesses of alternative locations to meet owner requirements.
Site Objectives	Attributes of a site which have been defined to be desirable.
Space Plan	An organized layout or chart developed to depict areas within the building for their various uses.

Sponsor(s)	Individuals at higher levels in the owner organization than the project team who have or share responsibility for the success or failure of the project. Typically these individuals would include business unit managers, operations managers, or the manager of engineering and construction.
Staffing	Process of identifying, recruiting, and selecting individuals to become members of the pre-project planning team.
Stakeholders	Individuals and organizations that are involved in or may be affected by project activities.
Sustainability	Sustainable design recognizes that products and processes are interdependent with the environmental, economic, and social systems surrounding them and implements measures to prevent an unsustainable compromise to these systems.
Supervising Discipline Engineer (SDE)	
Team	Personnel involved in and responsible for pre-project planning. These personnel may include owners, users, planners and consultants united for a common cause. A group which shares a common mission or a reason for working together, is interdependent in effectively achieving shared goals, shares a commitment to working together toward identifying and solving problems and is accountable as a functioning unit within a larger inter-organization context.
Team Building	A project-focused process that brings together key stakeholders in the project outcome….It seeks to resolve differences, remove roadblocks, and build and develop trust and commitment, a common mission statement, shared goals, interdependence, accountability among team members and problem solving skills.
Team Skills	The competence of the team members to perform the pre-project planning tasks. This competence may be required in such areas a technological know-how, communication ability, interpersonal skills, legal and regulatory matters, economic and financial

	modeling, etc.
Teamwork	The condition where individuals are functioning in concert to achieve a common objective and coordinating individual tasks to achieve those objectives all in an atmosphere where the individuals participating enjoy the experience and produce high quality results.
Technology Objectives	The goals of the owner in using technology to produce product, especially the use of new versus proven technology.
Technology(ies) Selection	The technology(ies) recommended as providing the greatest opportunity to meet the owner objectives.
Technology Team	Those members of the pre-project planning team and others having expertise in technological matters.
Time	The available duration.
User Survey	Questionnaire given to the customer to capture and prioritize needs.
Vulnerability assessment	Evaluation of the susceptibility of a facility to intentional injury or attack including both internal and external events (e.g., sabotage, crime, and attack), that result in adverse impacts.
Value Management	A style of management particularly dedicated to motivating people, developing skills and promoting synergies and innovation, with the aim of maximizing the overall performance of an organization.
Value Management Practices	Practices that, when used consistently and effectively, significantly increase the value of the project.

(Source: Implementation Resource 213-2, Front End Planning Toolkit)

APPENDIX B

CENTRAL TENDENCY DISTRIBUTION PROFILES

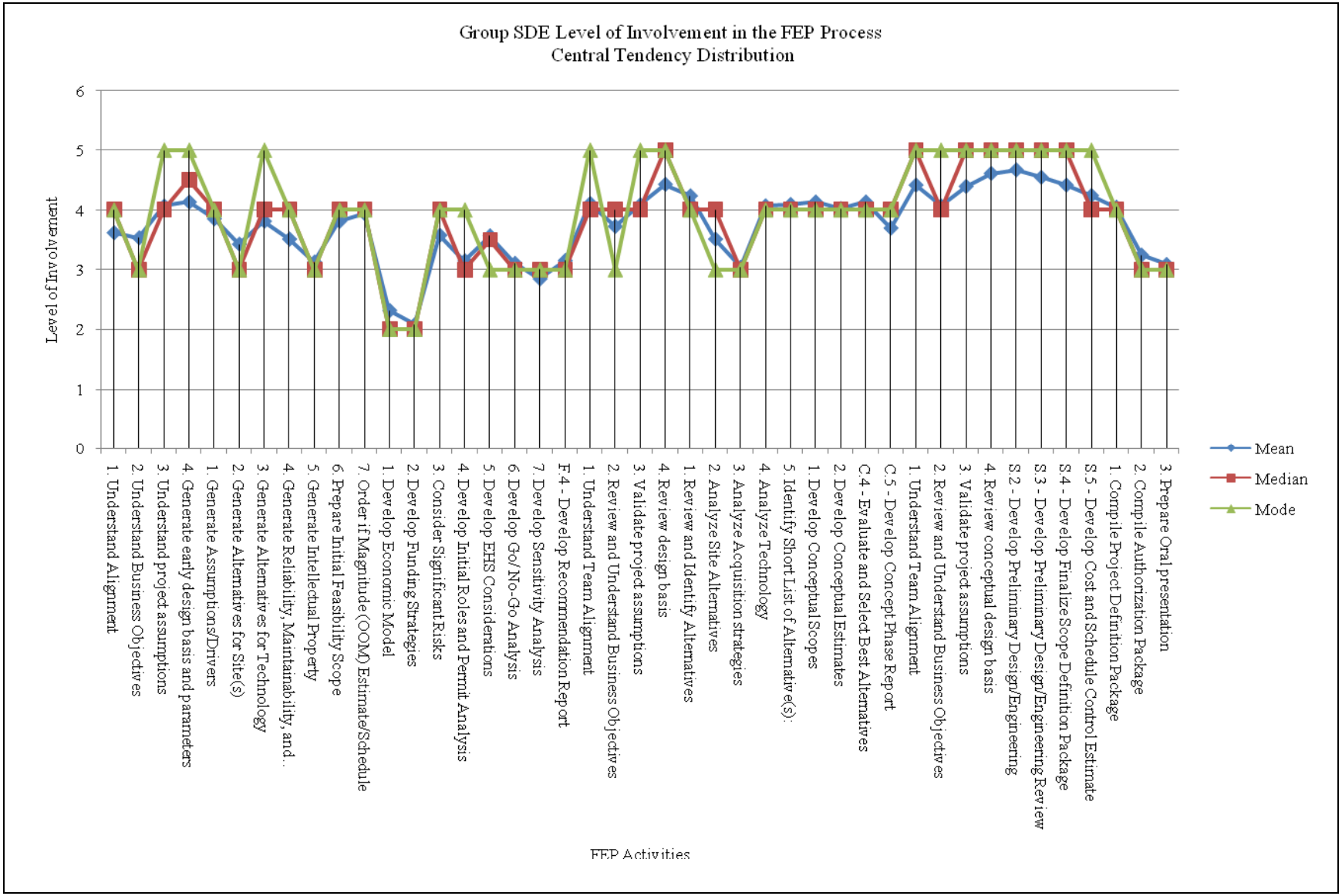


Figure B.1 - Central Tendency Distribution of the Group

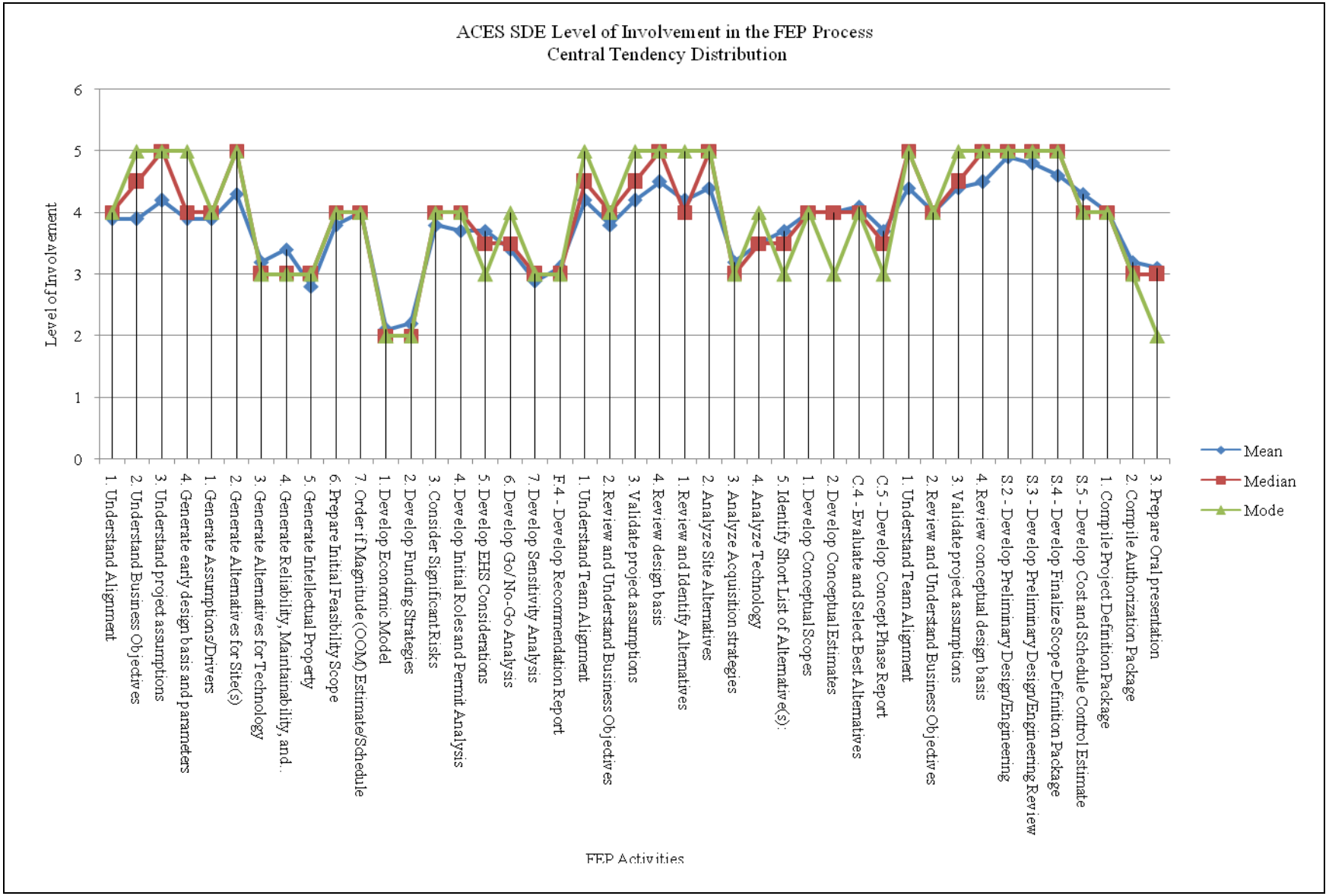


Figure B.2 - Central Tendency Distribution of the ACES SDE

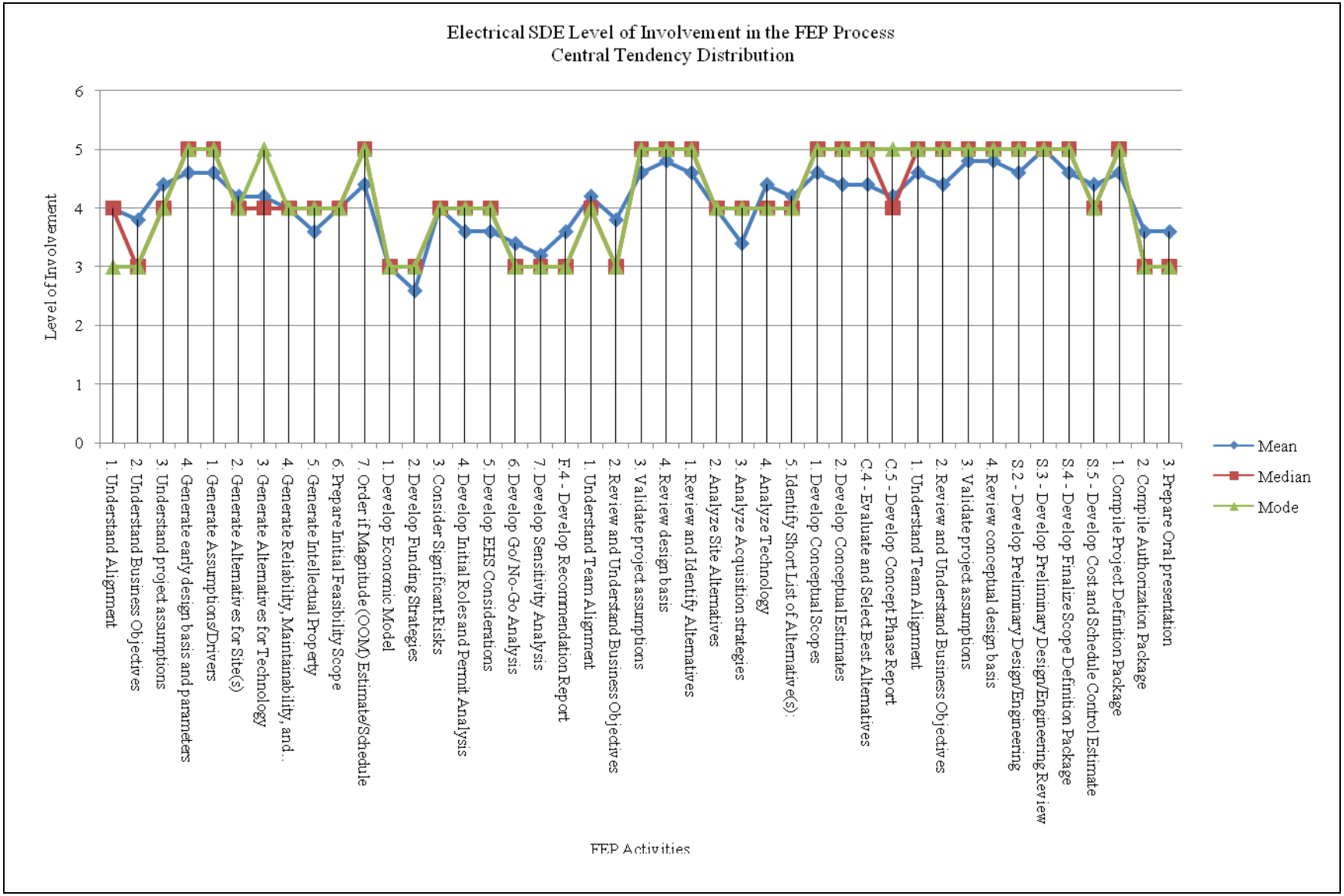


Figure B.3 - Central Tendency Distribution of the Electrical SDE

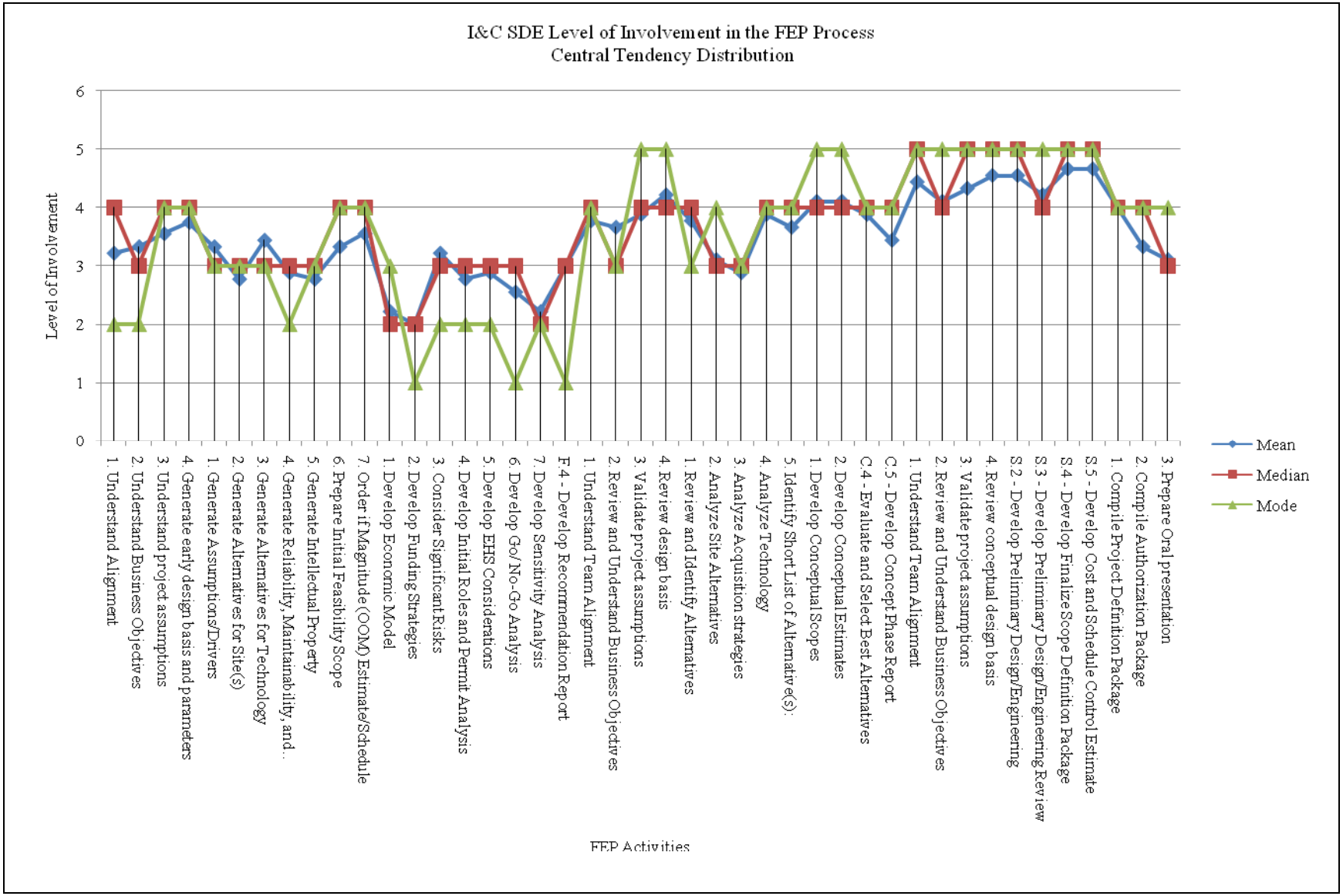


Figure B.4 – Central Tendency Distribution of the I&C SDE

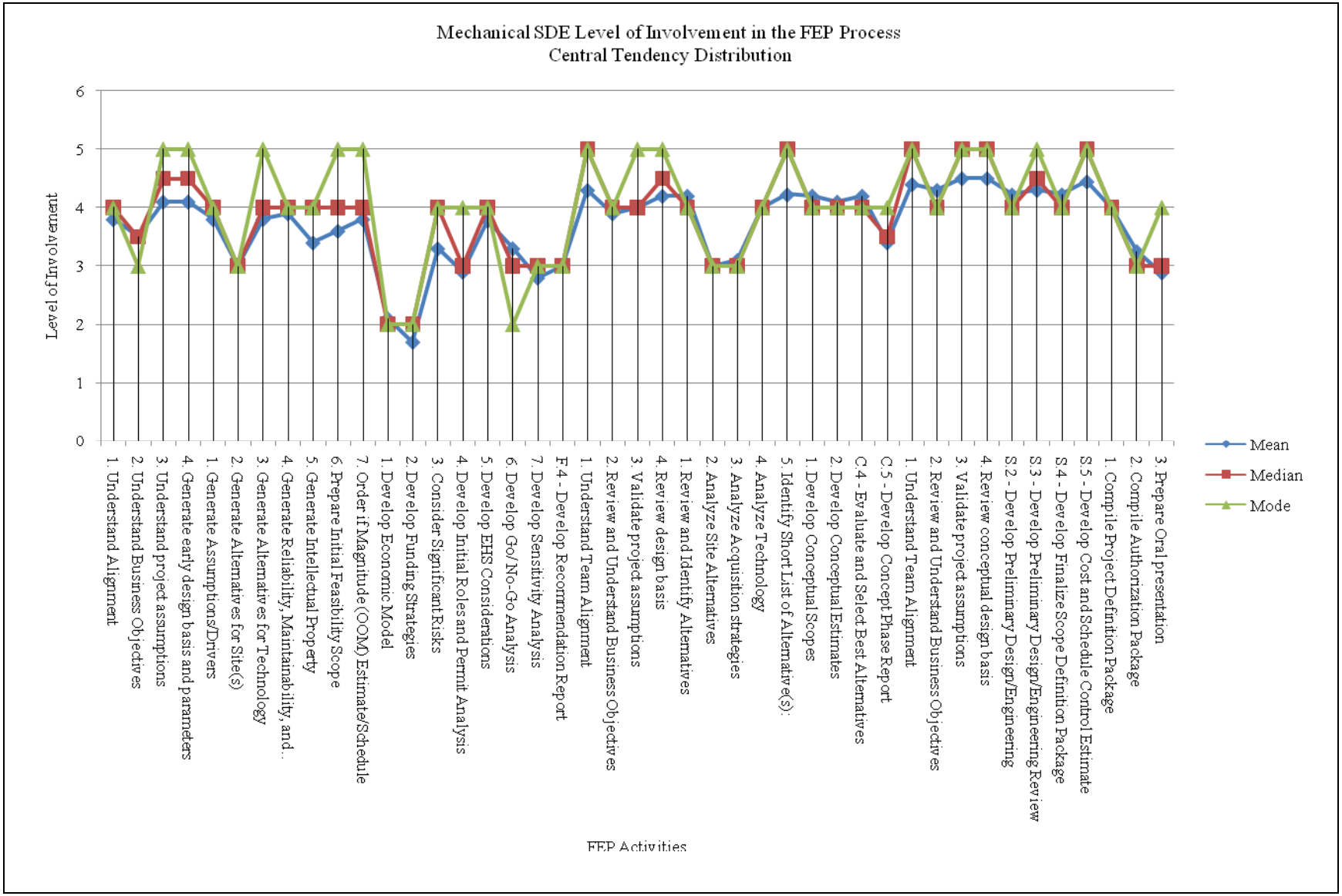


Figure B.5 – Central Tendency Distribution of the Mechanical SDE

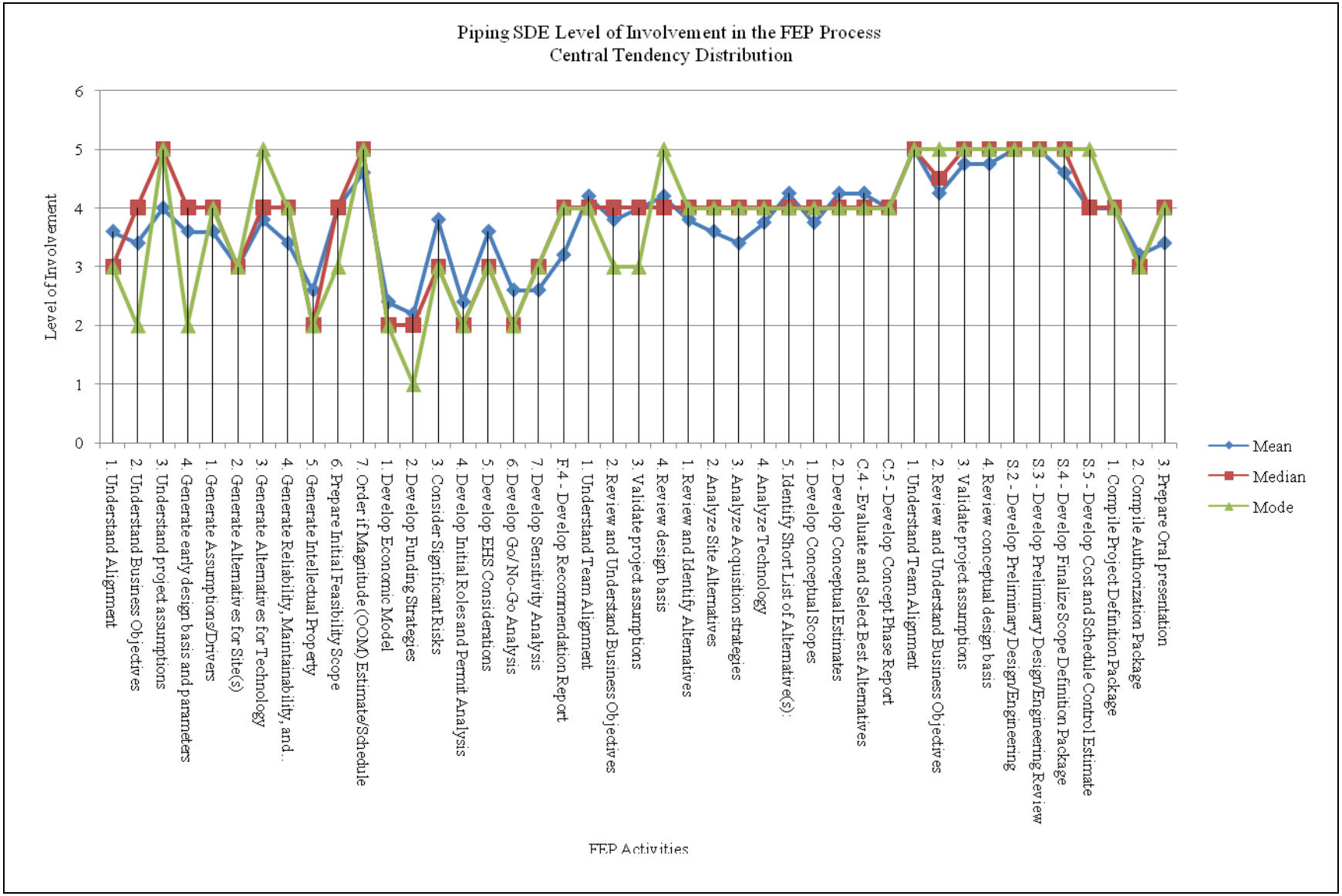


Figure B.6 - Central Tendency Distribution of the Piping SDE

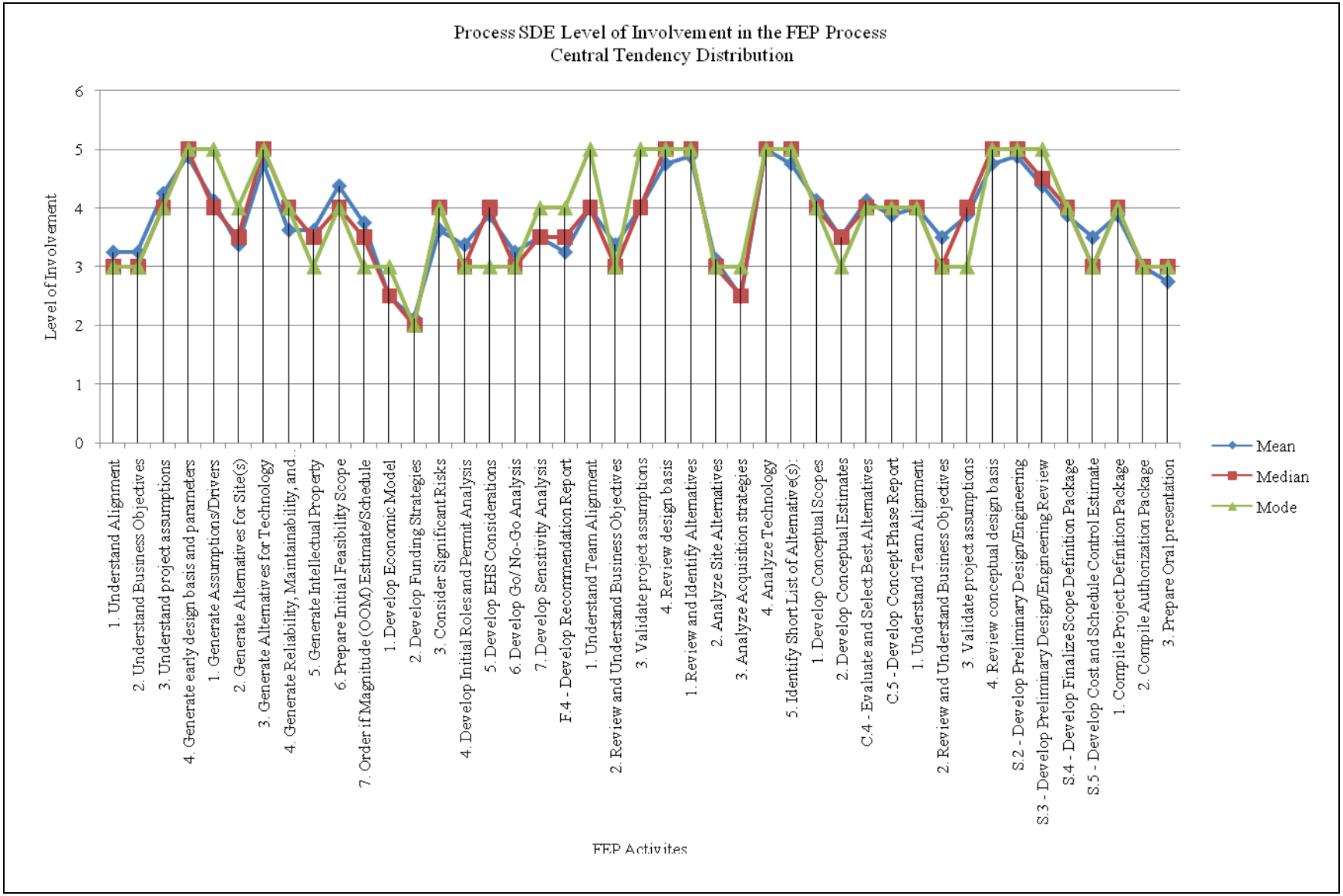


Figure B.7 - Central Tendency Distribution of the Process SDE

APPENDIX C

SDE DEVELOPMENT PROGRAM--FRONT END PLANNING: MODULE 1 SURVEY QUESTIONNAIRE

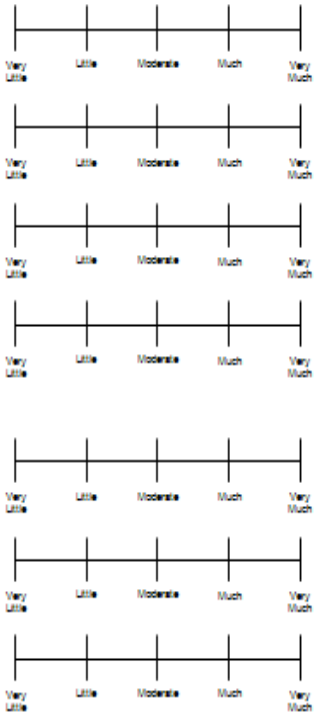
Feasibility:

F.1 – Initiate Phase

1. Alignment
2. Understand Business Objectives
3. Understand project assumptions
4. Generate early design basis and parameters

F.2 – Generate Options

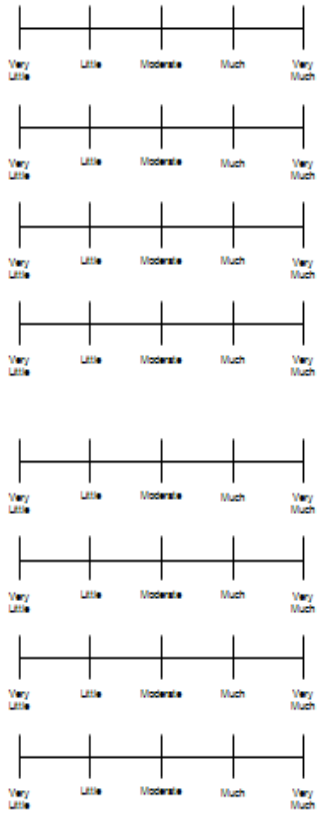
1. Assumptions/Drivers
2. Alternatives for Site(s)
3. Alternatives for Technology



4. Reliability, Maintainability and Operability Guidelines
5. Intellectual Property
6. Prepare Initial Feasibility Scope
7. Order of Magnitude (OOM) Estimate/Schedule

F.3 – Filtering Options

1. Economic Model
2. Funding Strategies
3. Consider Significant Risks
4. Initial Roles and Permit Analysis



5. EHS Considerations

6. Go/No-Go Analysis

7. Sensitivity Analysis

F.4 – Recommendation Report

Prepare a two-part report including a written recommendation and an oral presentation to be given to the decision makers.

Concept:

C.1 – Initiate Phase

1. Team Alignment

2. Review and Understand Business Objectives

3. Validate project assumptions

4. Review design basis

C.2 – Analyze Alternatives

1. Review and Identify Alternatives

2. Site

3. Acquisition strategies

4. Technology

5. Identify Short List of Alternative(s):

C.3 – Develop Conceptual Scopes and Estimates

1. Conceptual Scopes

2. Conceptual Estimates

C.4 – Evaluate and Select Best Alternatives

Evaluating and selecting best alternatives draws information from prior efforts of technology selection, site evaluation, and conceptual scopes.

C.5 – Concept Phase Report

Prepare a two-part recommendation including a written report and an oral presentation.

Detailed Scope:

S.1 – Initiate Phase

1. Team Alignment

2. Review and Understand Business Objectives

3. Validate project assumptions

4. Review conceptual design basis

S.2 – Preliminary Design/Engineering

Developing the preliminary design/engineering for the project is the primary activity of the Detailed Scope phase.

S.3 – Preliminary Design/Engineering Reviews

A review should be conducted to ensure that the development process is on track.

S.4 – Finalize Scope Definition Package

It may be necessary at this point to modify and adjust the scope based on this assessment.

S.5 – Cost and Schedule Control Estimate

With the detailed scope package finalized, estimates of both the cost and schedule for the project can be developed to the desired level of accuracy.

S.6 – Compile Project Definition Package

1. Project Definition Package.

2. Authorization Package.

3. Oral presentation.

APPENDIX D

INDIVIDUAL DISCIPLINE ALIGNMENT TABLE(S) OF STATISTICAL VALUES

Table D.1 - Group Statistical Value

Group Statistical Values								
Category/Statistical Method	Mean	Median	Mode	Std. Dev.	Lower Quartile	Min	Max	Upper Quartile
Feasibility								
F.1 - Initiate Phase								
1. Understand Alignment	3.62	4	4	1.15	3	1	5	4
2. Understand Business Objectives	3.53	3	3	1.18	3	1	5	5
3. Understand project assumptions	4.06	4	5	1.11	4	1	5	5
4. Generate early design basis and parameters	4.13	4.5	5	1.13	4	1	5	5
F.2 - Generate Options								
1. Generate Assumptions/Drivers	3.85	4	4	1.02	3	2	5	5
2. Generate Alternatives for Site(s)	3.43	3	3	1.19	3	1	5	4.5
3. Generate Alternatives for Technology	3.81	4	5	1.12	3	2	5	5
4. Generate Reliability, Maintainability, and Operability Guidelines	3.51	4	4	1.02	3	1	5	4
5. Generate Intellectual Property	3.13	3	3	1.12	2	1	5	4
6. Prepare Initial Feasibility Scope	3.81	4	4	1.06	3	1	5	5
7. Order of Magnitude (OOM) Estimate/Schedule	3.94	4	4	1.03	3	1	5	5
F.3 - Filtering Options								
1. Develop Economic Model	2.32	2	2	0.89	2	1	4	3
2. Develop Funding Strategies	2.09	2	2	0.80	2	1	4	3
3. Consider Significant Risks	3.57	4	4	1.08	3	1	5	4
4. Develop Initial Roles and Permit Analysis	3.15	3	4	1.10	2	1	5	4
5. Develop EHS Considerations	3.57	3.5	3	0.96	3	2	5	4
6. Develop Go/ No-Go Analysis	3.11	3	3	1.11	2	1	5	4
7. Develop Sensitivity Analysis	2.85	3	3	1.09	2	1	5	3.75
F.4 - Develop Recommendation Report	3.15	3	3	1.13	3	1	5	4
Concept								
C.1 - Initiate Phase								
1. Understand Team Alignment	4.11	4	5	0.94	3.5	2	5	5
2. Review and Understand Business Objectives	3.72	4	3	0.99	3	2	5	5
3. Validate project assumptions	4.09	4	5	0.95	3	2	5	5
4. Review design basis	4.43	5	5	0.83	4	2	5	5
C.2 - Analyze Alternatives								
1. Review and Identify Alternatives	4.23	4	4	0.73	4	3	5	5
2. Analyze Site Alternatives	3.51	4	3	1.20	3	1	5	4.5
3. Analyze Acquisition strategies	3.04	3	3	0.95	2.5	1	5	4
4. Analyze Technology	4.07	4	4	0.81	4	2	5	5
5. Identify Short List of Alternative(s):	4.09	4	4	0.79	4	2	5	5
C.3 - Develop Conceptual Scopes and Estimates								
1. Develop Conceptual Scopes	4.13	4	4	0.72	4	2	5	5
2. Develop Conceptual Estimates	4.02	4	4	0.86	3.25	2	5	5
C.4 - Evaluate and Select Best Alternatives	4.13	4	4	0.78	4	2	5	5
C.5 - Develop Concept Phase Report	3.70	4	4	0.99	3	1	5	4
Detailed Scope								
S.1 - Initiate Phase								
1. Understand Team Alignment	4.41	5	5	0.80	4	2	5	5
2. Review and Understand Business Objectives	4.07	4	5	0.83	3	3	5	5
3. Validate project assumptions	4.39	5	5	0.74	4	3	5	5
4. Review conceptual design basis	4.61	5	5	0.61	4	3	5	5
S.2 - Develop Preliminary Design/Engineering	4.67	5	5	0.56	4	3	5	5
S.3 - Develop Preliminary Design/Engineering Review	4.54	5	5	0.69	4	3	5	5
S.4 - Develop Finalize Scope Definition Package	4.41	5	5	0.75	4	2	5	5
S.5 - Develop Cost and Schedule Control Estimate	4.24	4	5	0.82	4	2	5	5
S.6 - Compile Project Definition Package								
1. Compile Project Definition Package	4.04	4	4	0.73	4	2	5	4.75
2. Compile Authorization Package	3.24	3	3	0.83	3	2	5	4
3. Prepare Oral presentation	3.09	3	3	1.09	2	1	5	4

Table D.2 - ACES SDE Statistical Values

ACES Statistical Values								
Category/Statistical Method	Mean	Median	Mode	Std. Dev.	Lower Quartile	Min	Max	Upper Quartile
Feasibility								
F.1 - Initiate Phase								
1. Understand Alignment	3.90	4	4	1.20	4	1	5	4.75
2. Understand Business Objectives	3.90	4.5	5	1.45	3.25	1	5	5
3. Understand project assumptions	4.20	5	5	1.40	3.5	1	5	5
4. Generate early design basis and parameters	3.90	4	5	1.29	3.25	1	5	5
F.2 - Generate Options								
1. Generate Assumptions/Drivers	3.90	4	4	0.99	3.25	2	5	4.75
2. Generate Alternatives for Site(s)	4.30	5	5	1.06	4	2	5	5
3. Generate Alternatives for Technology	3.20	3	3	1.14	2.25	2	5	3.75
4. Generate Reliability, Maintainability, and Operability Guidelines	3.40	3	3	0.84	3	2	5	4
5. Generate Intellectual Property	2.80	3	3	1.14	2	1	5	3
6. Prepare Initial Feasibility Scope	3.80	4	4	0.92	3.25	2	5	4
7. Order of Magnitude (OOM) Estimate/Schedule	4.00	4	4	1.15	4	1	5	4.75
F.3 - Filtering Options								
1. Develop Economic Model	2.10	2	2	0.99	1.25	1	4	2.75
2. Develop Funding Strategies	2.20	2	2	0.92	2	1	4	2.75
3. Consider Significant Risks	3.80	4	4	0.79	4	2	5	4
4. Develop Initial Roles and Permit Analysis	3.70	4	4	0.82	3.25	2	5	4
5. Develop EHS Considerations	3.70	3.5	3	1.06	3	2	5	4.75
6. Develop Go/ No-Go Analysis	3.40	3.5	4	0.97	3	2	5	4
7. Develop Sensitivity Analysis	2.89	3	3	1.36	2	1	5	4
F.4 - Develop Recommendation Report	3.11	3	3	1.17	3	1	5	4
Concept								
C.1 - Initiate Phase								
1. Understand Team Alignment	4.20	4.5	5	1.03	4	2	5	5
2. Review and Understand Business Objectives	3.80	4	4	1.14	3.25	2	5	4.75
3. Validate project assumptions	4.20	4.5	5	1.03	4	2	5	5
4. Review design basis	4.50	5	5	0.97	4.25	2	5	5
C.2 - Analyze Alternatives								
1. Review and Identify Alternatives	4.20	4	5	0.79	4	3	5	5
2. Analyze Site Alternatives	4.40	5	5	0.84	4	3	5	5
3. Analyze Acquisition strategies	3.20	3	3	1.03	3	1	5	3.75
4. Analyze Technology	3.50	3.5	4	0.85	3	2	5	4
5. Identify Short List of Alternative(s):	3.70	3.5	3	0.82	3	3	5	4
C.3 - Develop Conceptual Scopes and Estimates								
1. Develop Conceptual Scopes	4.00	4	4	0.82	3.25	3	5	4.75
2. Develop Conceptual Estimates	4.00	4	3	0.94	3	3	5	5
C.4 - Evaluate and Select Best Alternatives	4.10	4	4	0.74	4	3	5	4.75
C.5 - Develop Concept Phase Report	3.70	3.5	3	1.06	3	2	5	4.75
Detailed Scope								
S.1 - Initiate Phase								
1. Understand Team Alignment	4.40	5	5	0.97	4	2	5	5
2. Review and Understand Business Objectives	4.00	4	4	0.82	3.25	3	5	4.75
3. Validate project assumptions	4.40	4.5	5	0.70	4	3	5	5
4. Review conceptual design basis	4.50	5	5	0.71	4	3	5	5
S.2 - Develop Preliminary Design/Engineering	4.90	5	5	0.32	5	4	5	5
S.3 - Develop Preliminary Design/Engineering Review	4.80	5	5	0.42	5	4	5	5
S.4 - Develop Finalize Scope Definition Package	4.60	5	5	0.52	4	4	5	5
S.5 - Develop Cost and Schedule Control Estimate	4.30	4	4	0.67	4	3	5	5
S.6 - Compile Project Definition Package								
1. Compile Project Definition Package	4.00	4	4	0.67	4	3	5	4
2. Compile Authorization Package	3.20	3	3	0.92	3	2	5	3.75
3. Prepare Oral presentation	3.10	3	2	1.37	2	1	5	4

Table D.3 - Electrical SDE Statistical Values

Electrical Statistical Values								
Category/Statistical Method	Mean	Median	Mode	Std. Dev.	Lower Quartile	Min	Max	Upper Quartile
Feasibility								
F.1 - Initiate Phase								
1. Understand Alignment	4	4	3	1.00	3	3	5	5
2. Understand Business Objectives	3.8	3	3	1.10	3	3	5	5
3. Understand project assumptions	4.4	4	4	0.55	4	4	5	5
4. Generate early design basis and parameters	4.6	5	5	0.55	4	4	5	5
F.2 - Generate Options								
1. Generate Assumptions/Drivers	4.6	5	5	0.55	4	4	5	5
2. Generate Alternatives for Site(s)	4.2	4	4	0.84	4	3	5	5
3. Generate Alternatives for Technology	4.2	4	5	0.84	4	3	5	5
4. Generate Reliability, Maintainability, and Operability Guidelines	4	4	4	0.71	4	3	5	4
5. Generate Intellectual Property	3.6	4	4	0.55	3	3	4	4
6. Prepare Initial Feasibility Scope	4	4	4	0.71	4	3	5	4
7. Order of Magnitude (OOM) Estimate/Schedule	4.4	5	5	0.89	4	3	5	5
F.3 - Filtering Options								
1. Develop Economic Model	3	3	3	0.71	3	2	4	3
2. Develop Funding Strategies	2.6	3	3	0.55	2	2	3	3
3. Consider Significant Risks	4	4	4	0.71	4	3	5	4
4. Develop Initial Roles and Permit Analysis	3.6	4	4	0.89	4	2	4	4
5. Develop EHS Considerations	3.6	4	4	0.55	3	3	4	4
6. Develop Go/ No-Go Analysis	3.4	3	3	1.14	3	2	5	4
7. Develop Sensitivity Analysis	3.2	3	3	1.10	3	2	5	3
F.4 - Develop Recommendation Report	3.6	3	3	0.89	3	3	5	4
Concept								
C.1 - Initiate Phase								
1. Understand Team Alignment	4.2	4	4	0.84	4	3	5	5
2. Review and Understand Business Objectives	3.8	3	3	1.10	3	3	5	5
3. Validate project assumptions	4.6	5	5	0.55	4	4	5	5
4. Review design basis	4.8	5	5	0.45	5	4	5	5
C.2 - Analyze Alternatives								
1. Review and Identify Alternatives	4.6	5	5	0.55	4	4	5	5
2. Analyze Site Alternatives	4	4	4	0.71	4	3	5	4
3. Analyze Acquisition strategies	3.4	4	4	0.89	3	2	4	4
4. Analyze Technology	4.4	4	4	0.55	4	4	5	5
5. Identify Short List of Alternative(s):	4.2	4	4	0.45	4	4	5	4
C.3 - Develop Conceptual Scopes and Estimates								
1. Develop Conceptual Scopes	4.6	5	5	0.55	4	4	5	5
2. Develop Conceptual Estimates	4.4	5	5	0.89	4	3	5	5
C.4 - Evaluate and Select Best Alternatives	4.4	5	5	0.89	4	3	5	5
C.5 - Develop Concept Phase Report	4.2	4	5	0.84	4	3	5	5
Detailed Scope								
S.1 - Initiate Phase								
1. Understand Team Alignment	4.6	5	5	0.55	4	4	5	5
2. Review and Understand Business Objectives	4.4	5	5	0.89	4	3	5	5
3. Validate project assumptions	4.8	5	5	0.45	5	4	5	5
4. Review conceptual design basis	4.8	5	5	0.45	5	4	5	5
S.2 - Develop Preliminary Design/Engineering	4.6	5	5	0.89	5	3	5	5
S.3 - Develop Preliminary Design/Engineering Review	5	5	5	0.00	5	5	5	5
S.4 - Develop Finalize Scope Definition Package	4.6	5	5	0.55	4	4	5	5
S.5 - Develop Cost and Schedule Control Estimate	4.4	4	4	0.55	4	4	5	5
S.6 - Compile Project Definition Package								
1. Compile Project Definition Package	4.6	5	5	0.55	4	4	5	5
2. Compile Authorization Package	3.6	3	3	0.89	3	3	5	4
3. Prepare Oral presentation	3.6	3	3	0.89	3	3	5	4

Table D.4 - I&C SDE Statistical Values

I&C Statistical Analysis								
Category/Statistical Method	Mean	Median	Mode	Std. Dev.	Lower Quartile	Min	Max	Upper Quartile
Feasibility								
F.1 - Initiate Phase								
1. Understand Alignment	3.22	4	2	1.48	2	1	5	4
2. Understand Business Objectives	3.33	3	2	1.32	2	2	5	5
3. Understand project assumptions	3.56	4	4	1.13	3	2	5	4
4. Generate early design basis and parameters	3.75	4	4	1.04	3	2	5	4.25
F.2 - Generate Options								
1. Generate Assumptions/Drivers	3.33	3	3	1.12	3	2	5	4
2. Generate Alternatives for Site(s)	2.78	3	3	0.97	2	1	4	3
3. Generate Alternatives for Technology	3.44	3	3	0.88	3	2	5	4
4. Generate Reliability, Maintainability, and Operability Guidelines	2.89	3	2	1.27	2	1	5	4
5. Generate Intellectual Property	2.78	3	3	0.97	2	1	4	3
6. Prepare Initial Feasibility Scope	3.33	4	4	1.12	2	2	5	4
7. Order of Magnitude (OOM) Estimate/Schedule	3.56	4	4	0.88	3	2	5	4
F.3 - Filtering Options								
1. Develop Economic Model	2.22	2	3	0.83	2	1	3	3
2. Develop Funding Strategies	2.00	2	1	0.87	1	1	3	3
3. Consider Significant Risks	3.22	3	2	1.09	2	2	5	4
4. Develop Initial Roles and Permit Analysis	2.78	3	2	1.20	2	1	5	3
5. Develop EHS Considerations	2.89	3	2	1.05	2	2	5	3
6. Develop Go/ No-Go Analysis	2.56	3	1	1.42	1	1	5	3
7. Develop Sensitivity Analysis	2.22	2	2	0.97	2	1	4	3
F.4 - Develop Recommendation Report	3.00	3	1	1.58	2	1	5	4
Concept								
C.1 - Initiate Phase								
1. Understand Team Alignment	3.78	4	4	0.97	3	2	5	4
2. Review and Understand Business Objectives	3.67	3	3	1.12	3	2	5	5
3. Validate project assumptions	3.89	4	5	1.05	3	2	5	5
4. Review design basis	4.22	4	5	0.83	4	3	5	5
C.2 - Analyze Alternatives								
1. Review and Identify Alternatives	3.78	4	3	0.83	3	3	5	4
2. Analyze Site Alternatives	3.11	3	4	1.27	2	1	5	4
3. Analyze Acquisition strategies	2.89	3	3	0.78	2	2	4	3
4. Analyze Technology	3.89	4	4	0.33	4	3	4	4
5. Identify Short List of Alternative(s):	3.67	4	4	0.71	4	2	4	4
C.3 - Develop Conceptual Scopes and Estimates								
1. Develop Conceptual Scopes	4.11	4	5	1.05	4	2	5	5
2. Develop Conceptual Estimates	4.11	4	5	1.05	4	2	5	5
C.4 - Evaluate and Select Best Alternatives	3.89	4	4	0.93	4	2	5	4
C.5 - Develop Concept Phase Report	3.44	4	4	1.01	3	2	5	4
Detailed Scope								
S.1 - Initiate Phase								
1. Understand Team Alignment	4.44	5	5	0.73	4	3	5	5
2. Review and Understand Business Objectives	4.11	4	5	0.93	3	3	5	5
3. Validate project assumptions	4.33	5	5	0.87	4	3	5	5
4. Review conceptual design basis	4.56	5	5	0.73	4	3	5	5
S.2 - Develop Preliminary Design/Engineering	4.56	5	5	0.53	4	4	5	5
S.3 - Develop Preliminary Design/Engineering Review	4.22	4	5	0.83	4	3	5	5
S.4 - Develop Finalize Scope Definition Package	4.67	5	5	0.50	4	4	5	5
S.5 - Develop Cost and Schedule Control Estimate	4.67	5	5	0.50	4	4	5	5
S.6 - Compile Project Definition Package								
1. Compile Project Definition Package	4.00	4	4	1.00	4	2	5	5
2. Compile Authorization Package	3.33	4	4	1.12	2	2	5	4
3. Prepare Oral presentation	3.11	3	4	1.27	2	1	5	4

Table D.5 - Mechanical SDE Statistical Values

Mechanical Statistical Values								
Category/Statistical Method	Mean	Median	Mode	Std. Dev.	Lower Quartile	Min	Max	Upper Quartile
Feasibility								
F.1 - Initiate Phase								
1. Understand Alignment	3.80	4	4	1.32	4	1	5	4.75
2. Understand Business Objectives	3.50	3.5	3	1.18	3	1	5	4
3. Understand project assumptions	4.10	4.5	5	1.29	4	1	5	5
4. Generate early design basis and parameters	4.10	4.5	5	1.29	4	1	5	5
F.2 - Generate Options								
1. Generate Assumptions/Drivers	3.80	4	4	1.14	3.25	2	5	4.75
2. Generate Alternatives for Site(s)	3.00	3	3	1.25	2.25	1	5	3
3. Generate Alternatives for Technology	3.80	4	5	1.32	3	2	5	5
4. Generate Reliability, Maintainability, and Operability Guidelines	3.90	4	4	0.99	3.25	2	5	4.75
5. Generate Intellectual Property	3.40	4	4	1.58	2.25	1	5	4.75
6. Prepare Initial Feasibility Scope	3.60	4	5	1.51	2.25	1	5	5
7. Order of Magnitude (OOM) Estimate/Schedule	3.80	4	5	1.32	3	1	5	5
F.3 - Filtering Options								
1. Develop Economic Model	2.10	2	2	0.99	1.25	1	4	2.75
2. Develop Funding Strategies	1.70	2	2	0.48	1.25	1	2	2
3. Consider Significant Risks	3.30	4	4	1.64	2	1	5	4.75
4. Develop Initial Roles and Permit Analysis	2.90	3	4	1.37	2	1	5	4
5. Develop EHS Considerations	3.78	4	4	0.97	3	2	5	4
6. Develop Go/ No-Go Analysis	3.30	3	2	1.16	2.25	2	5	4
7. Develop Sensitivity Analysis	2.80	3	3	1.14	2	1	5	3
F.4 - Develop Recommendation Report	3.00	3	3	1.05	3	1	5	3
Concept								
C.1 - Initiate Phase								
1. Understand Team Alignment	4.30	5	5	1.06	4	2	5	5
2. Review and Understand Business Objectives	3.90	4	4	0.99	3.25	2	5	4.75
3. Validate project assumptions	4.00	4	5	1.05	3.25	2	5	5
4. Review design basis	4.20	4.5	5	1.03	4	2	5	5
C.2 - Analyze Alternatives								
1. Review and Identify Alternatives	4.20	4	4	0.63	4	3	5	4.75
2. Analyze Site Alternatives	3.00	3	3	1.41	2.25	1	5	3.75
3. Analyze Acquisition strategies	3.10	3	3	1.10	3	1	5	3.75
4. Analyze Technology	4.00	4	4	1.00	4	2	5	5
5. Identify Short List of Alternative(s):	4.22	5	5	0.97	3	3	5	5
C.3 - Develop Conceptual Scopes and Estimates								
1. Develop Conceptual Scopes	4.20	4	4	0.63	4	3	5	4.75
2. Develop Conceptual Estimates	4.10	4	4	0.57	4	3	5	4
C.4 - Evaluate and Select Best Alternatives	4.20	4	4	0.79	4	3	5	5
C.5 - Develop Concept Phase Report	3.40	3.5	4	1.26	3	1	5	4
Detailed Scope								
S.1 - Initiate Phase								
1. Understand Team Alignment	4.40	5	5	0.97	4	2	5	5
2. Review and Understand Business Objectives	4.30	4	4	0.67	4	3	5	5
3. Validate project assumptions	4.50	5	5	0.71	4	3	5	5
4. Review conceptual design basis	4.50	5	5	0.71	4	3	5	5
S.2 - Develop Preliminary Design/Engineering	4.22	4	4	0.67	4	3	5	5
S.3 - Develop Preliminary Design/Engineering Review	4.30	4.5	5	0.82	4	3	5	5
S.4 - Develop Finalize Scope Definition Package	4.22	4	4	0.97	4	2	5	5
S.5 - Develop Cost and Schedule Control Estimate	4.44	5	5	0.73	4	3	5	5
S.6 - Compile Project Definition Package								
1. Compile Project Definition Package	4.00	4	4	0.71	4	3	5	4
2. Compile Authorization Package	3.25	3	3	0.71	3	2	4	4
3. Prepare Oral presentation	2.89	3	4	1.05	2	1	4	4

Table D.6 - Piping SDE Statistical Values

Piping Statistical Values								
Category/Statistical Method	Mean	Median	Mode	Std. Dev.	Lower Quartile	Min	Max	Upper Quartile
Feasibility								
F.1 - Initiate Phase								
1. Understand Alignment	3.6	3	3	0.89	3	3	5	4
2. Understand Business Objectives	3.4	4	2	1.34	2	2	5	4
3. Understand project assumptions	4	5	5	1.41	3	2	5	5
4. Generate early design basis and parameters	3.6	4	2	1.52	2	2	5	5
F.2 - Generate Options								
1. Generate Assumptions/Drivers	3.6	4	4	1.14	3	2	5	4
2. Generate Alternatives for Site(s)	3	3	3	1.22	2	2	5	3
3. Generate Alternatives for Technology	3.8	4	5	1.30	3	2	5	5
4. Generate Reliability, Maintainability, and Operability Guidelines	3.4	4	4	1.52	3	1	5	4
5. Generate Intellectual Property	2.6	2	2	0.89	2	2	4	3
6. Prepare Initial Feasibility Scope	4	4	3	1.00	3	3	5	5
7. Order of Magnitude (OOM) Estimate/Schedule	4.6	5	5	0.55	4	4	5	5
F.3 - Filtering Options								
1. Develop Economic Model	2.4	2	2	1.14	2	1	4	3
2. Develop Funding Strategies	2.2	2	1	1.30	1	1	4	3
3. Consider Significant Risks	3.8	3	3	1.10	3	3	5	5
4. Develop Initial Roles and Permit Analysis	2.4	2	2	0.89	2	2	4	2
5. Develop EHS Considerations	3.6	3	3	0.89	3	3	5	4
6. Develop Go/ No-Go Analysis	2.6	2	2	0.89	2	2	4	3
7. Develop Sensitivity Analysis	2.6	3	3	1.14	2	1	4	3
F.4 - Develop Recommendation Report	3.2	4	4	1.10	2	2	4	4
Concept								
C.1 - Initiate Phase								
1. Understand Team Alignment	4.2	4	4	0.84	4	3	5	5
2. Review and Understand Business Objectives	3.8	4	3	0.84	3	3	5	4
3. Validate project assumptions	4	4	3	1.00	3	3	5	5
4. Review design basis	4.2	4	5	0.84	4	3	5	5
C.2 - Analyze Alternatives								
1. Review and Identify Alternatives	3.8	4	4	0.45	4	3	4	4
2. Analyze Site Alternatives	3.6	4	4	1.14	3	2	5	4
3. Analyze Acquisition strategies	3.4	4	4	0.89	3	2	4	4
4. Analyze Technology	3.75	4	4	0.50	3.75	3	4	4
5. Identify Short List of Alternative(s):	4.25	4	4	0.50	4	4	5	4.25
C.3 - Develop Conceptual Scopes and Estimates								
1. Develop Conceptual Scopes	3.75	4	4	0.50	3.75	3	4	4
2. Develop Conceptual Estimates	4.25	4	4	0.50	4	4	5	4.25
C.4 - Evaluate and Select Best Alternatives	4.25	4	4	0.50	4	4	5	4.25
C.5 - Develop Concept Phase Report	4	4	4	0.82	3.75	3	5	4.25
Detailed Scope								
S.1 - Initiate Phase								
1. Understand Team Alignment	5	5	5	0.00	5	5	5	5
2. Review and Understand Business Objectives	4.25	4.5	5	0.96	3.75	3	5	5
3. Validate project assumptions	4.75	5	5	0.50	4.75	4	5	5
4. Review conceptual design basis	4.75	5	5	0.50	4.75	4	5	5
S.2 - Develop Preliminary Design/Engineering	5	5	5	0.00	5	5	5	5
S.3 - Develop Preliminary Design/Engineering Review	5	5	5	0.00	5	5	5	5
S.4 - Develop Finalize Scope Definition Package	4.6	5	5	0.55	4	4	5	5
S.5 - Develop Cost and Schedule Control Estimate	4	4	5	1.00	3	3	5	5
S.6 - Compile Project Definition Package								
1. Compile Project Definition Package	4	4	4	0.71	4	3	5	4
2. Compile Authorization Package	3.2	3	3	0.45	3	3	4	3
3. Prepare Oral presentation	3.4	4	4	0.89	3	2	4	4

Table D.7 - Process SDE Statistical Values

Process Statistical Analysis								
Category/Statistical Method	Mean	Median	Mode	Std. Dev.	Lower Quartile	Min	Max	Upper Quartile
Feasibility								
F.1 - Initiate Phase								
1. Understand Alignment	3.25	3	3	0.71	3	2	4	4
2. Understand Business Objectives	3.25	3	3	0.71	3	2	4	4
3. Understand project assumptions	4.25	4	4	0.46	4	4	5	4.25
4. Generate early design basis and parameters	4.88	5	5	0.35	5	4	5	5
F.2 - Generate Options								
1. Generate Assumptions/Drivers	4.13	4	5	0.83	3.75	3	5	5
2. Generate Alternatives for Site(s)	3.38	3.5	4	1.06	2.75	2	5	4
3. Generate Alternatives for Technology	4.75	5	5	0.46	4.75	4	5	5
4. Generate Reliability, Maintainability, and Operability Guidelines	3.63	4	4	0.52	3	3	4	4
5. Generate Intellectual Property	3.63	3.5	3	0.74	3	3	5	4
6. Prepare Initial Feasibility Scope	4.38	4	4	0.52	4	4	5	5
7. Order of Magnitude (OOM) Estimate/Schedule	3.75	3.5	3	0.89	3	3	5	4.25
F.3 - Filtering Options								
1. Develop Economic Model	2.50	2.5	3	0.53	2	2	3	3
2. Develop Funding Strategies	2.13	2	2	0.64	2	1	3	2.25
3. Consider Significant Risks	3.63	4	4	0.74	3.75	2	4	4
4. Develop Initial Roles and Permit Analysis	3.38	3	3	0.92	3	2	5	4
5. Develop EHS Considerations	3.88	4	3	0.83	3	3	5	4.25
6. Develop Go/ No-Go Analysis	3.25	3	3	0.89	3	2	5	3.25
7. Develop Sensitivity Analysis	3.50	3.5	4	0.53	3	3	4	4
F.4 - Develop Recommendation Report	3.25	3.5	4	1.04	3	1	4	4
Concept								
C.1 - Initiate Phase								
1. Understand Team Alignment	4.00	4	5	0.93	3	3	5	5
2. Review and Understand Business Objectives	3.38	3	3	0.92	3	2	5	4
3. Validate project assumptions	4.00	4	5	0.93	3	3	5	5
4. Review design basis	4.75	5	5	0.46	4.75	4	5	5
C.2 - Analyze Alternatives								
1. Review and Identify Alternatives	4.88	5	5	0.35	5	4	5	5
2. Analyze Site Alternatives	3.13	3	3	0.99	2.75	2	5	3.25
3. Analyze Acquisition strategies	2.50	2.5	3	0.93	2	1	4	3
4. Analyze Technology	5.00	5	5	0.00	5	5	5	5
5. Identify Short List of Alternative(s):	4.75	5	5	0.46	4.75	4	5	5
C.3 - Develop Conceptual Scopes and Estimates								
1. Develop Conceptual Scopes	4.13	4	4	0.35	4	4	5	4
2. Develop Conceptual Estimates	3.50	3.5	3	0.93	3	2	5	4
C.4 - Evaluate and Select Best Alternatives	4.13	4	4	0.83	3.75	3	5	5
C.5 - Develop Concept Phase Report	3.88	4	4	0.64	3.75	3	5	4
Detailed Scope								
S.1 - Initiate Phase								
1. Understand Team Alignment	4.00	4	4	0.76	3.75	3	5	4.25
2. Review and Understand Business Objectives	3.50	3	3	0.76	3	3	5	4
3. Validate project assumptions	3.88	4	3	0.83	3	3	5	4.25
4. Review conceptual design basis	4.75	5	5	0.46	4.75	4	5	5
S.2 - Develop Preliminary Design/Engineering	4.88	5	5	0.35	5	4	5	5
S.3 - Develop Preliminary Design/Engineering Review	4.38	4.5	5	0.74	4	3	5	5
S.4 - Develop Finalize Scope Definition Package	3.88	4	4	0.99	3.75	2	5	4.25
S.5 - Develop Cost and Schedule Control Estimate	3.50	3	3	1.07	3	2	5	4.25
S.6 - Compile Project Definition Package								
1. Compile Project Definition Package	3.88	4	4	0.64	3.75	3	5	4
2. Compile Authorization Package	3.00	3	3	0.76	2.75	2	4	3.25
3. Prepare Oral presentation	2.75	3	3	0.89	2.75	1	4	3

APPENDIX E

BOX WHISKER PLOTS

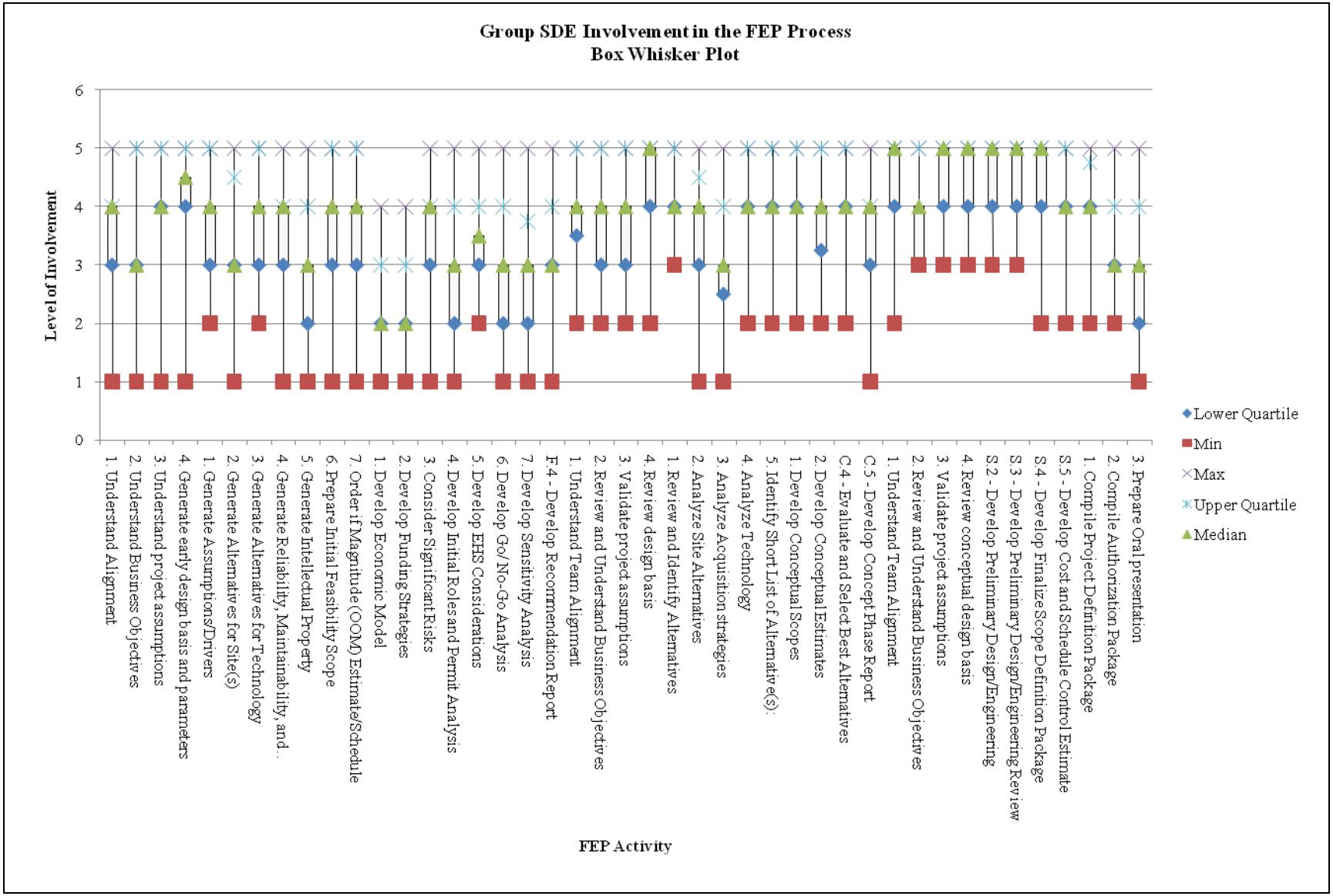


Figure E.1 - Group Involvement in the FEP Process Box Whisker Plot

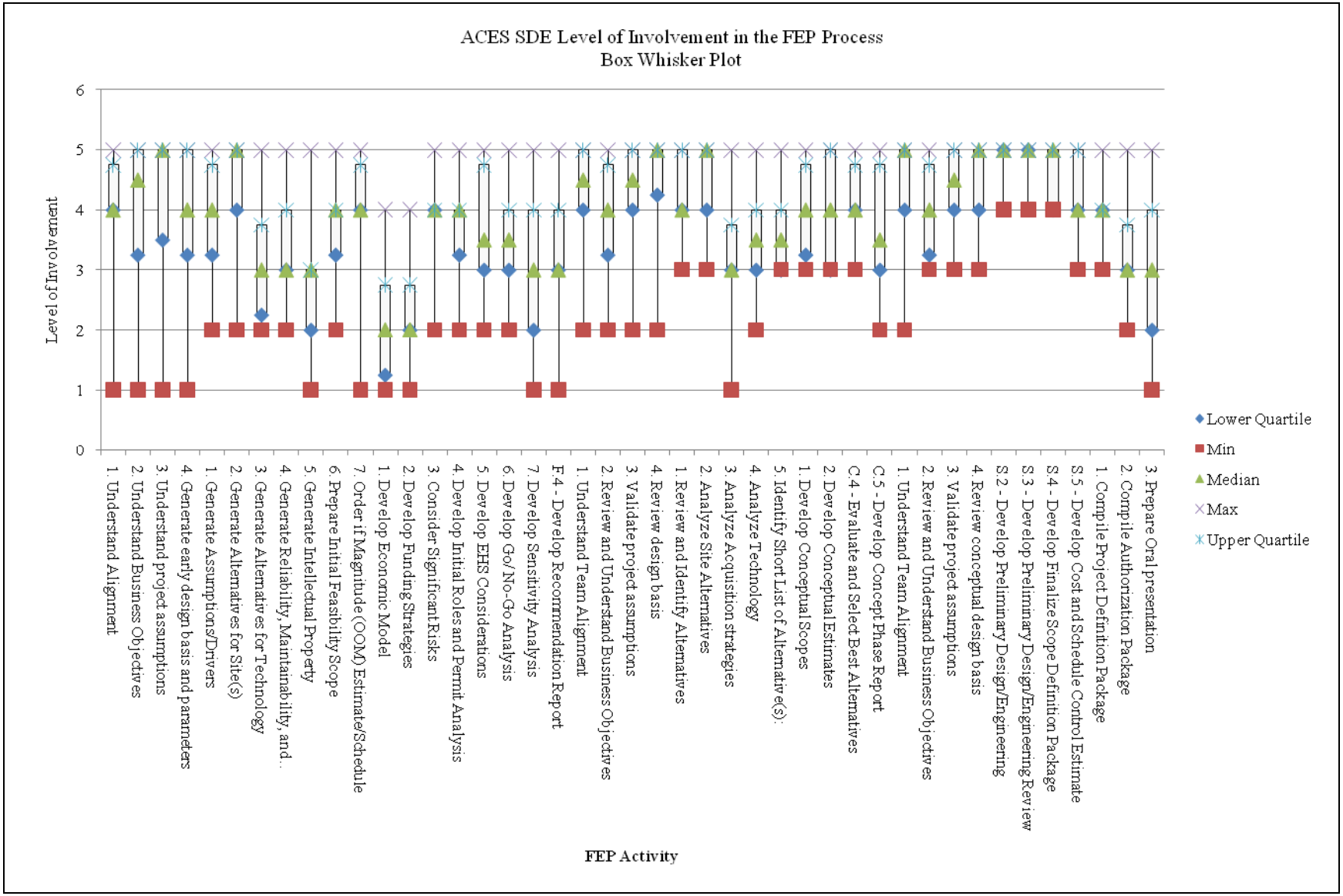


Figure E.2 - ACES SDE Involvement in the FEP Process Box Whisker Plot

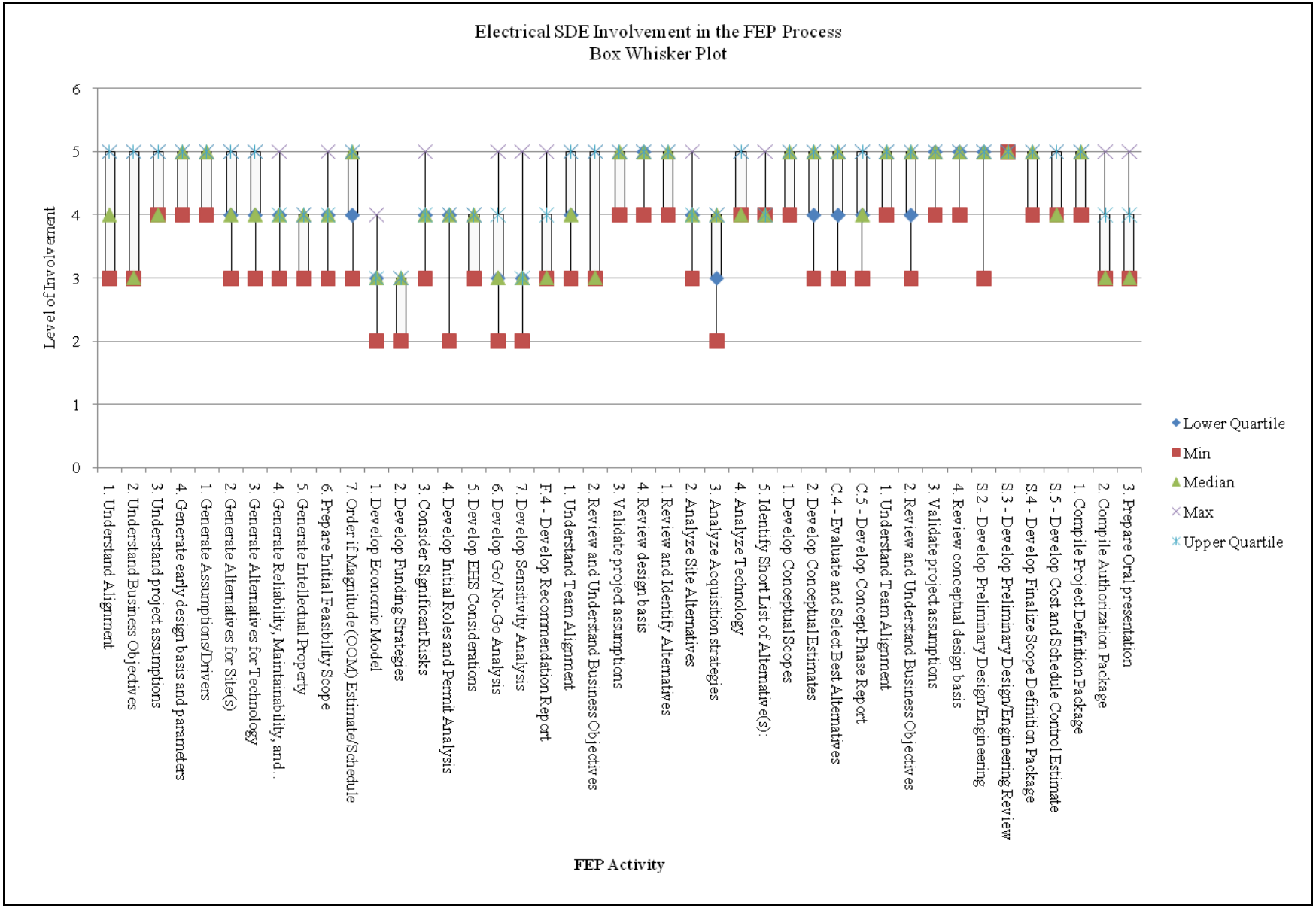


Figure E.3 - Electrical SDE Involvement in the FEP Process Box Whisker Plot

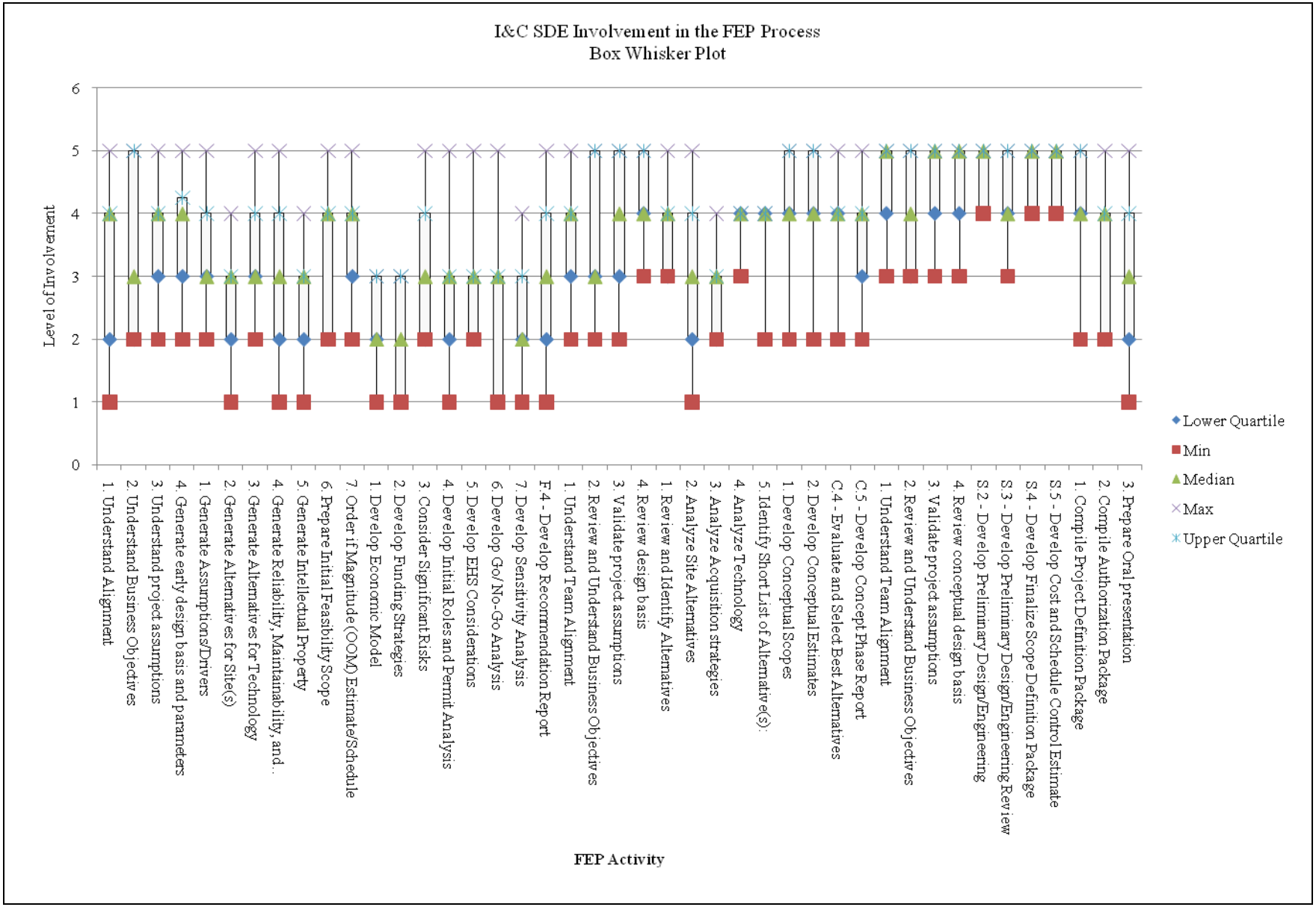


Figure E.4 – I&C SDE Involvement in the FEP Process Box Whisker Plot

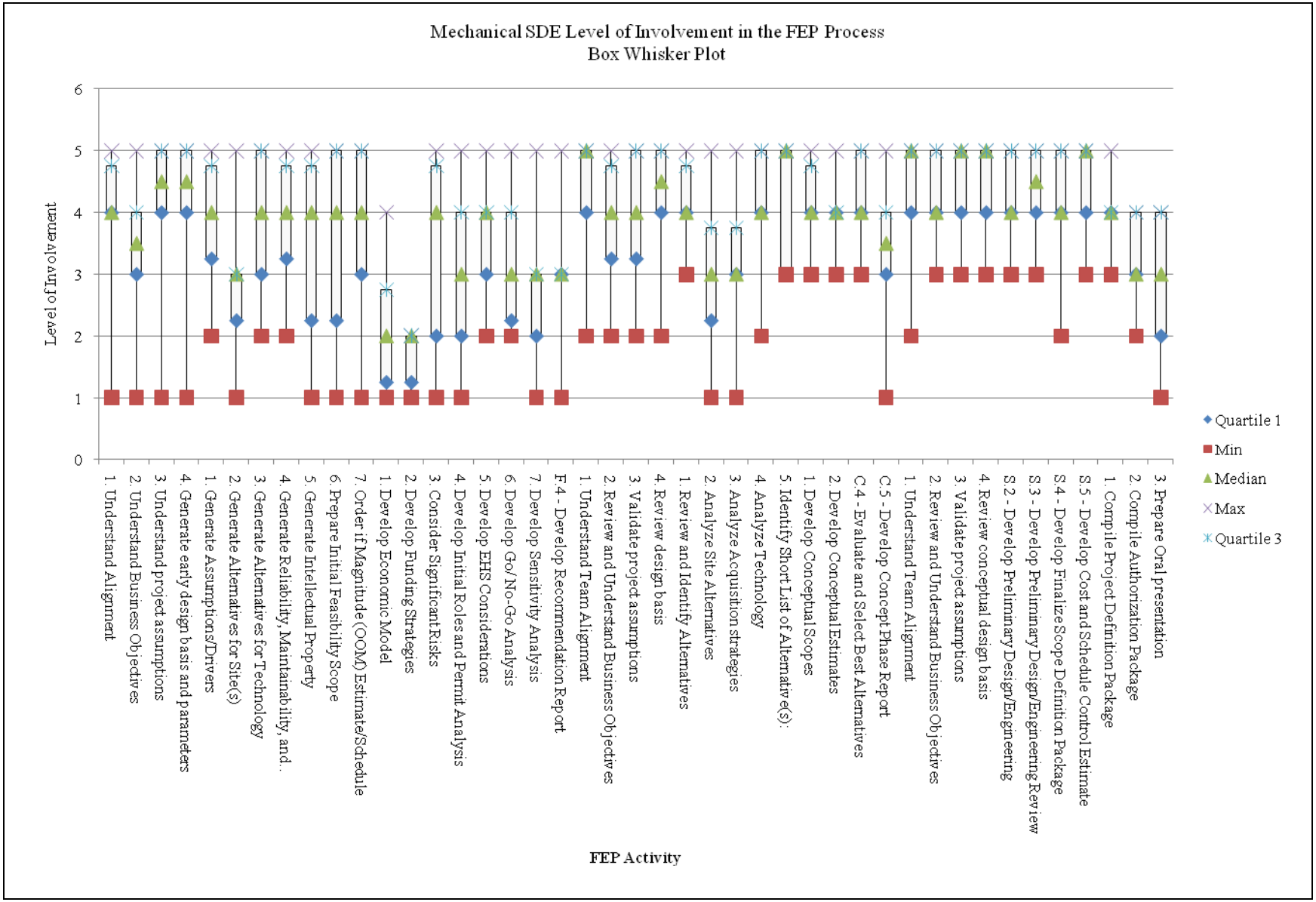


Figure E.5 – Mechanical SDE Involvement in the FEP Process Box Whisker Plot

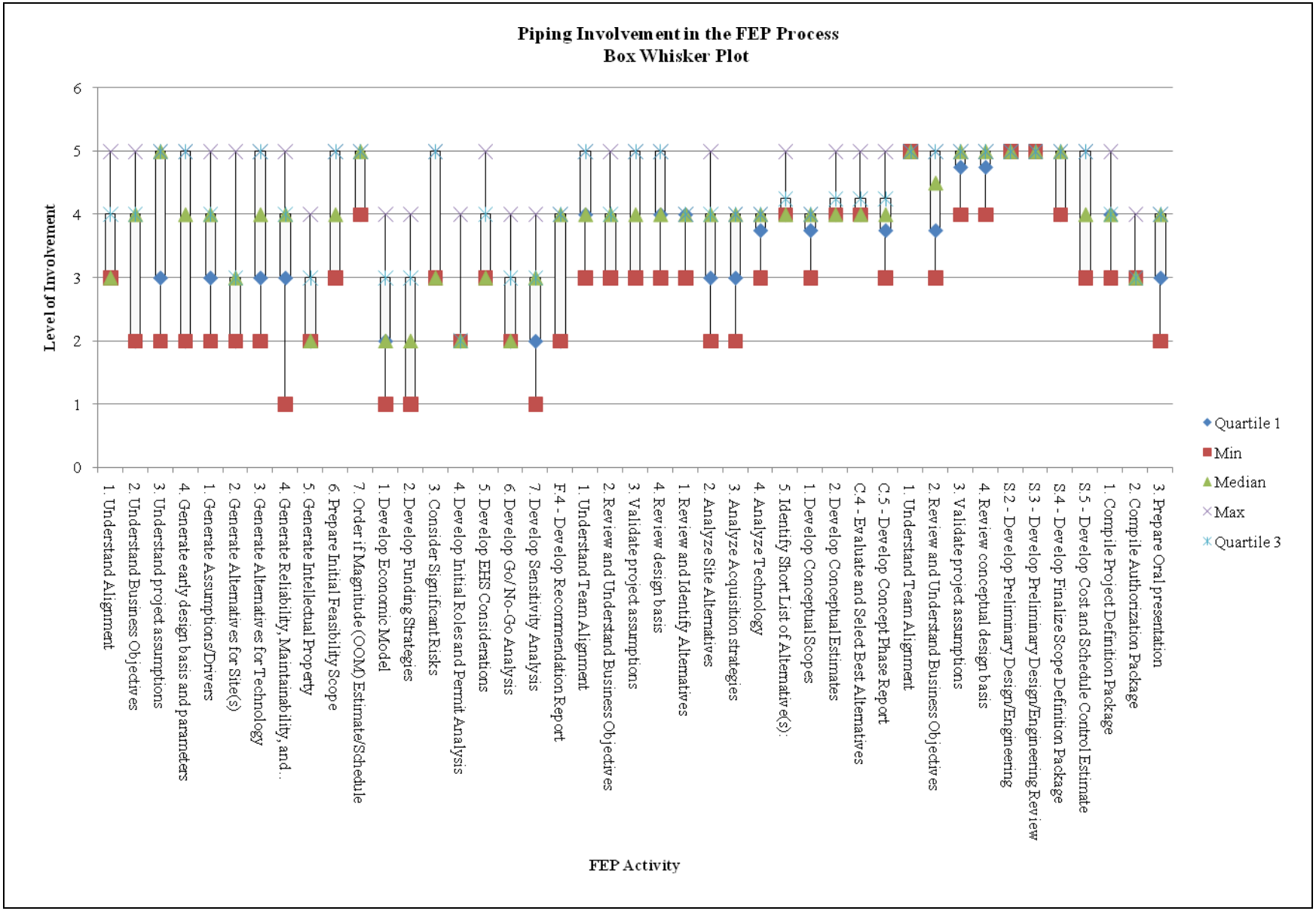


Figure E.6 – Piping SDE Involvement in the FEP Process Box Whisker Plot

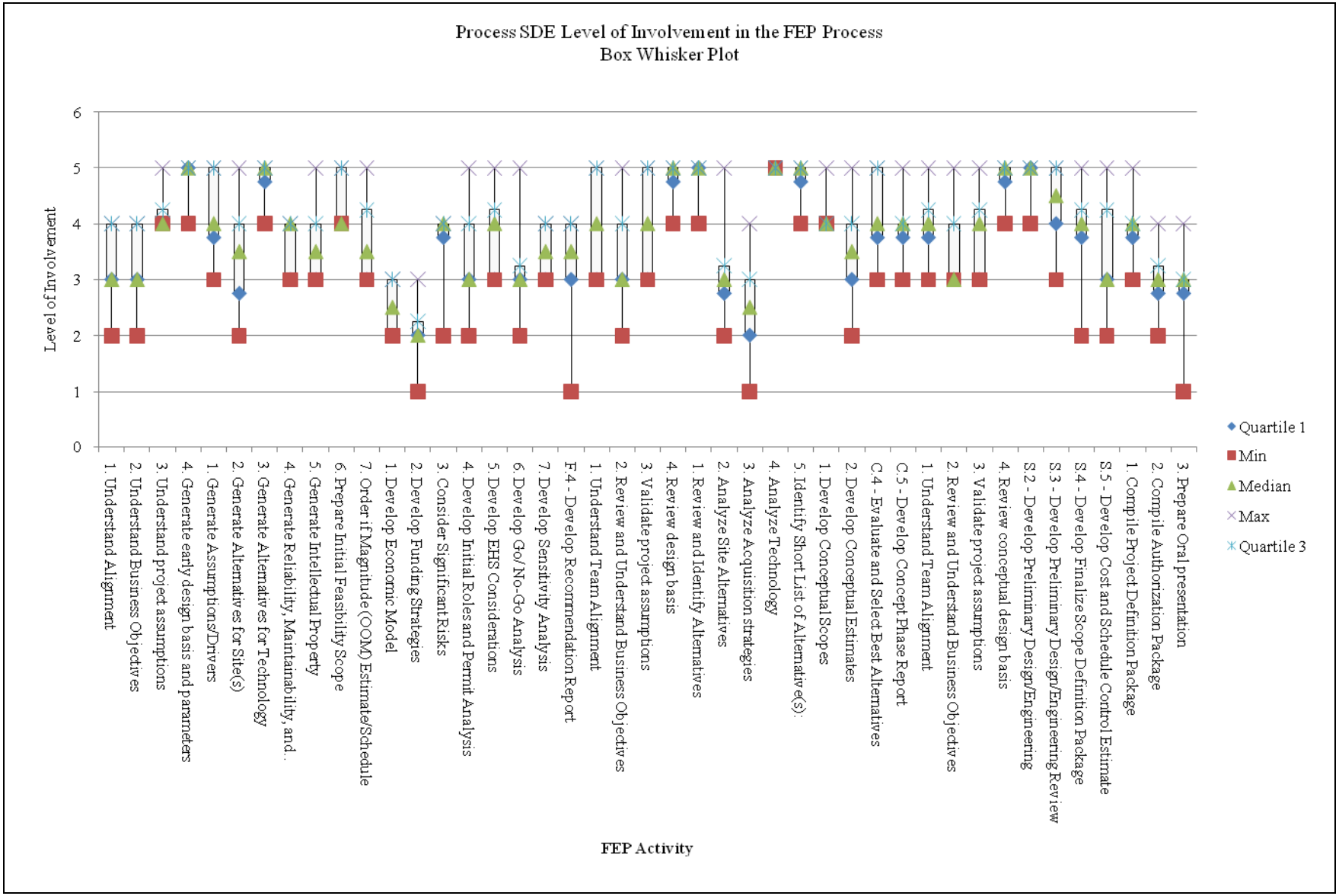


Figure E.7 – Process SDE Involvement in the FEP Process Box Whisker Plot

APPENDIX F

SDE LEVEL OF INVOLVEMENT MATRICES

Table F.1 – SDE Level of Involvement Matrix – Feasibility Phase

SDE Level of Involvement Matrix - Feasibility							
Category/Statistical Method	Group	ACES	Electrical	I&C	Mechanical	Piping	Process
Feasibility							
F.1 - Initiate Phase							
1. Understand Alignment	Much	Much	Much	Moderate	Much	Moderate	Moderate
2. Understand Business Objectives	Moderate	Much	Moderate	Moderate	Moderate	Moderate	Moderate
3. Understand project assumptions	Much	Very Much	Much	Much	Very Much	Much	Much
4. Generate early design basis and parameters	Very Much	Much	Very Much	Much	Very Much	Moderate	Very Much
F.2 - Generate Options							
1. Generate Assumptions/Drivers	Much	Much	Very Much	Moderate	Much	Much	Much
2. Generate Alternatives for Site(s)	Moderate	Very Much	Much	Moderate	Moderate	Moderate	Much
3. Generate Alternatives for Technology	Much	Moderate	Much	Moderate	Much	Much	Very Much
4. Generate Reliability, Maintainability, and Operability Guidelines	Much	Moderate	Much	Moderate	Much	Much	Much
5. Generate Intellectual Property	Moderate	Moderate	Much	Moderate	Much	Little	Moderate
6. Prepare Initial Feasibility Scope	Much	Much	Much	Much	Much	Much	Much
7. Order of Magnitude (OOM) Estimate/Schedule	Much	Much	Very Much	Much	Much	Very Much	Moderate
F.3 - Filtering Options							
1. Develop Economic Model	Little	Little	Moderate	Little	Little	Little	Moderate
2. Develop Funding Strategies	Little	Little	Moderate	Little	Little	Little	Little
3. Consider Significant Risks	Much	Much	Much	Moderate	Much	Moderate	Much
4. Develop Initial Roles and Permit Analysis	Moderate	Much	Much	Moderate	Moderate	Little	Moderate
5. Develop EHS Considerations	Moderate	Moderate	Much	Moderate	Much	Moderate	Much
6. Develop Go/ No-Go Analysis	Moderate	Much	Moderate	Little	Moderate	Little	Moderate
7. Develop Sensitivity Analysis	Moderate	Moderate	Moderate	Little	Moderate	Little	Much
F.4 - Develop Recommendation Report	Moderate	Moderate	Moderate	Little	Moderate	Much	Much

Table F.2 – SDE Level of Involvement Matrix – Concept & Detailed Scope Phases

SDE Level of Involvement Matrix							
Category/Statistical Method	Group	ACES	Electrical	I&C	Mechanical	Piping	Process
Concept							
C.1 - Initiate Phase							
1. Understand Team Alignment	Much	Very Much	Much	Much	Very Much	Much	Much
2. Review and Understand Business Objectives	Much	Much	Moderate	Moderate	Much	Much	Moderate
3. Validate project assumptions	Much	Very Much	Very Much	Much	Much	Much	Much
4. Review design basis	Very Much	Very Much	Very Much	Much	Very Much	Much	Very Much
C.2 - Analyze Alternatives							
1. Review and Identify Alternatives	Much	Much	Very Much	Much	Much	Much	Very Much
2. Analyze Site Alternatives	Moderate	Very Much	Much	Moderate	Moderate	Much	Moderate
3. Analyze Acquisition strategies	Moderate	Moderate	Much	Moderate	Moderate	Much	Moderate
4. Analyze Technology	Much	Very Much	Much	Much	Much	Much	Very Much
5. Identify Short List of Alternative(s):	Much	Much	Much	Much	Very Much	Much	Very Much
C.3 - Develop Conceptual Scopes and Estimates							
1. Develop Conceptual Scopes	Much	Much	Very Much	Much	Much	Much	Much
2. Develop Conceptual Estimates	Much	Much	Very Much	Much	Much	Much	Moderate
C.4 - Evaluate and Select Best Alternatives	Much	Much	Very Much	Much	Much	Much	Much
C.5 - Develop Concept Phase Report	Much	Moderate	Much	Much	Much	Much	Much
Detailed Scope							
S.1 - Initiate Phase							
1. Understand Team Alignment	Very Much	Very Much	Very Much	Very Much	Very Much	Very Much	Much
2. Review and Understand Business Objectives	Much	Much	Very Much	Much	Much	Very Much	Moderate
3. Validate project assumptions	Very Much	Very Much	Very Much	Very Much	Very Much	Very Much	Much
4. Review conceptual design basis	Very Much	Very Much	Very Much	Very Much	Very Much	Very Much	Very Much
S.2 - Develop Preliminary Design/Engineering	Very Much	Very Much	Very Much	Very Much	Much	Very Much	Very Much
S.3 - Develop Preliminary Design/Engineering Review	Very Much	Very Much	Very Much	Much	Very Much	Very Much	Very Much
S.4 - Develop Finalize Scope Definition Package	Very Much	Very Much	Very Much	Very Much	Much	Very Much	Much
S.5 - Develop Cost and Schedule Control Estimate	Much	Much	Much	Very Much	Very Much	Much	Moderate
S.6 - Compile Project Definition Package							
1. Compile Project Definition Package	Much	Much	Very Much	Much	Much	Much	Much
2. Compile Authorization Package	Moderate	Moderate	Moderate	Much	Moderate	Moderate	Moderate
3. Prepare Oral presentation	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate

APPENDIX G

INDIVIDUAL SDE DISCIPLINE VS. GROUP SDE RELATIONSHIP PROFILES

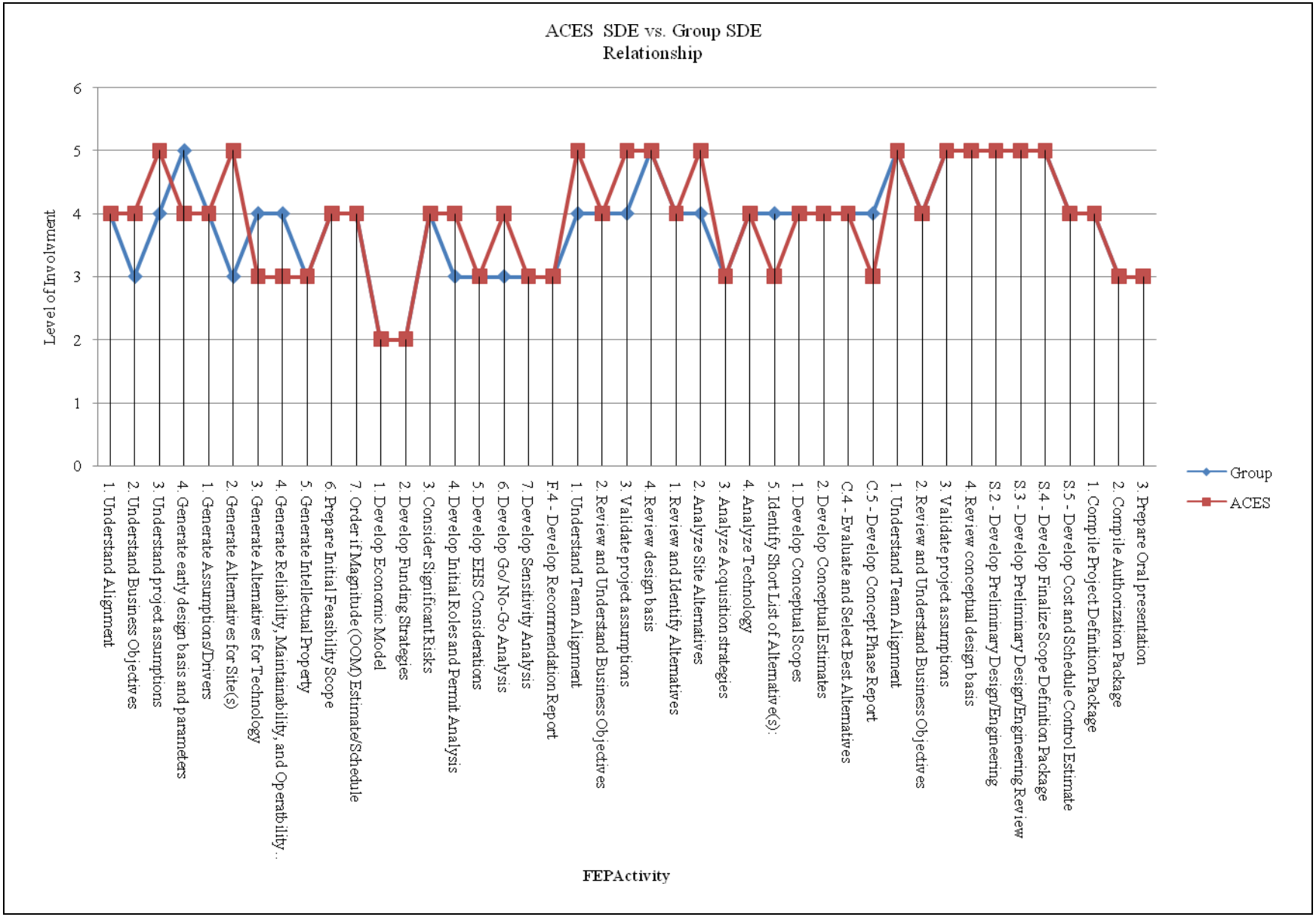


Figure G.1 – ACES SDE vs. Group SDE

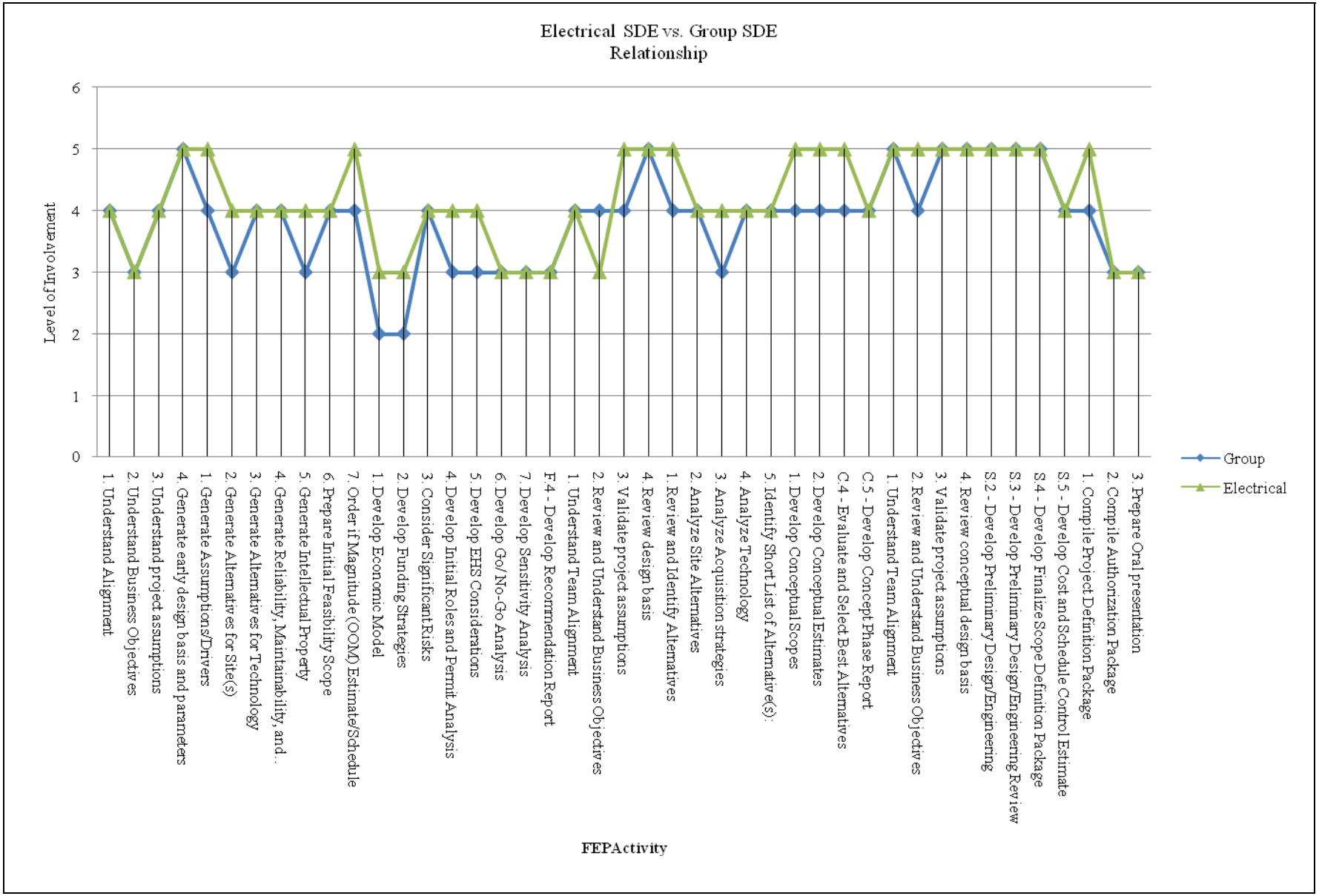


Figure G.2 – Electrical SDE vs. Group SDE

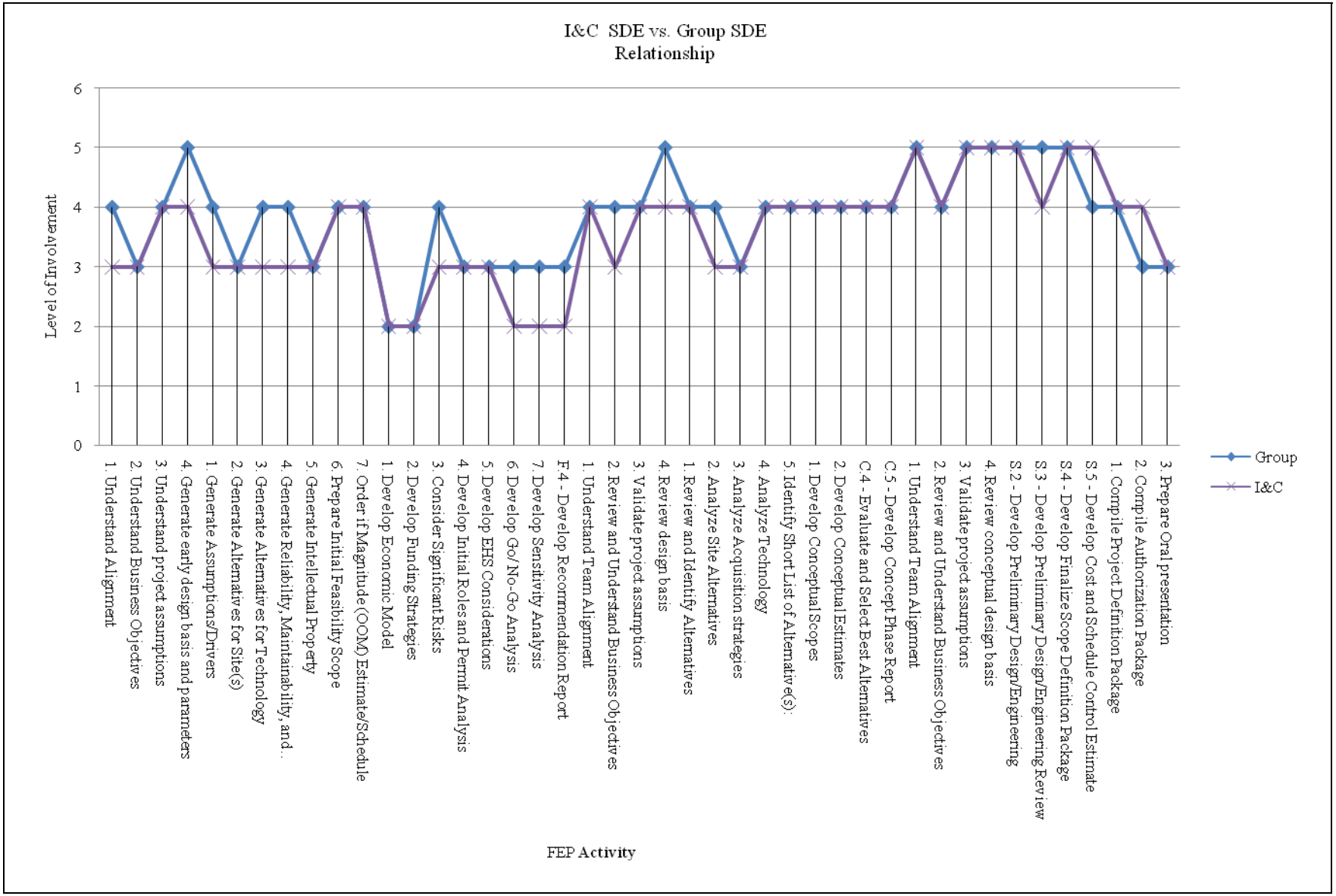


Figure G.3 – I&C SDE vs. Group SDE

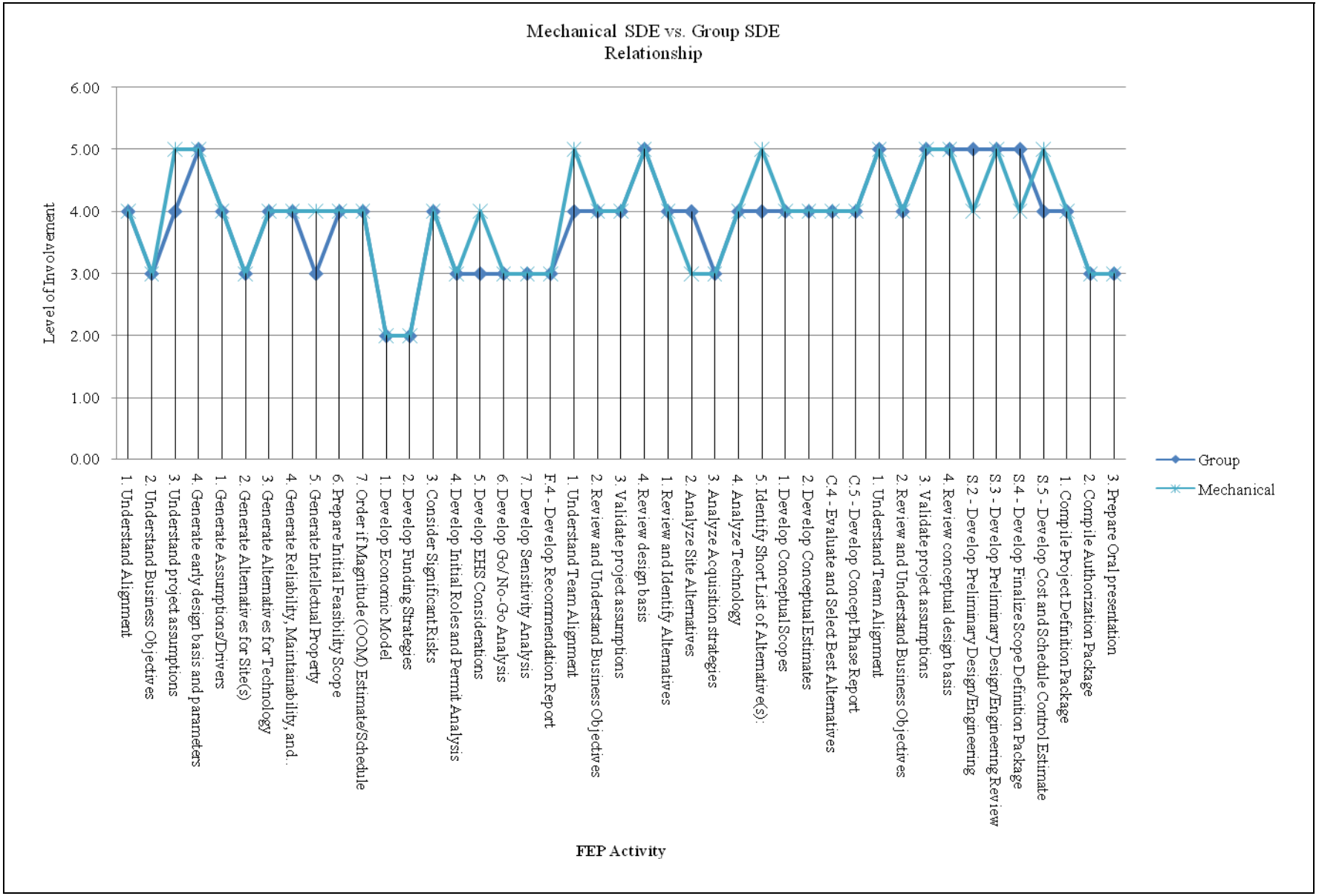


Figure G.4 – Mechanical SDE vs. Group SDE

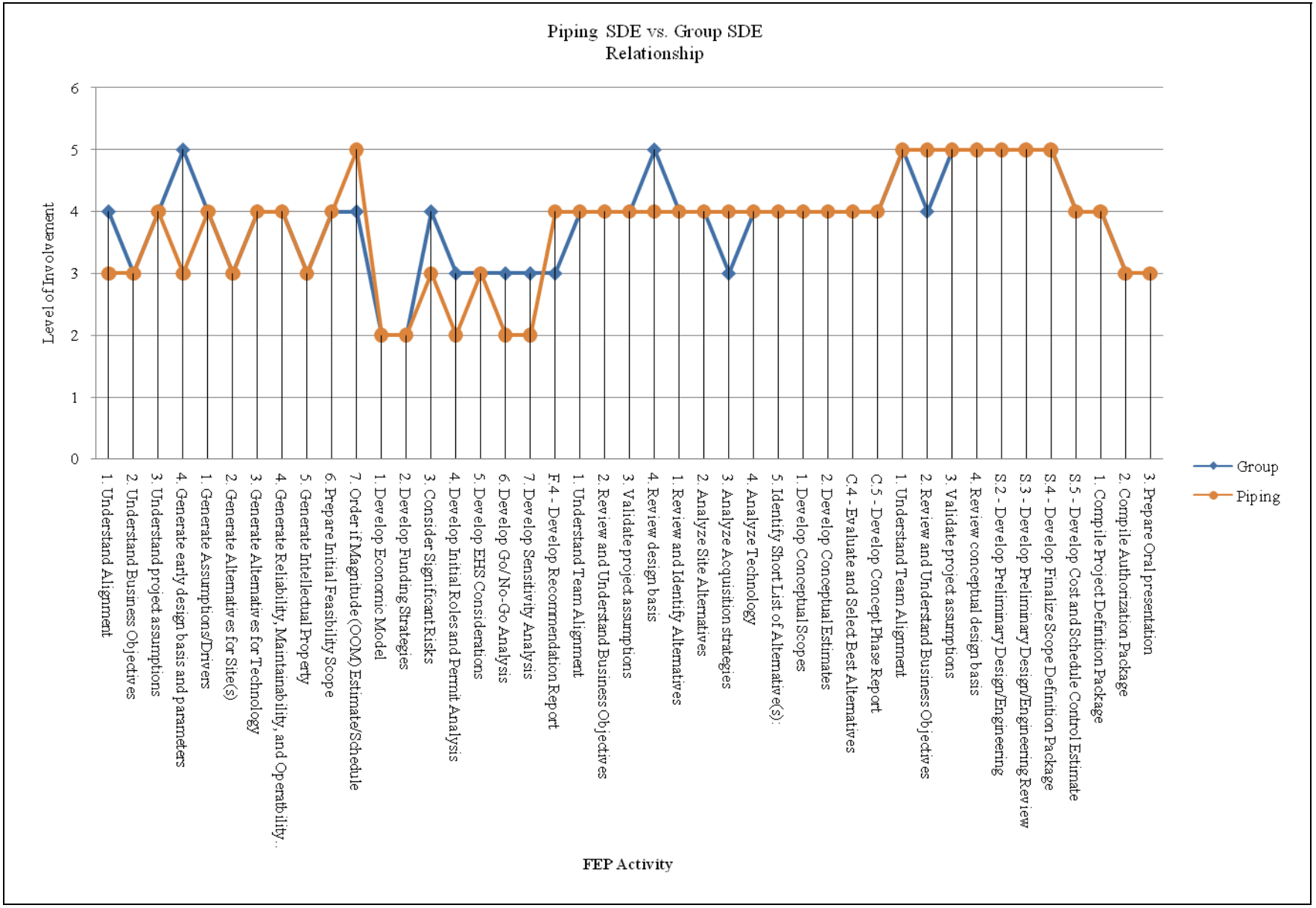


Figure G.5 – Piping SDE vs. Group SDE

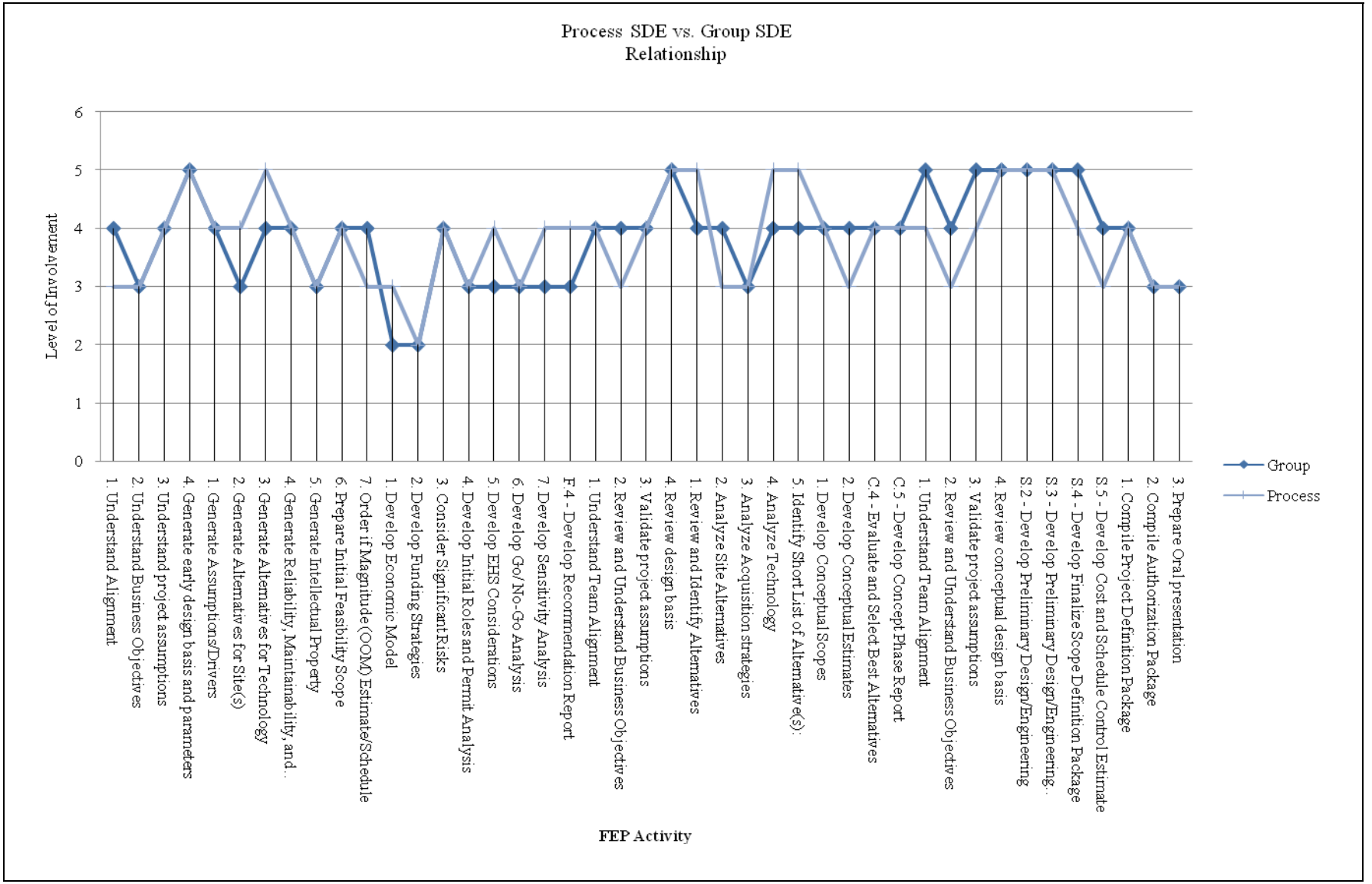


Figure G.6 – Process SDE vs. Group SDE

APPENDIX H

FRONT END PLANNING TOOLKIT ACTIVITY DEFINITIONS

Feasibility Phase
F.1 – Initiate Phase

1. Alignment

   At this point the person performing the feasibility phase (or a project team in some cases) analysis should be aligned to the project objectives if they exist. This person should review Phase Gate 0 deliverables and fill in the blanks as necessary. Typical issues to consider would include:

   - Resources available
   - Deliverables required
   - Expectations of sponsors

   See CII IR113-3, *Alignment During Pre-Project Planning: A Key to Project Success, Second Edition*, for more details on alignment.

2. Understand Business Objectives

   The person or team conducting feasibility analysis must develop an understanding of "why" the project is to be performed. The following topics should be addressed, but in many cases will be vague:

   - Products or building use requirements
   - Market or program strategy
   - Timing
   - Project strategy
   - Affordability/Feasibility
   - Capacity or volume
   - Future expansion considerations
   - Environmental
   - Project life cycle
   - Social issues

   See CII IR181-2, *International Project Risk Assessment*, for a good discussion on these issues.

3. Understand project assumptions

   Assumptions may be available from information given in Phase Gate 0. These assumptions should be questioned and clarified as much as possible to understand their reliability for the work to be performed during the Feasibility Phase.

   - Feasibility cost estimate and schedule milestones for project, including assumptions made in that estimate
   - Verify the permitting requirements, including processes, personnel, regulatory changes, schedules, location of permitting authority and the estimated time to go through the process.

- Verify that human resources can be dedicated to this project as necessary, or that consultants can be hired.
- Determine the availability of the proposed site
- Business model viability
- Availability of labor and materials for construction
- Raw materials availability for feedstock
- Project and operations funding availability
- Tax and legal issues

4. Generate early design basis and parameters

   Review any existing design basis documents, including requirements documentation and customer needs. Generate design parameters that will be used to frame the opportunity. Requirements may include:

   - Manufacturing philosophy
   - Space plan
   - Automation scope
   - User surveys
   - Process design basis
   - Capacity needs
   - Key design documents if available (i.e., existing drawings, geotechnical evaluations, Process Flow Diagrams, mechanical equipment arrangements (MEA), Site Plan, Building Program)
   - Regulatory requirements (e.g., U.S. Food and Drug Administration (FDA) Validation Requirements Identified)

F.2 – Generate Options

1. Assumptions/Drivers

   Assumptions: The project team should validate and expand on the list of Macro-Assumptions generated during the Initiate Phase (F.1). Each potential option may have its own list. This list is generally the items that will become parts of the Project Scope or Proposal but should also point out project boundaries or items NOT included in the Project.

   Drivers: Project drivers (cost, schedule, quality, maintenance, etc.) generated during the Initiate Phase (F.1) should be assessed with each option. A clear understanding of project justification should be agreed upon. The goal at this point is to understand drivers for the project and insure the options being considered satisfy those drivers.

2. Alternatives for Site(s)

   Develop a list of alternate locations that meet owner requirements. The following issues should be considered:

- Site availability
- Affordable cost
- Accessibility
- Skilled labor availability
- Environmental considerations

3. Alternatives for Technology

   Develop a list of available technologies in relation to organization needs and constraints. For example these technologies may include production process, information, automation, control networks, etc. This list should include new and existing technologies, and identify knowledge and technology gaps that team members must overcome.

   Note that the gaps are not solved at this phase. At this point, the organization is just trying to determine which technologies are feasible and identify areas of risk.

4. Reliability, Maintainability and Operability Guidelines

   Develop general guidelines related to reliability, maintainability, and operability.

5. Intellectual Property

   Recognize the potential for intellectual property issues in this project.

6. Prepare Initial Feasibility Scope

   Prepare the initial feasibility scope and define boundaries to provide enough information for generation of an Order of Magnitude Estimate. Include a brief description of existing conditions and project "Must Haves." This feasibility scope typically provides budget information for long term planning purposes.

7. Order of Magnitude (OOM) Estimate/Schedule

   An OOM estimate should be made using a parametric or factor technique to produce an expected cost range (±30–50% or higher). In addition, a milestone schedule should be developed. Estimators may add special provisions, escalation, contingency, and risk provisions. Costs may be provided from historical estimating database information if available. The estimate should be shown in summary form, attributed to the estimator.

   Note that the estimate at this stage is useful only to decide whether to proceed with further definition.

   See CII IR131-2, *Improving Early Estimates Best Practices Guide*.

F.3 – Filtering Options

Filtering options draws information from F.1 and F.2. These filtering criteria include: cost, benefits, economics, and other required decision-making considerations. This sub-process will eliminate options that are not feasible or fail to fit with the organization's strategy.

1. Economic Model

In most cases, economics will be the primary determinant for option selection. Standard organizational measures such as return on investment (ROI), cash flow of return (CFRR), net present value (NPV), benefit to cost (B/C), payback period, etc. are typically used.

2. Funding Strategies

   Strategies to be considered may include cash flow, funding source, market timing, regulatory need date, or project duration. These factors may lead to single or multiple/phased funding plans. For example, on a project where the risk is high and the return on investment is relatively low, it would be wise to approve funding for preliminary design in order to eliminate as many unknowns as necessary to insure that risks are within tolerable limits. Many owners now utilize a two- or three-step funding process that allows for adequate scope definition and risk assessment. This process is shown graphically below.

3. Consider Significant Risks

   Risk assessment is both qualitative and quantitative. At this point, risk assessment should address the following: probability of meeting business drivers; the variability of the project cost estimate; the variability of the project schedule; or other unusual issues.

4. Initial Roles and Permit Analysis

   Consider impact for local, state, and federal codes or permitting requirements to check for any major cost or schedule impacts.

5. EHS Considerations

   Identify potential Environmental, Health, and Safety concerns for each option. Potential concerns identified should be reflected in the recommendation.

6. Go/No-Go Analysis

   Assess each Option to eliminate any that exceed the allowable level of risk or fail to meet the “Must Have” list in the Feasibility Phase.

7. Strategic Fit

   Assess the strategic fit of each option with the organization’s vision or goals, and business drivers. Some options may support additional risk if they fit into the long range plans for your company. As an example; a strategic fit may be a technology-driven advancement that would change the way work is accomplished.

8. Sensitivity Analysis

   Sensitivity analysis, using ranges, is performed at this stage varying the key factors making up the model.

   This analysis helps access risk or gain as it pertains to the economic variables. As an example, this analysis may show the impact on return on investment (ROI) as it relates to capital verses savings. It may show that $1,000,000 in capital reduction may affect the project return by 1% but $50,000 in savings creates an additional 2%

in return. This would mean the project is “savings sensitive” and this area of the scope should be a more important area of focus.

F.4 – Recommendation Report

Prepare a two-part recommendation as follows:

- A written report stating the recommendation, followed by supporting documentation, PDRI assessment (if performed) and a description of the process used to arrive at the recommendation. Information to be included in the body of the report includes the Inputs into Phase Gate 1.
- An oral presentation should be given to the decision maker(s).

Concept Phase

C.1 – Initiate Phase

1. Team Alignment

   At this point a project team may be formed and should be aligned to the project objectives. The team should review Phase Gate 1 deliverables. Typical issues to consider in alignment would include:

   - The kickoff meeting should bring all key stakeholders to the table to begin working together in a team environment.
   - Roles and responsibilities should be identified during the kickoff meeting and continue to be updated as the project evolves and/or personnel change. See Selecting the Team (PDF file).
   - Discuss costs and schedule of activities that must be conducted during the Concept Phase. These activities may include value management and corporate best practices that will be used in this phase and subsequent phases. See CII IR184-2, *Value Management Toolkit* (only accessible to CII members).
   - Agree on resources required for Concept Phase execution.
   - Identify and discuss deliverables that must be completed during the Concept Phase, including accuracy of estimates and sponsor requirements.
   - Revisit the team charter (if available), including mission, constraints and objectives. If none is available, develop one. See The Charter (PDF file) and Charter Template (Word file).

   See CII IR113-3, *Alignment During Pre-Project Planning: A Key to Project Success, Second Edition*, for more details on alignment.

2. Review and Understand Business Objectives

   Consider economic variability in demand (seasonal and long term projections) as part of a sensitivity analysis to estimate the upside and downside potential of the opportunity. The following topics should be addressed:

   - Products or building use requirements
   - Market or Program strategy

- Timing
- Project strategy
- Affordability/Feasibility
- Capacity or volume
- Future expansion considerations
- Environmental
- Project life cycle
- Social issues

See CII IR181-2, *International Project Risk Assessment*, for a good discussion on these issues.
See CII RS12-1, *Project Objective Setting, Second Edition*, for a discussion of objective setting.

3. Validate project assumptions

   Assumptions should be available from the Feasibility Phase. These assumptions should be questioned and clarified as much as possible to understand the reliability of the work to be performed during the Concept Phase. Assumptions may include:

   - Feasibility cost estimate and schedule milestones for project, including assumptions made in that estimate
   - Verify the permitting requirements, including processes, personnel, regulatory changes, schedules, location of permitting authority and the estimated time to go through the process.
   - Verify that human resources can be dedicated to this project as necessary, or that consultants can be hired.
   - Determine the availability of the proposed site
   - Business model viability
   - Availability of labor and materials for construction
   - Raw materials availability for feedstock
   - Project and operations funding availability
   - Tax and legal issues

4. Review design basis

   Review any existing design basis documents, including requirements documentation and customer needs. If documents do not exist, request clarification. Requirements may include:

   - Manufacturing philosophy
   - Space plan
   - Automation scope
   - User surveys

- Process design basis
- Capacity needs
- Key design documents if available (i.e., existing drawings, geotechnical evaluations, Process Flow Diagrams, mechanical equipment arrangements (MEA), Site Plan, Building Program)
- Regulatory requirements (e.g., FDA Validation Requirements Identified)

C.2 – Analyze Alternatives

1. Review and Identify Alternatives

   Review alternatives identified during Feasibility Phase (e.g., site, technology, control strategy, contracting strategy, etc.). Many times, the Feasibility Phase alternatives are "high-level" in nature and not developed to the extent needed for Conceptual evaluation. This step may include identification of new alternatives to be considered in the Concept Phase that may be better than those identified during the Feasibility Phase. Guard against limiting the alternatives, because many times little technical input has been provided for those decisions.

2. Site

   Determining the site location and facility orientation on the site are critical steps during the Conceptual Phase. Assess relative strengths and weaknesses of alternate locations to meet owner requirements. The objective is fairly simple: find a location that maximizes benefits for the owner. Practical application of the objective is less straightforward. Site evaluation may address various issues including global region, country, local, master plan, vulnerability assessment, "inside the fence," or "inside the building." Other issues include:

   - Environmental Assessment
   - Permit Requirements
   - Utility Services
   - Fire Protection

   See Industrial PDRI Elements D3 and F1, and Building PDRI Elements A7, C3, and D1. Also see Evaluate Site(s) (PDF file).

3. Acquisition strategies

   Acquisition strategy many times drives schedule delivery and must be considered during the Conceptual Phase. Develop a preliminary strategy for identifying long lead items, design and construction delivery approach, consulting services, procurement tax implications, site and right-of-way acquisition (if applicable), new vs. renovation construction, etc. See CII IR165-2, *Owner's Tool for Project Delivery and Contract Strategy Selection User's Guide*, Second Edition.

   Included in the evaluation should be an assessment of modularization, pre-assembly, and off-site fabrication alternatives. See CII RS171-1, *PPMOF: A Framework for Decision-Making* and CII IR171-2, *PPMOF: Decision Framework and Tool*.

4. Technology

   Assess available technologies, including new and existing technologies, in relation to organizational needs, constraints, and project goals. The following may be addressed:

   - Process simplification
   - Preliminary hazard review
   - Environmental, Health and Safety (EHS) review
     - Identify and assess potential impacts technologies may have on the environment and safety and health of workers.
   - Scale-up criteria
   - Process simulations
   - Information technology
   - Technology protection/intellectual property
     - Defined as a product of the intellect that has commercial value, including copyrighted property such trade names or icons, and ideational property, such as patents, business methods, and industrial processes. If a new technology is being developed or expanded, care must be taken so as not in infringe upon existing patents or copyrights.
   - Energy conservation
   - Security
   - Audio/Visual
   - Automation
   - Control Strategies

   Refer to Industrial PDRI Element C1 and Building PDRI Element F8.

   For more information, see Analyze Technology (PDF file).

5. Identify Short List of Alternative(s):

   Eliminate alternatives that fail to meet the project objectives and other key drivers, and narrow alternatives for consideration to a workable list.

C.3 – Develop Conceptual Scopes and Estimates

The purpose of this process is to provide input for financial and non-financial analysis of the alternative evaluation effort.

1. Conceptual Scopes

   Preparing conceptual scopes pertains to both capital requirements and usage requirements for the alternatives. The purpose of this function is to provide input data for financial analysis during the evaluation of alternative(s) effort. The conceptual scope definition effort attempts to resolve the following four issues:

- Provide a means to reach agreement on provisions to be included
- Provide data for generation of usage requirements
- Reduce uncertainties to an "acceptable risk" level
- Balance the need for more detail and accuracy with the reality of available time and available study budget.

Conceptual scopes may include preliminary information on some or all areas listed in the table below:

Table: *Preliminary Information for Conceptual Scopes*

1. Process Facilities	2. Buildings	3. Utility Projects
o Design basis o Heat and material balances o Equipment list o Flow diagram o Plot plan o Special provisions o Cash flow o Approval document o Security Concerns o Service and utility requirements and usage	o Zoning o Use o Location o Land requirements o New/renovate o Building population o Environmental concerns o Parking/landscaping o Security concerns o Design potential cost impact o Roads and access o Utilities o Cafeteria/auditorium/laboratory requirements o Telecommunications/sophistication of electronics o Building type/finish/size/number of floors	o Control philosophy o Distributed control systems o Environmental o Noise limits/requirements o Metering o Safety concerns o Basic layout o Laws/standards/codes o Cable trench interconnections o Security Concerns o Station ground interconnections o Transformers/switch gear/disconnect switches o Limits to high/low voltage connections

2. Conceptual Estimates

The basis of Estimate is a listing of information available and any assumptions used during the development of the Conceptual Estimate. Some of these items may include:

a. Conceptual design information available or developed List of items included and not included in the project

b. Escalation basis

c. Estimate database (factored quantities, factored on equipment pricing, historical data or similar project)

d. Assumed project schedule and any overtime required to meet the schedule, including a high-level work breakdown structure. Conceptual planning for construction should be started at this point. These packages may be broken down by discipline:

i. Demolition
ii. Civil/Structural/Architectural
iii. Mechanical
iv. Electrical

e. Or by physical area of the site:
i. Site
ii. Offices
iii. Warehouse
iv. Production

f. Permits and taxes need to be looked at for cost and timing. Permits often cause delays in construction and need to be reviewed with the approving authorities as early as possible. Taxes vary widely from location to location. Companies may receive exemptions from sales tax if they are expanding a plant, or for new production equipment.

C.4 – Evaluate and Select Best Alternatives

Evaluating and selecting best alternatives draws information from prior efforts of technology selection, site evaluation, and conceptual scopes and estimates to develop a complete picture of each alternative so that valid comparisons can be made. These evaluation criteria include: cost, benefits, economics, and other required decision-making considerations. The conclusion of this function will produce all remaining information necessary for the preparation of the recommendations to be presented to the decision maker(s) concerning the selected alternative(s).

In most cases, economics will be the primary determinant for alternative selection. Economic analysis may be accomplished in a variety of methods, including a risk assessment study and sensitivity analysis. Standard company measures such as return on investment (ROI), cash flow rate of return (CFRR), net present value (NPV), etc, should be compared. These methods typically require input information that can be grouped into the following general categories:

- Benefits
    - Sales volumes and pricing forecast for each product/by-product for the economic life of the asset
    - Length of the economic life
- Project Investment and Timing
    - Capital cost
    - Capital project timing with yearly expected cash flows
    - Cost of financing the project with timing of cost
    - Date that the facility needs to be in production
- Working Capital

- Inventory quantities and values
- Accounts receivables expected levels and values

- Non-Operating Requirements
  - R&D expense
  - Sales, Advertisement, Distribution, and Administration (SADA) expense
  - General plant supporting investment, including utility capital and investment in raw material manufacturing facilities
  - Taxes
  - Incentives
- Operating Requirements
  - Purchased and/or manufactured raw material usage and cost
  - Utilities usage and cost
  - Various Labor types, usage, and costs
  - Operating rates, percent on-stream and percent on-specification production
  - Maintenance and repair cost (non-Labor)

One method of evaluating the alternatives may be to use a decision matrix. More information is given in the attached document. See Decision Matrix Method (PDF file).

C.5 – Concept Phase Report

Prepare a two-part recommendation as follows:

- A written report stating the recommendations, followed by supporting documentation, PDRI assessment (if performed) and a description of the process used to arrive at the recommendation. Information to be included in the body of the report includes the Inputs into Phase Gate 2.
- An oral presentation should be given to the decision maker(s).

Detailed Scope

S.1 – Initiate Phase

1. Team Alignment

   At this point a project team has typically already been formed and should be aligned to the project objectives. This phase typically involves an extensive amount of work and more team members. The team should review Phase Gate 2 deliverables. Typical issues to consider in alignment would include:

   - The kickoff meeting should bring all key stakeholders to the table to begin working together in a team environment, including integration of new team members such as the design and construction contractor(s). QA/QC, maintenance, and operations personnel should be involved.

- Identify roles and responsibilities during the kickoff meeting and continue to update them as the project evolves and/or personnel change. Identify key stakeholders and a communication plan for the Detailed Scope Phase.

  See Selecting the Team (PDF file), CII RS37-1, *Team Building: Improving Project Performance*, CII IR102-2, *Partnering ToolKit*, and CII IR134-2, *Tools for Effective Project Team Leadership*.

- Discuss budget and schedule for activities that must be conducted during the Detailed Scope Phase. These activities may include value management and corporate best practices that will be used in this phase and subsequent phases. See CII IR184-2, *Value Management Toolkit* (only accessible to CII members).
- Agree on resources required for Detailed Scope Phase execution.
- Identify and discuss deliverables that must be completed during the Detailed Scope Phase, to achieve desired accuracy of estimates and sponsor requirements.
- Revisit the team charter (if available), including mission, constraints and objectives. If none is available, develop one. See The Charter (PDF file) and Charter Template (Word file).

2. Review and Understand Business Objectives

   Consider economic variability in demand (seasonal and long term projections) as part of a sensitivity analysis to estimate the upside and downside potential of the opportunity. The following topics should be addressed:

   - Products or building use requirements
   - Market or program strategy
   - Timing
   - Project strategy
   - Affordability/Feasibility
   - Capacity or volume
   - Security
   - Future expansion considerations
   - Environmental
   - Sustainability
   - Project life cycle
   - Social issues

   See CII IR181-2, *International Project Risk Assessment (IPRA)*, for a good discussion on these issues. See CII RS12-1, *Project Objective Setting, Second Edition* for a discussion of objective setting.

3. Validate project assumptions

   Assumptions should be available from the Concept Phase. These assumptions should be questioned and clarified as much as possible to understand the reliability of the work to be performed during the Detailed Scope Phase. Be sure to involve operations and maintenance personnel and get their buy in on these assumptions. Assumptions may include:

   - Conceptual cost estimate and schedule milestones for project, including assumptions made in that estimate
   - Contracting and procurement strategy for future phases of this project
   - Verify the permitting requirements, including processes, personnel, regulatory changes, schedules, location of permitting authority and the estimated time to go through the process.
   - Verify that human resources can be dedicated to this project as necessary, or that consultants/contractors can be hired.
   - Determine the availability of the proposed site
   - Business model viability
   - Availability and delivery of labor and materials for construction
   - Raw materials availability for feedstock
   - Chosen technology(ies)
   - Project and operations funding availability
   - Tax and legal issues

4. Review conceptual design basis

   Review any existing conceptual design basis documents, including requirements documentation, chosen alternatives, and customer needs. If documents do not exist, request clarification. Requirements may include:

   - Manufacturing philosophy
   - Space plan
   - Automation scope
   - User surveys
   - Process design basis
   - Capacity needs
   - Key design documents if available (i.e., existing drawings, geotechnical evaluations, Process Flow Diagrams, mechanical equipment arrangements (MEA), Site Plan, Building Program)
   - Regulatory requirements (e.g., FDA Validation Requirements Identified)

S.2 – Preliminary Design/Engineering

For more information, see Scope Definition (PDF file).

Developing the preliminary design/engineering for the project is the primary activity of the Detailed Scope phase. Documentation of this information is key, either with in-house personnel or the help of consultants. The level of detail of this information depends on the complexity of the project and the time available. The lower the level of documentation for the project, the more potential for risk. The details can be found in Sections II and III of the Project Definition Rating Index (PDRI) for both buildings and industrial projects (PDF files). These categories lay out the critical requirements that must be defined during this phase. Major categories of preliminary design/engineering are listed below:

- Site information
- Building programming
- Process and mechanical
- Equipment
- Building/project design parameters
- Civil, structural and architectural
- Infrastructure
- Instrument and electrical
- Procurement strategy
- Deliverables
- Project controls
- Project execution plan

It should be noted that CII has developed several implementation products that address various specific activities that will be addressed in developing the preliminary design and engineering. Refer to the CII documents listed below for more information:

- IR BMM-3, *Implementing Project Security Practices*
- IR7-3, *Procurement and Materials Management: A Guide to Effective Project Execution*
- IR47-2, *Tools for Enhancing the Piping Engineering Process*
- IR111-3, *Core Competency Toolkit*
- IR121-2, *Planning for Startup*
- IR161-2, *Small Projects Toolkit*
- IR165-2, *Owner's Tool for Project Delivery and Contract Strategy Selection User's Guide*, Second Edition
- IR166-3, *CII Best Practices Guide: Improving Project Performance*, Second Edition
- IR171-2, *Prefabrication, Preassembly, Modularization, and Offsite Fabrication: Decision Framework and Tool*
- IR181-2, *International Project Risk Assessment (IPRA)*

- SP34-1, *Constructability Implementation Guide*
- RS6-6, *Work Packaging for Project Control*
- RS32-1, *Zero Injury Techniques*
- RS101-1, *Design for Safety*
- RS123-1, *Modeling the Lessons Learned Process*

S.3 – Preliminary Design/Engineering Reviews

At the approximate midpoint of detailed scope development, a review should be conducted to ensure that the development process is on track. This review allows the project team the opportunity to check for coordination among the different design activities and identify gaps. In some cases, an outside consultant may perform an independent review, particularly on high cost or profile projects. This is an excellent opportunity to assess the project using the PDRI.

S.4 – Finalize Scope Definition Package

The team should incorporate issues identified in S3 and/or PDRI 2i to ensure that risks are mitigated. Make sure to get stakeholder buy-in for the actions to be taken. It may be necessary at this point to modify and adjust the scope based on this assessment. Be sure that the project sponsor is aware of these changes. The project execution plan (PEP) will also need to be updated based on information developed in S3. It is essential that the actions take to finalize the scope definition package be well documented. See Project Execution Plan (PDF file)

S.5 – Cost and Schedule Control Estimate

See Risk Management and Estimating and Project Control Guidelines (PDF files).

With the detailed scope package finalized, estimates of both the cost and schedule for the project can be developed to the desired level of accuracy (in many cases this is ±10 percent accuracy). Estimators need to be involved in the project team and must be given the right information in a timely manner to ensure that an effective estimate is produced to meet obligations. This estimate will become the control budget for the project and all changes will be measured against it. This estimate may be evaluated by an independent, third party consultant.

It should be noted that a formal risk analysis should be conducted at the completion of the estimate to assess and establish contingency requirements.

S.6 – Compile Project Definition Package

See the Sample Outline of an Authorization Package (PDF file).

Compiling the project definition package includes assembling the information into a detailed project definition package, a project authorization package, and an oral presentation. These reports state recommendations, followed by supporting documentation, PDRI assessment (if performed) and a description of the process used to arrive at the recommendation. The project definition package is used as a detailed road map for project

execution. The project authorization package is an executive summary for the decision maker(s) and is many times accompanied with an oral presentation. Information to be included in the body of the report includes the Inputs into Phase Gate 3.

Project Definition Package. An effective and efficient path for continuation of the project will be met if the organization assembles all detailed information developed to this point. The activities undertaken will be those necessary to compile the project definition package. In addition to providing back-up for the project authorization, the definition package serves as a road map to be used during the execution phases of engineering, procurement and construction. The amount of detail and information will vary for every organization. However, all critical elements must be addressed, at least at the summary level.

Authorization Package. The final step before making a “Go” or “No Go” decision is to prepare an executive summary. This summary contains all the information necessary for the decision maker to evaluate the viability of the project and decide whether to provide funds for the venture. This summary is called the authorization package and consists of all elements of the project definition package plus a project justification, expected project benefits, and a summary level evaluation and recommendation.

Oral presentation. An oral presentation should be prepared summarizing the detailed scope and recommendations given in the authorization package, to be given to the decision maker(s).

(Source: Implementation Resource 213-2, Front End Planning Toolkit)