The Status of Systems Engineering in a South African Engineering Organisation: A Survey

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ABSTRACT

The technology advancement of the latter half of the twentieth century and into this century has been the most significant driver of the emergence of Systems Engineering as a critical skill in the development of complex systems. Not only did the advancement of technology affected the products, but, also the manner in which these products are being developed, manufactured, operated, supported and maintained. The challenges confronting many organisations seeking to implement Systems Engineering in their projects are far from trivial. The current practices and culture in most of these organisations often constrain the adoption of Systems Engineering.

A survey research was conducted to investigate the status of Systems Engineering at a South African Council for Scientific and Industrial Research (CSIR) using one of its business unit, namely Defence, Peace, Safety and Security (DPSS) as a unit of measure. The research instrument for the study was developed based on the international standards and capability maturity models of Systems Engineering, to assess the status of Systems Engineering and to investigate whether an association exist between the status of Systems Engineering and a Competency Area or Job Category at DPSS.

The results showed that the majority in the Competency Areas within DPSS utilises the specific practices associated with the technical processes of Systems Engineering in their projects and that there is no association between the status of Systems Engineering and Competency Area or Job Category. However, the study also shows that there is still room for improvement.

DECLARATION

I hereby declare that the work contained in this thesis is my own unaided work. It is being submitted for the degree of Master of Science in Engineering at the University of the Witwatersrand, Johannesburg. It has not been submitted before for degree purposes to any other university.

Signature: ___________________

Bafana Zephania Selepe

______day of _____________in the year____________

DEDICATION

To God and my parents, David and Maria

ACKNOWLEDGEMENTS

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I want to extend my gratitude to the CSIR's R&D Committee for permitting me to gather research data from its employees and to the employees of the DPSS for giving their valuable time and providing me with data for this study. Also, I would like to single out for special thanks: Dr. Kaven Naidoo for his keen interest and show of support for my studies. I am forever indebted to my wife and children for bearing with me throughout my studies.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The technology advancement of the latter half of the twentieth century and into this century has been the most significant driver of the emergence of Systems Engineering as a critical skill in the development of complex systems (Kossiakoff *et al.*, 2011). Not only did the advancement of technology affected the products, but, also the manner in which these products are engineered, manufactured, operated, and maintained (Kossiakoff *et al.*, 2011), (Blanchard, 2008).

1.2 Research Background/Context

The Council for Scientific and Industrial Research (CSIR) is Africa's leading technology development institution (CSIR Website, 2018). It supports the socio-economic development of the country through knowledge creation and knowledge application activities, to create a positive impact towards job creation, rural development and human capital development, as well as meeting the basic needs of the South African citizens (Horak, 2014). To run and successfully execute complex projects at such an organisation requires a robust multidisciplinary approach, and Systems Engineering provides such an approach.

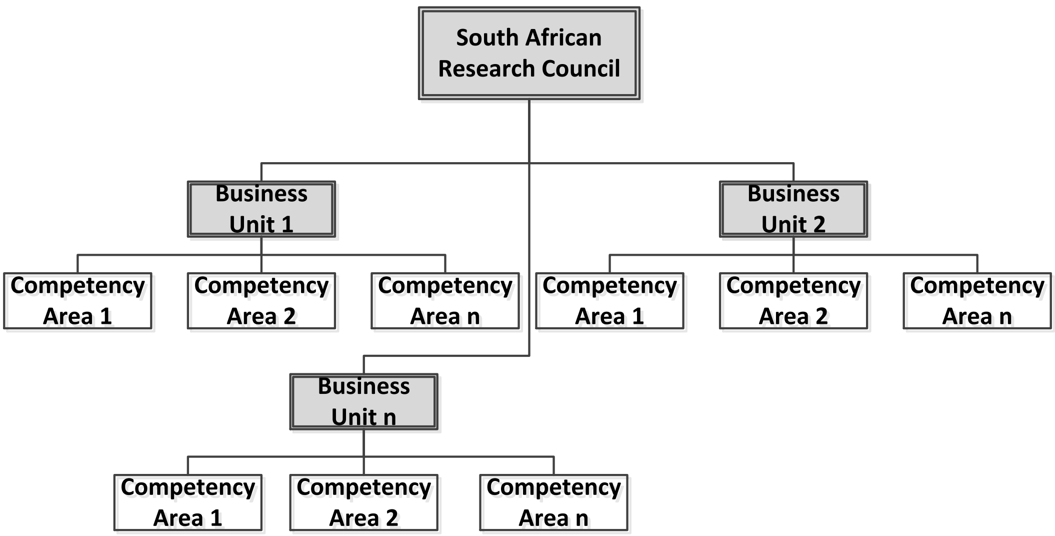


Figure 1. Structure of the South African Research Council

Figure 1 depicts the structure of the CSIR. The structure comprises of business units, and each business unit in turn comprises of Competency Areas. At the time of this study, there were nine business units within the CSIR. This study focused only on one of the CSIR's business unit, namely the Defence, Peace, Safety and Security (DPSS). As such, the interpretation of the results, as well as conclusions of this study, are not generalisable to the whole of the CSIR.

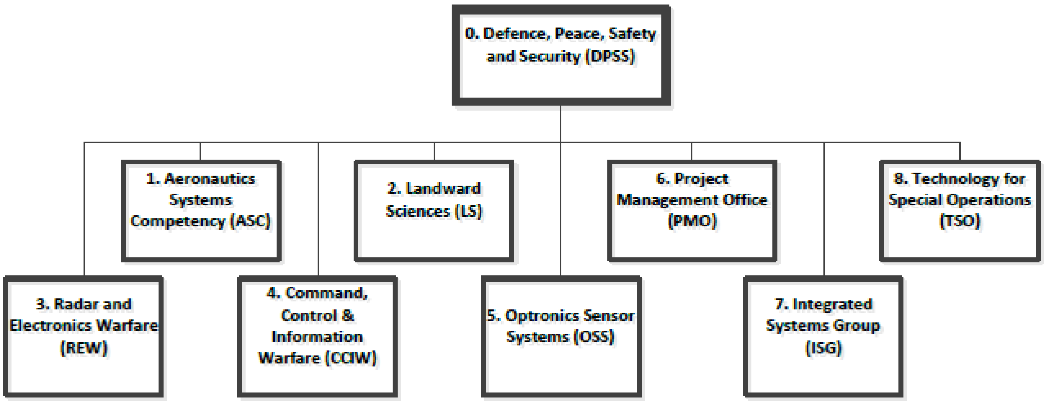


Figure 2: The structure of DPSS showing its eight competency areas

Figure 2 depicts the structure of DPSS. At the time of this study, there were eight competency areas within DPSS. Within the CSIR's context, a competency area refers to a group of researchers (including technologists, engineers and scientist) with related knowledge and skills focusing on a specific domain of scientific and industrial research, such as for example the Aeronautics Systems.

1.3 Problem Statement/Motivation

The preliminary investigation suggests that there is an awareness about Systems Engineering at DPSS as evident by the study conducted by (Malik, Erasmus and Pretorius, 2016). However, its application seems to be more on ad hoc basis instead of being proactively planned. The study by (Malik, Erasmus and Pretorius, 2016), explored some of the most important aspects of Systems Engineering Management, but, did not address the status of specific practices associated with the technical aspects of Systems Engineering. This research project, thus, proposes to build on the exploratory study of (Malik, Erasmus and Pretorius, 2016) by addressing the status (utilisation) of specific practices associated with the technical processes of Systems Engineering when executing technology development projects at DPSS.

1.4 Research Questions

The associated research questions, within the context of executing the technology development projects in DPSS, are as follows:

1. What is the status (utilisation) of specific practices associated with the technical processes of Systems Engineering?
2. Is there an association between the status of specific practices associated with the technical processes of Systems Engineering and Competency Area?
3. Is there an association between the status of specific practices associated with the technical processes of Systems Engineering and Job Category?

1.5 Research Objective

By answering the above research questions, within the context of executing the technology development projects in DPSS, the specific objectives of this study are:

1. To assess the status of specific practices associated with the technical processes of Systems Engineering.
2. To investigate whether an association exist between the statuses of specific practices associated with the technical processes of Systems Engineering and Competency.
3. To investigate whether an association exist between the statuses of specific practices associated with the technical processes of Systems Engineering and Job Categories.

1.6 Hypotheses

To address the research problem effectively and achieve the objectives of this study, within the context of executing the technology development projects in DPSS, it was:

1. Hypothesised that there is no difference between proportions those who agree and those who do not agree with the utilisation of the specific practices for Systems Engineering in their projects.
2. Hypothesised that there is no association between the status (utilisation) of the specific practices for Systems Engineering and Competency Areas.
3. Hypothesised that there is no association between the status (utilisation) of the specific practices for Systems Engineering and Job Categories.

1.7 Summary of Research Method

The study researched the respondents' opinions about the status of specific practices of systems engineering at DPSS. Based on the literature review, a theoretical framework for the study was developed that consists of the following seven focus areas associated with the technical processes of Systems Engineering:

1. Stakeholder Needs and Requirements Analysis
2. System Requirements Analysis
3. System Architecture
4. System Design and Analysis
5. Assessment, Selection and Implementation
6. System Integration
7. System Verification and Validation

Each focus area, in turn, consists of specific practices associated with that focus area. The questionnaire for this study was designed based on this framework. For each specific practice, respondents were requested to select only one response from a 5-point Likert scale (1 = strongly agree to 5 = strongly disagree), which in their opinion best represent their judgement about the extent to which their project is utilising that specific practice in fulfilment of a specific Focus Area of the Systems Engineering Process. Contented validity and pilot testing of the questionnaire were performed before actual data collection. The reliability test was also performed using the data collected from 47 respondents. Obtained data were analysed using both descriptive and inferential statistics.

1.8 Limitations or Scope

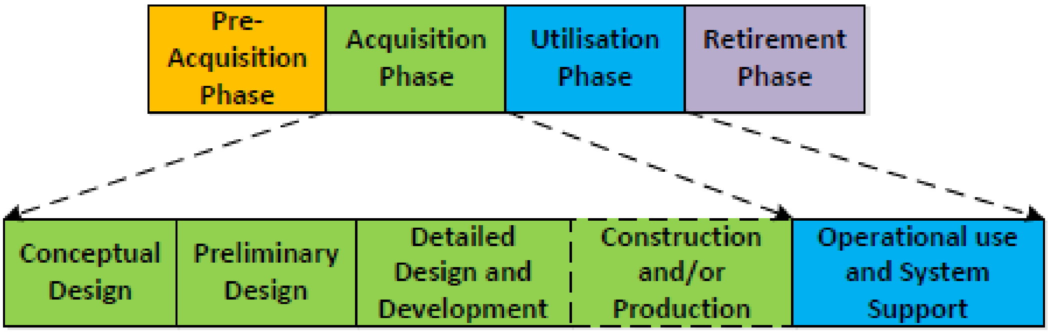


Figure 3: System Product Life-cycle

The current study focuses on the first three phases of the acquisition stage for a human engineered system as shown in Figure 3.

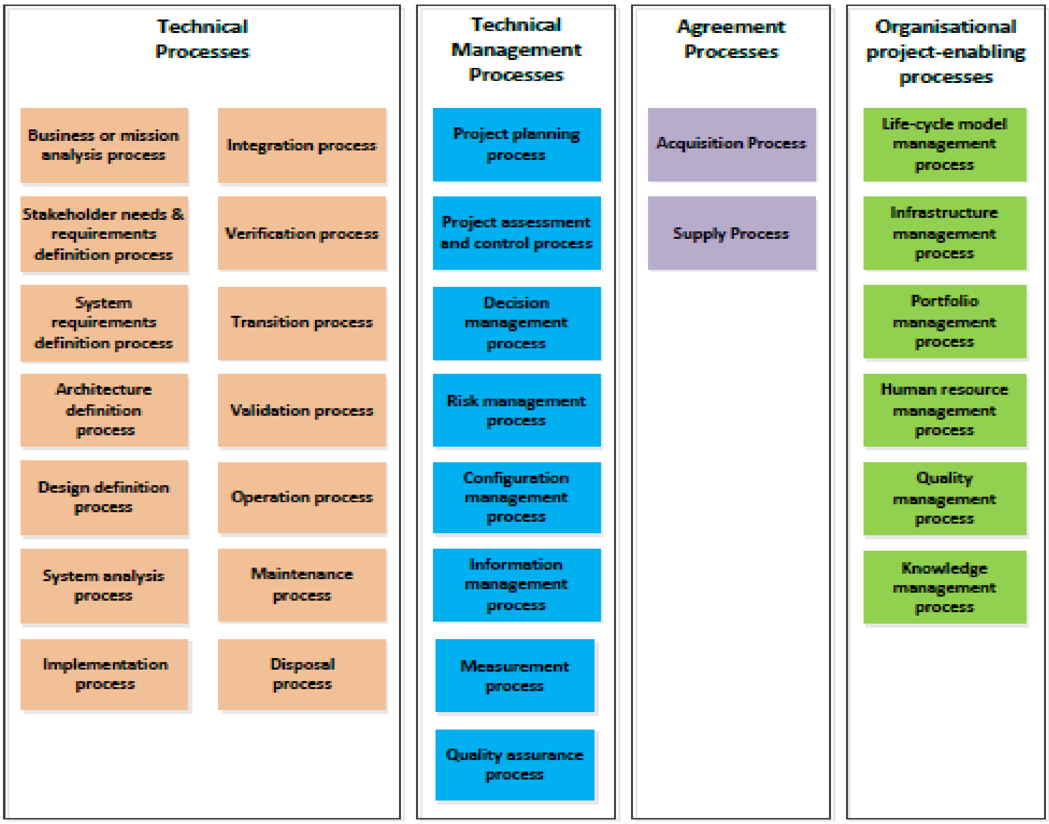


Figure 4: System Life cycle processes (Sources: (INCOSE, 2015)**)**

Figure 4 shows the System life cycle processes in accordance with the Systems Engineering Standard International standard, ISO/IEC/IEEE 15288 (INCOSE, 2015). There are four process groups in this standard, namely the technical, management, agreement and organisational project-enabling processes. The current study focuses only on the technical processes, excluding the Business or Mission analysis and Transition Process as well as the last three processes namely the Operation, Maintenance and Disposal processes, which essentially forms part of the utilisation and retirement phases of the system lifecycle (see Figure 2). The management, agreement and organisational-enabling processes were beyond the scope of this study. As such, the interpretation of the results, as well as conclusions of the present study are to be understood on this basis.

1.9 Outline of Chapters

Chapter 1	• This chapter provides an introduction, justification for the study, research objectives, and a summary of the research method used for this study. • The background of an organisation where the research was conducted is also presented. • The structure of the research report is also described in this chapter.
Chapter 2	• This chapter presents a critical review of the relevant literature. This include concepts of a system and systems engineering. • The theoretical framework of the study is also presented in this chapter.
Chapter 3	• This chapter presents the research method used for this study. This includes research design, data collection, data analysis, validity, reliability, bias and ethical considerations.
Chapter 4	• This chapter includes data analysis and interpretation of the results.
Chapter 5	• This chapter includes the discussion of the results, conclusions, recommendations and implications for future studies.

CHAPTER 2: LITERATURE REVIEW

In this chapter the concepts associated with a system and systems engineering are explored. It also introduces the importance of systems engineering and the theoretical framework of the study. This will allow a preliminary understanding about the specific practices associated with the technical processes of systems engineering from the literature. The study is structured into two parts. Part I mainly focuses on identifying key concepts and establishing a theoretical framework. Part II focuses on introducing the survey study and the results.

2.1 Systems Engineering

Systems engineering provides a framework to facilitate the process of defining, analysing, specifying, manufacturing, operating and supporting complex systems (Faulconbridge and Ryan, 2003). The review of the literature (Faulconbridge and Ryan, 2003), (Blanchard, 2008), (Kossiakoff *et al.* (2011), reveals that the emphasis of Systems Engineering remains on the system as a whole and the sustenance of a robust multidisciplinary approach. (Faulconbridge and Ryan, 2003) argued that, project management, quality assurance, integrated logistics support, and a variety of engineering specialisations are but elements of a coordinated systems engineering effort. (Blanchard, 2008) asserted that with more complex systems being built and used, an understanding of the concept of a system and mastering the systems engineering methods are critical for systems designers.

2.2 System Concepts

Systems abound in our environment, both natural and human-made. The circulation of waters in the oceans, the weather and climate system, and the food chain are some of the examples of natural systems. The telecommunication networks, air transportation networks and roads network are some of the examples of human-made systems. Natural systems comes about as the results of nature (Blanchard, 2008). Human-made systems are developed and built by humans to satisfy their needs and desires (Blanchard, 2008). The systems considered in this study "*are man-made, created and utilised to provide products or services in defined environments for the benefit of users and other stakeholders*"(INCOSE, 2015).

2.2.1 Definition of a System

The definition of the term 'system' depends on the users, context, and ultimate goal. In systems engineering context, a system may defined as:

"an integrated composite of people, products, and processes that provide a capability to satisfy a stated need or objective"(DAU, 2001).

"a collection of interacting subsystems that, if properly organized, can provide a synergistic output" (Kerzner, 2009).

"*a combination of interacting elements organized to achieve one or more stated purposes*" (ISO/IEC/IEEE, 2015).

"*a construct of different elements that together produce results not obtainable by the elements alone"* (INCOSE, 2015).

"*An integrated composite of people, products, and processes that provide a capability to satisfy a stated need or objective*" (ANSI/EIA, 2003).

These definitions indicate that a system contains internal elements with interfaces (connections) between them and by identifying the system of interested (SOI), external system boundary is implied (Buede and Miller, 2016), (PPI, 2014). As illustrated in Figure 5 of the Airlift Capability System, when we draw the boundary around chosen system elements, we establish the system of interest (also called system context) which consists of those system elements and their interconnections that exist within the defined boundary (PPI, 2014).

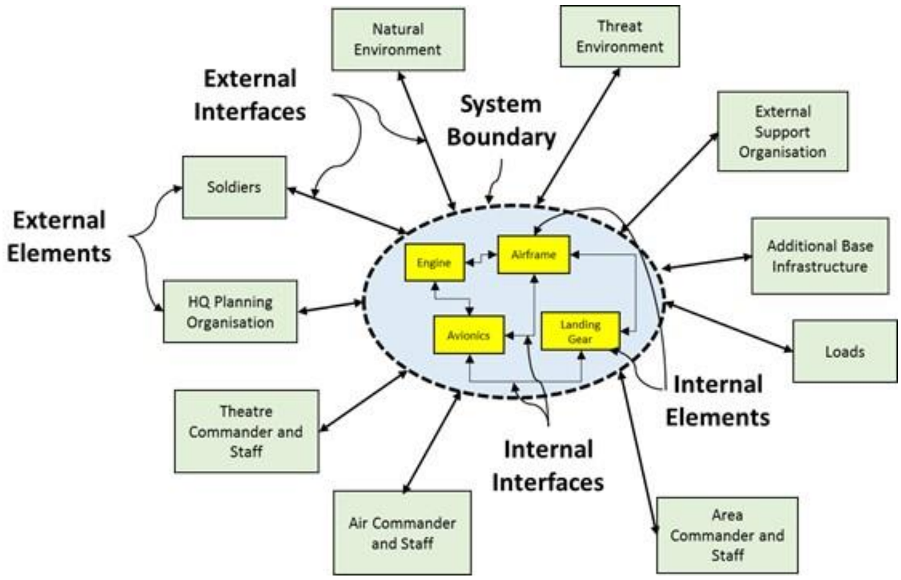


Figure 5: Airlift Capability System (adapted from PPI, 2014)

(Blanchard, 2008) described a system as a combination of interdependent elements working together towards a common goal, and (Sarngadharan and Minimol, 2009) added, "*by accepting inputs and producing outputs in an organised transformation process*".

Referring to Figure 5, acceptance of the inputs into the systems and the transfer of outputs to the external system's elements is accomplished through external interfaces. The interdependent elements which are logically organised to form a system are often called subsystems (ISO/IEC/IEEE, 2008).

According to (Blanchard, 2008) and (Sarngadharan and Minimol, 2009), a system may be either conceptual/abstract or physical. A conceptual/abstract system is an orderly arrangement of interdependent ideas or contracts (Blanchard, 2008). A physical system on the other hand occupy a space (Sarngadharan and Minimol, 2009), and according to (INCOSE, 2015), a physical system it is made up of objects such (i.e. hardware, software, and firmware), processes, people, information, techniques, facilities, services, and other support elements.

2.2.2 Characteristics of a System

The definition of a system implies some characteristics that are present in all systems namely: *organization (order)*, *interaction*, *interdependence, integration* and a *central objective* (Nesan and Kumar, no date), (Eisner, 2008), (Blanchard, 2008)

i. Organisation (order) of the system

The word organisation implies the structure and order and it pertains to an arrangement of components within a system (Blanchard, 2008), (Nesan and Kumar, no date). It is the intentional logical arrangement of elements that help to accomplish objectives.

The organisation structure (organogram) of a business system, for instance, can be represented by the hierarchical relationships starting with the Chief Executive Officer at the top and leading down to the blue – collar workers at the bottom of the structure. The structure portrays the relationship of the system and its subsystems, it defines the governance structure, shows the channel of formal communication and legitimises the chain of command (Nesan and Kumar, no date). The structure of a computer system, for instance, comprises of the input device, an output device, one or more storage units and a central processing unit (CPU). When systematically connected they work synergistically as a whole to produce useful data (Nesan and Kumar, no date).

The elements of a system are organised systematically following a specific plan, and each element has a specific role to play within the system (Buede and Miller, 2016), (Nesan and Kumar, no date), (ISO/IEC/IEEE, 2008).

ii. Interactions

Interaction pertains to how each element works together with other elements of the system and enables the system to operate as required (Buede and Miller, 2016), (Faulconbridge and Ryan, 2003) (Buede and Miller, 2016). In the case of a business system, for example, the procurement element must interact with production element, advertising with sales and payroll with personnel (Nesan and Kumar, no date). In the case of a computer system, the input device interacts with the central processing unit to solve a problem, in turn, the main memory holds programs and data that the arithmetic unit utilises for the calculations (Nesan and Kumar, no date).

iii. Interdependence

Interdependence means that the elements of a system are depended on one another. It implies that, within the system, the elements depends on the input of other elements for proper functioning: that is, the output of one element is the required input for another element within the system (Blanchard, 2008), (Buede and Miller, 2016).

The interdependencies of system elements is critical to the functioning of the system. In short, no element of the system can function in isolation since it depends on the inputs that it acquires from other system elements to perform its required functions (Buede and Miller, 2016). The elements of a system interact with each other to accomplish a common purpose (Buede and Miller, 2016) (Blanchard, 2008).

iv. Integration

Integration leads to the holism of a system (Blanchard, 2008) (Nesan and Kumar, no date). The process of synthesis, analysis and evaluation serves to achieve the prime objective of the system (Blanchard, 2008).

Integration is concerned with how harmoniously the system elements are organised together. It relates to the parts of the system working together harmoniously although each part accomplishes a unique function (Nesan and Kumar, no date). Successful integration leads to synergy and the overall impact than when the individual element operates independently (Blanchard, 2008) (Nesan and Kumar, no date).

v. Orientation towards the objective:

Last but not least, another characteristic of a system is its central objective. The critical argument here is that the users need to know the central objective of the desired system early in the feasibility study for the successful design and development of the system (Nesan and Kumar, no date). (Blanchard, 2008) cautioned that political and other organisational considerations often obscure the real objective for the system, and System Engineers need to work around these obstacles and keep their focus on the real objective. As stated by (Blanchard, 2008), a system is an assemblage of a set of components working together to achieve the common objective. The system's elements should be oriented towards the system's common objective and when they interact with each other, they must achieve this objective. Optimisation of individual elements within the system does not necessarily result in an optimised system, in fact, the opposite might happen (Blanchard, 2008). Knowledge of the central objective of the system is key to decisions relating to system optimisation.

2.3 Systems Engineering Concepts

For several decades now, systems engineering proved to be beneficial for the design and development of large and complex systems (Liu, 2016). In the past, a single engineer could plan and execute a project, but, nowadays it is no longer possible (CIESE, 2008). In today's projects, engineers work in multidisciplinary teams and often, these engineers specialise in a single discipline, for example mechanical, aeronautical, electrical or software engineering (CIESE, 2008). On the other hand, systems engineering is interdisciplinary, and from a management perspective, its main focus is on improving the way engineers from different disciplines work together to accomplish the common objective of the project (CIESE, 2008). While this may sound like project management, the main difference lies "*in an emphasis on the technical aspect of the project than the contractual, financial and schedule aspect that seem to be the overarching focus of project management"* (Jorg, 2011).

2.3.1 Definition of Systems Engineering

(INCOSE, 2015) defines systems engineering as:

"*an interdisciplinary approach and means to enable the realisation of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, then proceeding with design synthesis and system validation while considering the complete problem: operation, performance, test, manufacturing, cost and schedule, training and support and disposal. Systems engineering integrates all the disciplines and specialty groups into a team effort forming a structured development process that proceeds from concept to production to operation. Systems engineering considers both the business and the technical needs of all customers with the goal of providing a quality product that meets the user needs.*"

Hall (1962) cited in (Boord and Hoffman, 2016) defined Systems Engineering as:

"*a process that is comprised of a number of activities that will assist in the definition of the requirements for a system, transform these requirements into a system through design and development efforts, and provide for the operations and sustainment of the system in its operational environment*"

According to (Kossiakoff *et al.*, 2011):

"*Systems engineering is focused on the system as a whole; it emphasizes its total operation. It looks at the system from the outside, that is, at its interactions with other systems and the environment, as well as from the inside. It is concerned not only with engineering design of the system but also with external factors, which can significantly constrain the design. These include the identification of customer needs, the system requirements, the capabilities of operating personnel, and such other factors as must be correctly reflected in system requirements documents and accommodated in the system design.*

2.4 The Core Concepts of Engineering Design

Jain et al, 2008 cited in (Jain and Chandrasekaran, 2008), identified five core concepts of engineering design relevant to systems engineering namely value, context, trade-offs, abstraction and interdisciplinarity.

i. Value

Jain and Chandrasekaran (2008) emphasizes that systems exist to offer value to their stakeholders. According to Microsoft (2005) cited in (Jain and Chandrasekaran, 2008), a well-established value model provides guidance to helps improve the quality of trade-off decisions made during the conceptual design of the system. (Jain and Chandrasekaran, 2008) argued that, knowing the value proposition for a desired system is critical to success. (Jain and Chandrasekaran, 2008) claimed that designing for value in shape and form of the 'whole' system (holistic perspective) is rarely addressed by design courses in current engineering curricula. According to (Jain and Chandrasekaran, 2008), the discipline centred design (partial design) constrains the ability to recognise the significance of the entire system design as manifested in the desired final system.

(Jain and Chandrasekaran, 2008) are of the view that, "*the intellectual content of most engineering disciplines is component-oriented and value-neutral*". (Jain and Chandrasekaran, 2008) identified the critical distinction between systems engineering and other engineering disciplines to be the systems engineering's concern with stakeholder value as opposed to the value-neutral orientation of other engineering disciplines. (Jain and Chandrasekaran, 2008) argued that, realisation of successful systems require an understanding of the relative value of alternative system concepts to success-critical stakeholders, and the configuration of system elements and people into a system that satisfies the value propositions of those success-critical stakeholders.

ii. System Context

During the engineering design of a system, it is essential to distinguish between system content and system context (Moriarty, 1994). (Jain and Chandrasekaran, 2008) argued that a context relates to "*conceptualising beyond the multidisciplinary content contributions*". It also considers how engineering design is practised within a 'context.' (Moriarty, 1994) argued that, for any given engineering design, the context grounds and conditions the constraints and content of that particular engineering design. According to (Jain and Chandrasekaran, 2008), the constraints define the extent of the engineering design and incorporate issues associated with "*regulatory requirements, all forms of rules related to performance, scalability, security, stress, volume, choice of technology, etc.*"

(Moriarty, 1994) alluded that, the content is embedded within the context. The content is essentially the core of engineering design, and it includes the steps and processes of designing the system, on the other hand, the context is the world out of which the need for a system originated and the environment in which the system will eventually have to operate (Moriarty, 1994). (Jain and Chandrasekaran, 2008) highlighted that the context sets the internal and external interfaces for a given system. (Jain and Chandrasekaran, 2008) also cautioned that a lack of contextual understanding of the system leads to an isolation of the problem from the solution. The result is a sub-optimal system solutions that do not address the needs of customers and users. Thus, it is critical that system designers understand both the content (i.e., the system functionality) as well as the context (i.e., system operational environment) of the system of interest (Jain and Chandrasekaran, 2008).

i. Trade-offs

A critical element of evaluating design concepts is a selection process based on established selection criteria and trade-off analysis (INCOSE/AIAA, 1997). The objective of evaluating concepts based on selection criteria and trade-offs such as feasibility, cost, schedule or technical performance is to realise the most optimal concept that will satisfy the stakeholders' needs and requirements (Jain and Chandrasekaran, 2008). A design which is driven by a single option precludes consideration of other concepts which may influence the decision to implement that option. Several concepts should be identified and assessed based on their strengths and weaknesses, and the results should be utilised to make a selection of the most optimal solution for further development (Jain and Chandrasekaran, 2008).

The goal of conducting a trade-off analysis is to understand how and to what extent the total design can address the functionality needed by the user-community (Jain and Chandrasekaran, 2008), (ISO/IEC/IEEE, 2008). The system-level design presents an opportunity for assessing each user requirements (needs) versus the cost and benefit of addressing each one of those requirements (Jain and Chandrasekaran, 2008). Trade-off requires that the users-community prioritises their requirements into essential, conditional, optional, or other similar categories, and based on the requirements classification scheme, resources are assigned for designing and implementing a system solution that can fulfil those requirements (Jain and Chandrasekaran, 2008). Due to limited resources, recommended solutions can only be thought of as optimal, not perfect since trade-offs often have to be addressed and settled (Jain and Chandrasekaran, 2008).

ii. Abstraction

One of the essential skills of system engineers is the ability to abstract a system's functional design concept independent of a specific solution (Blanchard, 2008), (Buede and Miller, 2016), (ISO/IEC/IEEE, 2008). Separating the system's functional design from its solutions provides more flexibility and fosters exploration of alternative solutions (ISO/IEC/IEEE, 2008). Abstraction enables system engineers to move between various levels of the system’s functional breakdown structure without losing the guiding system architectural design principles (Jain and Chandrasekaran, 2008). According to (Jain and Chandrasekaran, 2008), traditionally, engineers have been required to move directly from understanding the users’ needs to the actual design of the product to satisfy those needs. This approach may be too risky since the solution may be selected too early, without proper assessment of alternative means to address the users' needs, and thus leading to "*inefficient, costly, and often, unscalable and inflexible solution*" (Jain and Chandrasekaran, 2008).

The review of the literature suggests that nowadays it is common to find technological developments that are driven by the need to implement 'faster, cheaper, and better' approaches, (Jain and Chandrasekaran, 2008) cautioned that committing to a design solution very early may prove to be a costly proposition in both the short- and the long-run.

i. Interdisciplinarity

In general, it is agreed that the success of systems design relies heavily on the integration of two or more, often diverse disciplines (Blanchard, 2008). By involving unrelated multi-disciplines in systems design, traditional gaps in the language, approach, and methods gradually disappear (Jain and Chandrasekaran, 2008). The multidisciplinary characteristics of systems design enable the team members to contribute their discipline knowledge and perspectives towards system development effort (Jain and Chandrasekaran, 2008). The holistic system design approach is based on the premise that design should be viewed from the perspectives of all relevant stakeholders and disciplines. (Jain and Chandrasekaran, 2008) cautioned that, a design team that does not involve relevant disciplines would most probably overlook the essential aspects of the missing discipline(s). (Jain and Chandrasekaran, 2008) emphasised that, when analysing the functionality of a system and transforming it into a design, it is imperative to address its design with a multidisciplinary team that shares a common understanding of the adopted design process and methodology.

ii. The system life cycle concept

Fundamental to the practice of life-cycle engineering is the understanding of the system life-cycle (Blanchard, 2008). Referring to Figure 6, a system begins with the identification of a need and extends through conceptual and preliminary design, detail design and development, production and/or construction, distribution, customer use, support, and then phase-out and disposal (Blanchard, 2008). The life-cycle concept is universal in its applicability (Blanchard, 2008). It originates with the perception of a need and terminates with product phase-out and disposal (Blanchard, 2008). Between these end points there are two major life-cycle phases:

- **Acquisition phase** involving the several iterative steps necessary to define the need, perform the design, test and evaluate, and finally produce and distribute the product (Blanchard, 2008).
- **Utilization phase** involving activities required to deal with the product in being. These include operating, maintaining, modifying, retiring, and product disposal (Blanchard, 2008).

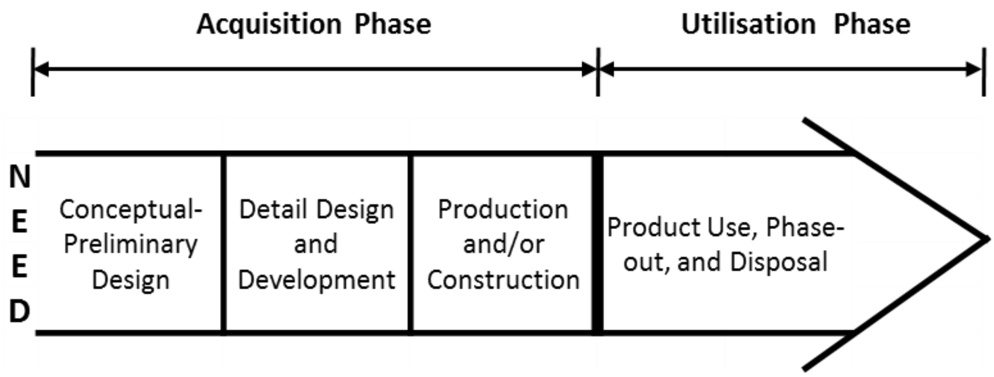


Figure 6. Generic System Life-Cycle adapted from Blanchard (2008)

A system starts with user/customer requirements; requirements are the basis for systems functions; higher-level requirements can be refined by lower-level requirements; higher-level functions are decomposed by lower-level functions (Blanchard, 2008). Each function is performed by one or more components. These relationships are essential for successfully translating the systems requirements into component attributes, providing system rationale, and providing traceability for systems design activities (Blanchard, 2008).

2.5 Importance of Systems Engineering

The importance of systems engineering in the development of complex systems has for over 50 years through heuristic, intuitive wisdom been highly regarded (Honour, 2014). Goode (1957) cited by (Honour, 2014) stated that systems engineering has since its recognition in the 1950s been used to develop products that ranged from aircraft, software, ships, computers and environmental control, urban and infrastructure automobiles. Hall (1993) in (Honour and Mar, 2001) asserted that Systems Engineering practitioners had always been acknowledged as technical leaders of complex technology development projects. Managers heuristically understand that to avoid producing immature, unsafe, and unsupportable products some level of systems engineering is essential and use this judgment when staffing their projects (Honour, 2014). Managers also heuristically know that adding too many systems engineers to a project may lead to "paralysis by analysis" (Honour, 2014).

The notion of the heuristic value of Systems Engineering is depicted graphically in Figure 7. The costs to identify and correct requirements errors can use the significant amount of the project budget as systems become more complex (Haskins *et al.*, 2004). There are two primary drivers of the cost associated with errors in complex systems development projects namely; the cost of identification and the cost of correction (Haskins *et al.*, 2004).

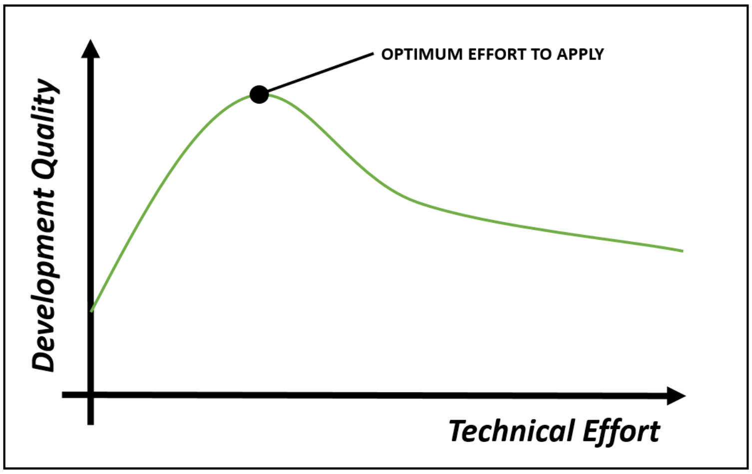


Figure 7: Heuristic SE Value (adapted from Honour, (2001))

The study by (Haskins *et al.*, 2004) focused on the element of the cost of correction. This study aimed to determine how the cost of fixing errors behaves as the project progresses. Three approaches were applied to assess the relative costs namely; the bottom-up cost method, the total cost breakdown method and the top-down hypothetical project method (Haskins *et al.*, 2004). The study assumed the development of a hardware/software system with project characteristics comparable to those used in the development of a large, complex spacecraft, a military aircraft, or a small communications satellite (Haskins *et al.*, 2004). This study reported that the cost-to-fix an error increases exponentially as the project advances through its phases (Haskins *et al.*, 2004). Suppose the cost of correcting a requirement error detected during requirements phase is set to 1 unit. Then the cost of correcting errors during the design phase will range between 3 to 8 units; during the manufacturing/build phase between 7 to 16 units; during integration and test phase between 21 to 78 units and; during the operations phase ranges from 29 units to more than 1500 units (Haskins *et al.*, 2004). The key results are presented in Table 1 below.

Table 1: Comparison of Methods 1, 2, & 3 Cost Factors per Life Cycle Phase (Haskins et al., 2004)

	Method 1 – Bottom-Up Cost Factors	Method 2 – Total Cost Breakdown Cost Factors	Method 3 – Top-Down Hypo Project Cost Factors
Requirements	1X	1X	1X
Design	8X	3X – 4X	4X
Build	16X	13X – 16X	7X
Test	21X	61X – 78X	28X
Operations	29X	157X – 186X	1615X

The emergence of Systems Engineering proved to be the most effective means to manage complexity and change right from its early beginnings (INCOSE, 2015). Due to continuing escalation of both change and complexity in products, services, and society, the primary goal of the Systems Engineer remains to be the reduction of the uncertainty associated with the development of new systems or upgrades to existing complex systems (INCOSE, 2015). Figure 8 illustrate the behaviour of the life cycle cost (LCC) of a system over time.

The basis of Figure 8 is a statistical analysis performed in 1993 on projects within the US Department of Defence (DOD) by the Defence Acquisition University (INCOSE, 2015). Along the timeline is the percentage of the actual life cycle cost (LCC) accrued over time. Figure 8 also indicates that the cost of the concept phase of a new system is on average 8% of the total LCC (INCOSE, 2015). The amount of the LCC committed over time as a result of project decisions is represented by the committed costs curve. Figure 8 also shows that 80% of the total LCC has already been committed when only 20% of the actual cost has been accrued (INCOSE, 2015). As indicated by the diagonal arrow under the committed cost curve, errors are less expensive to remove early during the system life cycle (INCOSE, 2015).

The ever-increasing complexity impacting on innovation is another factor driving the need for systems engineering (INCOSE, 2015). Not many products are introduced as the big-bang of an invention; instead, the majority of products and services in the current market are the results of incremental development (INCOSE, 2015). The implication is that the life cycle of modern products and services are both extended and subject to high levels of uncertainty (INCOSE, 2015). In the current century, a well-defined system engineering process is key in creating as well as sustaining a competitive advantage (INCOSE, 2015).

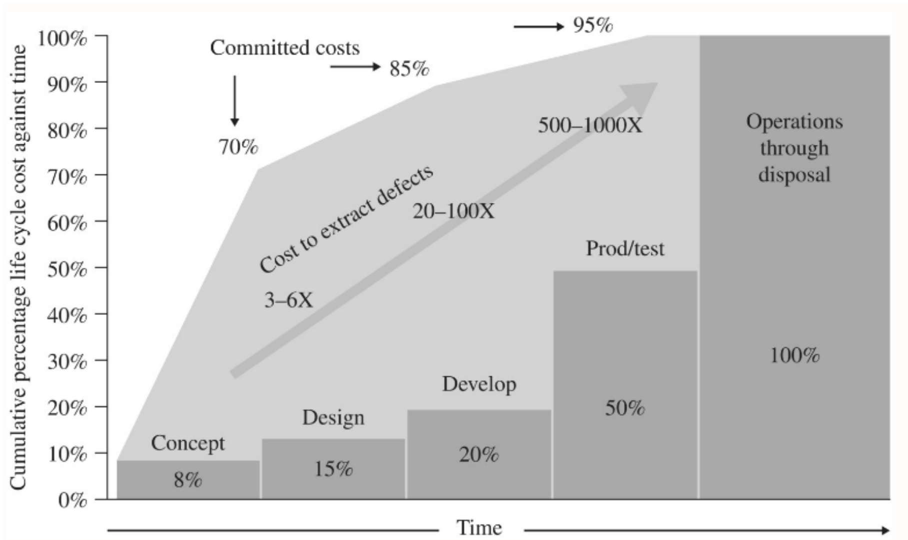


Figure 8: Committed life cycle cost against time (INCOSE, 2015).

As presented in Figure 9, over the past 40 years, the development and market penetration of new technology have accelerated by more than a factor of four (INCOSE, 2015). The time it took to attain 25% market penetration was reduced from about 50 years to below 12 years (INCOSE, 2015). The lead time from prototype development to 25% market penetration decreased from 44 to 17 years on average (INCOSE, 2015). Two research projects demonstrated the value of systems engineering from the effectiveness and return on investment (ROI) perspectives. The following briefly discussed the outcomes.

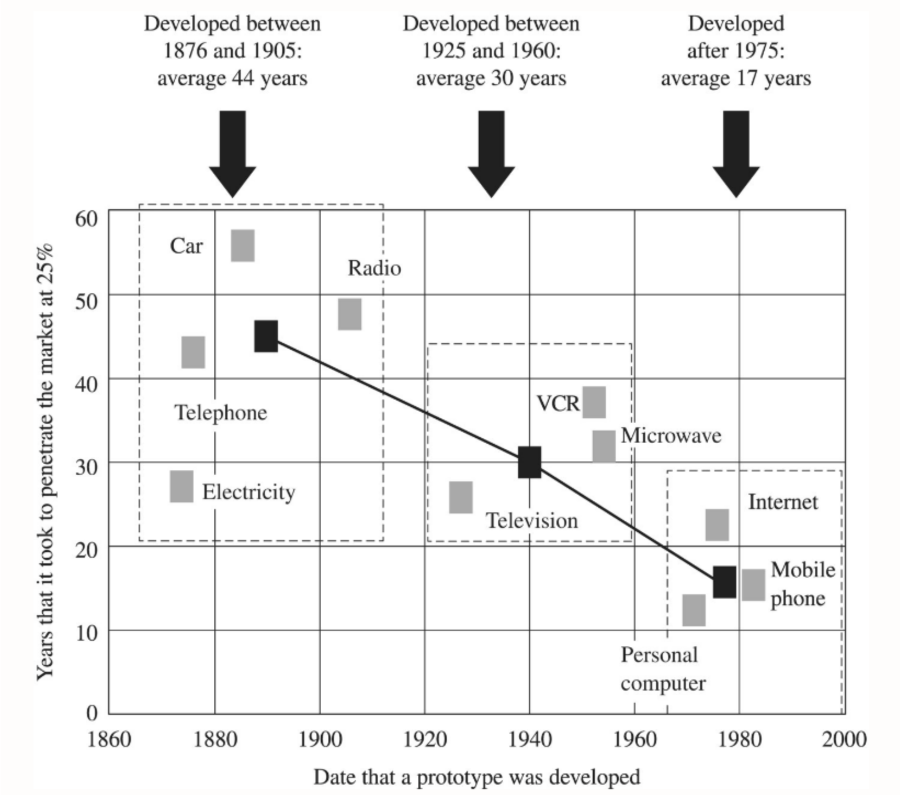


Figure 9: Technology acceleration over the past 140 years (INCOSE, 2015)

2.5.1 Systems Engineering Effectiveness

In the study which was conducted by Carnegie-Mellon University, anonymised data from the defence and space projects were analysed to examining the correlation between business outcomes (cost, timescale and technical quality) and systems engineering capability (high, medium and low) (Elm and Goldenson, 2012). The key findings are presented in Figure 10. Business outcomes were characterised by top third, middle third and bottom third. Companies which deployed low systems engineering capability achieve top-third outcomes of only 15% (Elm and Goldenson, 2012). From these results, it may be concluded that; an average high-value project deploying a high level of system engineering capability more than trebles its likelihood of project success compared to the one which deploys a low level of systems engineering capability; For a very complex project, deploying a low level of systems engineering capability presents a likelihood of 92% of not achieving top-third business outcomes (INCOSE, 2015).

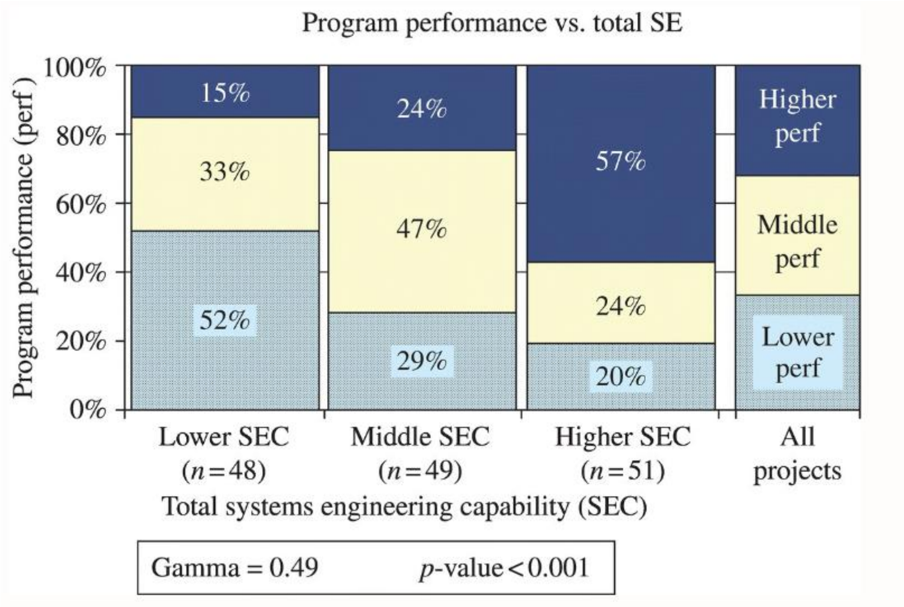


Figure 10: Total SE Capability vs. Project Performance (Elm and Goldenson, 2012)

2.5.2 Systems Engineering Return on Investment (ROI)

(Honour, 2013) investigated the overspent on the project against the percentage of the development effort spent on system-level cross-disciplinary activities. A model of the return on investment (ROI) of allocated extra systems engineering effort to a project was the primary outcome (Honour, 2013). The key results of a 15 years research with data from 94 programs were that; for projects that spent only 1% on systems engineering activities, they overspend on their budget by 53% percent and the ROI of allocating more SE was 7:1 and; projects that spent an average of 7% on systems engineering activities overrun their budget by only 15% and the ROI of allocating more systems engineering was still 3.5:1 (Honour, 2013). Presented in Figure 11, the study also found that the optimum level for allocating a budget to systems engineering activities is 12-15% (Honour, 2013).

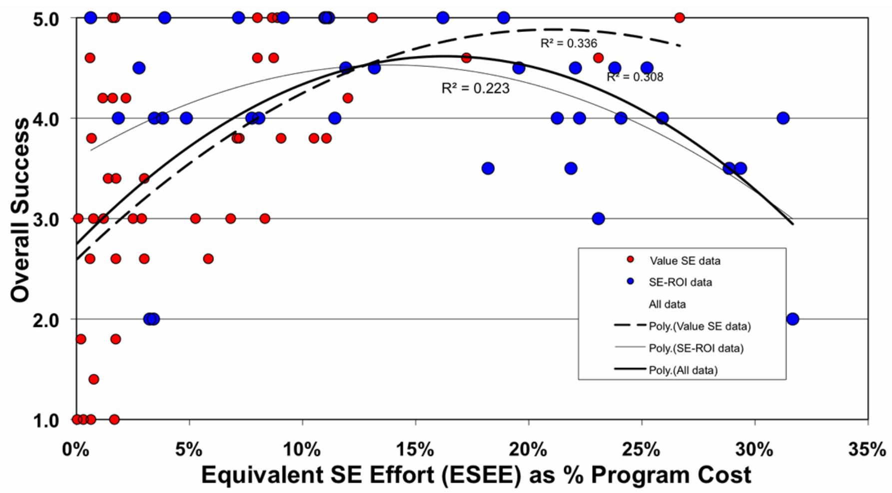


Figure 11: Correlation plot: overall success (OSi) against SE (ESEEi) (Honour, 2013)

2.6 Theoretical Framework

The framework for this study is based on the Systems Engineering Body of Knowledge (SEBok), Systems Engineering International Standards and Capability Models, in particular, the SECM, EIA/IS 731. Currently, there are three systems engineering capability models; SE-CMM, SECAM and SECM (EIA/IS 731). The two models SE-CMM and SECAM were combined to form the SECM, EIA/IS 731, which was harmonised with the three systems engineering standards namely IEEE 1220, EIA 632 and ISO/IEC 15288 (Sheard and Lake, 1998).

2.6.1 Comparisons of Standards and Capability models

Both Capability Models and Standards describe good systems engineering practice, but they do so in a slightly different manner (Sheard and Lake, 1998).

While standards must undergo a rigorous industry approval process, in order to satisfy the guidelines, such as those established by, for example, ANSI, ISO or IEC, capability models do not require such process, and , can be developed by anyone with the resources (Sheard and Lake, 1998).

Both the capability models and the standards state what needs be done, but attempt not to state how to do systems engineering. Sheard and Lake (1998) maintained that some people view a “what” in capability models and standards as a “how.” However, it is a matter of viewpoint. Sheard and Lake (1998) stated that the new standards and capability models have both strived to circumvent this issue by concentrating on processes and their related activities and tasks or requirements (the “what’s”), not on methods and tools (the “how’s”).

While standards give generally accepted good practices, capability models provide the means to assess the maturity of an organisation’s systems engineering capability and to formulate a roadmap along which an organisation’s process improvement effort can progress (Sheard and Lake, 1998).

2.6.2 Utility of Systems Engineering Standards

The SC7 formed an ad hoc System Engineering Study group with the aim to survey the utility of the systems engineering standards for organisations seeking to implement systems engineering in their projects (Patterson, Porteus and Richter, 2002).

The group concluded that organisations would need the three standards namely the ISO/IEC 15288, EIA 632, and IEEE 1220 (Patterson, Porteus and Richter, 2002).

According to Patterson, Porteus and Richter (2002)

- ISO/IEC 15288 defines the processes needed during a system’s life cycle,
- EIA 632 defines the set of requirements for engineering a system, and
- IEEE 1220 defines the systems engineering process itself.

Figure 43 in APPENDIX A shows the differences between the four SE standards.

2.6.3 Brief history of the SECM, EIA 731

The Systems Engineering Capability Maturity Model (SE-CMM) came about as the result of the SE-CMM Project (Patterson, Porteus and Richter, 2002).
The SE-CMM project was formed by individuals from academia, government and industry under the auspices of the SEI (Patterson, Porteus and Richter, 2002). This

collaboration was as known as the Enterprise Process Improvement Collaboration (EPIC) (Patterson, Porteus and Richter, 2002).

According to Patterson, Porteus and Richter (2002), the SE-CMM "describes the essential elements of an organisation’s systems engineering process that must exist to ensure good systems engineering".

Patterson, Porteus and Richter (2002) also added that the SE-CMM presents a reference framework for comparing actual Organisation's systems engineering practices against essential elements defined in the model.

According to Patterson, Porteus and Richter (2002), the SE-CMM covered all phases of the system life cycle and was intended to help organisations "*improve their practice of systems engineering through self-assessment and guidance in the use of statistical process control principles*".

According to Patterson, Porteus and Richter (2002), at the same time when EPIC was developing the SE-CMM, INCOSE was working on the SECAM. The SECAM comprised of a questionnaire based on the two standards, namely the ANSI/EIA 632, Processes for Engineering a System, and IEEE 1220, Application and Management of the Systems Engineering Process.

EPIC’s SE-CMM and INCOSE’s SECAM were merged into one model and assessment method under the auspices of a project charted under the EIA G-47 Systems Engineering Committee (Patterson, Porteus and Richter, 2002). The product of this project was the EIA Interim Standard (EIA/IS) 731-1, Systems Engineering Capability Model (SECM) and EIA/IS 731-2, Systems Engineering Capability Model (SECM) Appraisal Method (Patterson, Porteus and Richter, 2002). Figure 44 in APPENDIX B provides a comparison of process, focus, and key Focus Areas in the three SE Capability Models

2.6.4 Theoretical Framework of the current study

The framework for this study includes a set of activities to assess the extent to which systems engineering specific practices have been performed in a project. As stated in chapter 1, this study is limited to the technical aspect of the Systems Engineering, and the management and other aspect are beyond the scope of this study. The study is also limited to the acquisition phase of a generic product life cycle. There are seven Focus Areas in this framework, which define the technical aspect of the Systems Engineering Process namely:

1. Stakeholder Need and Requirements definition
2. System Requirements Analysis
3. System Architecture
4. System design and Analysis
5. Assessment, Selection and Implementation
6. System Integration
7. System Verification and Validation

Each Focus Area, in turn, comprises of Specific Practices related to that Focus Area. "*A Specific Practice is an activity that is essential to accomplishing the purpose of a Focus Area, or that helps accomplish the purpose of the Focus Area more effectively or efficiently*" (EIA, 2002). This chapter explains the Focus Areas of the framework together with Specific Practices in each one of them.

2.6.4.1 Stakeholder Needs and Requirements Definition

The purpose of the 'Stakeholder Needs and Requirements Definition' is to elicit a set of clear and concise stakeholder needs related to a new or modified system and to transform these needs into a verifiable set of stakeholder requirements for that system (Board BKCASE Editorial, 2014). The related specific practices in this Focus Area include:

1. The definition of the Operational Concepts (i.e., how the system will be used) and other life-cycle concepts (i.e., how the system will be acquired, deployed, supported, and retired) of the desired system to ensure a better understanding of the stakeholder requirements.

2. The use the Operational Concept and other lifecycle concepts (acquisition, deployment, support, and retirement) to identify the different stakeholders who may affect or be affected by the system across its total life cycle.

3. The analyses of stakeholder requirements to verify the completeness of expected services and Operational Scenarios, Conditions, Operational Modes, and Constraints.

4. The elicitation, capturing, or consolidation of stakeholder needs and expectations as well as any other constraints emanating from the Operational Concept and other system lifecycle concepts as well as from the Business Analysis processes.

5. The project validates the content and significance of each stakeholder requirement with the relevant stakeholders to establish the rationale for its existence.

6. The identification of potential risks (or threats and hazards) that could be generated by the stakeholder requirements using established risk management practices.

7. The syntheses, recording, baselining and managing stakeholder requirements and the potential risks associated with them.

2.6.4.2 System Requirements Analysis

The purpose of 'System Requirements Analysis' is to identify and define all of the requirements at the system level that describe the functions which the system as a whole must perform to satisfy the stakeholder needs and requirements (Board BKCASE Editorial, 2014). The related specific practices in this Focus Area include:

1. The use of the principles of system requirements analysis to transforms the stakeholder requirements into system requirements.

2. Establishment of upward traceability of system requirements with the stakeholder needs and requirements.

3. Establishment of a bi-directional traceability between requirements at adjacent levels of the system hierarchy.

4. Verification of the quality and completeness of each system requirement and the consistency of the set of system requirements.

5. Validation of the content and relevance of each system requirement against the set of stakeholder requirements.
6. Identification of potential risks (or threats and hazards) that could be generated by the system requirements.
7. Upon approval of the requirements, the establishment of control baselines along with other system definition elements using the established configuration management process.

2.6.4.3 System Architecture

The purpose of the System Architecture "*is to generate System Architecture alternatives, to select one or more alternative(s) that frame stakeholder concerns and meet system requirements, and to express this in a set of consistent views*" (Board BKCASE Editorial, 2014). Related specific practices in this Focus Area include:

1. Determination of the System Context including its Boundary with elements of the External Environment to enable an understanding of expected Operational Scenarios and System Behaviour within its context of use.
2. Identification of system requirements associated with the Operational Conditions (e.g., safety, dependability, interfaces, human factors, environmental conditions etc.) that would influence the definition of the architectural elements.
3. Identification system requirements associated with the Life Cycle Constraints (e.g., maintenance, disposal, deployment) that would influence the definition of the architectural elements.
4. Development of Candidate Architecture Models and Views using appropriate modelling techniques and tools in conjunction with the stakeholder requirements and system requirements analysis processes.
5. Verification and validation the system models by simulations if modelling techniques and tools permit. Where possible, use design tools to check the feasibility and validity of the system, and possibly build mock-ups or use executable architecture prototypes or simulators.

2.6.4.4 System Design and Analysis

The purpose of the ‘System Design’ is to provide sufficient information about the system, and its elements to enable the implementation consistent with architectural entities as defined in models and views of the system architecture. ‘System Analysis’, on the other hand, is used to perform trade-off studies and includes modelling and simulation, cost analysis, technical risks analysis, and effectiveness analysis (Board BKCASE Editorial, 2014). Related specific practices in this Focus Area include:

1. The definition of interfaces "that are necessary for the level of detail and understanding of the architecture. This includes the internal interfaces between the system elements and the external interfaces with other" external systems.

2. Determination of design properties applicable to system elements to satisfy the architectural characteristics.

3. For each system element, derivation of requirements corresponding to allocation, alignment, and partitioning of design properties and system requirements to the system elements.

2.6.4.5 Assessment, Selection and Implementation

The purpose of ‘Assessment and Selection’ is to provide a structured, analytical framework for objectively identifying, characterizing and evaluating a set of alternatives for a decision at any point in the system life cycle and select the most beneficial course of action (Board BKCASE Editorial, 2014). ‘Implementation’ yield the lowest-level system elements in the system hierarchy (Board BKCASE Editorial, 2014). During implementation, system elements can made, bought, or reused. Related specific practices in this Focus Area include:

1. Assessment and selection of the preferred candidate architecture(s) using the architecture evaluation criteria in conjunction with the established risk management and decision management processes.

2. Producing the system elements using the established implementation strategy (i.e., the outcome of the make or buy decision).

3. Conducting unit testing and recording evidence that the system elements meets their requirements and the associated verification and validation criteria.

2.6.4.6 System Integration

'System integration' consists of taking delivery of the implemented system elements, assembling the elements together, and performing the verification and validation actions (V&V actions) in the course of the assembly. The ultimate goal is to ensure that the individual system elements function properly as an integrated set and meet the design properties or characteristics of the system (Board BKCASE Editorial, 2014). Related specific practices of this Focus Area include:

1. Development of the integration strategy and documenting it in a System Integration Plan.

2. Definition of verification activities that should be performed as part of system integration in the System Integration Plan.

3. Identification of the configurations of aggregates that should be assembled and verified in the System Integration Plan.

4. The integration actions, which include checking of delivered configurations, conformance of implemented elements, compatibility of interfaces, and ensuring availability of mandatory documentation.

5. The integration actions, which include the integration of system components to constitute aggregates in the order prescribed by the System Integration Plan and Assembly Instructions/Procedures using the correct tools.

6. The integration actions, which include verification of each aggregate to check if the aggregate is correctly assembled according to established procedures.

2.6.4.7 System Verification and Validation

'Verification' activities are used to provide evidence that the system and its elements were produced "*according to the selected and appropriate methods, techniques, standards, or rules*" (Board BKCASE Editorial, 2014). 'Validation' activities are used to provide evidence that the system and its elements, when taken in combination, satisfy the stakeholder needs and requirements (Board BKCASE Editorial, 2014). Related specific practices in this Focus Area include:

1. Development of a verification and validation strategy and document it in a Verification and Validation Plan.

2. The verification and validation plan clearly defines the appropriate verification and validation techniques to be applied, such as inspection, analysis, simulation, peer-review, testing, and demonstration etc., based on the best decisions of the project to perform every verification and validation action according to the given constraints.

3. Verification and validation actions, which include carrying out verification and "validation procedures at the right time, in the expected environment, with the expected means, tools, and techniques" (Board BKCASE Editorial, 2014).

4. Verification and validation actions, which include capturing and recording the results obtained when performing verification and validation actions using defined verification and validation procedures and means.

5. Verification and validation actions, which include analyses of acquired results and comparing them to the expected results so that the status may be recorded as either compliant or non- compliant.

2.7 Conclusion

This chapter provided a review of the literature gathered on various topics related to the study and introduced the theoretical framework of study. This framework consists of eight Focus Areas. Each Focus Area, in turn, comprises of specific practices related to that Focus Area. A specific practice is an activity that is essential to accomplishing the purpose of a specific Focus Area or that helps accomplish the purpose of the Focus Area more effectively or efficiently. In the next chapter, the explanation of the research methods used to collect and analyse data is provided.

CHAPTER 3

RESEARCH METHODS

This chapter presents the method used including research design, sampling, instrumentation, data collection and analysis procedures, validity analysis, reliability analysis, pretesting the study instrument and the ethical considerations.

3.1 Research Design

The study employed a quantitative approach using a cross-sectional survey research design. This was accomplished through a descriptive rating Likert-type survey used to collect quantitative data from 56 participants at DPSS. This method allows for a statistical analysis of the data and provides the means to describe the current state of affairs at the time of the study, and it was for this reason, it was chosen (Salkind, 2012). Generally, it has been agreed that the purpose of survey design is to generalise from a sample to the population so that one can make inferences about some characteristics, attitudes, or behaviour of that population (Creswell, 2014), (Fowler, 2014), (Dillman, Smyth and Christian, 2014).

The study sought to collect and analyse data in order to describe the status of Systems Engineering at DPSS. A survey research design is the preferred data collection procedure for this purpose since it enables collection of data from a sample of the target population by asking a set of questions, analyse responses and interprets the results to describe that population (Fowler, 2014).

(Dillman, Smyth and Christian, 2014) pointed out that, a key feature of survey design, which differentiates it from other methods of inquiry is that it can provide a very close approximation of the distribution of a characteristic in a population by studying only some members of that population. It enables the researcher to generalise the outcomes of the study with high accuracy, from a sample to the population, making it a very efficient method of learning about individuals and populations (Dillman, Smyth and Christian, 2014).

With the survey design, a researcher limits data collection to a sample of the target population and thus enables limited resources to be employed on fewer people and yet achieve outcomes that are only marginally less accurate than they would be if everyone were surveyed (Dillman, Smyth and Christian, 2014). In a similar vein, (Creswell, 2014) agrees that the advantages of a survey are economy of design and rapid turnaround in data collection and analysis.

3.2 Target Population

The target population was defined as individuals employed within the eight competency areas in DPSS, and working on various technology development projects. The target population was restricted to the technical staff, including researchers, technologists/engineer/knowledge applicators, systems engineers and technical managers who were directly involved with technology development projects.

A census survey was conducted where two hundred and forty-one (N = 241) potential participant made up a targeted population at the time of the research (03 September 2018 to 12 November 2018). Two hundred and forty-one questionnaires (241) were distributed to all eligible participants. Table 2 shows the calculation of the sample size for Chi-Squared test using the G*Power 3.1.9.2 statistical analysis software (FAUL *et al.*, 2007). Given the desired power (1- β) of 80 %, α level of 5 % and the effect size (w) of 0.3 (medium), the required total sample size was determined to be 108 responses.

Table 2. A priori: Compute required sample size – given α, power, and effect size.

χ^2 tests - Goodness-of-fit tests **Analysis:** A priori: Compute required sample size		
Input:	Effect size (*w*)	0.3
	α err prob	0.05
	Power (1-*β* err prob)	0.8
	df	2
Output:	Noncentrality parameter λ	9.7200000
	Critical χ^2	5.9914645
	Total sample size	108
	Actual power	0.8036939

Referring to Table 2:

- *w* is the effect size, and (Cohen, 1988) suggested that a *w* of 0.1 be considered a small effect, 0.3 be considered medium, and 0.5 be considered large.
- *α* err prob ("Alpha") is the chance of making a type I error, that is, the probability of rejecting the null hypothesis when the null hypothesis is true.
- *β* err prob ("Beta") is the chance of making a type II error, that is, the probability of failing to reject the null hypothesis when the alternative hypothesis is true.
- (1-β) err prob refers to the power of the test, and it refers the probability of making a correct decision (i.e., to reject the null hypothesis) when the null hypothesis is false.
- *df* refers to the degree of freedom, and for the chi-squared test for goodness-of-fit, it calculated based on the following formula:
    - df = (k-1), where k is the number of categories. For the current study, the number of categories is 3, hence df = 3 – 1 = 2

3.3 Instrumentation

The primary data were collected using a self-administered online questionnaire. According to (Rule and John, 2011), a questionnaire is an instrument that has a set of questions to which participants should answer either on their own (self-administered) or in the presence of a researcher. They help the researcher to gather information from many people simultaneously (Rule and John, 2011). (Rule and John, 2011) argued that careful construction of sound, unambiguous set of field questions could influence the effectiveness of a questionnaire in meeting the objective of the study.

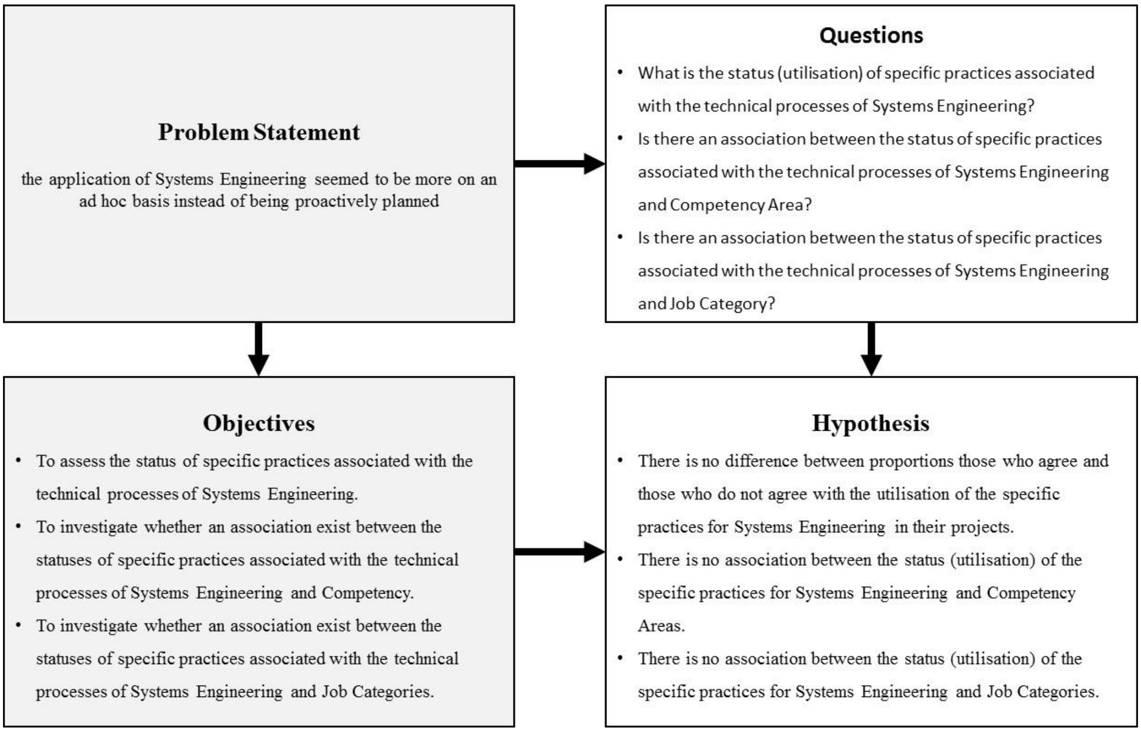


Figure 12: Linkages between the research problem statement, research objectives, research questions and hypotheses

Figure 12 illustrates the linkages between the research problem statement, research objectives, research questions and hypotheses. In section 2.1 of this report, the origin and description of Systems Engineering were presented. The concepts of a system and systems engineering were discussed in section 2.2 and section 2.3, respectively. In section 2.4, the core concepts of engineering design relevant to systems engineering were explained. The literature review about the importance of system engineering was presented in section 2.5, and finally, in section 2.6, the theoretical framework for this study was described in detail.

The questionnaire for this study was constructed based on this framework and this framework, in turn, was based on the reviewed literature. Furthermore, it includes a set of questions designed to evaluate the extent to which the specific practices associated with the technical processes of systems engineering have been applied in a project. The questionnaire comprises of an introduction, a section to record the demographic information, and seven sections for the research questions. Each section corresponds to one of the seven Focus Areas in the theoretical framework. For each research question, participants were requested to select only one response from a 5-point Likert scale (1 = strongly agree to 5 = strongly disagree), which in their opinion best represent their judgement about the extent to which their projects was applying a specific practice of system engineering. The questionnaire can been viewed in APPENDIX E

3.4 Data Collection

The survey data was collected through the Survey Monkey.com account. Each respondent was invited to participate through the email with a link to the online questionnaire. The Survey Monkey allows researchers to design their surveys using customised templates, post them on websites and e-mail the link to the survey for participants to complete (Creswell, 2014). This software application can also generate results and relay them back to the researcher as descriptive statistics and graphed information (Creswell, 2014). The researcher can then download results into a spreadsheet for further analysis (Creswell, 2014).
The collection of data through the Internet was particularly appealing given its low cost, the speed of collecting and analysing data, and economies of scale (Dillman, Smyth and Christian, 2014). The proliferation of mobile devices, particularly smartphones and smart tablets has contributed to the rise in online behaviour since these devices provide the primary means of connecting to the Internet to many people (Dillman, Smyth and Christian, 2014).

According to Couper (2000) cited in (Dillman, Smyth and Christian, 2014), web surveys provide the capability to collect responses from a large numbers of people in a relatively short period of time, often can be conducted at a reasonably low cost, particularly when the e-mail is the only form of communication with sample members; "*thousands or even tens of thousands of questionnaires can be completed in a single day with the results available for review and analysis immediately"*. It was mainly for these reasons this data collection method was used for this study.

The issue raised with this method is the response rate. Nonresponse error is the discrepancy between the estimates generated when only some of the sampled units respond compared to when all of them respond (Dillman, Smyth and Christian, 2014). It happens when those who do not respond differ from those who do in a way that affects the estimate (Dillman, Smyth and Christian, 2014). The wave analysis procedure was used to check for nonresponse bias and the common responses remained essentially the same. In wave analysis, according to Leslie (1972) cited in (Creswell, 2014), the researcher examines returns on select items week by week to determine if common responses do change. Based on the assumption that those who return surveys in the final weeks of the response period are nearly all nonrespondents, if the responses begin to change, a potential exists for nonresponse error. The following measures were taken to increase the response rate:

- The first email was the pre-notification to all members of the sample that the survey is coming.
- The second email was sent one week after the first email. This email had a link to the actual online survey.
- The third email was sent one week after the second email. This email was about post-delivery reminder and thank-you.
- The fourth email was sent about four weeks after the second email. This email was about non-response follow-up to those who did not respond to the survey.

In total the administration period lasted for nine weeks.

3.5 Data Analysis

Data collected from the survey website was downloaded and statistically analysed using the IBM SPSS Statistics Version 25. Descriptive statistics were used to present the initial data.

An assessment of the normality of data distribution is a prerequisite for many statistical tests since the normally distributed data is an underlying assumption in parametric testing. This assumption specifies that the dependent variable must be approximately normally distributed for each group of the independent variable (Leedy and Ormrod, 2015).

Normality test were found not to be appropriate since the collected data for this study was essentially opinion scores in ordinal responses collected through a Likert-type survey. According to (Andreas Mauthe, Tyson and Cerqueira, 2012), "*non-normally distributed user opinion scores in nominal or ordinal responses should not be analysed using parametric statistics*". This then required a non-parametric statistical approach.

Non-parametric techniques do not have stringent requirements and do not make assumptions about the population's underlying distribution (Pallant, 2016). Despite being less stringent, non-parametric statistics do have their limitations. They tend to be less sensitive than their more powerful parametric equivalents and may fail to detect differences that exist between groups (Pallant, 2016). If one has suitable data it is advisable to utilise a parametric technique were possible (Pallant, 2016).

Non-parametric techniques are most appropriate for use when data are measured on nominal (categorical) and ordinal (ranked) scales (Pallant, 2016). They are also suitable for very small samples and when the data do not meet the stringent requirements of the parametric techniques (Pallant, 2016). There are many different non-parametric procedures for a variety of situations. The most popular ones include:

1. Chi-square test for goodness of fit
2. Chi-square test for independence
3. Fisher's exact test of independence
4. McNemar's Tests
5. Cochran's Q Test
6. Kappa Measure of Agreement
7. Mann-Whitney U test
8. Wilcoxson Signed Ranked Test
9. Kruskal-Wallis Test, and
10. Friedman Test

To achieve the specific objectives of this study and to test the significance of the results, the Chi-Squared test for goodness of fit and the Fisher's exact test were found to be the most appropriate. Other non-parametric procedures that compare the differences between the groups (e.g. Mann-Whitney U test, Wilcoxson Signed Ranked Test, Kruskal-Wallis Test) makes assumptions about the similarity of the distributions of the groups being compared. The Chi-Squared Test and the Fisher's exact test do not make this assumption, and it was mainly for this reason these procedures were employed.

A chi-square test is used to test hypotheses about the distribution of observations in different categories (The Open University, no date). The null hypothesis is that observed frequencies are equal to the expected frequencies (except for chance differences)(The Open University, no date). And if this is true, then the value of the χ^2 is zero. However, if this is not true, the value of the χ^2 increases (The Open University, no date). The larger the value of the χ^2, the more likely it is that the distributions of the observed and expected frequencies are statistically significantly different (The Open University, no date).

For the results of a chi-square test to be relied upon, the expected frequencies should not be very small, and as a rule of thumb, chi-square test should not be used if more than 20% of the expected frequencies have a value of less than 5 (The Open University, no date). Fisher's exact test is the most appropriate choice if this requirement cannot be met especially when the sample size is small (Pallant, 2016). Unlike many significance tests, a Fisher's exact test does not have an equation to calculate an estimates of the probability of a value of a test statistic; instead, one calculates the probability of getting the observed data, and all data sets with more extreme deviations, under the null hypothesis that the proportions are the same (McDonald, 2019).

Research Question 1 - What is the status (utilisation) of specific practices associated with the technical processes of Systems Engineering?

- **Null Hypothesis 1** - There is no difference between proportions those who agree and those who do not agree with the utilisation of the specific practices for Systems Engineering in their projects.

The chi-square goodness-of-fit test (with $\alpha = .05$) was performed at 95% confidence interval, to assess whether the proportions of the respondents who agree, neither agree nor disagree and disagree with the utilisation of systems engineering specific practices in their projects differed from one another.

Research Question 2 - Is there an association between the status of specific practices associated with the technical processes of Systems Engineering and Competency Area?

- **Null Hypothesis 2** - There is no association between the status (utilisation) of the specific practices for Systems Engineering and Competency Areas.

The Fisher's test of independence (with $\alpha = .05$) was performed at 95% confidence interval, to investigate whether the proportions among the Technology Application Group, Integrated Systems Group, and Technology for Special Operations were the same, in other words, that there is no relationship between the status of systems engineering specific practices and any of the three groups.

Research Question 3 - Is there an association between the status of specific practices associated with the technical processes of Systems Engineering and Job Category?

- **Null Hypothesis 3** - There is no association between the status (utilisation) of the specific practices for Systems Engineering and Job Categories.

The Fisher's test of independence (with α = .05) was performed at 95% confidence interval, to investigate whether the proportions of Discipline Engineers, Systems Engineers, and Managers were the same, in other words, that there is no association (relationship) between the status of systems engineering specific practices and any of the three job categories.

3.6 Assumptions tests

The assumptions of the Chi-Square test include:

1. "*The data in the cells should be frequencies, or counts of cases rather than percentages or some other transformation of the data*" (Mchugh, 2013). The data in are frequencies or counts. Thus this assumption was met.
2. "*The levels (or categories) of the variables are mutually exclusive. That is, a particular subject fits into one and only one level of each of the variables*" (Mchugh, 2013). The subjects do fit into one and only one level of each of the variables. Thus this assumption was met.
3. "*Each subject may contribute data to one and only one cell in the χ2. If, for example, the same subjects are tested over time such that the comparisons are of the same subjects at Time 1, Time 2, Time 3, etc., then χ2 may not be used*" (Mchugh, 2013). The study is essentially a cross-sectional survey and each subject contributed data to one and only one cell in the χ2. Thus this assumption was met.
4. "*The study groups must be independent. This means that a different test must be used if the two groups are related. For example, a different test must be used if the researcher's data consists of paired samples, such as in studies in*

which a parent is paired with his or her child" (Mchugh, 2013). The data was organised into Competency Areas and Job Title with the intention to conduct a separate Chi-Squared Test for each of the three specific objectives of the study. Thus this assumption was met.

5. "*There are 2 variables, and both are measured as categories, usually at the nominal level. However, data may be ordinal data*" (Mchugh, 2013). For each of the three specific objectives of the study, the data comprised of two variables. Thus this assumption was thus met.
6. "*The value of the cell expecteds should be 5 or more in at least 80% of the cells, and no cell should have an expected of less than one*" (Mchugh, 2013). The expected cell frequencies were more than 5, and when the expected cell frequencies was less than 5, a Fisher's exact test was used instead. Thus this assumption was met.

3.7 Validity and Reliability

The questionnaire for this study was developed and tested for both validity and reliability to ensure that it is sound and reliable to be used for this research.

3.7.1 Validity

Validity refers to the amount of systematic or built-in error in the measurement of the instrument (Norland, 1990). (Drost, 2011) explained that it mainly is concerned with the meaningfulness of components in research. According to (Creswell, 2014), validity relates to whether the researcher can derive meaningful and useful results from the scores on the instrument. (Creswell, 2014) suggested four types of validity that researchers should consider namely, Content Validity, Predictive or Concurrent Validity and Construct Validity. (Hubley and Zumbo, 1996) argued that the Construct Validity is the overriding objective in the validity assessments, and it concentrates on whether the scores are useful and have positive outcomes when applied in practice.

The approach adopted for this research was to perform the Lawshe's content validity analysis of the study instrument using a panel of experts from industry and academia. According (Lawshe, 1975), a content validity panel should normally comprise of experts in the field of identifying domain or domain universe from which responses are solicited, and the ideal composition of the panel should range from 10- 20 experts. The consensus among the panel members can be quantified by determining the Content Validity Ratio (CVR) using the Lawshe's equation (Lawshe, 1975):

$$CVR = \left(\frac{ne - \frac{n}{2}}{\frac{n}{2}}\right)$$

Where:

- ne is the number of panellists indicating essential.
- $\frac{n}{2}$ is the total number of panellist divided by two.
- CVR is the content validity ratio which is a direct linear transformation from the panellist saying essential.

Table 3 shows the minimum values of the CVR and CVR_t for a one Tailed Test, p = .05.

Table 3: CVR and CVRt for a one Tailed Test, p = .05. (Lawshe, 1975)

Minimum Values of CVR and CVR$_t$ One Tailed Test, p = .05	
No. of Panelists	**Min Value***
5	0.99
6	0.99
7	0.99
8	0.75
9	0.78
10	0.62
11	0.59
12	0.56
13	0.54
14	0.51
15	0.49
20	0.42
25	0.37
30	0.33
35	0.31
40	0.29

Content validity analysis of the study instrument was performed in July 2018. Data were collected through the SurveyMonkey.com account. A panel of eleven (N = 11) experts took the survey. These experts were selected based on the level of education, relevant experience and knowledge in systems Engineering, Systems Engineering Management or Engineering Programme/Project Management. The panel was asked to rate each item in the questionnaire as essential, useful but not essential and not necessary. The results from this analysis were used to improve the study instrument. The results of this test are provided in APPENDIX F of this report.

3.7.2 Pretesting the Questionnaire

The current study instrument was pilot tested before actual data collection. (Brotherton, 2015) stated that a newly contracted questionnaire requires pilot testing before its implementation. This testing aims to expose any possible errors, deficiencies, omissions, etc. in the questionnaire and correct them before it is

employed to collect the actual data (Brotherton, 2015). Various means may be used to achieve this; the most appropriate being a pilot test administered to people typifying those who are going to be the actual respondents (Brotherton, 2015). The rationale for this is that if this test shows that there are no issues, then it is highly probable that applying it on a larger scale with actual respondents will produce comparable reactions and vice versa (Brotherton, 2015). The study instrument was pilot tested on four Systems Engineers from DPSS.
Participant were requested rate the overall quality of the construction of the questionnaire using the following scale:

1 **Poor**: not good, with much room for improvement.
2 **Good**: could still be made better.
3 **Excellent**: no need for further improvement.

Participant were requested to rate the overall length of the questionnaire using the following scale:

1 **Much too long**: not good, with much room for improvement.
2 **Somewhat lengthy**: good, but could still be made better.
3 **About right**: no need for further improvement.

Participant were also requested to give any additional comments. The results and comments obtained from this analysis were incorporated into the final questionnaire. The results of this test are provided in APPENDIX G of this report

3.7.3 Reliability

The current study instrument was subjected to reliability analysis using the study sample of 47 participants. According to (Drost, 2011), reliability is the degree to which measurements are repeatable. Bollen (1989) cited in (Drost, 2011), argued that it relates to the consistency of the measurement, or as stated by Nunnally (1978) cited in (Drost, 2011) as the stability of measurement over different situations in which similar results should be expected. (Drost, 2011) cautioned about the possibility of a very reliable measure that may still not be valid. Hence, Nunnally, (1978) cited in (Drost, 2011) argued that reliability is essential but not enough to satisfy the condition for validity. Reliability refers to the random error in measurement. It indicates the accuracy or precision of the measuring instrument (Norland, 1990). It is the degree to which the observed variable measures the true value and is error free (Drost, 2011).

The reliability of the study instrument was tested by calculating the Cronbach's alpha coefficient to determine its internal consistency. According to Nunnally (1978) cited in (Drost, 2011), a Cronbach's alpha coefficient of 0.7 or more is considered acceptable. Further (Bagozzi and Yi, 1988) argued that a scale is said to be reliable if the reliability value of each construct is higher than 0.60. The Cronbach's alpha coefficient of the study instrument was determined to be 0.9 and was considered to be excellent (Bagozzi and Yi, 1988). The results of this test are provided in APPENDIX H of this report

3.8 Ethical Considerations

It is important that research which involves gathering data from people (human participants) treat them fairly and meets ethical standards (Creswell, 2014). Broadly speaking this involves full disclosure (telling them about the research), non-coercion, and privacy issues (Creswell, 2014). Writing about these anticipated ethical issues is required in making an argument for a study (Creswell, 2014).

Researchers need to protect their research participants; develop a trust with them; promote the integrity of research; guard against misconduct and impropriety that might reflect on their organisations or institutions; and cope with new, challenging problems (Babbie *et al.*, 2014). Because ethical issues are important and ambiguous, different professional bodies have their version of a code of ethics (Babbie *et al.*, 2014). There are general ethical guidelines researchers should adhere to (Babbie *et al.*, 2014) namely:

- Voluntary participation;
- Protection of participants from harm;
- Anonymity and confidentiality (privacy);

- Deceiving subjects; and
- Debriefing (in cases where participants might need it).

To effectively address the ethical issues, consideration was given to both the University's and CSIR's research code of ethics. Ethical clearance number (**MIAEC 075/18**) was obtained from the university and institutional permission was granted by the CSIR's Research Ethics Committee to collect data for this study from its employees. The Ethical Clearance and Institutional Permission are attached in APPENDIX C of this report

During data collection, all participants were provided with an informed consent letter outlining the goal of the study, confidentiality measure, voluntary participation, and exposure to risk. The letter of consent is attached in APPENDIX D of this report. To ensure anonymity, the questionnaire did not require participants to provide their names. In this way, no participant could be linked to any specific completed questionnaire.

CHAPTER 4

DATA ANALYSIS AND INTEPRETATIONS OF THE RESULTS

This chapter presents the data analysis and interpretation of the results from 47 questionnaires completed by respondents who were employed at DPSS from August to November 2018. The purpose of this study was to investigate the status of specific practices associated with the technical processes of Systems Engineering during technology development projects at DPSS.

The associated research questions were as follows:

- **RQ 1** - What is the status (utilisation) of specific practices associated with the technical processes of Systems Engineering?
- **RQ 2** - Is there an association between the status of specific practices associated with the technical processes of Systems Engineering and Competency Area?
- **RQ3** - Is there an association between the status of specific practices associated with the technical processes of Systems Engineering and Job Category?

By answering the research questions, the research objectives were:

- **RO 1** - To assess the status of specific practices associated with the technical processes of Systems Engineering.
- **RO 2** - To investigate whether an association exist between the statuses of specific practices associated with the technical processes of Systems Engineering and Competency.
- **RO 2** - To investigate whether an association exist between the statuses of specific practices associated with the technical processes of Systems Engineering and Job Categories.

And the following hypotheses were tested:

- **H_01** - There is no difference between proportions those who agree and those who do not agree with the utilisation of the specific practices for Systems Engineering in their projects.

- **H_A1** - There is a difference between proportions those who agree and those who do not agree with the utilisation of the specific practices for Systems Engineering in their projects.

- **H_02** - There is no association between the status (utilisation) of the specific practices for Systems Engineering and Competency Areas.
- **H_A2** - There is an association between the status (utilisation) of the specific practices for Systems Engineering and Competency Areas.

- **H_03** - There is no association between the status (utilisation) of the specific practices for Systems Engineering and Job Categories.
- **H_A3** - There is an association between the status (utilisation) of the specific practices for Systems Engineering and Job Categories.

As stated in chapter 1, the scope of this study was limited to aspects related to the technical processes of Systems Engineering, and focuses on the development phase of product life cycle, the management and other related aspects are beyond the scope of this study.

4.1 Response Rate

A census survey was conducted between 03 September 2018 and 12 November 2018. All eight Competency Areas within DPSS participated in the study. Data was obtained from 59 of a potential of 241 respondents, representing a response rate of 24%. Of the 59 responses, 47 fully completed the questionnaire. Given the actual sample size of 47 respondents, α level of 5 % and effect size (w) of 0.46 (medium to large), the achieved power (1- β) was 81 %. Table 4 provides the power calculation for Chi-Squared test using the G*Power 3.1.9.2 statistical analysis software (FAUL *et al.*, 2007).

Table 4. Post hoc: Compute achieved power – given α, sample size, and effect size

χ^2 tests - Goodness-of-fit tests **Analysis:** Post hoc: Compute achieved power		
Input:	Effect size *w*	0.46
	α err prob	0.05
	df	2
Output:	Noncentrality parameter λ	9.9452000
	Critical χ^2	5.9914645
	Total sample size	47
	Power (1-β err prob)	0.8131734

4.2 Demographic Data

The questions in this section of the questionnaire were about the respondents' number of years of service at DPSS, the number of years involved in technology development projects, job titles, and the engineering life-cycle phase of their project at the time of the survey.

4.2.1 Competency Areas in which Respondents were employed

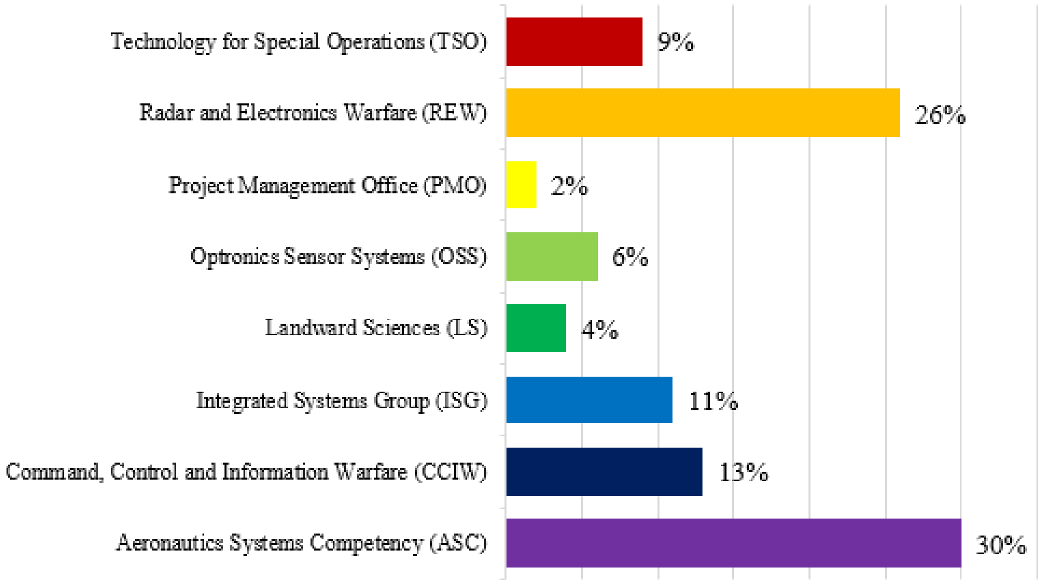


Figure 13. Frequency of responses per Competency Area

Figure 13 shows a bar chart of frequency of responses for Competency Areas. Of the 47 respondents who completed the questionnaire, over 50 % came from ASC and REW. This might have been due the sizes (i.e., amount of employees) of these two Competency Areas. The sizes of ASC and REW are relatively large as compared to the other groups.

4.2.2 Job Titles of the Respondents

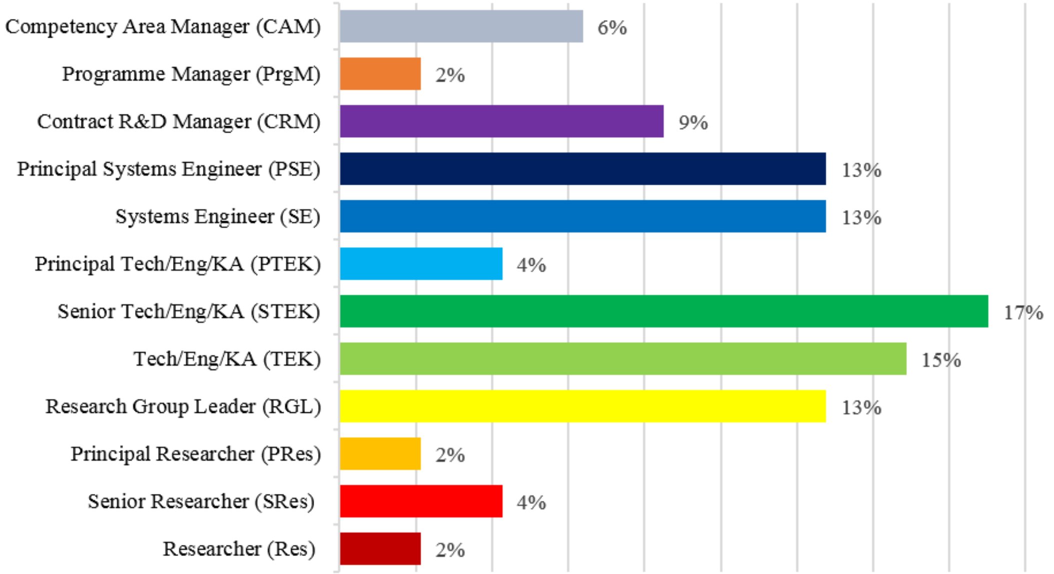


Figure 14. Frequency of responses per Job Title

In Figure 14 , it evident that the majority (over 50 %) of the responses came from Technologist/Engineer/Knowledge Applicators (TEK, STEK and PTEK) and Systems Engineers (SE and PSE). This might be attributed to the fact that these individuals are mainly the ones that work on product development projects. The responses from Researchers (Res, SRes, and Pres) made up 6 % of the responses. This might have been due to the nature of work that researchers do (i.e. pure research). Since the present study is about Systems Engineering, it is possible that some researchers might have thought that this study has little to do with their work. The low response rate from Program Manager can be attributed to their small population size.

4.2.3 Respondents Years' Service at DPSS

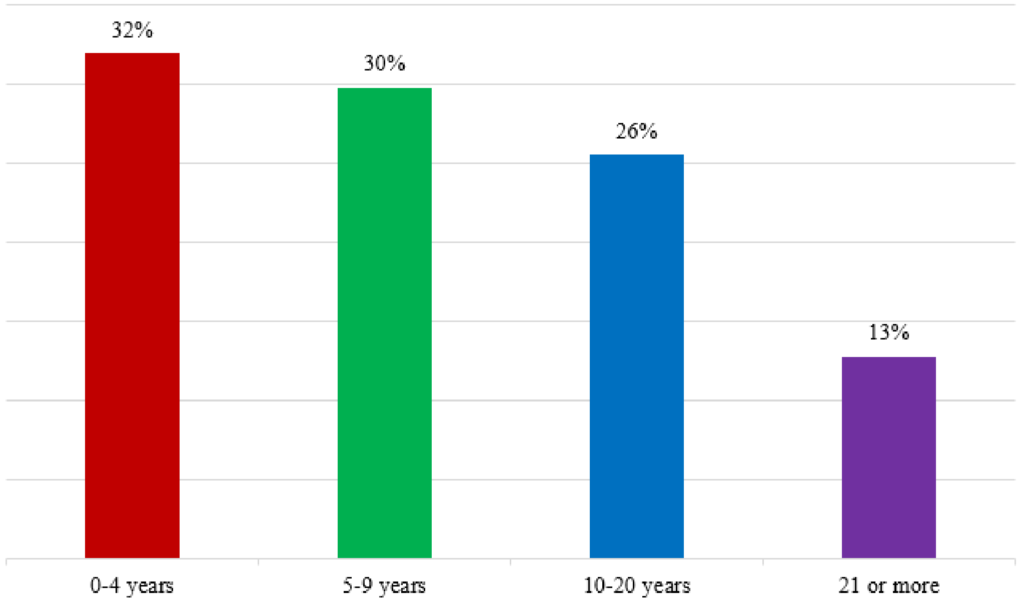


Figure 15. Frequencies responses for Years of Service at DPSS.

Figure 15 shows a bar chart of the frequency of responses for years of service at DPSS. Of the 47 respondents, 32 % have been employed at DPSS for 4 or fewer years, and, the majority (68 %) have been with the organisation for five years or more.

4.2.4 Respondents tenure in technology development projects

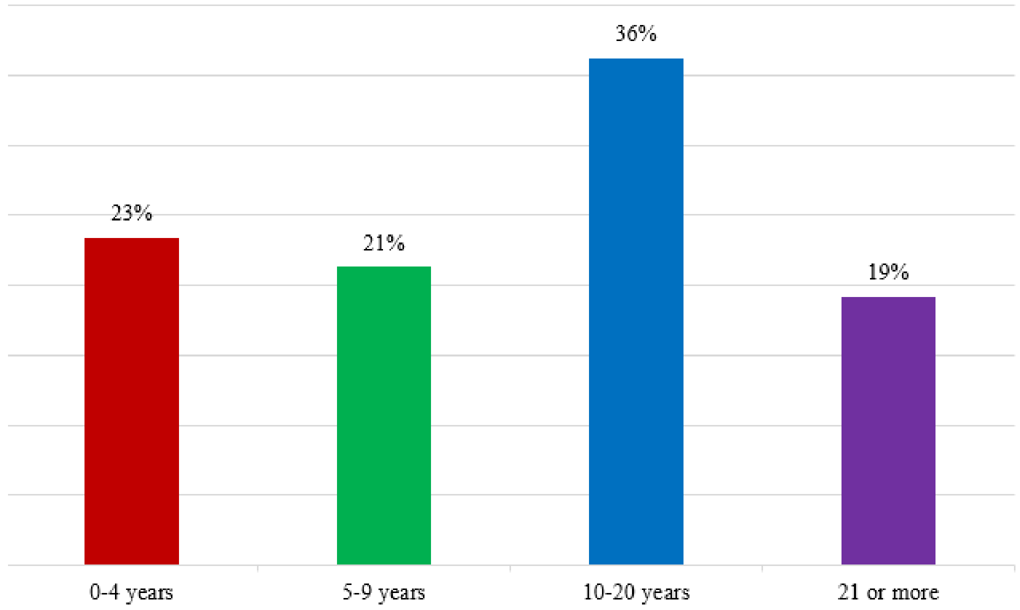


Figure 16. Frequency of responses for Tenure Technology Development Projects

Figure 16 shows a bar chart of the frequency of responses for years in technology development projects. This question is different from the previous question, as it sought to ascertain tenure in the field, as opposed to tenure at one institution. Figure 16 shows that 23 % of the participants have been involved in technology development projects for 4 or fewer years, and, 77 % of have been involved for five years or more. It is also evident from this figure that more 50 % of the participant has 10 or more years of experience in technology development projects.

4.2.5 Respondents Highest Level of Education

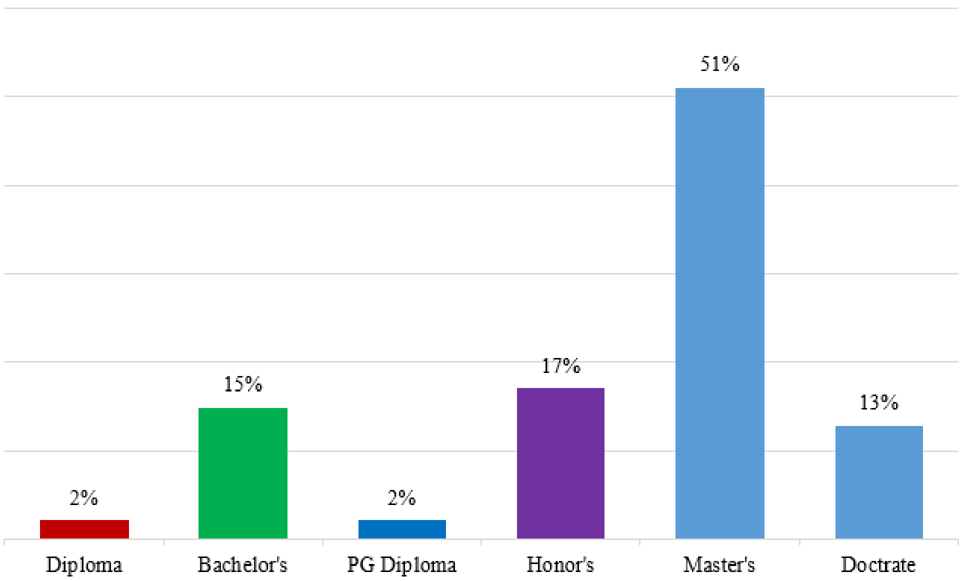


Figure 17. Frequency of responses for Highest Level of Education

Figure 17 shows a bar chart of frequency of responses for highest level of education. Of the 47 respondents, 17 % reported having the education level of bachelor's or below, and, 83 % reported having a postgraduate qualification with 51 % having achieved the Master's and 13 % a Doctorate qualification. This did not come as a surprise since the CSIR is a research institute with many employees aspiring to getting higher qualifications.

4.2.6 Systems Engineering Training

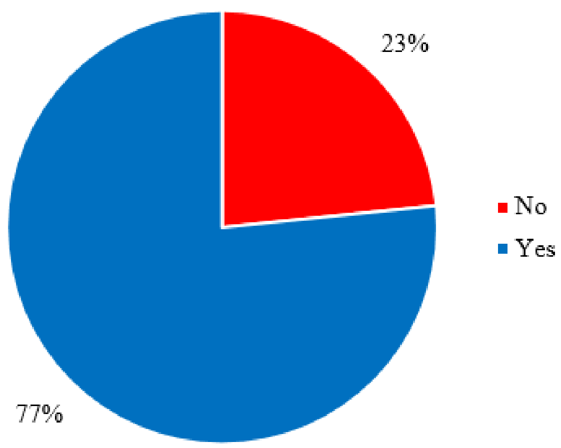


Figure 18. Frequency of responses for Systems Engineering training attendance

Figure 18 shows 77 % of the respondents had undergone some form of training in systems engineering.

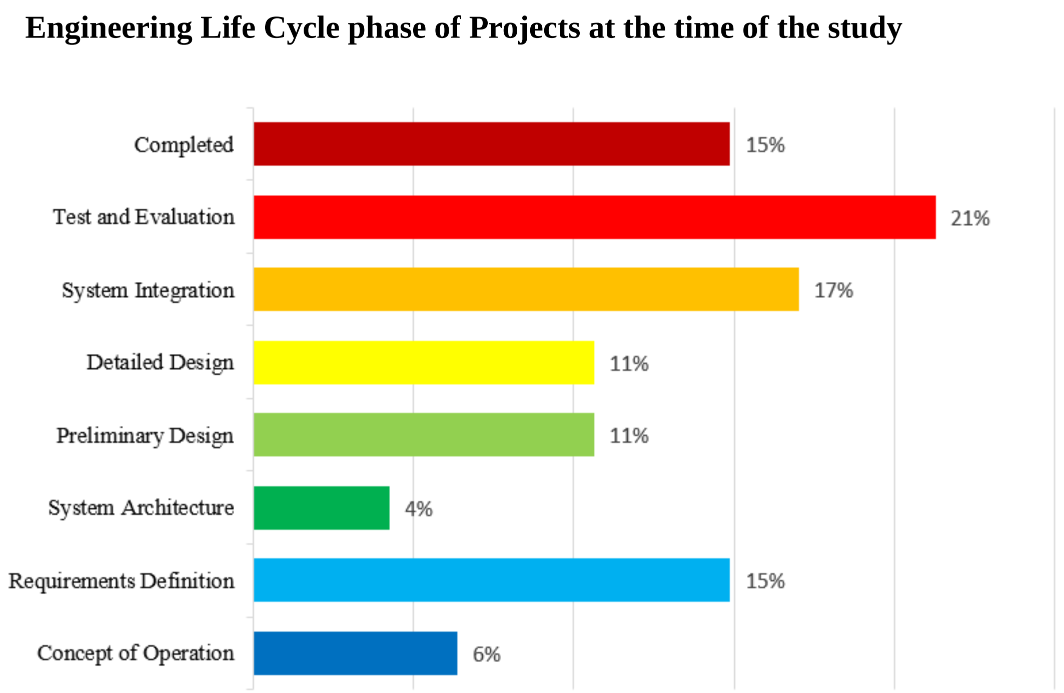


Figure 19. Frequency of responses for Project Lifecycle Phases

Figure 19 shows a bar chart of frequency of responses for Project Lifecycle Phases. The aim of this question was to learn how far the product lifecycle are the technology development projects at DPSS. Figure 19 shows that the majority (over 50 %) of the projects have entered the system integration phase (SysInt) and of those projects, 21% are in the test and evaluation phase while 15 % are completed.

4.3 Descriptive Statistics of research questions

The research questions were organised into seven sections corresponding to the seven focus areas of the study's theoretical framework. For each question, related to a specific practice of systems engineering, participants were asked to select only one response from a 5-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree), which in their opinion best represent their judgement about the extent to which their projects were performing that specific practice.

Due to small sample size, the frequency of responses 'strongly agree' and 'agree' were added together into 'agree', and the frequency of responses 'strongly disagree' and 'disagree' were added together into 'disagree'.

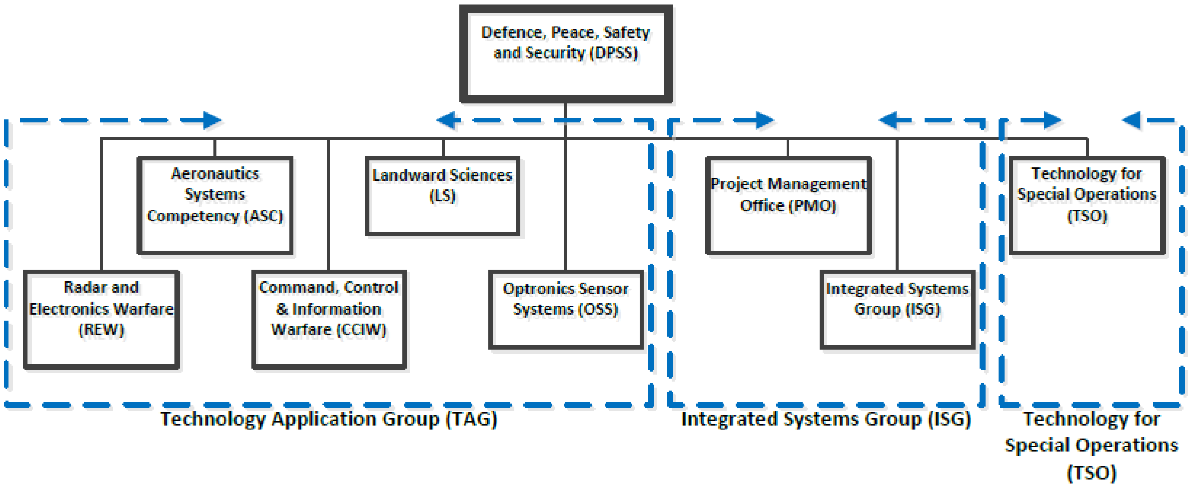


Figure 20: The classification of Competency Areas into three groups, TAG, ISG and TSO was

For purposes of investigating whether an association exist between the status of Systems Engineering and Competency Areas, participants' responses were classified into three groups, namely Technology Application Group (TAG), Integrated Systems Group (ISG) and Technology for Special Operations (TSO) (see Figure 20). The rationale behind this was that Competency Areas classified under TAG were very similar in terms of the kind of work they do (i.e., scientific and industrial research), though each specialises in a specific technology domain, were as PMO and ISG offered project management and systems engineering services and TSO was primarily involved in new products development projects.

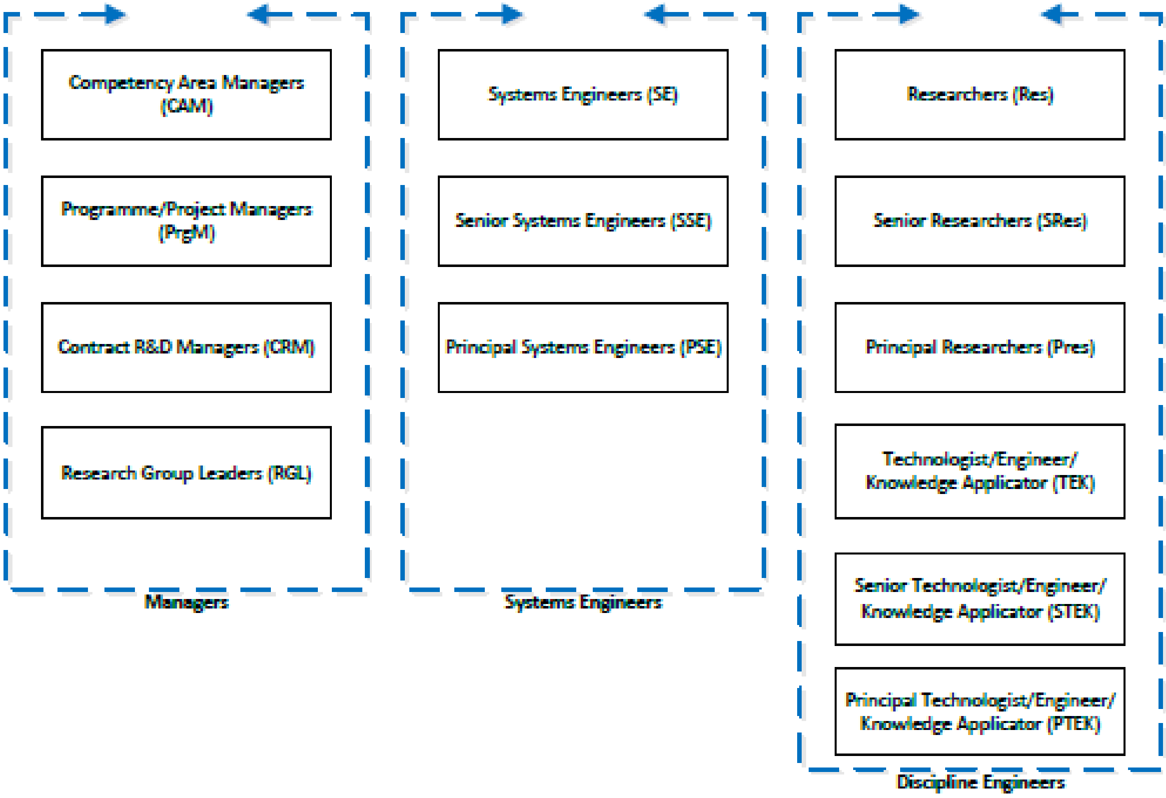


Figure 21: The categorisation of Job Titles into three Job Categories, Managers, Systems Engineers and Discipline Engineer

For purposes of investigating whether an association exist between the status of Systems Engineering and Job Categories, participants' responses were categorised into three Job Categories, namely Managers, Systems Engineers and Discipline Engineers (see Figure 21). The rationale behind this was that respondents with job titles categorised under Managers primarily perform the management duties, Systems Engineering focuses on the coordination of all of the disciplines, tasks, and activities necessary to develop systems (ISO/IEC/IEEE, 2008), while Discipline engineers, or designers, perform the design definition of each concerned system element; they provide strong support (knowledge and competencies) to systems engineers, in the evaluation and selection of candidate system architectures and system elements (ISO/IEC/IEEE, 2008).

Overall, the results showed that the frequencies of the three responses (i.e., Disagree, Neither Agree nor Disagree and Disagree) were different (i.e., not equally distributed) with the 'Agree' response being the most frequent response.

RQ 1 - *What is the status (utilisation) of specific practices associated with the technical processes of Systems Engineering*?

RO 1 - *To assess the status of specific practices associated with the technical processes of Systems Engineering*.

H_01 - *There is no difference between proportions of those who agree and those who do not agree with the utilisation of the specific practices for Systems Engineering in their projects*.

H_A1 - *There is a difference between proportions of those who agree and those who do not agree with the utilisation of the specific practices for Systems Engineering in their projects*.

4.3.1 Stakeholder Needs and Requirements Analysis

The frequency tables for Stakeholder Need and Requirements Analysis can be viewed in APPENDIX I.

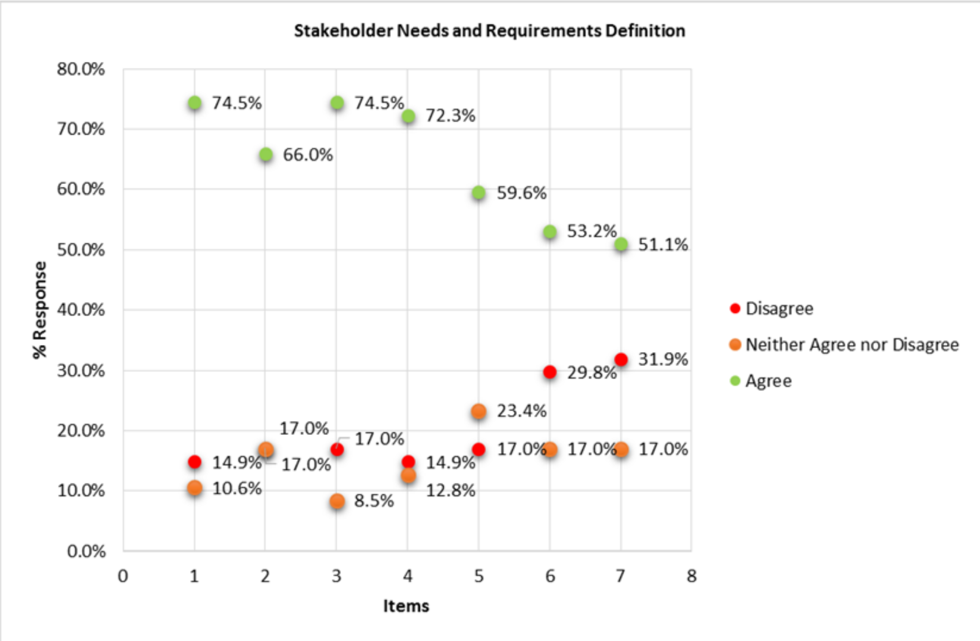


Figure 22: Frequencies of the responses for Stakeholder Needs and Requirements Analysis

There were seven questions in this section and their names were coded StReq_1 to StReq_7 in the IBM SPSS statistics version 25. The results indicated that frequencies of the three responses (Disagree, Neither Agree nor Disagree, and Agree) were different, with the 'Agree' response being the most frequent response. This is shown in Figure 22, where 51.1 % to 74.5 % of the respondents agree, 8.5 % to 23.4 % neither agree nor disagree and 14.9 % to 31.9 %

disagree. Overall, the proportions were high among those who agree with the utilisation of specific practices for Stakeholder Need and Requirements Analysis in their projects.

Table 5: Chi-Square Goodness-of-Fit Test for Stakeholder Need and Requirements Analysis

	Chi-Square	df	Asymp. Sig.
StReq_1	35.915[a]	2	.000
StReq_2	22.511[a]	2	.000
StReq_3	36.298[a]	2	.000
StReq_4	32.213[a]	2	.000
StReq_5	14.851[a]	2	.001
StReq_6	9.489[a]	2	.009
StReq_7	8.213[a]	2	.016

a. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 15.7.

In Table 5, the Chi-Square Goodness-of-Fit Tests (with $\alpha = .05$) revealed that the frequencies of the three responses (Disagree, Neither Agree nor Disagree, and Agree) were statistically significantly different, $p < 0.05$, consequently the null hypothesis could not be accepted. Therefore, the frequencies of the three responses were not the same, with an 'Agree' response being the most frequent response. These findings would suggest that there is a difference between the proportions of those who agree and those who disagree with the utilisation of these specific practices in their projects. These findings were expected and are consistent with the view that the process of Systems Engineering begins in earnest with the definition of the stakeholders' problem by identifying and converting their needs and expectations into a validated set of stakeholder requirements (Blanchard, 2008).

4.3.2 System Requirements Analysis

The frequency tables for System Requirements Analysis can be viewed in APPENDIX J.

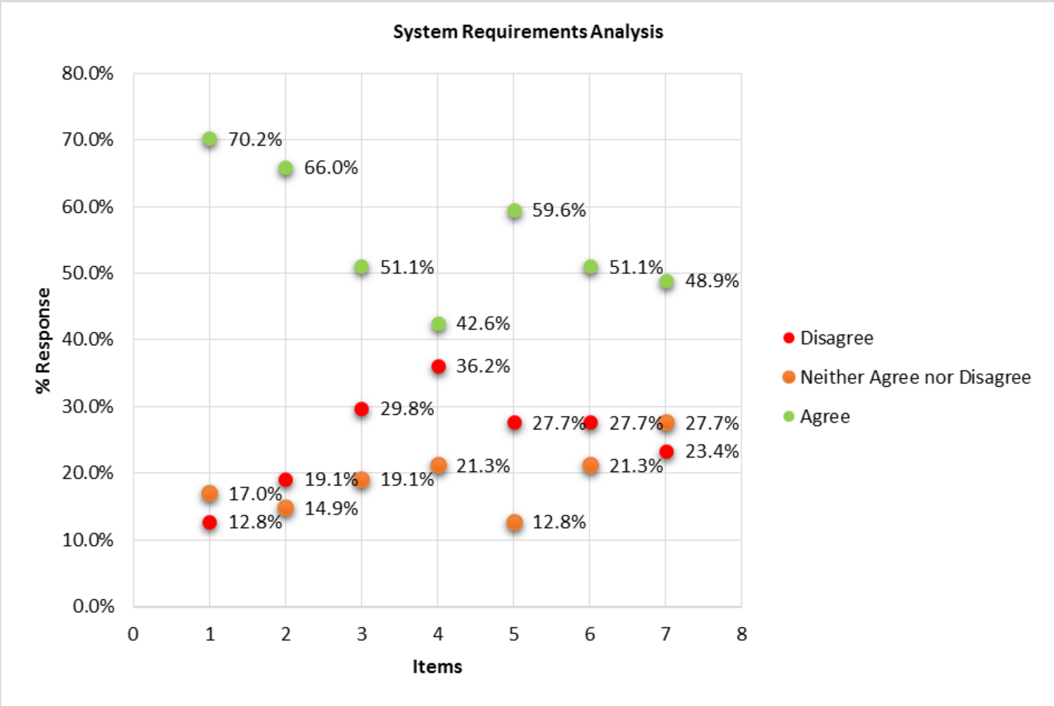


Figure 23: Frequency of responses for System Requirements Analysis

This section also comprised of seven questions, and their names were coded SyReq_1 to SyReq_7 in the IBM SPSS statistics version 25. The results indicated that the frequencies of the three responses (Agree, Neither Agree nor Disagree, and Disagree) were different with an ‘Agree’ response being the most frequent response. This is shown in Figure 23, where 42.6 % to 70.2 % of the respondents returned ‘Agree’ responses, 12.8 % to 27.7 % returned ‘Neither Agree nor Disagree’ responses, and 12.8 % to 36.2 % returned ‘Disagree’ responses. Overall, the proportions were high among those who use the specific practices for System Requirements Analysis in their projects.

Table 6: Chi-Square Goodness-of-Fit Test for System Requirements Analysis

	Chi-Square	df	Asymp. Sig.
SyReq_1	28.894[a]	2	.000
SyReq_2	22.638[a]	2	.000
SyReq_3	7.447[a]	2	.024
SyReq_4	3.362[a]	2	**.186**
SyReq_5	16.128[a]	2	.000
SyReq_6	6.936[a]	2	.031
SyReq_7	5.277[a]	2	**.071**

a. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 15.7.

Table 6, with the exception of questions SyReq_4 and SyReq_7, the Chi-Square Goodness-of-Fit Tests (with $\alpha = .05$) revealed that the frequencies of the three responses were statistically significantly different, $p < 0.05$, consequently the null hypothesis could not be accepted. Hence, the proportions of the three responses were not the same, with an 'Agree' response being the most preferred response. These findings would suggest that there is a difference between the proportions of those who agree and those who disagree with the utilisation of these specific practices in their projects. These findings were expected since at the core of Systems Engineering is the establishment of a complete but minimum set of system requirements based on the stakeholder requirements, and early in the project life cycle (ISO/IEC/IEEE, 2008), (Blanchard, 2008), (Buede and Miller, 2016), (Faulconbridge and Ryan, 2003).

For questions StReq_4 and StReq_7, the chi-square goodness-of-fit tests revealed that the proportions of the three responses were not statistically significantly different, $p = 0.189$ and $p = 0.071$ respectively, consequently the null hypothesis could not be rejected. Thus, there is no difference between the proportions of those who agree and those who disagree with the utilisation of these two specific practices in their projects. These findings were not expected, since for question StReq_4 (this project, upon approval of the requirements, establishes control baselines along with other system definition elements using the established configuration management process), poor definition of system requirements has been cited as one of the factors that led to many project failures (Elm and Goldenson, 2013), (Mansor, Yahaya and Okazaki, 2016). For StReq_7 (this project, upon approval of the requirements, establishes control baselines along with other system definition elements using the established configuration management process), it was also not expected since requirements baselining and requirements management is the cornerstone of Systems Engineering. Without adequate requirements baselining and management, it would be difficult to manage the 'scope creep' and the related costs associated with unstable requirements (Forsberg, Mooz and Cotterman, 2005), (Elm and Goldenson, 2013).

4.3.3 System Architecture

The frequency tables for System Architecture can be viewed in APPENDIX K.

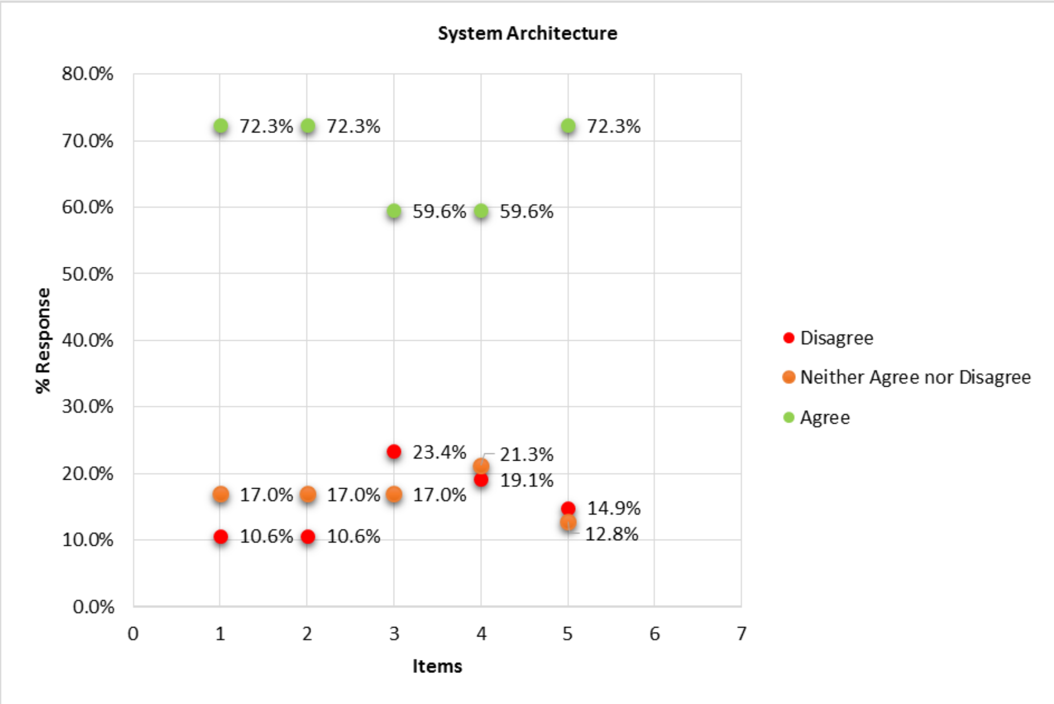


Figure 24: Frequencies of responses on System Architecture

This section comprised of five questions and their names were coded SyArc_1 to SyArc_5 in the IBM SPSS statistics version 25. The results showed that the frequencies of the three responses (Disagree, Neither Agree nor Disagree, and Agree) were different, with an 'Agree' response being the most frequent response. This is shown in Figure 24, where 59.6 % to 72.3 % of the respondents returned 'Agree' responses, 12.8 % to 21.3 % returned 'Neither Agree nor Disagree' responses, and 10.6 % to 23.4 % returned 'Disagree' responses. Overall, the proportions were high among those who agreed with the utilisation of the specific practices for System Architecture in their projects.

Table 7: Summary of Chi-Square Tests for System Architecture

	Chi-Square	df	Asymp. Sig.
SyArc_1	32.468[a]	2	.000
SyArc_2	32.468[a]	2	.000
SyArc_3	14.851[a]	2	.001
SyArc_4	14.596[a]	2	.001
SyArc_5	32.213[a]	2	.000
a. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 15.7.			

In Table 7, the Chi-Square Goodness-of-Fit Tests (with $\alpha = .05$) revealed that the frequencies of the three responses were statistically significantly different, $p < 0.05$, consequently the null hypothesis could not be accepted. Hence, the frequencies of the three responses were not the same, with an 'Agree' response being the most frequent response. These findings would suggest that there is a difference between the proportions of those who agree and those who disagree with the utilisation of these specific practices in their projects. These findings were expected. According to (INCOSE/AIAA, 1997), the design of a system should follow requirements, and requirements should not be used to document the design on an after-the-fact basis. The System Architecture allow a proper assessment of alternative means to address the users' needs, thus avoiding predetermined and potentially "*inefficient, costly, and often, unscalable and inflexible solutions*." (Jain and Chandrasekaran, 2008).

4.3.4 System Design and Analysis

The frequency tables for System Design and Analysis can be viewed in APPENDIX L.

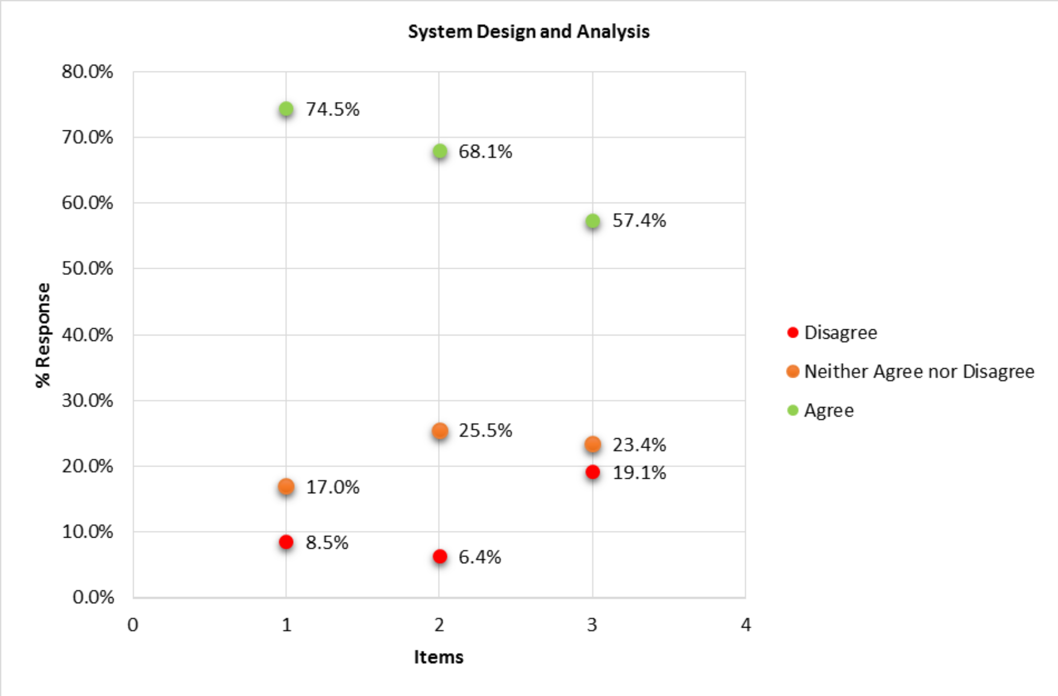


Figure 25: Frequencies of the responses for System Design and Analysis

This section comprised of three questions and their names were coded Sy_Des_Anl_1 to Sy_Des_Anl_3 in the IBM SPSS statistics version 25. The results showed that the frequencies of the three responses (Disagree, Neither Agree nor Disagree, and Agree) were different with an 'Agree' response being the most frequent response. This is shown in Figure 25, where 57.4 % to 74.5 % of the respondents returned 'Agree' responses, 17 % to 25.5 % returned 'Neither Agree nor Disagree' responses, and 6.4 % to 19 % returned 'Disagree' responses. Overall, the proportions were high among those who agree with the utilisation of the specific practices for System Design and Analysis in their projects.

Table 8: Summary of Chi-Square Tests for System Design and Analysis

	Chi-Square	df	Asymp. Sig.
Sy_Des_Anl_1	36.298[a]	2	.000
Sy_Des_Anl_2	28.128[a]	2	.000
Sy_Des_Anl_3	12.426[a]	2	.002

a. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 15.7.

In Table 8, the Chi-Square Goodness-of-Fit Tests (with $\alpha = .05$) revealed that the frequencies of the three responses were statistically significantly different, $p < 0.05$, consequently the null hypothesis could not be accepted. Therefore, the frequencies of the three responses were not the same, with an ‘Agree’ response being the most frequent response. These findings would suggest that there is a difference between the proportions of those who agree and those who disagree with the utilisation of these specific practices in their projects. These findings were expected since the goal of systems engineering is to ensure the implementation of the balanced solution (INCOSE/AIAA, 1997). The definition of the technical problem is a top-down activity – “*from the system to its many layers of subsystems*”. It involves performing the detailed analyses using appropriate analytical methods (e.g., simulation and modelling, structured analysis, information modelling, object-oriented analysis, rapid prototyping) (ISO/IEC/IEEE, 2008).

4.3.5 Assessment, Selection and Implementation

The frequency tables for Assessment, Selection and Implementation can be viewed in APPENDIX M.

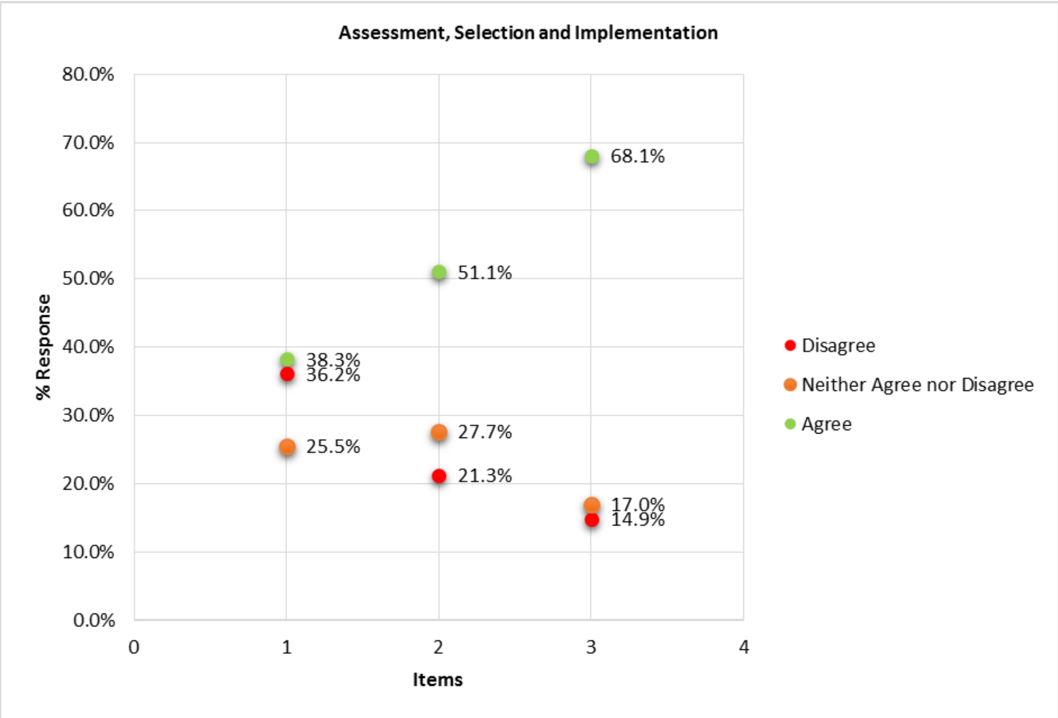


Figure 26: Frequencies of the responses for Assessment, Selection and Implementation

This section also comprised of three questions and their names were coded Ass_Sel_Imp_1 to Ass_Sel_Imp_3 in the IBM SPSS statistics version 25. The results showed that the frequencies of the three responses (Disagree, Neither Agree nor Disagree, and Agree) were different with an ‘Agree’ response being the most frequent response. This is shown in Figure

26, where 38.3 % to 68.1 % of the respondents returned ‘Agree’ responses, 17 % to 27.7 % returned ‘Neither Agree nor Disagree’ responses, and 14.9 % to 36.2 % returned ‘Disagree’ responses. Overall, the proportions were high among those who agree with the utilisation of the specific practices for Assessment, Selection and Implementation in their projects.

Table 9: Summary of Chi-Square Tests for Assessment, Selection and Implementation

	Chi-Square	df	Asymp. Sig.
Ass_Sel_Imp_1	1.319[a]	2	**.517**
Ass_Sel_Imp_2	6.936[a]	2	.031
Ass_Sel_Imp_3	25.574[a]	2	.000

a. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 15.7.

In Table 9, with the exception of question Ass_Sel_Imp_1, the Chi-Square Goodness-of-Fit Tests (with $\alpha = .05$) revealed that the frequencies of the three responses were statistically significantly different, $p < 0.05$, consequently the null hypothesis could not be accepted. Hence, the frequencies of the three responses were not the same, with an ‘Agree’ response being the most frequent response. These findings would suggest that there is a difference between the proportions of those who agree and those who disagree with the utilisation of these two specific practices in their projects. These findings were expected since the customers would expect the suppliers to assess their needs and determine the best alternative to meet those needs (INCOSE/AIAA, 1997). The ultimate objective of Assessment and Selection is to perform trade studies to assess and evaluate alternatives that may meet the stakeholder and system requirements and assist with the determination of a well-balanced resolution for each system element as well as the system as a whole (ISO/IEC/IEEE, 2008).

For question Ass_Sel_Imp_1, the chi-square goodness-of-fit tests revealed that the frequencies of responses were not statistically significantly different, $p = 0.517$, consequently the null hypothesis could not be rejected. Thus, the frequencies of responses were the same, and the differences were due to chance. This finding would suggest that there is no difference between the proportions of those who agree and those who disagree with the utilisation of this specific practices (*This project assesses and selects the preferred candidate architecture(s) using the architecture evaluation criteria in conjunction with the established risk management and decision management processes*) in their projects.

4.3.6 System Integration

The frequency tables for System Integration can be viewed in APPENDIX N.

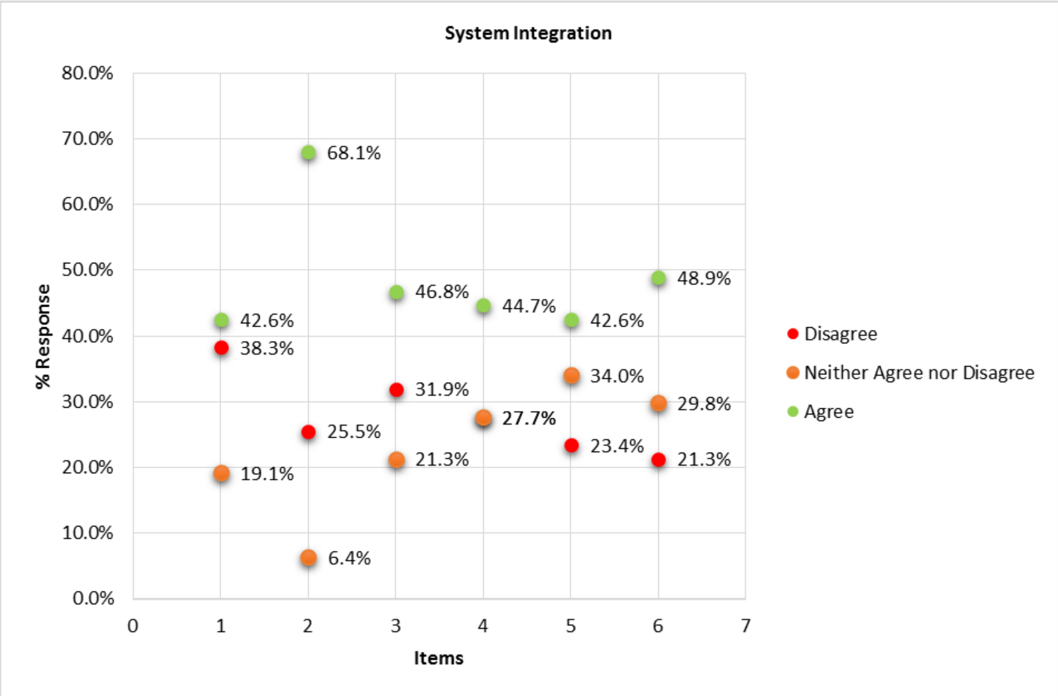


Figure 27: Frequencies of the responses for System Integration

There were six questions in this section and their names were coded SyInt_1 to SyInt_6 in the IBM SPSS statistics version 25. The results indicated that the frequencies of the three responses (Disagree, Neither Agree nor Disagree, and Agree) were different. This is shown in Figure 27, where 42.6 % to 68.1 % of the respondents returned 'Agree' responses, 6.4 % to 34 % returned 'Neither Agree nor Disagree' responses, and 21.3 % to 38.4 % returned 'Disagree' responses. Overall, the proportions were high among those who agree with the utilisation of the specific practices for System Integration in their projects.

Table 10: Summary of Chi-Square Tests for System Integration

	Chi-Square	df	Asymp. Sig.
SyInt_1	4.383[a]	2	.112
SyInt_2	28.128[a]	2	**.000**
SyInt_3	4.638[a]	2	.098
SyInt_4	2.723[a]	2	.256
SyInt_5	2.596[a]	2	.273
SyInt_6	5.660[a]	2	.059
a. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 15.7.			

In Table 10, with the exception of question SyInt_2, the chi-square goodness-of-fit tests revealed that the proportions of the three responses were not statistically significantly different, $p > 0.05$, consequently the null hypothesis could not be rejected. Thus, the proportions of the three responses were the same, and the differences were due to chance. These findings would suggest that there is no difference between the proportions of those who agree and those who disagree with the utilisation of these specific practices in their projects. These findings were not expected since System Integration forms one of the critical elements of the systems engineering approach. It refers to the planned set of activities that brings together smaller units of a system into larger units (INCOSE/AIAA, 1997). The other two equally essential processes, namely verification and validation, are performed as the integral part of the System Integration processes (ISO/IEC/IEEE, 2008).

For question StReq_2 (*The integration plan of this project defines verification activities that should be performed as part of system integration.*), the Chi-Square Goodness-of-Fit Tests (with $\alpha = .05$) revealed that the proportions of the three responses were statistically significantly different, $p < 0.01$, consequently the null hypothesis could not be accepted. Therefore, the proportions of the three responses were not the same, with an 'Agree' response being the most frequent response. This finding would suggest that there is a difference between the proportions of those who agree and those who disagree with the utilisation of this specific practices in their projects, and this was expected.

4.3.7 System Verification and Validation

The frequency tables for System Verification and Validation can be viewed in APPENDIX O.

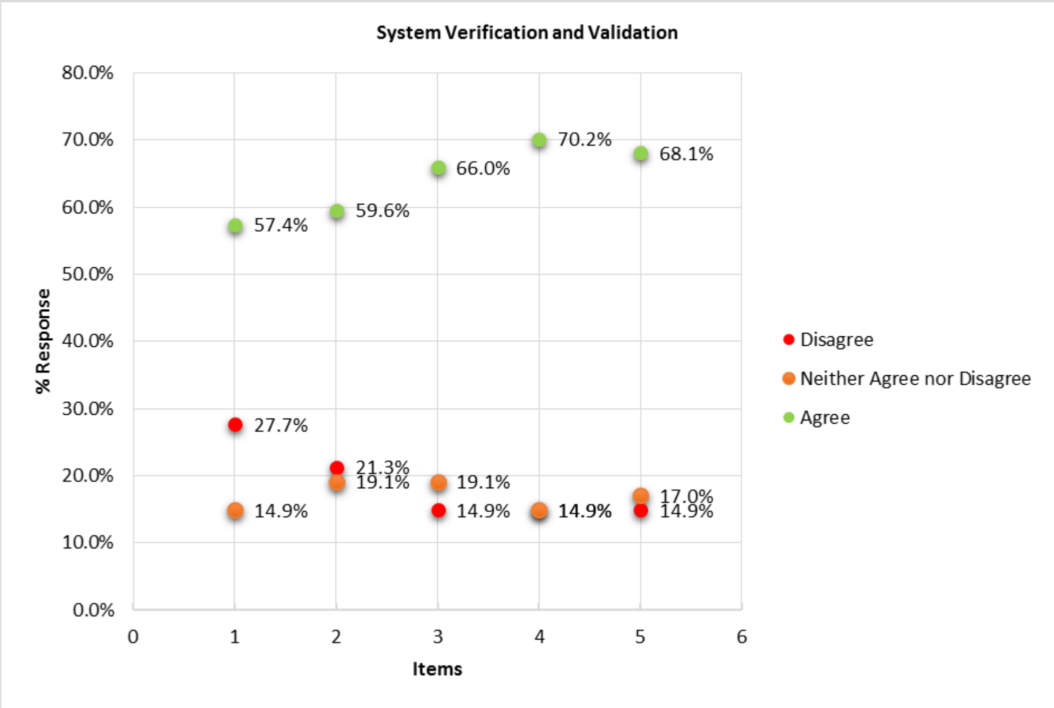


Figure 28: Frequencies of the responses for System Verification and Validation

There were five questions in this section and their names were coded SyVV_1 to SyVV_5 in the IBM SPSS statistics version 25. The results showed that the frequencies of the three responses (Disagree, Neither Agree nor Disagree, and Agree) were different with an 'Agree' response being the most frequent response. This is shown in Figure 28, where 57.4 % to 70.2 % of the respondents returned 'Agree' responses, 14.9 % to 19.1 % returned 'Neither Agree nor Disagree' responses, and 14.9 % to 27.7 % returned 'Disagree' responses. Overall, the proportions were high among those who use the specific practices for System Verification and Validation in their projects.

Table 11: Summary of Chi-Square Tests for System Verification and Validation

	Chi-Square	df	Asymp. Sig.
SyVV_1	13.447[a]	2	.001
SyVV_2	14.596[a]	2	.001
SyVV_3	22.638[a]	2	.000
SyVV_4	28.766[a]	2	.000
SyVV_5	25.574[a]	2	.000

a. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 15.7.

In Table 11, the Chi-Square Goodness-of-Fit Tests (with $\alpha = .05$) revealed that the frequencies of three responses were statistically significantly different, $p < 0.05$, consequently the null hypothesis could not be accepted. Therefore, the frequencies of the three responses were not the same, with an 'Agree' response being the most frequent response. These findings would suggest that there is a difference between the proportions of those who agree and those who disagree with the utilisation of these specific practices in their projects. These findings were expected and were consistent with the Systems Engineering approach to verify the system against the system requirements and validated the system against the Stakeholder Requirements (also called User Requirements).

RQ 2 - *Is there an association between the status of specific practices associated with the technical processes of Systems Engineering and Competency Area*?
RO 2 - *To investigate whether an association exist between the statuses of specific practices associated with the technical processes of Systems Engineering and Competency Area*.
H_02 - *There is no association between the status (utilisation) of the specific practices for Systems Engineering and Competency Areas*.
H_A2 - *There is an association between the status (utilisation) of the specific practices for Systems Engineering and Competency Areas*.

4.3.8 Stakeholder Needs and Requirements Analysis

The results of a Fisher's Exact Test for Stakeholder Needs and Requirements Analysis are provided in Table 104 to Table 124 in APPENDIX P.

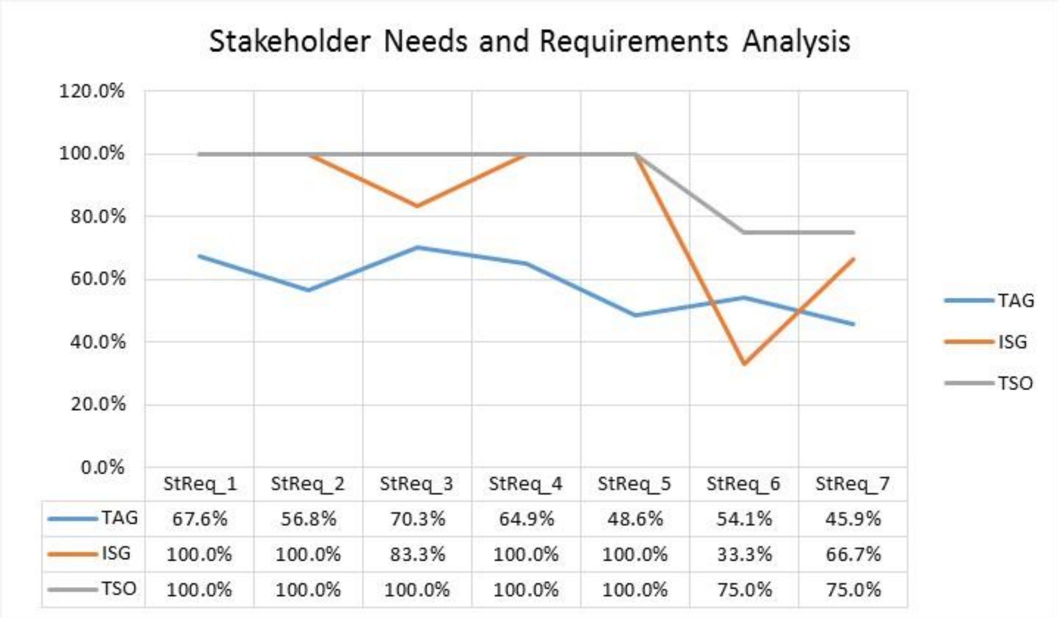


Figure 29: Proportions (% within group) of 'Agree' responses for Stakeholder Needs and Requirements Analysis per Competency Area.

The results showed that the proportions of the respondents who returned the 'Agree' responses were different between TAG, ISG and TSO. This is shown in Figure 29 were the proportions were 75 % to 100 % from TSO, 33.3 % to 100.0 % from ISG and 45.9 % to 70.3 % from TAG. Overall, the proportions were high among TSO and ISG compared to the TAG. There might be various reasons for these differences, and some of them could be as follows:

- The reason for the highest proportion among TSO is that, this Competency Area, most often than not, carried out new product development projects for their customers, and they have been following the systems engineering approach for quite some time.
- The ISG had most of its members with a job title of a Systems Engineer and often provided Systems Engineering and Project Management support to other Competency Areas within DPSS. They also carried out their own projects, which can be characterised as complex enterprise development projects or the System of Systems (SoS) type projects as opposed to product development projects.
- The Competency Areas in the TAG, on the other hand, were involved in either new or ongoing scientific and industrial research work, but also carried out new product development projects or upgrades or modification of existing products or systems. There were a mix of technology push (i.e. the need for the technology originated within the CSIR) and market pull (i.e. the need for the technology originated from customers) projects among the TAG. This might explain the inconsistent application

of the specific practices for Stakeholders Needs and Requirements Analysis among the TAG.

Table 12: Fisher's Exact Test for Competency Area * Stakeholder Needs and Requirements Analysis Crosstabulation

	Fisher's Exact Test Value	Exact Sig. (2-sided)
StReq_1	2.329	0.629
StReq_2	4.206	0.323
StReq_3	1.282	0.932
StReq_4	2.696	0.591
StReq_5	6.208	0.109
StReq_6	4.602	0.266
StReq_7	2.313	0.766

In Table 12, the Fisher’s exact tests of independence (with $\alpha = .05$) revealed that the proportions between TSO, ISG and TAG were not statistically significantly different, $p > 0.05$, consequently, the null hypothesis could not be rejected. Therefore, the proportions between TSO, ISG and TAG were the same, and the differences were due to chance. These findings would suggest that there is no association between the status of the specific practices for Stakeholder Needs and Requirements Analysis and Competency Areas in DPSS.

4.3.9 System Requirements Analysis

The results of a Fisher’s Exact Test for System Requirements Analysis are provided in Table 125 to Table 145 in APPENDIX P.

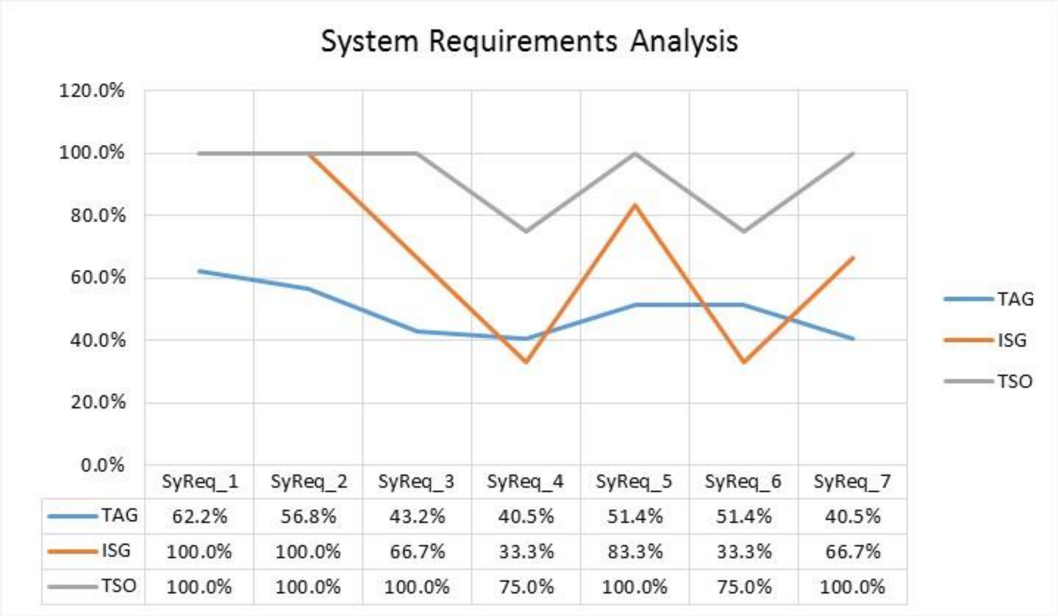


Figure 30: Proportions (% within group) of 'Agree' responses for System Requirements Analysis per Competency Area.

The results showed that the proportions of the respondents who returned the 'Agree' responses were different between TAG, ISG and TSO. This is shown in Figure 30 were the proportions were 75 % to 100 % from TSO, 67 % to 100 % from ISG and 41 % to 62 % from TAG. Overall, the proportions were high among TSO and ISG compared to the TAG. There reason provided above for Stakeholder Needs and Requirements Analysis are also applicable for System Requirements Analysis.

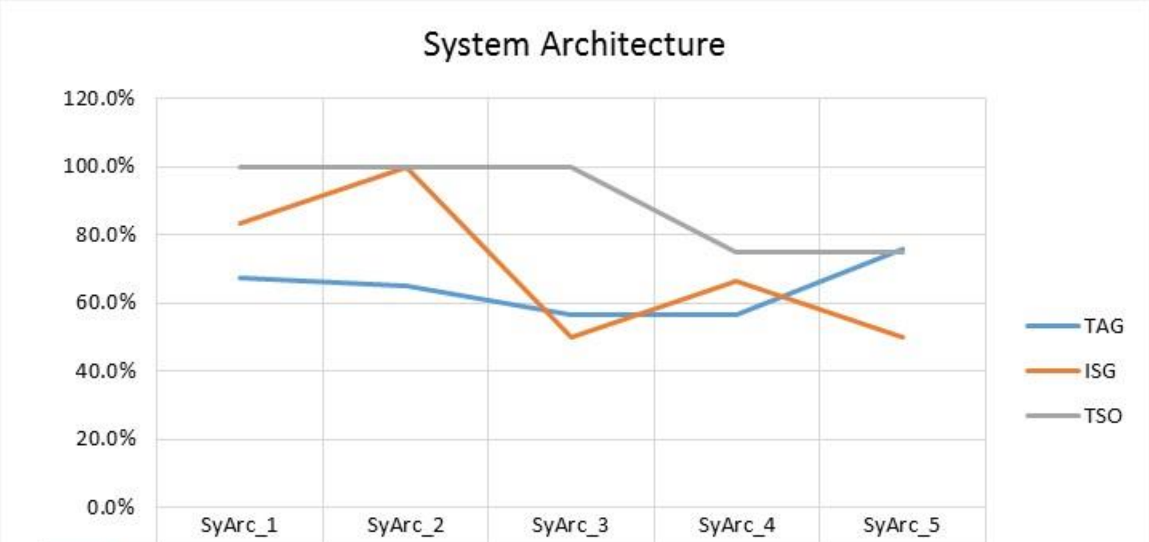
Table 13: Fisher's Exact Test for Competency Area * System Requirements Analysis Crosstabulation

	Fisher's Exact Test Value	Exact Sig. (2-sided)
SyReq_1	3.185	0.473
SyReq_2	4.238	0.315
SyReq_3	4.087	0.362
SyReq_4	2.281	0.765
SyReq_5	3.625	0.391
SyReq_6	2.168	0.782
SyReq_7	4.476	0.293

In Table 13, the Fisher's exact tests of independence (with $\alpha = .05$) revealed that the proportions between TSO, ISG and TAG were not statistically significantly different, $p > 0.05$; consequently, the null hypothesis could not be rejected. Therefore, the proportions between TSO, ISG and TAG were the same, and the differences were due to chance. These findings would suggest that there is no association between the status of the specific practices for System Requirements Analysis and Competency Areas in DPSS.

4.3.10 System Architecture

The results of a Fisher's Exact Test for System Architecture are provided in Table 146 to Table 160 in APPENDIX P.



	SyArc_1	SyArc_2	SyArc_3	SyArc_4	SyArc_5
TAG	67.6%	64.9%	56.8%	56.8%	75.7%
ISG	83.3%	100.0%	50.0%	66.7%	50.0%
TSO	100.0%	100.0%	100.0%	75.0%	75.0%

Figure 31: Proportions (% within group) of 'Agree' responses for System Architecture per Competency Area.

The results showed that the proportions of the respondents who returned the 'Agree' responses were different between the TAG, ISG and TSO. This is shown in Figure 31, were the proportions were 75 % to 100 % in TSO, 50.0 % to 100 % in ISG and 56.8 % to 75.7 % in TAG. Overall, the proportions were the highest among TSO, compared to TAG and ISG. A possible explanation for these differences might be that the TAG might have been following the traditional design approach (i.e. whereby engineers are expected to move directly from understanding the problem of the customer to defining its solution without following the system engineering approach) or for both TAG and ISG, some of their projects might have not been complex enough to warrant the use of some of these specific practices or it might also have been due to the tailoring of systems engineering processes.

Table 14: Fisher's Exact Test for Competency Area * System Architecture Crosstabulation

	Fisher's Exact Test Value	Exact Sig. (2-sided)
SyArc_1	2.429	0.664
SyArc_2	2.793	0.548
SyArc_3	3.142	0.543
SyArc_4	1.399	0.935
SyArc_5	5.864	0.134

In Table 14, the Fisher's exact tests of independence (with $\alpha = .05$) revealed that the proportions between TSO, ISG and TAG were not statistically significantly different, $p > 0.05$; consequently, the null hypothesis could not be rejected. Hence, the proportions between TSO, ISG and TAG were the same, and the differences were due to chance. These findings would suggest that there is no association between the status of the specific practices for System Architecture and Competency Area in DPSS.

4.3.11 System Design and Analysis

The results of a Fisher's Exact Test for System Design and Analysis are provided in Table 161 to Table 169 in APPENDIX P.

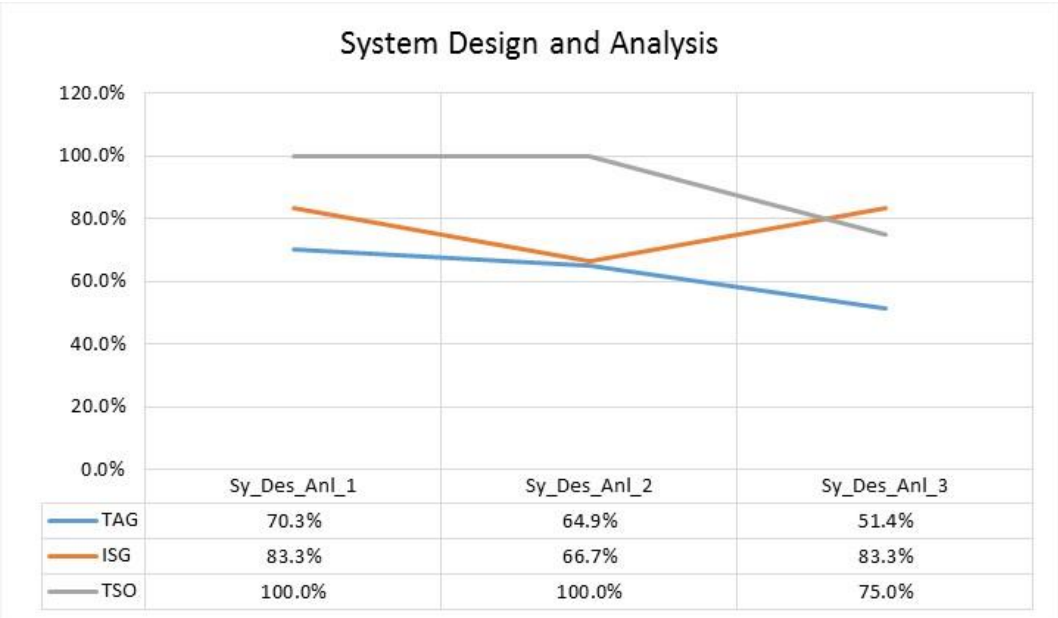


Figure 32: Proportions (% within group) of 'Agree' responses for System Design and Analysis per Competency Area

The results showed that the proportions of the respondents who returned the ‘Agree’ responses were different between TAG, ISG and TSO. This is shown in Figure 32, were the proportions were 75 % to 100 % from TSO, 67 % to 83.3 % from ISG and 51.4 % to 70.3 % from TAG. Overall, the proportions were the high among the TSO and ISG compared to the TAG. A possible reason for these differences might be that the competency areas in the TAG might have been doing these activities informally without knowing that they were doing them.

Table 15: Fisher’s Exact Test for Competency Area * System Design and Analysis Crosstabulation

	Fisher's Exact Test Value	Exact Sig. (2-sided)
Sy_Des_Anl_1	2.669	0.534
Sy_Des_Anl_2	3.202	0.483
Sy_Des_Anl_3	3.052	0.586

In Table 15, the Fisher’s exact tests of independence (with $\alpha = .05$) revealed that the proportions between TSO, ISG and TAG were not statistically significantly different, $p > 0.05$, consequently, the null hypothesis could not be rejected. Hence, the proportions between TSO, ISG and TAG were the same, and the differences were due to chance. These findings would suggest that there is no association between the status of the specific practices for System Design and Analysis and Competency Areas in DPSS.

4.3.12 Assessment, Selection and Implementation

The results of a Fisher’s Exact Test for Assessment, Selection and Implementation are provided in Table 170 to Table 178 in APPENDIX P.

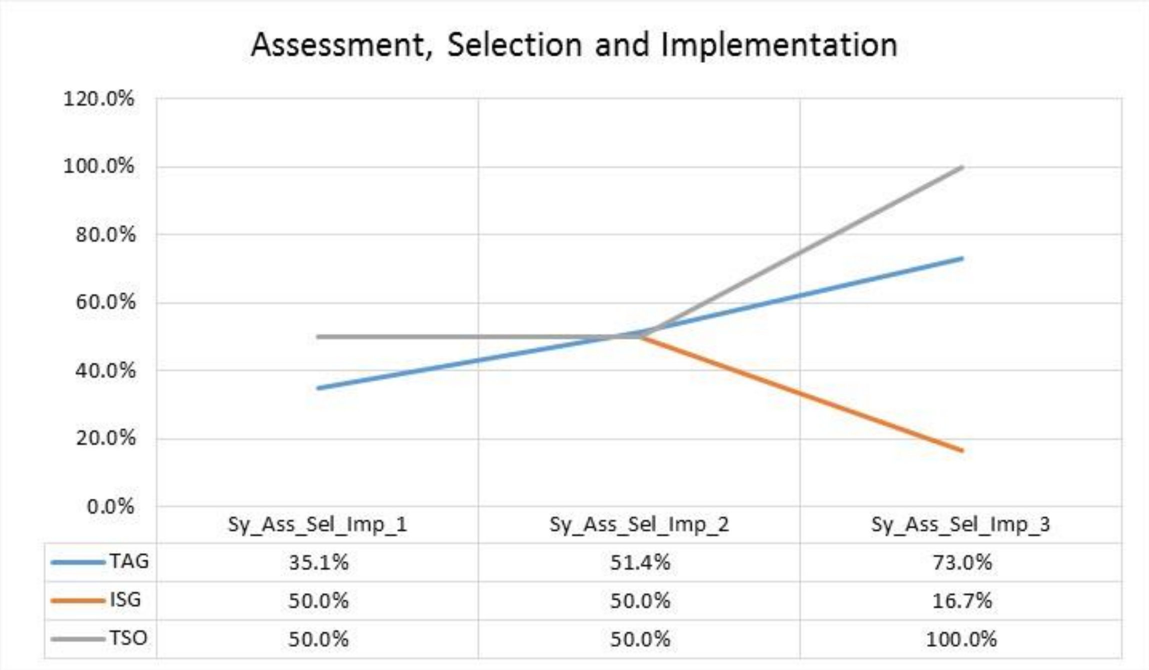


Figure 33: Proportions (% within group) of 'Agree' responses for Assessment, Selection and Implementation per Competency Area

The results showed that the proportions of the respondents who returned the 'Agree' responses were different between TAG, ISG and TSO. This is shown in Figure 33, were the proportions were 50 % to 100 % from TSO, 16.7 % to 50 % from ISG and 35.1 % to 73 % from TAG. Except for question Ass_Sel_Imp_3 (*This project conducts unit testing and records evidence that the system elements meets their requirements and the associated verification and validation criteria*), overall, the proportions between the three groups were not much different. For Ass_Sel_Imp_3, the proportions were much high among TSO and TAG compared to ISG. A possible explanation for these differences might be that the projects at ISG can be characterised as enterprise architecture development or System of Systems (SoS) type projects as opposed to product development, and as such, unit testing might not have been necessary.

Table 16: Fisher's Exact Test for Competency Area *Assessment, Selection and Implementation Crosstabulation

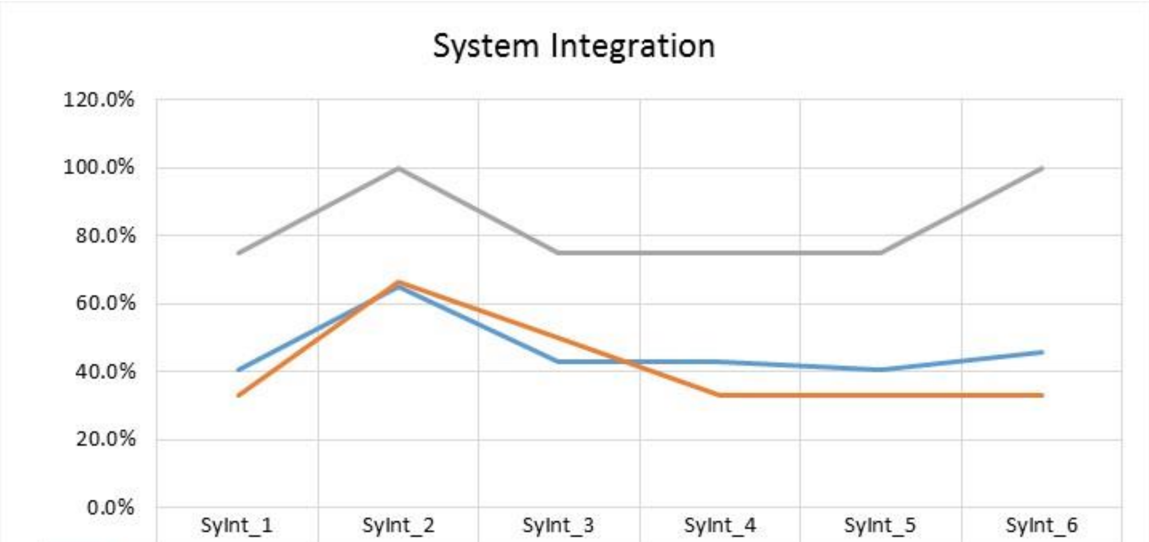
	Fisher's Exact Test Value	Exact Sig. (2-sided)
Ass_Sel_Imp_1	2.875	0.629
Ass_Sel_Imp_2	5.002	0.215
Ass_Sel_Imp_3	8.535	**0.037**

In Table 16, with the exception of question Ass_Sel_Imp_3, the Fisher's exact tests of independence (with $\alpha = .05$) revealed that the proportions between TSO, ISG and TAG were not statistically significantly different, $p > 0.05$, consequently, the null hypothesis could not be rejected. Therefore, the proportions between Managers, Systems Engineer and Discipline Engineer were the same, and the differences were due to chance. These findings would suggest that there is no association between the status of these two specific practices for Assessment, Selection and Implementation and Competency Areas in DPSS.

For question Ass_Sel_Imp_3, the results of the Fisher's exact test of independence (with $\alpha = .05$) revealed that the proportions between TSO, ISG and TAG were statistically significantly different, $p = 0.025$ (i.e., $p < 0.05$), consequently the null hypothesis could not be accepted. Therefore, the proportions between TSO, ISG and TAG were not the same. This finding would suggest that there is an association between the status of this specific practice and Competency Areas in DPSS, with the ISG less inclined to practising it.

4.3.13 System Integration

The results of a Fisher's Exact Test for System Integration are provided in Table 179 to Table 196 in APPENDIX P.



	SyInt_1	SyInt_2	SyInt_3	SyInt_4	SyInt_5	SyInt_6
TAG	40.5%	64.9%	43.2%	43.2%	40.5%	45.9%
ISG	33.3%	66.7%	50.0%	33.3%	33.3%	33.3%
TSO	75.0%	100.0%	75.0%	75.0%	75.0%	100.0%

Figure 34: Proportions (% within group) of 'Agree' responses for System Integration per Competency Area

The results showed that the proportions of the respondents who returned the 'Agree' responses were different between TAG, ISG and TSO. This is shown in Figure 34, were the proportions were 75 % to 100 % from TSO, 33.3 % to 64.9 % from ISG and 40.5 % to 64.9 % from TAG. Overall, the proportions were the highest among the TSO. A possible reason for these differences might be that TSO carried out new product development projects for their customers, and System Integration is a critical capability for these types of projects.

Table 17: Fisher's Exact Test for Competency Area * System Integration Crosstabulation

	Fisher's Exact Test Value	Exact Sig. (2-sided)
SyInt_1	2.012	0.830
SyInt_2	1.989	0.857
SyInt_3	1.623	0.871
SyInt_4	2.283	0.789
SyInt_5	5.15	0.220
SyInt_6	5.833	0.150

In Table 17, the Fisher's exact tests of independence (with $\alpha = .05$) revealed that the proportions between TSO, ISG and TAG were not statistically significantly different, $p > 0.05$; consequently, the null hypothesis could not be rejected. Therefore, the proportions between TSO, ISG and TAG were the same, and the differences were due to chance. These findings would suggest that there is no association between the status of the specific practices for System Integration and Competency Areas in DPSS.

4.3.14 System Verification and Validation

The results of a Fisher's Exact Test for System Verification and Validation are provided in Table 197 to Table 211 in APPENDIX P.

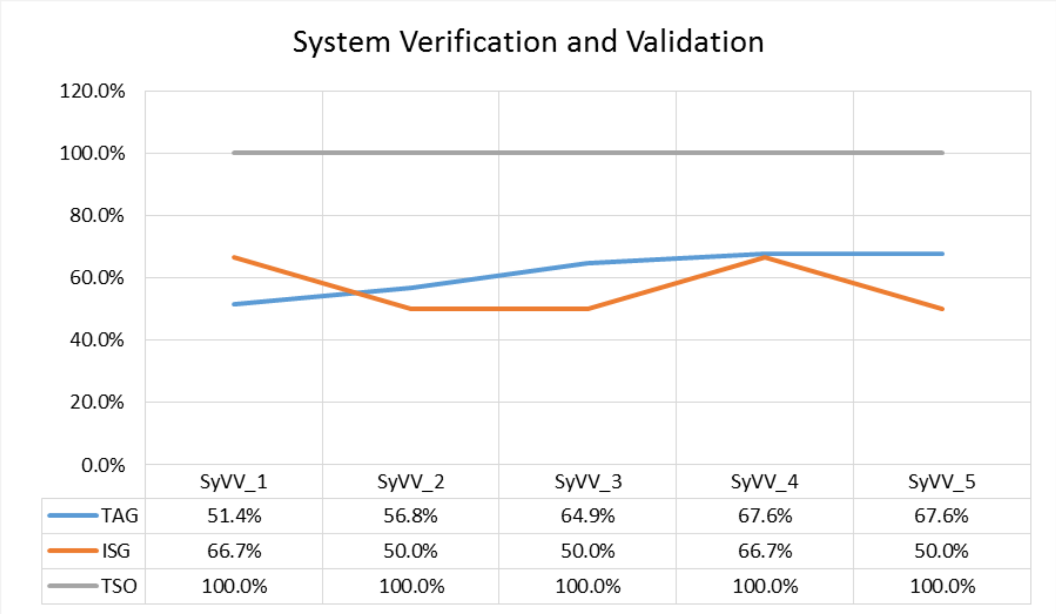


Figure 35: Proportions (% within group) of 'Agree' responses for System Verification and Validation per Competency Area

The results showed that the proportions of the respondents who returned the 'Agree' responses were different between TAG, ISG and TSO. This is shown in Figure 35, were the proportions were all 100 % from TSO, 50 % to 66.7 % from ISG and 51.4 % to 67.6 % from TAG. Overall, the proportions were the highest among the TSO. A possible reason for these differences might be that TSO carried out new product development projects for their customers, and System Verification and Validation is a critical capability for these types of projects.

Table 18: Fisher's Exact Test for Competency Area * System Verification and Validation Crosstabulation

	Fisher's Exact Test Value	Exact Sig. (2-sided)
SyVV_1	3.251	0.502
SyVV_2	2.55	0.693
SyVV_3	2.988	0.483
SyVV_4	1.352	1.000
SyVV_5	2.594	0.644

In Table 18, the Fisher's exact tests of independence (with $\alpha = .05$) revealed that the proportions between TSO, ISG and TAG were not statistically significantly different, $p > 0.05$; consequently, the null hypothesis could not be rejected. Therefore, the proportions between TSO, ISG and TAG were the same, and the differences were due to chance. These findings would suggest that there is no association between the status of the specific practices for System Verification and Validation and Competency Areas in DPSS. These findings were as expected since the Competency Areas in DPSS, and where necessary, follow the systems engineering approach to carry out their projects.

RQ 3 - *Is there an association between the status of specific practices associated with the technical processes of Systems Engineering and Job Category?*
RO 3 - *To investigate whether an association exist between the statuses of specific practices associated with the technical processes of Systems Engineering and Job Categories.*
H_03 - *There is no association between the status (utilisation) of the specific practices for Systems Engineering and Job Categories.*
H_A3 - *There is an association between the status (utilisation) of the specific practices for Systems Engineering and Job Categories.*

4.3.15 Stakeholder Needs and Requirements Analysis

The results of a Fisher's Exact Test for Stakeholder Needs and Requirements Analysis are provided in Table 212 to Table 232 in APPENDIX Q.

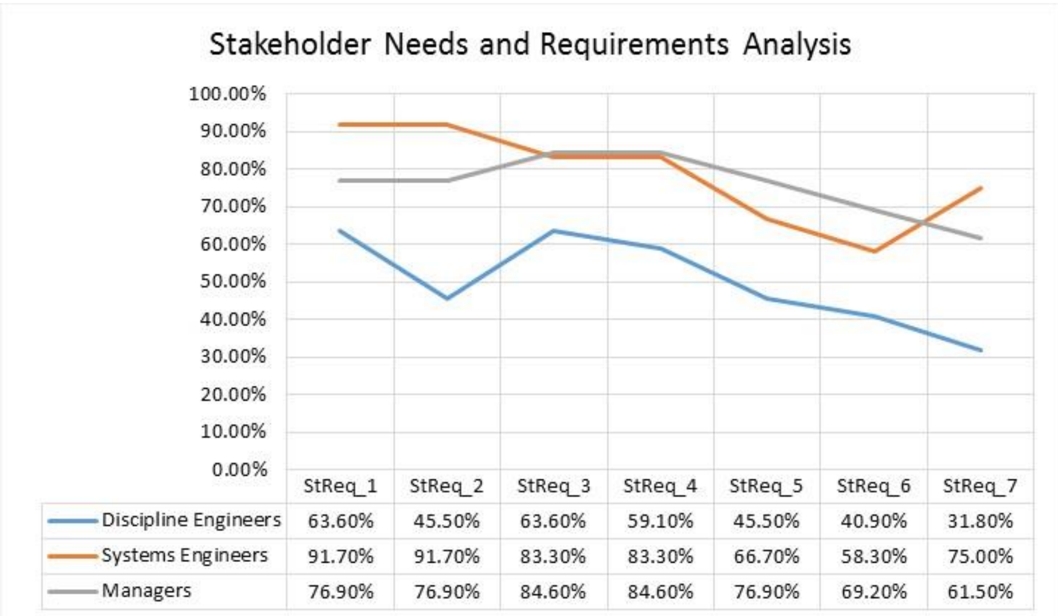


Figure 36: Proportions (% within group) of 'Agree' responses for Stakeholder Needs and Requirements Analysis per Job Category.

The results showed that the proportions of the respondents who returned the 'Agree' responses were different between Managers, Systems Engineer and Discipline Engineer. This is shown in Figure 36 were the proportions were 61.5 % to 84.6 % for Managers, 58.3 % to 91.7 % for Systems Engineers and 31.8 % to 63.6 % for Discipline Engineers. Overall, the proportions were high among Systems Engineers and Managers compared to Discipline Engineers. A possible reason for these differences might be that Discipline Engineers are usually not involved during the early stages of the projects, which are characterised by contract negotiations and the definition of requirements, between the customers and the management team, including Systems Engineers.

Table 19: Fisher's Exact Test for Job Category * Stakeholder Needs and Requirements Analysis Crosstabulation

	Fisher's Exact Test Value	Exact Sig. (2-sided)
StReq_1	3.328	0.578
StReq_2	8.089	0.063
StReq_3	3.953	0.414
StReq_4	4.489	0.342
StReq_5	6.826	0.131
StReq_6	7.268	0.107
StReq_7	6.612	0.146

In Table 19, the Fisher's exact tests of independence (with $\alpha = .05$) revealed that the proportions between Managers, Systems Engineer and Discipline Engineer were not statistically significantly different, $p > 0.05$, consequently, the null hypothesis could not be rejected. Therefore, the proportions between Managers, Systems Engineer and Discipline Engineer were the same, and the differences were due to chance. These findings would suggest that there is no association between the status of specific practices for Stakeholder Needs and Requirements Analysis and Job Category in DPSS.

4.3.16 System Requirements Analysis

The results of a Fisher's Exact Test for System Requirements Analysis are provided in Table 233 to Table 253 in APPENDIX Q

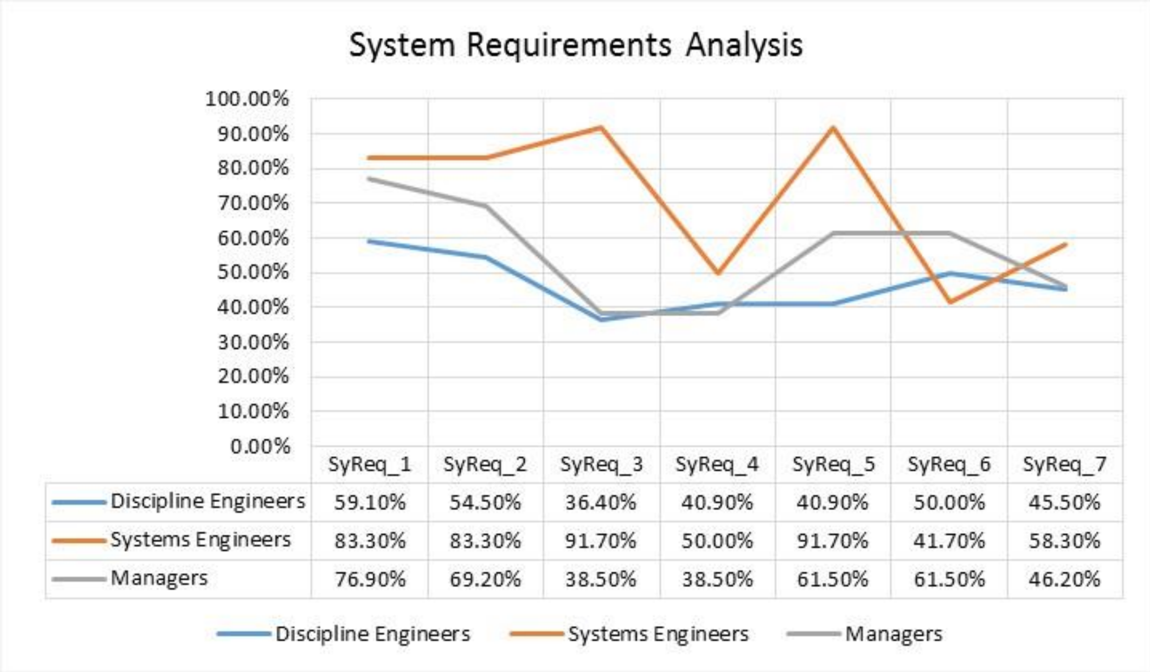


Figure 37: Proportions (% within group) of 'Agree' responses for System Requirements Analysis per Job Category.

The results showed that the proportions of the respondents who returned the 'Agree' responses were different between Managers, Systems Engineer and Discipline Engineer. This is shown in Figure 37 were the proportions were 39 % to 77 % from Managers, 42 % to 92 % from Systems Engineers and 36 % to 59 % from Discipline Engineers. Overall, the proportions were high among Systems Engineers and Managers compared to Discipline Engineers. A possible reason for these differences might be that Discipline Engineers are usually not involved during the early stages of the projects, which are characterised by contract negotiations and the definition of requirements, between the customers and the management team, including Systems Engineers.

Table 20: Fisher's Exact Test for Job Category * System Requirements Analysis Crosstabulation

	Fisher's Exact Test Value	Exact Sig. (2-sided)
SyReq_1	4.577	0.331
SyReq_2	2.834	0.623
SyReq_3	10.483	**0.025**
SyReq_4	1.221	0.911
SyReq_5	8.29	0.060
SyReq_6	1.883	0.804
SyReq_7	2.264	0.716

In Table 20, with the exception of question SyReq_3, the Fisher's exact tests of independence (with $\alpha = .05$) revealed that the proportions between Managers, Systems Engineer and Discipline Engineer were not statistically significantly different, $p > 0.05$, consequently, the null hypothesis could not be rejected. Hence, the proportions between Managers, Systems Engineer and Discipline Engineer were the same, and the differences were due to chance. These findings would suggest that there is no association between the status of the specific practices for System Requirements Analysis and Job Category in DPSS.

For question SyReq_3, the results of the Fisher's exact test of independence (with $\alpha = .05$) revealed that the proportions between Managers, Systems Engineer and Discipline Engineer were statistically significantly different, $p = 0.025$ (i.e. $p < 0.05$), with the Systems Engineers more inclined to agree with the utilisation of this specific practice compared to Mangers and Discipline Engineers, consequently the null hypothesis could be accepted. Therefore, the proportions between Managers, Systems Engineer and Discipline Engineer were not same.

This finding would suggest that there is an association between the status of the specific practice StReq_3 (This project establishes a bi-directional traceability between requirements at adjacent levels of the system hierarchy) and Job Category at DPSS, with the Systems Engineers been most likely to agree with its utilisation as compared to Managers and Discipline Engineers. A possible reason for this might be that ensuring the traceability of requirements is a function usually performed by Systems Engineers.

4.3.17 System Architecture

The results of a Fisher's Exact Test for System Architecture are provided in Table 254 to Table 268 in APPENDIX Q.

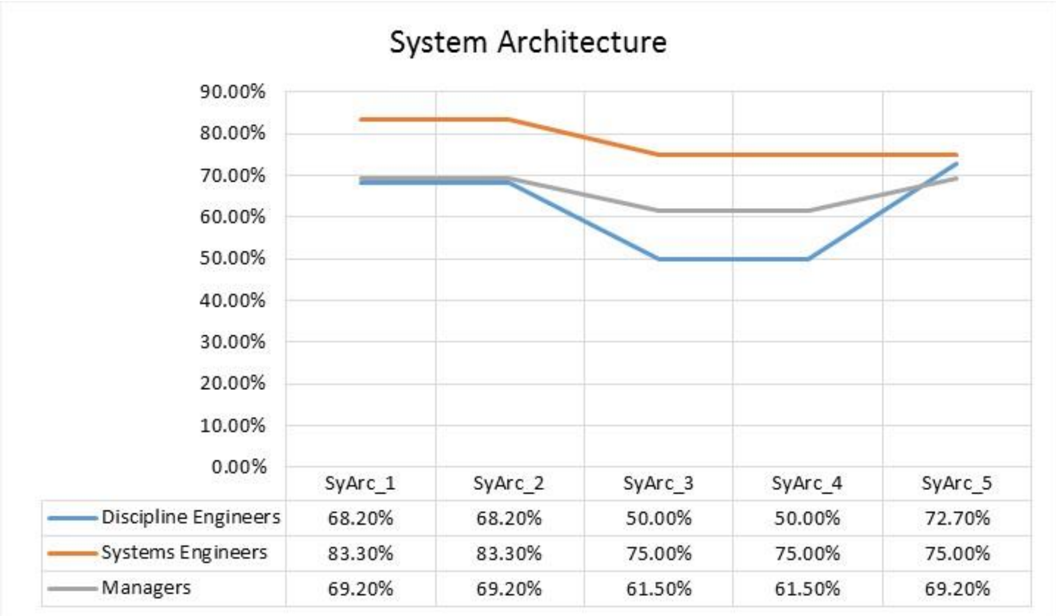


Figure 38: Proportions (% within group) of 'Agree' responses for System Architecture per Job Category

The results showed that the proportions of respondents who returned the 'Agree' responses were different between Managers, Systems Engineer and Discipline Engineer. This is shown in Figure 38, were the proportions were 61.5 % to 69.2 % from Managers, 75.0 % to 83.3 % from Systems Engineers and 50 % to 72.2 % from Discipline Engineers. Overall, the proportions were the highest among Systems Engineers compared to Managers and Discipline Engineers. A possible reason for these differences might be that Systems Engineers predominantly perform the System Architecture function.

Table 21: Fisher's Exact Test for Job Category * System Architecture Crosstabulation

	Fisher's Exact Test Value	Exact Sig. (2-sided)
SyArc_1	3.918	0.415
SyArc_2	3.918	0.415
SyArc_3	2.047	0.753
SyArc_4	5.987	0.198
SyArc_5	2.117	0.752

In Table 21, the Fisher's exact tests of independence (with $\alpha = .05$) revealed that the proportions between Managers, Systems Engineer and Discipline Engineer were not statistically significantly different, $p > 0.05$, consequently, the null hypothesis could not be rejected. Hence, the proportions between Managers, Systems Engineer and Discipline Engineer were the same, and the differences were due to chance. These findings would suggest that there is no association between the status of the specific practices of System Architecture and Job Category in DPSS.

4.3.18 System Design and Analysis

The results of a Fisher's Exact Test for System Design and Analysis are provided in Table 269 to Table 277 in APPENDIX Q.

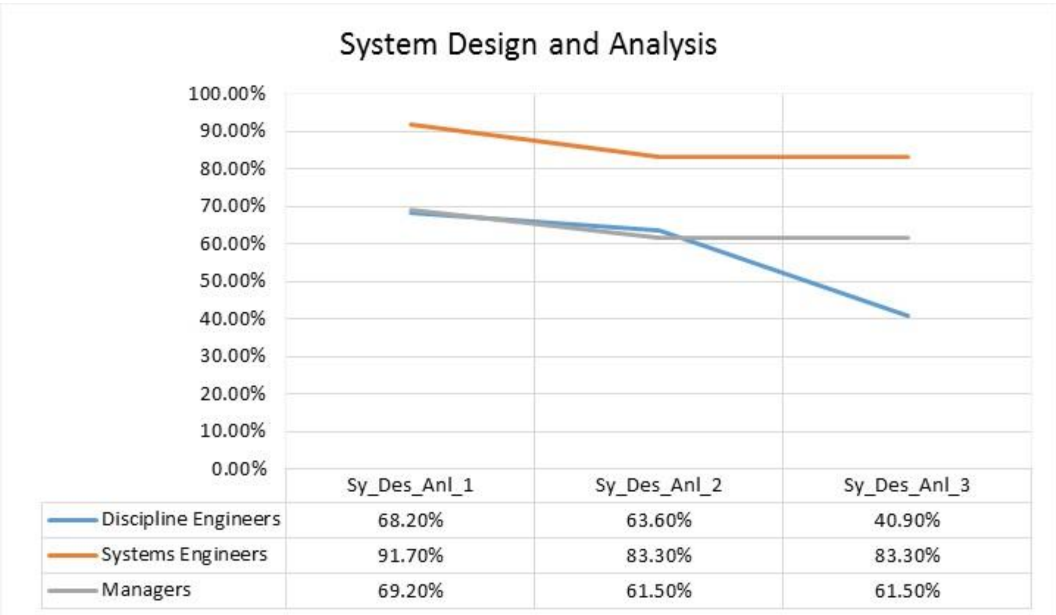


Figure 39: Proportions (% within group) of 'Agree' responses for System Design and Analysis per Job Category

The results showed that the proportions of respondents who returned the 'Agree' responses were different between Managers, Systems Engineer and Discipline Engineer. This is shown in Figure 39, were the proportions were 61.5 % to 69.2 % from Managers, 83.3 % to 91.7 % from Systems Engineers and 40.9 % to 68.2 % from Discipline Engineers. Overall, the proportions were the highest among Systems Engineers compared to Manager and Disciple Engineers. A possible reason for these differences might be that systems engineers usually perform the interface definition and subsystem requirements derivations functions.

Table 22: Fisher's Exact Test for Job Category * System Design and Analysis Crosstabulation

	Fisher's Exact Test Value	Exact Sig. (2-sided)
Sy_Des_Anl_1	9.913	**0.017**
Sy_Des_Anl_2	3.187	0.541
Sy_Des_Anl_3	6.023	0.197

In Table 22, with the exception of question Sel_Des_Anl_1, the Fisher's exact tests of independence (with α = .05) revealed that the proportions between Managers, Systems Engineer and Discipline Engineer were not statistically significantly different, $p > 0.05$, consequently, the null hypothesis could not be rejected. Therefore, the proportions between Managers, Systems Engineer and Discipline Engineer were the same, and the differences were due to chance. These findings would suggest that there is no association between the status of these two specific practices for System Design and Analysis and Job Category in DPSS.

For question Sy_Des_Anl_1 (*this project defines interfaces that are necessary for the level of detail and understanding of the architecture. This includes the internal interfaces between the system elements and the external interfaces with other external systems*), the results of the Fisher's exact test of independence (with α = .05) revealed that the proportions between Managers, Systems Engineer and Discipline Engineer were statistically significantly different, $p = 0.025$ (i.e. $p < 0.05$), consequently the null hypothesis could be accepted. Therefore, the proportions between Managers, Systems Engineer and Discipline Engineer were not same. This finding would suggest that there is an association between the status of this specific practice and Job Category with Systems Engineers more inclined to agree with its utilisation as compared to Managers and Discipline Engineers. A possible reason for this might be that systems engineers usually perform the interface definition function.

4.3.19 Assessment, Selection and Implementation

The results of a Fisher's Exact Test for Assessment, Selection and Implementation are provided in Table 278 to Table 286 in APPENDIX Q.

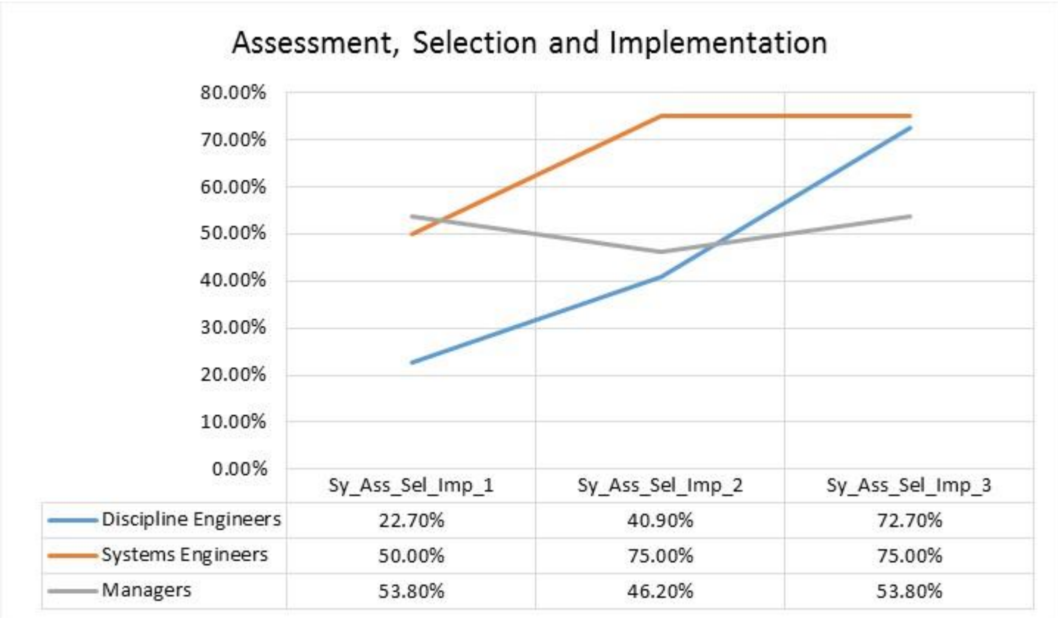


Figure 40: Proportions (% within group) of 'Agree' responses for Assessment, Selection and Implementation per Job Category

The results showed that the proportions of the respondents who returned the 'Agree' responses were different between Managers, Systems Engineer and Discipline Engineer. This is shown in Figure 40, were the proportions were 46.2 % to 53.8 % from Managers, 50 % to 75 % from Systems Engineers and 22.7 % to 72.7 % from Discipline Engineers. Overall, the proportions between the Systems Engineers, Managers and Discipline Engineers were not much different from one another.

Table 23: Fisher's Exact Test for Job Category * Assessment, Selection and Implementation Crosstabulation

	Fisher's Exact Test Value	Exact Sig. (2-sided)
Ass_Sel_Imp_1	4.641	0.319
Ass_Sel_Imp_2	5.43	0.241
Ass_Sel_Imp_3	4.885	0.316

In Table 23, the Fisher's exact tests of independence (with $\alpha = .05$) revealed that the proportions between Managers, Systems Engineer and Discipline Engineer were not statistically significantly different, $p > 0.05$, consequently, the null hypothesis could not be rejected. Therefore, the proportions between Managers, Systems Engineer and Discipline Engineer were the same, and the differences were due to chance. These findings would suggest that there is no association between the status of the specific practices for Assessment, Selection and Implementation and Job Category in DPSS.

4.3.20 System Integration

The results of a Fisher's Exact Test for System Integration are provided in Table 287 to Table 304 in APPENDIX Q.

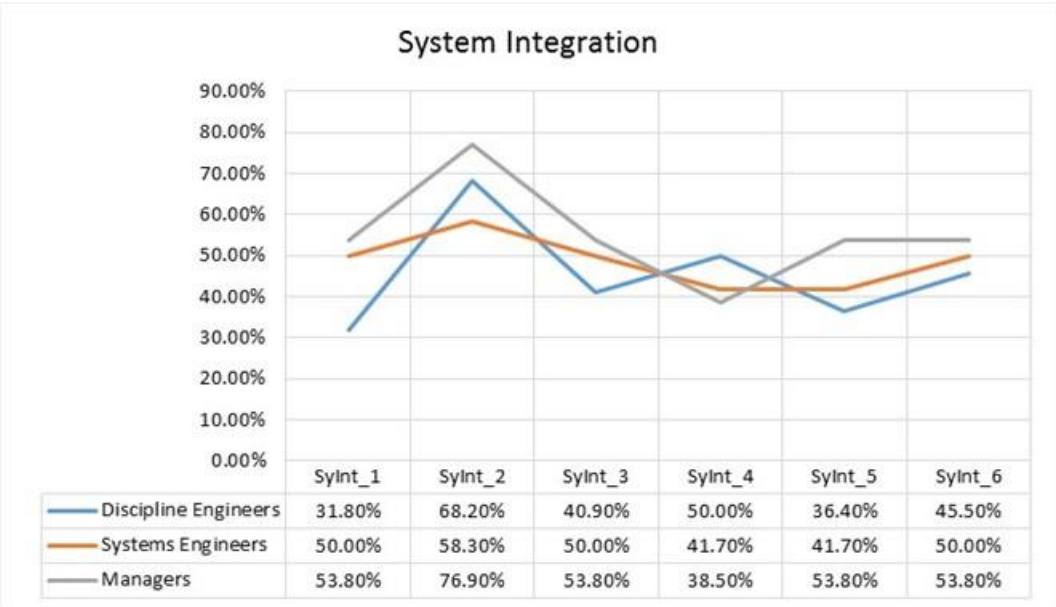


Figure 41: Proportions (% within group) of 'Agree' responses for System Integration per Job Category

The results showed that the proportions of respondents who returned the 'Agree' responses were different between Managers, Systems Engineer and Discipline Engineer. This is shown in Figure 41, were the proportions were 38.5 % to 76.9 % from Managers, 41.7 % to 58.3 % from Systems Engineers and 31.8 % to 68.2 % from Discipline Engineers. Overall, the proportions between the Systems Engineers, Managers and Discipline Engineers were not much different from one another.

Table 24: Fisher's Exact Test for Job Category * System Integration Crosstabulation

	Fisher's Exact Test Value	Exact Sig. (2-sided)
SyInt_1	2.858	0.618
SyInt_2	1.938	0.819
SyInt_3	1.105	0.935
SyInt_4	1.421	0.882
SyInt_5	3.482	0.489
SyInt_6	3.308	0.529

In Table 24, the Fisher's exact tests of independence (with $\alpha = .05$) revealed that the proportions between Managers, Systems Engineer and Discipline Engineer were not statistically significantly different, $p > 0.05$, consequently, the null hypothesis could not be rejected. Therefore, the proportions between Managers, Systems Engineer and Discipline Engineer were the same, and the differences were due to chance. These findings would suggest that there is no association between the status of the specific practices for System Integration and Job Category in DPSS.

4.3.21 System Verification and Validation

The results of a Fisher's Exact Test for System Verification and Validation are provided in Table 305 to Table 319 in APPENDIX Q.

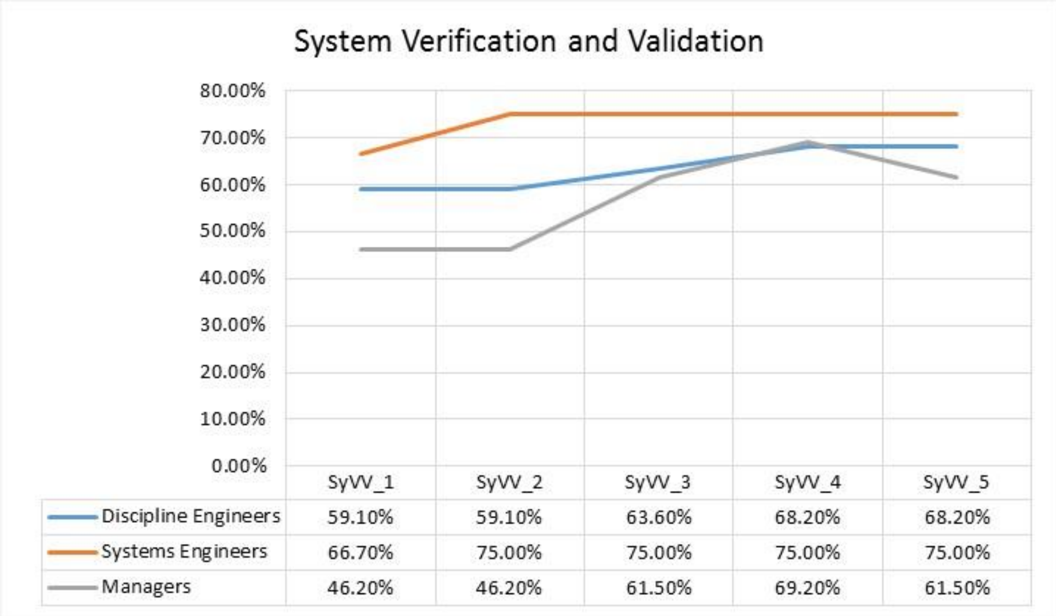


Figure 42: Proportions (% within group) of 'Agree' responses for System Verification and Validation per Job Category

The results showed that the proportions of respondents who returned the 'Agree' responses were different between Managers, Systems Engineer and Discipline Engineer. This is shown in Figure 42, were the proportions were 46.2 % to 69.2 % from Managers, 66.7 % to 75 % from Systems Engineers and 59.1 % to 68.2 % from Discipline Engineers. Overall, the proportions were the highest among the Systems Engineers. A possible reason for these differences might be that one of the critical roles of a Systems Engineer on a project is that of a System Integrator and System Verification and Validation facilitates this role.

Table 25: Fisher's Exact Test for Job Category * System Verification and Validation Crosstabulation

	Fisher's Exact Test Value	Exact Sig. (2-sided)
SyVV_1	1.817	0.833
SyVV_2	2.62	0.661
SyVV_3	4.242	0.394
SyVV_4	3.878	0.471
SyVV_5	3.499	0.509

In Table 25, the Fisher's exact tests of independence (with $\alpha = .05$) revealed that the proportions between Managers, Systems Engineer and Discipline Engineer were not statistically significantly different, $p > 0.05$, consequently, the null hypothesis could not be rejected. Therefore, the proportions between Managers, Systems Engineer and Discipline

Engineer were the same, and the differences were due to chance. These findings would suggest that there is no association between the status of the specific practices for System Verification and Validation and Job Category in DPSS. These findings were as expected since the systems engineering approach requires the involvement of relevant stakeholders, including Managers, Systems Engineer and Discipline Engineer.

4.4 Conclusion

To address the research question of the status (utilisation) of systems engineering when executing technology development projects at DPSS, the research instrument for the study was developed based on the international standard, especially the (ISO/IEC/IEEE, 2008), the Systems Engineering Body of Knowledge (SEBok) and the Systems Engineering capability maturity models (EIA/IS 731-1).

This instrument was then subjected to Content Validity Assessment, based on Lawshe's approach, using a panel of 11 subject matter experts from industry and academia (Lawshe, 1975). These experts were selected based on the level of education, knowledge and years of relevant experience in the field of Systems Engineering. The results from the Content Validity Assessment were used to improve the instrument. The results for Content Validity Assessment of the instrument may be viewed in APPENDIX F.

After the content validity assessment, the research instrument was also pre-tested tested on four Systems Engineers from DPSS, before using it to collect the actual data. The results and comments obtained from this analysis were used to refine the final instrument. The results for the pretests of the instrument may be viewed in APPENDIX G.

The reliability of the instrument was also assessed based on Cronbach's alpha coefficient (Bagozzi and Yi, 1988). This test was performed using the data collected from 47 respondents. The Cronbach's alpha coefficients of individual items of the scales and the overall Cronbach's alpha coefficients of the instrument were found to have met the acceptable limits. The results for Reliability Assessment of the instrument may be viewed in APPENDIX H. The collected data was statistically analysed using the IBM SPSS Statistics Version 25.

Based on the approach used to develop the research instrument, the results of content validity and reliability assessment of instrument, and the statistical analysis of the collected data using the IBM SPSS Statistics Version 25, it can be concluded that the instrument used and the obtained results are both valid and reliable.

This chapter presented the data analysis and interpretation of the results. In Chapter 5, the discussions, conclusions and recommendations based on these results are presented.

CHAPTER 5

DISCUSSIONS, CONCLUSIONS AND RECOMMENDATIONS

The challenges confronting many organisations seeking to implement the systems engineering process in their technology development projects is far from trivial. Often, current practices and culture in many of these organisations stifle the implementation of the systems engineering process in their projects, and in many instances, there is a scope for growth. The purpose of this study was to investigate the status (utilisation) of systems engineering during technology development projects at DPSS.

In this chapter, the results of the data analysis presented in Chapter 4 are discussed relative to the research objectives outlined in chapter 1. The conclusions are provided, and recommendations to improve the practice of systems engineering at DPSS based on the research results are proposed.

Discussions

- **Objective 1**: To assess the status of specific practices for Systems Engineering in DPSS.

1. Stakeholder Need and Requirements Analysis

Overall, the proportions were high among those who used the specific practices for Stakeholder Need and Requirements Analysis in their projects. The Chi-Square Goodness-of-Fit Tests revealed that the proportions were statistically significantly different. Thus, the proportion of those who used the specific practices for Stakeholder Need and Requirements Analysis in their projects was more than those who did not use them.

These findings were expected and consistent with the view that the systems engineering process begins in earnest with the definition of the stakeholders' problem by identifying and converting their needs and expectations into a validated set of stakeholder requirements (Blanchard, 2008). To solve the stakeholders' problem, it is critical to identify and quantify the systems' operational requirements and to define how well and under what conditions the system must accomplish its purpose (INCOSE/AIAA, 1997). Timely analysis and integration of stakeholder needs and requirements can achieve substantial long-term savings (INCOSE/AIAA, 1997). The key questions the Stakeholder Needs and Requirements Analysis attempt to answer are, what is the general problem we are trying to solve, and what are the influencing factors and constraints? (INCOSE/AIAA, 1997)

Needs are capabilities or things that are lacking but wanted or desired by one or more stakeholders (ISO/IEC/IEEE, 2008). Requirements are formal structured statements that can be verified and validated (ISO/IEC/IEEE, 2008). When a decision is made to meet a need, that need generates to a requirement or set of requirements (ISO/IEC/IEEE, 2008). Projects success depends on satisfying the stakeholders' requirements. The goal of Stakeholder Needs and Requirements Analysis is to define the stakeholder requirements for a system that can provide the capabilities needed by stakeholders in a defined environment (ISO/IEC/IEEE, 2008).

2. System Requirements Analysis

Overall, the proportions were high among those who used the specific practices for System Requirements Analysis in their projects. Except for questions SyReq_4 and SyReq_7, the Chi-Square Goodness-of-Fit Tests revealed that the proportions were statistically significantly different. Thus, the proportion of those who used these specific practices for System Requirements Analysis in their projects was more than those who did not use them. These findings were expected since at the core of the Systems Engineering approach is the establishment of a complete but minimum set of system requirements from defined stakeholder requirements early in the project life cycle.

Having defined the stakeholder requirements for a system that can provide the services required by stakeholders in a defined environment, System Requirements Analysis converts the stakeholder requirements (user-oriented view of desired capabilities) into system requirements (technical view of a solution that meets the operational needs of the user) to the extent necessary to enable feasible and economical design solutions (ISO/IEC/IEEE, 2008), (Blanchard, 2008), (INCOSE, 2015). System requirements analysis support the definition of what the system must be able to do, in its operational environment, to produce the required operational behaviours (ISO/IEC/IEEE, 2008). They state WHAT (not HOW) the system must do to meet the stakeholder requirements (Blanchard, 2008), (Buede and Miller, 2016).

For SyRq_4 and SyRq_7, the Chi-Square Goodness-of-Fit Tests revealed that the proportions were not statistically significantly different. Thus, the proportion of those who used the specific practices StRq_4 (*This project verifies the quality and completeness of each system requirement and the consistency of the set of system requirements.*) and StRq_7 (*This project, upon approval of the requirements, establishes control baselines along with other system definition elements using the established configuration management process*) in their projects was not different from those who did not use them. These findings were not expected. a lack of quality and completeness of each system requirement, and, a lack of consistency of a set system requirements, are some of the factors that led to many project failures (Firesmith, 2007). Requirements baselining and requirements management are the cornerstone of Systems Engineering. Without adequate requirements baselining and management, it would be difficult to manage the 'scope creep' and the related costs associated with unstable requirements (Firesmith, 2007)

3. System Architecture

Overall, the proportions were high among those who used the specific practices for System Architecture in their projects. The Chi-Square Goodness-of-Fit Tests revealed that the proportions were statistically significantly different. Thus, the proportion of those who used the specific practices for System Architecture in their projects was more than those who did not use them. These findings were expected since System Architecture assures avoidance of predetermined design solutions. The design of a system should follow requirements, and requirements do not document design on an after-the-fact basis (INCOSE/AIAA, 1997).

With the definition of system operational requirements, the maintenance and support concept, and the identification and prioritisation of the Technical Performance measures (TPMs), the basic system architecture has been established (ISO/IEC/IEEE, 2008). Architecture deals with a top-level system structure (configuration), its operational interfaces, anticipated utilisation profile (use case scenarios), and the environment within which it is to operate; then it describes how these various requirements for the system interact (ISO/IEC/IEEE, 2008). This, in turn, leads to a description of the functional architecture, which evolves from functional analysis and is a description of the system in functional terms. From this analysis, and through the requirements allocation process and the definition of various resource requirements necessary for the system to accomplish its mission, the physical architecture is defined (ISO/IEC/IEEE, 2008). Through the application of this process, one can evolve from the WHATs (Logical or Functional Architecture) to the HOWs (Physical Architecture) of the system (INCOSE/AIAA, 1997), (Buede and Miller, 2016).

Architecture also helps to create an understanding of how does the system affect its environment, as well as how is it affected by environment and constraints from which it is to operate (ISO/IEC/IEEE, 2008). Architecture defines the system hierarchy and its hardware and software elements, and it also helps to identify enabling elements (such as test, training and production equipment) (ISO/IEC/IEEE, 2008). Architecture also plays an important role when assessing and evaluative alternatives which may satisfy stakeholder needs and expectations and the selection of a balanced solution for each system element as well as for the system as a whole (ISO/IEC/IEEE, 2008).

The development of a system representation that allows interactions with customers and other stakeholders is the best means of drawing out requirements (ISO/IEC/IEEE, 2008). The goal of system architecture is to provide the "best" possible architecture made of suitable system elements and interfaces, that is, the architecture that answers, at best, all the stakeholder and system requirements, depending on agreed limits or margins of each requirement (ISO/IEC/IEEE, 2008).

4. System Design and Analysis

Overall, the proportions were high among those who use the specific practices for System Design and Analysis in their projects. The Chi-Square Goodness-of-Fit Tests revealed that the proportions were statistically significantly different. Thus, the proportion of those who used the specific practices for System Design and Analysis in their projects was more than those who did not use them. These findings were expected since System Design and Analysis ensure implementation of the balanced solution.

Defining the detailed technical problem is a top-down activity. It entails conducting the detailed analyses through appropriate analytical methods (e.g., structured analysis, object-oriented analysis, simulation and modelling, information modelling, rapid prototyping) (ISO/IEC/IEEE, 2008). System Design and Analysis ensures suitability and effectiveness of the solution through development of models and prototypes to reduce the technical risks (ISO/IEC/IEEE, 2008).

System Architecture and System Design are two different but complementary concepts (ISO/IEC/IEEE, 2008). System Architecture is a more abstract, high-level structure of systems and system elements, conceptualisation oriented, global, and focuses on the mission of the system and its operational concepts (ISO/IEC/IEEE, 2008). It addresses the architectural principles, concepts, properties, and characteristics of the system of interest (ISO/IEC/IEEE, 2008). It also aggregates and deals with incremental insights obtained about the specified requirements and emergent properties and behaviours of the system and system elements while managing suitability, viability, and affordability (ISO/IEC/IEEE, 2008).

System design, on the other hand, is more technology-oriented, through physical, structural, environmental, and operational properties, forcing decisions for implementation by focusing on compatibility with technologies and other design elements and feasibility of construction and integration (ISO/IEC/IEEE, 2008). It uses the outputs from the System Architecture (e.g., architecture description, feasibility analyses, system balance trades, vetted requirements) to design a system that can provide the capabilities needed by stakeholders in a defined environment (ISO/IEC/IEEE, 2008).

Analysis refers to all the processes and procedures to be used for formal and informal trade studies, including system analysis, cost-benefit effectiveness analyses, and strength, weakness, opportunity, threat (SWOT) analysis (ISO/IEC/IEEE, 2008).

5. Assessment, Selection and Implementation

Overall, the proportions were high among those who used the specific practices for Assessment, Selection and Implementation in their projects. Except for question Ass_Sel_Imp_1, the Chi-Square Goodness-of-Fit Tests revealed that the proportions were statistically significantly different. Thus, the proportion of those who used these specific practices for Assessment, Selection and Implementation in their projects was more than those who did not use them. These findings were expected since stakeholders expect project teams to assess their needs and determine the most balanced alternative which meets their expectations.

The main objective of Assessment and Selection is to perform trade off studies to assess alternative system concepts that may satisfy specified requirements. Trade-off analysis is a tool to assist with the selection of the best solution for the system amongst many alternatives (ISO/IEC/IEEE, 2008).

Assessment and selection provide a systematic, analytical framework for objectively identifying, characterising and evaluating a set of alternatives for a decision at any point in the system life cycle and select the most beneficial course of action (ISO/IEC/IEEE, 2008). Implementation yield the lowest-level system elements in the system hierarchy through the established implementation strategy (ISO/IEC/IEEE, 2008).

For Ass_Sel_Imp_1, the Chi-Square Goodness-of-Fit Tests revealed that the proportions were not statistically significantly different. Thus, the proportion of those who used the specific practice Ass_Sel_Imp_1 (*This project assesses and selects the preferred candidate architecture(s) using the architecture evaluation criteria in conjunction with the established risk management and decision management processes*), was not different from those who did not use it. Depending on the project requirements, it would recommend to implement the project risk assessment and decision management as part of the candidate architecture(s) or concept selection reviews.

6. System Integration

Overall, the proportions were high among those who used the specific practices for System Integration in their projects. Except for question SyInt_2, the Chi-Square Goodness-of-Fit Tests revealed that the proportions were not statistically significantly different. Thus, the proportion of those who used these specific practices for System Integration in their projects was not different from those who did not use them. These findings were not as expected. A possible explanation might be that many projects are once-off (e.g. technology demonstrators) and designers implement their own design, and as a result see no need for documentation.

System Integration forms one of the critical elements of the systems engineering approach. It refers to the planned set of activities to assemble the smaller units of the system into bigger units (ISO/IEC/IEEE, 2008).

As these units are assembled, they are also tested to ensure that they are work as expected (ISO/IEC/IEEE, 2008). System Integration involves receiving the system components, assembling the system components, and concurrently performing the verification and validation actions on the system elements and the system (ISO/IEC/IEEE, 2008). The ultimate goal is to ensure that the individual system elements function correctly as an integrated set and meet the design properties or characteristics of the system (Board BKCASE Editorial, 2014).

For Ass_Sel_Imp_1, the Chi-Square Goodness-of-Fit Tests revealed that the proportions were statistically significantly different. Thus, the proportion of those who used this specific practice StReq_2 (The integration plan of this project defines verification activities that should be performed as part of system integration.), was different to those who did not use it.

7. System Verification and Validation

Overall, the proportions were high among those who used the specific practices for System Verification and Validation in their projects. The Chi-Square Goodness-of-Fit Tests revealed that the proportions were statistically significantly different. Thus, the proportion of those who used the specific practices for System Verification and Validation in their projects was more than those who did not use them. These findings were expected. The purpose of the verification process is to confirm that the system meets the specified design requirements (ISO/IEC/IEEE, 2008). In the case of non-conformances, the process provides the required information to effect appropriate corrective actions (ISO/IEC/IEEE, 2008). Non-compliances are faults or errors in the design and need to be corrected before delivering the system to the customer.
As a result of the successful implementation on the system verification process, objective evidence that the as-built system satisfies requirements is provided (ISO/IEC/IEEE, 2008). Through assessment, verification provide evidence that the system was built correctly, meaning that, it meet the specified design requirements against which it was built (ISO/IEC/IEEE, 2008). On the other hand, through assessment, validation process confirm

that the system being built, meets stakeholders' needs and requirements in its operational environment (INCOSE, 2015), (Faulconbridge and Ryan, 2003).

Conclusion for Objective 1

Except for the specific practices for System Integration, overall, the proportion of those who used the specific practices for System Engineering in their projects was more than those who did not use them. For System Integration, overall, the proportions were the same.

Objective 2: To investigate whether an association exist between the status of specific practices of Systems Engineering and Competency Areas in DPSS.

1. Stakeholder Needs and Requirements Analysis

Overall, the proportions for those who used the specific practices for Stakeholder Needs and Requirements Analysis were high among the TSO and ISG compared to the TAG. However, the results of Fisher's exact tests of independence revealed that the proportions were not statistically significantly different. Thus, there was no association between the status of the specific practices for Stakeholder Needs and Requirements Analysis and Competency Areas in DPSS.

2. System Requirements Analysis

Overall, the proportions for those who used the specific practices for System Requirements Analysis were high among TSO and ISG compared to the TAG. However, the results of Fisher's exact tests of independence revealed that the proportions were not statistically significantly different. Thus, there was no association between the status of the specific practices for System Requirements Analysis and Competency Areas in DPSS.

3. System Architecture

Overall, the proportions for those who used the specific practices for System Architecture, were the highest among TSO, compared to TAG and ISG. However, the results of Fisher's exact tests of independence revealed that the proportions were not statistically significantly different. Thus, there was no association between the status of the specific practices for System Architecture and Competency Areas in DPSS.

4. System Design and Analysis

Overall, the proportions for those who used the specific practices for System Design and Analysis were the high among the TSO and ISG compared to the TAG. However, the results of Fisher's exact tests of independence revealed that the proportions were not statistically significantly different. Thus, there was no association between the status of the specific practices for System Design and Analysis and Competency Areas in DPSS.

5. Assessment, Selection and Implementation

Except for question Ass_Sel_Imp_3, overall, the proportions for those who used the specific practices for Assessment, Selection and Implementation, between the three groups were not much different. The results of Fisher's exact tests of independence, also revealed that the proportions were not statistically significantly different. Thus, there was no association between the status of these specific practices for Assessment, Selection and Implementation and Competency Areas in DPSS.

For Ass_Sel_Imp_3, the proportions were very high among TSO and TAG compared to ISG. The results of Fisher's exact tests of independence revealed that the proportions were statistically significantly different. Thus, there was an association between the status of the specific practice Ass_Sel_Imp_3 (This project conducts unit testing and records evidence that the system elements meets their requirements and the associated verification and validation criteria) and Competency Areas in DPSS, with the ISG less inclined to using this specific practice. A possible reason for this might be due to the types of projects at the ISG (i.e. Enterprise development project versus Product development Projects).

6. System Integration

Overall, the proportions for those who used the specific practices for System Integration were the highest among the TSO. However, the results of Fisher's exact tests of independence revealed that the proportions were not statistically significantly different. Thus, there was no association between the status of the specific practices for System Integration and Competency Areas in DPSS.

7. System Verification and Validation

Overall, the proportions for those who used the specific practices for System Verification and Validation were also the highest among the TSO. However, the results of Fisher's exact tests of independence revealed that the proportions were not statistically significantly different. Thus, there was no association between the status of the specific practices for System Verification and Validation and Competency Areas in DPSS.

Conclusion for objective 2

Overall, there was no association between the status of the specific practices for Systems Engineering and Competency Areas in DPSS.

Objective 3: To investigate whether an association exist between the status of specific practices for Systems Engineering and Job Categories in DPSS.

1. Stakeholder Need and Requirements Analysis

Overall, the proportions for those who used the specific practices for Stakeholder Need and Requirements Analysis were high among Systems Engineers and Managers compared to Discipline Engineers. However, the results of Fisher's exact tests of independence revealed that the proportions were not statistically significantly different. Thus, there was no association between the status of specific practices for Stakeholder Needs and Requirements Analysis and Job Category in DPSS.

2. System Requirements Analysis

Overall, the proportions for those who used the specific practices for System Requirements Analysis were high among Systems Engineers and Managers compared to Discipline Engineers. Except for question SyReq_3, the results of Fisher's exact tests of independence revealed that the proportions were not statistically significantly different. Thus, there was no association between the status of these specific practices for System Requirements Analysis and Job Category in DPSS.

For question SyReq_3, the results of Fisher's exact tests of independence revealed that the proportions were statistically significantly different. Thus, there was an association between the status of a specific practice StReq_3 (This project establishes a bi-directional traceability between requirements at adjacent levels of the system hierarchy) and Job Category at DPSS, with the Systems Engineers been most likely to use it compared to Managers and Discipline Engineers. A possible reason for this might be that ensuring the traceability of requirements is a function usually performed by Systems Engineers.

3. System Architecture

Overall, the proportions for those who used the specific practices for System Architecture were the highest among Systems Engineers compared to Managers and Discipline Engineers. However, the results of Fisher's exact tests of independence revealed that the proportions were not statistically significantly different. Thus, there was no association between the status of specific practices for System Architecture and Job Category in DPSS.

4. System Design and Analysis

Overall, the proportions for those who used the specific practices for System Design and Analysis were the highest among Systems Engineers compared to Manager and Disciple Engineers. Except for question Sel_Des_Anl_1, the results of Fisher's exact tests of independence revealed that the proportions were not statistically significantly different. Thus, there was no association between the status of these specific practices for System Design and Analysis and Job Category in DPSS.

For question Sy_Des_Anl_1, the results of the Fisher's exact tests of independence revealed that the proportions were statistically significantly different, thus, an association exist between a specific practice Sy_Des_Anl_1 (*this project defines interfaces that are necessary for the level of detail and understanding of the architecture. This includes the internal interfaces between the system elements and the external interfaces with other external systems*) and Job Category with Systems Engineers more incline to practising it than

Managers and Discipline Engineers. A possible reason for this might be that systems engineers usually perform the interface definition function.

5. Assessment, Selection and Implementation

Overall, the proportions for those who used the specific practices for Assessment, Selection and Implementation, between the Systems Engineers, Managers and Discipline Engineers were not much different from one another. The results of Fisher’s exact tests of independence also revealed that the proportions were not statistically significantly different. Thus, there was no association between the status of specific practices for Assessment, Selection and Implementation and Job Category in DPSS.

6. System Integration

Overall, the proportions for those who used the specific practices for System Integration, between the Systems Engineers, Managers and Discipline Engineers were not much different from one another. The results of Fisher’s exact tests of independence also revealed that the proportions were not statistically significantly different. Thus, there was no association between the status of specific practices for System Integration and Job Category in DPSS.

7. System Verification and Validation

Overall, the proportions for those who used the specific practices for System Verification and Validation were the highest among the Systems Engineers compared to Manager and Disciple Engineers. However, the results of Fisher’s exact tests of independence revealed that the proportions were not statistically significantly different. Thus, there was no association between the status of specific practices for System Verification and Validation and Job Category in DPSS.

Conclusion for objective 3

Overall, there was no association between the status of specific practices for Systems Engineering and Job Category in DPSS.

In summary, to address the research question of the status (utilisation) of systems engineering when executing technology development projects at DPSS, overall, the results indicated that, the proportion of those who used the specific practices for System Engineering in their projects is more than those who do not use them, and that there was no association between the status of the specific practices for Systems Engineering and Competency Areas or Job Category in DPSS.

Recommendations

It was observed that some projects are not applying the following specific practices of Systems Engineering:

1. *Verification of the quality and completeness of each system requirement and the consistency of the set of system requirements*.

The recommendation would be for the researcher to establish as to why the verification of requirement is not done in some of the projects at DPSS, and to recommend to the project leaders to foster the project environments whereby the system requirements review meetings are held to review and approve the system requirements.

2. *Upon approval of the requirements, the establishment of control baselines along with other system definition elements using the established configuration management process.*

The recommendation would be for project leaders (contract manager, project managers, systems engineers, etc.) within the organisation to require and ensure compliance to the organisation's configuration management policies and procedures and update them where there are shortcomings.

3. *Assessment and selection of preferred candidate architecture(s) using the architecture evaluation criteria in conjunction with the established risk management and decision management processes*

Depending on the project requirements, it would be recommended to implement the project risk assessment and decision management as part of the candidate architecture(s) or concept selection reviews.

4. *The study showed that the proportion of those who used specific practices for System Integration was not different from those who did not use them.*

The recommendation would be a further investigation into how is System Integration implemented in a research and development environment such as at DPSS, and how does it compare to the generally accepted Systems Engineering Standards and Systems Engineering Maturity model.

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APPENDIX A

Comparison of Systems Engineering Standards

Table 3. SE Standard Differences

MIL-STD-499B	EIA/IS 632	IEEE 1220	EIA 632	ISO/IEC 15288
Scope of Standard				
Defines total system approach for the development of defense systems. Specification on "the performing activity".	Defines total system approach for the development of systems. Definition of what "the performing activity" does. This standard was the demilitarized version of MIL-STD-499B, which was never officially approved by, but used extensively by industry and the Air Force.	Defines the interdisciplinary tasks that are required throughout a system's life cycle to transform customer needs, requirements, and constraints into a system solution. Specifies the requirements for the systems engineering process and its application throughout the system's life cycle.	Defines thirteen processes and 34 requirements for engineering a system. The focus is on implementing the requirements of the standard within a defined engineering life cycle, which can be applied in any enterprise-based life cycle phase to engineer or reengineer a system.	Will address both system engineering and management (business) processes. The focus is on the "system" versus the "components," where component standards like ISO/IEC 12207 - *Software Life Cycle Processes* will apply.
Level of Abstraction				
Medium level of abstraction -- Activity level	Same as 499B	More detailed than 499B - Detailed Task level	Higher level of abstraction than previous standards, less than 15288.	Highest level of abstraction.
System Life Cycle				
Example: • Pre-Concept • Concept Exploration and Definition • Demonstration and Validation • Engineering and Manufacturing Development • Production and Deployment • Operations and Support	Example: • Market Requirements • Concept Definition and Feasibility • Concept Validation • Design and Verification • Production and Deployment • Operations and Support	Typical: • System Definition • Subsystem Definition • Preliminary Design • Detailed Design • Fabrication, Assembly, Integration, and Test • Production • Customer Support	Enterprise-Based: • Assessment of Opportunities • Solicitation and Contract Award • System Concept Development • Subsystem Design and Pre-Deployment • Deployment/ Installation and Operations and Support	Life Cycle Processes: • Concept Process • Development Process • Production Process • Operations Process • Support Process • Decommissioning or Disposal Process
SEMP Guidance				
2-page section on SEMP in the Detailed Requirements section and a template in Appendix B. Appendix on guidance for developing a SE Master Schedule.	2-page section on SEMP in the Detailed Requirements section and an 8 page template in Appendix B. Appendix on guidance for developing a SE Master Schedule.	Ten-page "informative" Annex gives SEMP template.	One requirement calls for the creation of an engineering plan. The expected outcomes (or expected content) of this plan is provided in Annex C.	Will not be a specific engineering plan, more than likely. But, planning the system life cycle and application of the generic processes will likely be required.

Figure 43. Systems Engineering Standard Differences (Sheard and Lake, 1998)

APPENDIX B

Comparison of Systems Engineering Capability Model

Table 1. Comparison of Process, Focus, and Key Focus Areas in the Three SE Capability Models

SE-CMM (PAs)		SECM(EIA/IS 731) (FAs)		SECAM (KFAs)	
		Engineering, Technical, or Systems Engineering Areas			
PA06	Understand Customer Needs and Expectations	1.1	Define Stakeholder and System Level Requirements	3.1	System Concept Definition
PA02	Derive and Allocate Requirements	1.2	Define Technical Requirements	3.2	Requirements and Functional Analysis
PA03	Evolve System Architecture	1.3	Define Solution	3.3	System Design
PA01	Analyze Candidate Solutions	1.4	Assess and Select	3.4	Integrated Engineering Analysis
PA05	Integrate System	1.5	Integrate System	3.5	System Integration
PA07	Verify and Validate System	1.6	Verify System	3.6	System Verification
		1.7	Validate System	3.7	System Validation
PA04	Integrate Disciplines		(see 2.3 below)		(see 1.4 below)
		Project or Management Areas			
PA12	Plan Technical Effort	2.1	Plan and Organize	1.1	Planning
PA11	Monitor and Control Technical Effort	2.2	Monitor and Control	1.2	Tracking and Oversight
	(PA04 above)	2.3	Integrate Disciplines	1.4	Intergroup Coordination
	(PA18 below)	2.4	Coordinate with Suppliers	1.3	Subcontract Management
PA10	Manage Risk	2.5	Manage Risk	1.7	Risk Management
	(none)	2.6	Manage Data	1.8	Data Management
PA09	Manage Configurations	2.7	Manage Configurations	1.5	Configuration Management
PA08	Ensure Quality	2.8	Ensure Quality	1.6	Quality Management
		Organization or Environment Areas			
PA13	Define Organization's SE Process	3.1	Define and Improve the Systems Engineering Process	2.1	Process Management and Improvement
PA14	Improve Organization's SE Process				
PA17	Provide Ongoing Knowledge and Skills	3.2	Manage Competency	2.2	Competency Development
PA15	Manage Product Line Evolution	3.3	Manage Technology	2.3	Technology Management
PA16	Manage Systems Engineering Support Environment	3.4	Manage Systems Engineering Support Environment	2.4	Environment and Tool Support
PA18	Coordinate With Suppliers		(see 2.4 above)		(see 1.3 above)

Figure 44. Comparison of Systems Engineering Capability Models (Sheard and Lake, 1998)

APPENDIX C

Ethics Clearance

Ethics Clearance

From:	Bruno Emwanu<Bruno.Emwanu@wits.ac.za>
To:	Bafana Selepe<BSelepe@csir.co.za>
CC:	BERNADETTE Sunjka<Bernadette.Sunjka@wits.ac.za>
Date:	23/08/2018 19:58
Subject:	Selepe Bafana ethics clearance number

Dear Bafana,

I am pleased to inform you that the School Ethics Committee has completed assessing your ethics application for your Investigational research project and clearance has been provided.

The ethics clearance number for your research report is MIAEC 075/18.
Please use your ethics clearance number as a reference for all future correspondence on this matter.
By copy of this email, your supervisor is also informed.
Regards,
Dr. Emwanu

CSIR Intitutional Permission

From:	R&D Ethics
To:	Bafana Selepe
Date:	13/06/2018 12:11
Subject:	Re: CSIR Research Ethics Committee Query submission for proposal

Dear Bafana,

Thank you for submitting your query to the CSIR REC.

Your proposed research is a low risk study that will involve data collection through questionnaires. In line with the CSIR REC SOPs, all research projects that involve the collection of data from human participants should be submitted for research ethical review and approval. However, since you project is not core CSIR R&D, the University where the qualification is registered should grant primary research ethics clearance. After which, the project may proceed with institutional permission from the CSIR to use their personnel as research participants.

Kind regards,
Siphelele
>>> Bafana Selepe 06/06/2018 14:13 >>>
Dear Madam/Sir

I would like to know if my research project requires ethical clearance. Attached is the query form.

Kind regards,

Bafana Selepe
DPSS Aeronautical Systems Competency
CSIR
PO Box 395
Pretoria, 0001
South Africa
(tel) +2712 841 3775
http://www.csir.co.za

From: Tendani Tsedu
To: Bafana Selepe
Date: 09/03/2019 15:22
Subject: Re: Request to use CSIR and DPSS name in my research report and Article

Hi Bafana,

Thanks for the document.

As CSIR Marketing and Communication we are comfortable that you proceed with the research as we see limited damage to CSIR brand and reputation as this is a build-up study to other research done in 2016 and 17.

All the best and thank you for contacting us to hear our view on this matter.

Regards,

CSIR
our future through science

Tendani Tsedu
Group Manager: Marketing and Communication
Tel: +27 12 841 3417
Cell: +27 82 945 1980
Email: mtsedu@csir.co.za
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APPENDIX D

Letter of Consent

SCHOOL OF MECHANICAL, INDUSTRIAL & AERONAUTICAL ENGINEERING

The Status of Systems Engineering Practice: A Survey

Welcome to My Survey

Dear Respondent

Thank you for agreeing to participate in this research project. The purpose of this research survey is to assess the extent to which the commonly agreed specific practices of a systems engineering process are being performed during technology development projects at DPSS. The scope of this research project is limited to the technical aspect of Systems Engineering; the management aspect is beyond the scope of this project. The specific practices that will be assessed include:

1. Stakeholder and System Requirements Analysis
2. System Architecture
3. Design and System Analysis
4. Assessment, Selection and Implementation
5. Integration, Verification and Validation

All your answers will be treated as confidential, and you will not be identified in any of the research reports emanating from this research. The results of the study will be used for academic purposes only and may be published in an academic journal. We will provide you with a summary of the results on request. Please note that your participation in the study is voluntary. Your participation in this study is very important to us. You may choose not to participate, and you may also withdraw from the study at any time without any negative consequences. Answering the questionnaire, however, will be regarded as an indication that you have read and understood the information provided above, and, that you give your consent to participate in the study on a voluntary basis.

The estimated time to complete this questionnaire is 10 minutes.

Thank you very much for your support!

APPENDIX E

Research Instrument

The Status of Systems Engineering Practice in a South African Engineering Organisation: A Survey

1. Demographic Information

*1. At which competency area are you currently employed at DPSS?

- ◯ Integrative Systems Group
- ◯ Programme Office
- ◯ Technology for Special Operations
- ◯ Radar & EW Systems
- ◯ Optronic Sensor Systems
- ◯ Landward Sciences
- ◯ Command Control & Information
- ◯ Aeronautic Systems
- ◯ Other (please specify)

*2. Which of the following best describe your current job title?

- ◯ Competency Area Manager
- ◯ Business Development Manager

1

- ◯ Contract R&D Manager
- ◯ Research Group Leader
- ◯ Programme Manager
- ◯ Project Manager
- ◯ Senior Project Manager
- ◯ Systems Engineer
- ◯ Senior Systems Engineer
- ◯ Principal Systems Engineer
- ◯ Chief Systems Engineer
- ◯ Tech/Eng/KA
- ◯ Senior Tech/Eng/KA
- ◯ Principal Tech/Eng/KA
- ◯ Chief Tech/Eng/KA
- ◯ Researcher
- ◯ Senior Researcher
- ◯ Principal Researcher
- ◯ Chief Researcher
- ◯ Other (please specify)

2

* 3. About how long have you been employed at DPSS?

- 0-1 years
- 2-4 years
- 5-9 years
- 10-20 years
- 21 or more years

* 4. About how long have you been involved in technology development projects?

- 0-1 years
- 2-4 years
- 5-9 years
- 10-20 years
- 21 or more years

3

* 5. What is the highest degree or level of education you have completed?

- Diploma
- Post Graduate Diploma
- Bachelor's
- Honor's
- Master's
- Doctorate
- Other (please specify)

* 6. Have you ever attended a course (both formal and informal) in Systems Engineering?

- Yes
- No
- Other (please specify)

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2. Project Characteristics

* 7. Think of any suitable technology development project at DPSS, current or recently completed, that you are/have been involved, and, indicate its engineering lifecycle phase at the time of this survey.

- Concept of Operation definition (or Mission Analysis)
- Requirements definition
- System Architecture
- Preliminary Design
- Detail Design
- System Integration
- Test and Evaluation
- Completed
- Other (please specify)

5

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3. Stakeholder Needs and Requirements definition

The purpose of the "**STAKEHOLDER NEEDS AND REQUIREMENTS DEFINITION**" activities is to elicit a set of clear and concise stakeholder needs related to a new or modified system and to transform these needs into a verifiable set of stakeholder requirements for that system. This section includes statements each of which you may agree or disagree with depending on your opinion about the status of the practice of these activities in your project. Please indicate the degree of your agreement or disagreement with each statement using the following scale: **Strongly Disagree, Disagree, Neither agree nor disagree, Agree, Strongly Agree**

* 8. This project defines the Operational Concepts (i.e., how the system will be used) and other life-cycle concepts (i.e., how the system will be acquired, deployed, supported, and retired) of the desired system to ensure a better understanding of the stakeholder requirements.

- Strongly disagree
- Disgree
- Neutral/Neither agree or disagree
- Agree
- Strongly Agree

6

* 9. This project uses the operational concept and other lifecycle concepts (acquisition, deployment, support, and retirement) to identify the different stakeholders who may affect or be affected by the system across its total life cycle.

- Strongly Disagree
- Disagree
- Neutral/Neither agree nor disagree
- Agree
- Strongly Agree

* 10. This project analyses the stakeholder requirements to verify the completeness of expected services and operational scenarios, conditions, operational modes, and constraints.

- Strongly Disagree
- Disagree
- Neutral/Neither agree nor disagree
- Agree
- Strongly Agree

7

* 11. This project elicits, captures, or consolidates the stakeholder needs and expectations as well as any other constraints emanating from the operational concept and other system lifecycle concepts as well as from the business analysis processes.

- Strongly Disagree
- Disagree
- Neutral/Neither agree nor disagree
- Agree
- Strongly Agree

* 12. This project validates the content and significance of each stakeholder requirement with the relevant stakeholders to establish the rationale for its existence.

- Strongly Disagree
- Disagree
- Neutral/Neither agree nor disagree
- Agree
- Strongly Agree

8

* 13. This project identifies potential risks (or threats and hazards) that could be generated by the stakeholder requirements using established risk management practices.

- Strongly Disagree
- Disagree
- Neutral/Neither agree nor disagree
- Agree
- Strongly Agree

* 14. This project synthesises, records, baselines and manages stakeholder requirements and potential risks associated with them.

- Strongly Disagree
- Disagree
- Neutral/Neither agree nor disagree
- Agree
- Strongly Agree

9

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4. System Requirements Analysis

The purpose of "**SYSTEM REQUIREMENTS ANALYSIS**" activities is to identify and define all of the requirements at the system level that describe the functions which the system as a whole must perform to satisfy the stakeholder needs and requirements. This section includes statements each of which you may agree or disagree with depending on your opinion about the status of the practice of these activities in your project. Please indicate the degree of your agreement or disagreement with each statement using the following scale: **Strongly Disagree, Disagree, Neither agree nor disagree, Agree, Strongly Agree**

* 15. This project uses the principles of system requirements analysis to transforms the stakeholder requirements into system requirements.

- Strongly Disagree
- Disagree
- Neutral/Neither agree nor disagree
- Agree
- Strongly Agree

10

* 16. This project establishes upward traceability of system requirements with the stakeholder needs and requirements.

- Strongly Disagree
- Disagree
- Neutral/Neither agree nor disagree
- Agree
- Strongly Agree

* 17. This project establishes a bi-directional traceability between requirements at adjacent levels of the system hierarchy.

- Strongly Disagree
- Disagree
- Neutral/Neither agree nor disagree
- Agree
- Strongly Agree

11

* 18. This project verifies the quality and completeness of each system requirement and the consistency of the set of system requirements.

- Strongly Disagree
- Disagree
- Neutral/Neither agree nor disagree
- Agree
- Strongly Agree

* 19. This project validates the content and relevance of each system requirement against the set of stakeholder requirements.

- Strongly Disagree
- Disagree
- Neutral/Neither agree nor disagree
- Agree
- Strongly Agree

12

* 20. This project identifies potential risks (or threats and hazards) that could be generated by the system requirements.

- Strongly Disagree
- Disagree
- Neutral/Neither agree nor disagree
- Agree
- Strongly Agree

* 21. This project, upon approval of the requirements, establishes control baselines along with other system definition elements using the established configuration management process.

- Strongly Disagree
- Disagree
- Neutral/Neither agree nor disagree
- Agree
- Strongly Agree

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5. System Architecture

The purpose of the "**SYSTEM ARCHITECTURE**" activities is to generate System Architecture alternatives, to select one or more alternative(s) that frame stakeholder concerns and meet system requirements, and to express this in a set of consistent views. This section includes statements each of which you may agree or disagree with depending on your opinion about the status of the practice of these activities in your project. Please indicate the degree of your agreement or disagreement with each statement using the following scale: **Strongly Disagree, Disagree, Neither agree nor disagree, Agree, Strongly Agree**

* 22. This project determines the system context including its boundary with elements of the external environment to enable an understanding of expected operational scenarios and system behaviour within its context of use.

- Strongly Disagree
- Disagree
- Neutral/Neither agree nor disagree
- Agree
- Strongly Agree

14

* 23. This project identifies system requirements associated with the operational conditions (e.g., safety, dependability, interfaces, human factors, environmental conditions etc.) that would influence the definition of the architectural elements.

- Strongly Disagree
- Disagree
- Neutral/Neither agree nor disagree
- Agree
- Strongly Agree

* 24. This project identifies system requirements associated with the life cycle constraints (e.g., maintenance, disposal, deployment) that would influence the definition of the architectural elements.

- Strongly Disagree
- Disagree
- Neutral/Neither agree nor disagree
- Agree
- Strongly Agree

15

* 25. This project develops candidate architecture models and views using appropriate modelling techniques and tools in conjunction with the stakeholder requirements and system requirements analysis processes.

- Strongly Disagree
- Disagree
- Neutral/Neither agree nor disagree
- Agree
- Strongly Agree

* 26. This project verifies and validates the system models by simulations if modelling techniques and tools permit. Where possible, the project uses design tools to check the feasibility and validity of the system, and possibly build mock-ups or using executable architecture prototypes or simulators.

- Strongly Disagree
- Disagree
- Neutral/Neither agree nor disagree
- Agree
- Strongly Agree

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6. System Integration

"**SYSTEM INTEGRATION**" consists of taking delivery of the implemented system elements which compose the system-of-interest (SoI), assembling these implemented elements together, and performing the verification and validation actions (V&V actions) in the course of the assembly. The ultimate goal of system integration is to ensure that the individual system elements function properly as a whole and satisfy the design properties or characteristics of the system. This section includes statements each of which you may agree or disagree with depending on your opinion about the status of the practice of these activities in your project. Please indicate the degree of your agreement or disagreement with each statement using the following scale: **Strongly Disagree, Disagree, Neither agree nor disagree, Agree, Strongly Agree**

* 27. This project develops the integration strategy and documents it in a System Integration Plan.

- Strongly Disagree
- Disagree
- Neutral/Neither agree nor disagree
- Agree
- Strongly Agree

17

* 28. The integration plan of this project defines verification activities that should be performed as part of system integration.

- Strongly Disagree
- Disagree
- Neutral/Neither agree nor disagree
- Agree
- Strongly Agree

* 29. The integration plan of this project identifies the configurations of aggregates that should be assembled and verified.

- Strongly Disagree
- Disagree
- Neutral/Neither agree nor disagree
- Agree
- Strongly Agree

18

* 30. The integration actions of this project include checking of delivered configurations, conformance of implemented elements, compatibility of interfaces, and ensuring availability of mandatory documentation.

- Strongly Disagree
- Disagree
- Neutral/Neither agree nor disagree
- Agree
- Strongly Agree

* 31. The integration actions of this project include integration of system components to constitute aggregates in the order prescribed by the integration plan and assembly procedures using the correct tools.

- Strongly Disagree
- Disagree
- Neutral/Neither agree nor disagree
- Agree
- Strongly Agree

19

* 32. The integration actions of this project include verification of each aggregate to check if the aggregate is correctly assembled according to established procedures.

- Strongly Disagree
- Disagree
- Neutral/Neither agree nor disagree
- Agree
- Strongly Agree

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7. System Verification and Validation

"**VERIFICATION**" activities are used to provide evidence that the system and its elements were produced according to the selected and appropriate methods, techniques, standards, or rules. "**VALIDATION**" activities are used to provide evidence that the system and its elements, when taken in combination, satisfy the stakeholder needs and requirements. This section includes statements each of which you may agree or disagree with depending on your opinion about the status of the practice of these activities in your project. Please indicate the degree of your agreement or disagreement with each statement using the following scale: **Strongly Disagree, Disagree, Neither agree nor disagree, Agree, Strongly Agree**

* 33. This project develops a verification and validation strategy and documents it in a verification and validation plan.

- ◯ Strongly Disagree
- ◯ Disagree
- ◯ Neutral/Neither agree nor disagree
- ◯ Agree
- ◯ Strongly Agree

21

* 34. The verification and validation plan of this project clearly defines the appropriate verification and validation techniques to be applied, such as inspection, analysis, simulation, peer-review, testing, demonstration etc., based on the best decisions of the project to perform every verification and validation action according to the given constraints.

- ◯ Strongly Disagree
- ◯ Disagree
- ◯ Neutral/Neither agree nor disagree
- ◯ Agree
- ◯ Strongly Agree

* 35. The verification and validation actions of this project include carrying out verification and validation procedures at the right time, in the expected environment, with the expected means, tools, and techniques.

- ◯ Strongly Disagree
- ◯ Disagree
- ◯ Neutral/Neither agree nor disagree
- ◯ Agree
- ◯ Strongly Agree

22

* 36. The verification and validation actions of this project include capturing and recording the results obtained when performing verification and validation actions using defined verification and validation procedures and means.

- Strongly Disagree
- Disagree
- Neutral/Neither agree nor disagree
- Agree
- Strongly Agree

* 37. The verification and validation actions of this project include analyses of acquired results and compare them to the expected results so that the status may be recorded as either compliant or non-compliant.

- Strongly Disagree
- Disagree
- Neutral/Neither agree nor disagree
- Agree
- Strongly Agree

23

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8. System Design and Analysis

The purpose of the "**SYSTEM DESIGN**" activities is to provide sufficient information about the system, and its elements to enable the implementation consistent with architectural entities as defined in models and views of the system architecture. "**SYSTEM ANALYSIS**", on the other hand, is used to perform trade-off studies and includes modelling and simulation, cost analysis, technical risks analysis, and effectiveness analysis. This section includes statements each of which you may agree or disagree with depending on your opinion about the status of the practice of these activities in your project. Please indicate the degree of your agreement or disagreement with each statement using the following scale: **Strongly Disagree, Disagree, Neither agree nor disagree, Agree, Strongly Agree**

* 38. This project defines interfaces that are necessary for the level of detail and understanding of the architecture. This includes the internal interfaces between the system elements and the external interfaces with other external systems.

- Strongly Disagree
- Disagree
- Neutral/Neither agree nor disagree
- Agree
- Strongly Agree

24

* 39. This project determines design properties applicable to system elements to satisfy the architectural characteristics.

- Strongly Disagree
- Disagree
- Neutral/Neither agree nor disagree
- Agree
- Strongly Agree

* 40. For each system element, this project derives requirements corresponding to allocation, alignment, and partitioning of design properties and system requirements to the system elements.

- Strongly Disagree
- Disagree
- Neutral/Neither agree nor disagree
- Agree
- Strongly Agree

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9. Assessment, Selection and Implementation

"**ASSESSMENT AND SELECTION**" form part of the decision management activities of the systems engineering process, and the purpose is to provide a structured, analytical framework for objectively identifying, characterising and evaluating a set of alternatives for a decision at any point in the system life cycle and select the most beneficial course of action. The "**IMPLEMENTATION**" activities yield the lowest-level system elements in the system hierarchy (system breakdown structure). During implementation, system elements are made, bought, or reused. This section includes statements each of which you may agree or disagree with depending on your opinion about the status of the practice of these activities in your project. Please indicate the degree of your agreement or disagreement with each statement using the following scale: **Strongly Disagree, Disagree, Neither agree nor disagree, Agree, Strongly Agree**

* 41. This project assesses and selects the preferred candidate architecture(s) using the architecture evaluation criteria in conjunction with the established risk management and decision management processes.

- Strongly Disagree
- Disagree
- Neutral/Neither agree nor disagree
- Agree
- Strongly Agree

26

* 42. This project produces the system elements using the established implementation strategy (i.e., the outcome of the make or buy decision).

- Strongly Disagree
- Disagree
- Neutral/Neither agree nor disagree
- Agree
- Strongly Agree

* 43. This project conducts unit testing and records evidence that the system elements meets their requirements and the associated verification and validation criteria.

- Strongly Disagree
- Disagree
- Neutral/Neither agree nor disagree
- Agree
- Strongly Agree

27

APPENDIX F

Content Validity Test

Table 26. The Demographics of the Panel

Id	Job Title	Years in Systems Engineering	Years in Project Management	Highest Qualification	Current Employer
1	Systems Engineer	8	6	Bachelor's	1. CSIR
2	Program Manager	15	15	Master's	1. CSIR
3	Systems Engineer	20	5	Bachelor's	2. DENEL (SOC)
4	Engineering Manager	7	7	Master's	2. DENEL (SOC)
5	Engineering Manager	10	7	Master's	2. DENEL (SOC)
6	Program Manager	4	4	Master's	2. DENEL (SOC)
7	Systems Engineer	20	20	Master's	2. DENEL (SOC)
8	Systems Engineer	23	18	Master's	2. DENEL (SOC)
9	Engineering Manager	31	31	Master's	3. RDM (RF) (PTY) LTD
10	Project Manager	9	9	PG Diploma	4. SANDF
11	University Lecturer	30	25	Doctorate	5. University of Pretoria

Table 27. Content Validity test results for Stakeholder Needs and Requirements Analysis

Item	Id 1	Id 2	Id 3	Id 4	Id 5	Id 6	Id 7	Id 8	Id 9	Id 10	Id 11	CVR	Decision
StReq 1	x	x	x	x	x	x	x	x	x	x	x	1	Retain
StReq 2	x	x	x	x	x	x	x	x	x	x	x	1	Retain
StReq 3		x	x	x	x	x	x	x	x	x	x	0,818	Retain
StReq 4	x	x	x	x	x	x	x	x	x			0,636	Retain
StReq 5		x	x	x		x	x	x	x	x	x	0,636	Retain
StReq 6	x	x	x	x		x	x	x	x	x	x	0,818	Retain
StReq 7	x	x	x	x		x	x	x	x	x	x	0,818	Retain
StReq 8	x		x	x	x	x	x	x	x	x	x	0,818	Retain
StReq 9	x	x	x	x	x	x	x	x	x		x	0,818	Retain
											CVI	**0,818**	

Table 28. Content Validity test results for System Requirements Analysis

Item	Id 1	Id 2	Id 3	Id 4	Id 5	Id 6	Id 7	Id 8	Id 9	Id 10	Id 11	CVR	Decision
SyReq 1	x		x	x	x	x	x	x	x	x	x	0,818	Retain
SyReq 2	x		x	x	x	x	x	x	x	x	x	0,818	Retain
SyReq 3	x	x	x	x		x	x	x	x	x	x	0,818	Retain
SyReq 4	x	x	x	x		x	x	x	x	x	x	0,818	Retain
SyReq 5		x	x	x		x	x	x	x	x	x	0,636	Retain
SyReq 6	x		x	x		x	x	x	x	x	x	0,636	Retain
SyReq 7	x	x	x	x	x	x	x	x	x	x	x	1	Retain
SyReq 8	x	x	x	x	x	x	x	x	x	x	x	1	Retain
SyReq 9	x	x	x	x	x	x	x	x	x	x	x	1	Retain
											CVI	**0,838**	

Table 29. Content Validity test results for System Architecture

	Id 1	Id 2	Id 3	Id 4	Id 5	Id 6	Id 7	Id 8	Id 9	Id 10	Id 11	CVR	Decision
SyArc 1	x	x	x	x	x	x	x	x	x	x	x	1	Retain
SyArc 2		x	x	x		x			x	x	x	0,273	Discard
SyArc 3	x	x	x	x		x	x		x		x	0,455	Discard
SyArc 4	x	x	x	x	x	x	x	x	x		x	0,818	Retain
SyArc 5		x	x	x	x	x	x	x	x		x	0,636	Retain
SyArc 6	x	x	x	x	x	x	x	x	x	x	x	1	Retain
SyArc 7	x	x	x	x	x	x	x	x	x	x	x	1	Retain
SyArc 8	x	x	x	x	x	x	x		x	x	x	0,818	Retain
SyArc 9				x	x	x	x		x	x	x	0,273	Discard
SyArc 10	x	x	x	x	x	x	x	x	x	x	x	1	Retain
SyArc 11				x		x	x	x	x	x	x	0,273	Discard
SyArc 12	x			x	x	x	x	x	x	x	x	0,636	Retain
											CVI	**0,682**	

Table 30. Content Validity test results for System Design and Analysis

Item	Id 1	Id 2	Id 3	Id 4	Id 5	Id 6	Id 7	Id 8	Id 9	Id 10	Id 11	CVR	Decision
DeAnal_ SyAna 1	x			x	x	x		x	x	x	x	0,455	Discard
DeAnal_ SyAna 2	x	x	x	x	x	x	x	x	x	x	x	1	Retain
DeAnal_ SyAna 3		x	x	x	x	x	x	x	x	x	x	0,818	Retain
DeAnal_ SyAna 4	x	x	x	x	x	x	x	x	x	x	x	1	Retain
											CVI	**0,818**	

Table 31. Content Validity test results for System Assessment and Selection

Item	Id 1	Id 2	Id 3	Id 4	Id 5	Id 6	Id 7	Id 8	Id 9	Id 10	Id 11	CVR	Decision
Ass_Sel 1		x		x	x	x	x	x	x	x	x	0,636	Retain
Ass_Sel 2	x	x	x	x	x	x	x	x	x		x	0,818	Retain
Ass_Sel 3			x	x	x	x	x	x	x		x	0,455	Discard
Ass_Sel 4	x	x		x	x	x	x	x	x		x	0,636	Retain
											CVI	**0,636**	

Table 32. Content Validity test results for System Implementation

Item	Id 1	Id 2	Id 3	Id 4	Id 5	Id 6	Id 7	Id 8	Id 9	Id 10	Id 11	CVR	Decision
SyImp 1	x	x			x	x	x	x	x		x	0,455	Discard
SyImp 2	x	x	x		x	x	x	x	x		x	0,636	Retain
SyImp 3	x	x	x	x	x	x	x	x	x		x	0,818	Retain
SyImp 4	x	x	x		x	x	x	x	x		x	0,636	Retain
SyImp 5	x	x	x	x	x	x	x	x	x	x	x	1	Retain
											CVI	**0,709**	

Table 33. Content Validity test results for System Integration

Item	Id 1	Id 2	Id 3	Id 4	Id 5	Id 6	Id 7	Id 8	Id 9	Id 10	Id 11	CVR	Decision
SyInt 1	x	x	x	x	x	x	x	x	x	x	x	1	Retain
SyInt 2	x	x	x	x	x	x	x	x	x	x	x	1	Retain
SyInt 3	x	x	x		x	x	x	x	x	x	x	0,818	Retain
SyInt 4	x	x	x		x	x	x	x	x	x	x	0,818	Retain
SyInt 5	x		x	x	x	x	x	x	x	x	x	0,818	Retain
SyInt 6	x		x	x	x	x	x	x	x	x	x	0,818	Retain
SyInt 7	x	x	x		x	x	x	x	x	x	x	0,818	Retain
											CVI	**0,87**	

Table 34. Content Validity test results for System Verification and Validation

	Id 1	Id 2	Id 3	Id 4	Id 5	Id 6	Id 7	Id 8	Id 9	Id 10	Id 11	CVR	Decision
SyVV 1	x	x	x	x	x	x	x	x	x	x	x	1	Retain
SyVV 2			x		x	x	x	x	x	x	x	0,455	Discard
SyVV 3	x	x	x		x	x	x	x	x	x	x	0,818	Retain
SyVV 4			x	x		x		x	x		x	0,091	Discard
SyVV 5			x		x	x	x	x	x		x	0,273	Discard
SyVV 6	x	x	x		x	x	x	x	x		x	0,636	Retain
SyVV 7		x	x		x	x	x	x	x	x	x	0,636	Retain
SyVV 8	x	x	x	x	x	x	x	x	x	x	x	1	Retain
SyVV 9	x	x	x	x	x	x	x	x	x		x	0,818	Retain
SyVV 10			x			x	x	x	x		x	0,091	Discard
											CVI	**0,582**	

Table 35. Content Validity test results for System Architecture after removing discarded items

	Id 1	Id 2	Id 3	Id 4	Id 5	Id 6	Id 7	Id 8	Id 9	Id 10	Id 11	CVR	Decision
SyArc 1	x	x	x	x	x	x	x	x	x	x	x	1	Retain
SyArc 4	x	x	x	x	x	x	x	x	x		x	0,818	Retain
SyArc 5		x	x	x	x	x	x	x	x		x	0,636	Retain
SyArc 6	x	x	x	x	x	x	x	x	x	x	x	1	Retain
SyArc 7	x	x	x	x	x	x	x	x	x	x	x	1	Retain
SyArc 8	x	x	x	x	x	x	x		x	x	x	0,818	Retain
SyArc 10	x	x	x	x	x	x	x	x	x	x	x	1	Retain
SyArc 12	x			x	x	x	x	x	x	x	x	0,636	Retain
											CVI	**0,864**	

Table 36. Content Validity test results for System Design and Analsis after removing discarded items

	Id 1	Id 2	Id 3	Id 4	Id 5	Id 6	Id 7	Id 8	Id 9	Id 10	Id 11	CVR	Decision
DeAnal_ SyAna 2	x	x	x	x	x	x	x	x	x	x	x	1	Retain
DeAnal_ SyAna 3		x	x	x	x	x	x	x	x	x	x	0,818	Retain
DeAnal_ SyAna 4	x	x	x	x	x	x	x	x	x	x	x	1	Retain
											CVI	0,939	

Table 37. Content Validity test results for System Assessment and Selection after removing discarded items

	Id 1	Id 2	Id 3	Id 4	Id 5	Id 6	Id 7	Id 8	Id 9	Id 10	Id 11	CVR	Decision
Ass_Sel 1		x		x	x	x	x	x	x	x	x	0,636	Retain
Ass_Sel 2	x	x	x	x	x	x	x	x	x		x	0,818	Retain
Ass_Sel 4	x	x		x	x	x	x	x	x		x	0,636	Retain
											CVI	**0,697**	

Table 38. Content Validity test results for System Implementation after removing discarded items

	Id 1	Id 2	Id 3	Id 4	Id 5	Id 6	Id 7	Id 8	Id 9	Id 10	Id 11	CVR	Decision
SyImp 2	x	x	x		x	x	x	x	x		x	0,636	Retain
SyImp 3	x	x	x	x	x	x	x	x	x		x	0,818	Retain
SyImp 4	x	x	x		x	x	x	x	x		x	0,636	Retain
SyImp 5	x	x	x	x	x	x	x	x	x	x	x	1	Retain
											CVI	0,773	

Table 39. Content Validity test results for System Verification and Validation after removing discarded items

	Id 1	Id 2	Id 3	Id 4	Id 5	Id 6	Id 7	Id 8	Id 9	Id 10	Id 11	CVR	Decision
SyVV 1	x	x	x	x	x	x	x	x	x	x	x	1	Retain
SyVV 3	x	x	x		x	x	x	x	x	x	x	0,818	Retain
SyVV 6	x	x	x		x	x	x	x	x		x	0,636	Retain
											CVI	0,818	

Table 40. Content Validity test results of the overall scale after removing discarded items

	Id 1	Id 2	Id 3	Id 4	Id 5	Id 6	Id 7	Id 8	Id 9	Id 10	Id 11	CVR	Decision
StReq 1	x	x	x	x	x	x	x	x	x	x	x	1	Retain
StReq 2	x	x	x	x	x	x	x	x	x	x	x	1	Retain
StReq 3		x	x	x	x	x	x	x	x	x	x	0,818	Retain
StReq 4	x	x	x	x	x	x	x	x	x			0,636	Retain
StReq 5		x	x	x		x	x	x	x	x	x	0,636	Retain
StReq 6	x	x	x	x		x	x	x	x	x	x	0,818	Retain
StReq 7	x	x	x	x		x	x	x	x	x	x	0,818	Retain
StReq 8	x		x	x	x	x	x	x	x	x	x	0,818	Retain
StReq 9	x	x	x	x	x	x	x	x	x		x	0,818	Retain
SyReq 1	x		x	x	x	x	x	x	x	x	x	0,818	Retain
SyReq 2	x		x	x	x	x	x	x	x	x	x	0,818	Retain
SyReq 3	x	x	x	x		x	x	x	x	x	x	0,818	Retain
SyReq 4	x	x	x	x		x	x	x	x	x	x	0,818	Retain
SyReq 5		x	x	x		x	x	x	x	x	x	0,636	Retain
SyReq 6	x		x	x		x	x	x	x	x	x	0,636	Retain
SyReq 7	x	x	x	x	x	x	x	x	x	x	x	1	Retain
SyReq 8	x	x	x	x	x	x	x	x	x	x	x	1	Retain
SyReq 9	x	x	x	x	x	x	x	x	x	x	x	1	Retain
SyArc 1	x	x	x	x	x	x	x	x	x	x	x	1	Retain
SyArc 4	x	x	x	x	x	x	x	x	x		x	0,818	Retain
SyArc 5		x	x	x	x	x	x	x	x		x	0,636	Retain
SyArc 6	x	x	x	x	x	x	x	x	x	x	x	1	Retain
SyArc 7	x	x	x	x	x	x	x	x	x	x	x	1	Retain
SyArc 8	x	x	x	x	x	x	x		x	x	x	0,818	Retain
SyArc 10	x	x	x	x	x	x	x	x	x	x	x	1	Retain
SyArc 12	x			x	x	x	x	x	x	x	x	0,636	Retain
DeAnal_ SyAna 2	x	x	x	x	x	x	x	x	x	x	x	1	Retain
DeAnal_ SyAna 3		x	x	x	x	x	x	x	x	x	x	0,818	Retain
DeAnal_ SyAna 4	x	x	x	x	x	x	x	x	x	x	x	1	Retain
Ass_Sel 1		x		x	x	x	x	x	x	x	x	0,636	Retain
Ass_Sel 2	x	x	x	x	x	x	x	x	x		x	0,818	Retain

Ass_Sel 4	x	x		x	x	x	x	x	x		x	0,636	Retain
SyImp 2	x	x	x		x	x	x	x	x		x	0,636	Retain
SyImp 3	x	x	x	x	x	x	x	x	x		x	0,818	Retain
SyImp 4	x	x	x		x	x	x	x	x		x	0,636	Retain
SyImp 5	x	x	x	x	x	x	x	x	x	x	x	1	Retain
SyInt 1	x	x	x	x	x	x	x	x	x	x	x	1	Retain
SyInt 2	x	x	x	x	x	x	x	x	x	x	x	1	Retain
SyInt 3	x	x	x		x	x	x	x	x	x	x	0,818	Retain
SyInt 4	x	x	x		x	x	x	x	x	x	x	0,818	Retain
SyInt 5	x		x	x	x	x	x	x	x	x	x	0,818	Retain
SyInt 6	x		x	x	x	x	x	x	x	x	x	0,818	Retain
SyInt 7	x	x	x		x	x	x	x	x	x	x	0,818	Retain
SyVV 1	x	x	x	x	x	x	x	x	x	x	x	1	Retain
SyVV 3	x	x	x		x	x	x	x	x	x	x	0,818	Retain
SyVV 6	x	x	x		x	x	x	x	x		x	0,636	Retain
											CVI	**0,834**	

APPENDIX G

Pretesting of Questionnaire

Table 41. Desmographics of participants who participated in the prestesting of the questionnaire

Respondent ID	Competency Area	Job Title	Year at DPSS	Year in Tech Development Projects	Highest Qualification	Systems Engineering Training
1	Aeronautic Systems	Principal Systems Engineer	2-4 years	21 or more years	Honour's	Yes
2	Aeronautic Systems	Principal Systems Engineer	5-9 years	21 or more years	Honour's	Yes
2	Aeronautic Systems	Senior Engineer	5-9 years	5-9 years	Master's	Yes
4	Integrative Systems Group	Systems Engineer	2-4 years	2-4 years	Bachelor's	Yes

To test understandability of the questions, participants were requested to choose only one response based on the followings question.

How would you rate the understandability of this question?

The following response options were provided to choose from:

- 1 = Confusing - (not good, with much room for improvement.)
- 2 = Somewhat understandable - (good, but could still be made better.)
- 3 = Understandable - (no need for further improvement.)

Table 42. Results for Presting of the Questionnaire

Id	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
4	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3

Table 43. Results for Presting of the Questionnaire (Continued)

Id	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
2	3	3	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3	3
3	2	3	3	1	3	3	3	3	3	3	3	3	3	3	2	3	3	3
4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3

To test the overall quality of construction/design the questionnaire, participants were required to answer the following question.

How would you rate the overall quality of the construction of this questionnaire?

The following response options were provided to choose from:

- Poor: not good, with much room for improvement.
- Good: could still be made better.
- Excellent: no need for further improvement.

To test the length of this questionnaire, participants were required to answer the following question.

How would you rate the length of this questionnaire?

Much too long: not good, with much room for improvement.

- Somewhat lengthy: good, but could still be made better.
- About right: no need for further improvement.

Responses

1. About right

2. Somewhat lengthy
3. Somewhat lengthy
4. Somewhat lengthy

Participants were also requested to provide other suggestions to improve the questionnaire and the following comments were provided.

1. Add a progress bar. The level of questions assumes a project size and complexity much higher than what is typical in the DPSS context. Since DPSS projects are typically small (<R20m), many processes have to be informal, but they must still be done.
2. I'm not sure what to suggest to shorten it but it took quite a lot longer than 10 minutes to review it. Perhaps filling it in would be quicker than reviewing it.

The results from this test were used to improve the questionnaire before actual data collection

APPENDIX H

Testing Reliability of the Scales

1. Scale: Stakeholder Requirements Analysis

Table 44. Case Processing Summary Stakeholder Requirements Analysis

		N	%
Cases	Valid	47	100.0
	Excluded[a]	0	.0
	Total	47	100.0

a. Listwise deletion based on all variables in the procedure.

Table 45. Reliability Statistics Stakeholder Requirements Analysis

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.911	.912	7

Table 46. Item-Total Statistics Stakeholder Requirements Analysis

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Question 1	21.00	27.739	.733	.769	.897
Question 2	21.17	27.101	.812	.748	.889
Question 3	21.04	28.085	.641	.505	.907
Question 4	21.06	27.191	.817	.758	.888
Question 5	21.23	27.792	.735	.625	.897
Question 6	21.51	27.821	.670	.647	.904
Question 7	21.57	26.989	.717	.656	.899

2. Scale: System Requirements Analysis

Table 47. Case Processing Summary System Requirements Analysis

		N	%
Cases	Valid	47	100.0
	Excluded[a]	0	.0
	Total	47	100.0

a. Listwise deletion based on all variables in the procedure.

Table 48. Reliability Statistics System Requirements Analysis

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.893	.892	7

Table 49. Item-Total Statistics System Requirements Analysis

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Question 8	19.34	25.360	.652	.602	.882
Question 9	19.60	22.942	.762	.711	.868
Question 10	19.91	24.384	.730	.608	.872
Question 11	20.04	23.563	.742	.625	.871
Question 12	19.77	24.792	.683	.533	.878
Question 13	19.79	25.954	.612	.553	.886
Question 14	19.81	25.289	.655	.544	.881

1. **Scale: System Architecture**

Table 50. Case Processing Summary System Architecture

		N	%
Cases	Valid	47	100.0
	Excluded[a]	0	.0
	Total	47	100.0

a. Listwise deletion based on all variables in the procedure.

Table 51. Reliability Statistics System Architecture

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.813	.816	5

Table 52. Item-Total Statistics System Architecture

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Question 15	14.30	10.040	.665	.591	.761
Question 16	14.28	10.031	.648	.693	.765
Question 17	14.55	9.166	.688	.587	.750
Question 18	14.57	9.598	.591	.443	.782
Question 19	14.30	10.822	.442	.331	.824

2. **Scale: System Design and Analysis**

Table 53. Case Processing Summary System Design and Analysis

		N	%
Cases	Valid	47	100.0
	Excluded[a]	0	.0
	Total	47	100.0

a. Listwise deletion based on all variables in the procedure.

Table 54. Reliability Statistics System Design and Analysis

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.896	.897	3

Table 55. Item-Total Statistics System Design and Analysis

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Question 20	7.15	2.912	.803	.695	.844
Question 21	7.21	2.910	.852	.741	.804
Question 22	7.47	2.950	.734	.550	.906

3. **Scale: System Assessment, Selection and Implementation**

Table 56. Case Processing Summary System Assessment, Selection and Implementation

		N	%
Cases	Valid	47	100.0
	Excluded[a]	0	.0
	Total	47	100.0

a. Listwise deletion based on all variables in the procedure.

Table 57. Reliability Statistics System Assessment, Selection and Implementation

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.732	.740	3

Table 58. Item-Total Statistics System Assessment, Selection and Implementation

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Question 23	6.83	2.970	.462	.217	.764
Question 24	6.47	3.037	.632	.431	.569
Question 25	6.15	2.782	.590	.408	.603

4. Scale: System Integration

Table 59. Case Processing Summary System Integration

		N	%
Cases	Valid	47	100.0
	Excluded[a]	0	.0
	Total	47	100.0

a. Listwise deletion based on all variables in the procedure.

Table 60. Reliability Statistics System Integration

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.925	.927	6

Table 61. Item-Total Statistics System Integration

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Question 26	16.21	18.649	.802	.661	.910
Question 27	15.68	18.222	.809	.691	.909
Question 28	16.04	18.824	.824	.744	.906
Question 29	15.94	19.409	.733	.625	.919
Question 30	15.98	20.586	.775	.772	.915
Question 31	15.89	19.401	.785	.793	.912

5. Scale: System Verification and Validation

Table 62. Case Processing Summary System Verification and Validation

		N	%
Cases	Valid	47	100.0
	Excluded[a]	0	.0
	Total	47	100.0

a. Listwise deletion based on all variables in the procedure.

Table 63. Reliability Statistics System Verification and Validation

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.933	.937	5

Table 64. Item-Total Statistics System Verification and Validation

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Question 32	14.06	11.496	.754	.590	.934
Question 33	13.96	11.737	.805	.678	.921
Question 34	13.87	12.592	.863	.759	.913
Question 35	13.81	11.941	.870	.834	.908
Question 36	13.83	12.014	.854	.817	.911

6. Scale: Overall

Table 65. Case Processing Summary Overall

		N	%
Cases	Valid	47	100.0
	Excluded[a]	0	.0
	Total	47	100.0

a. Listwise deletion based on all variables in the procedure.

Table 66. Reliability Statistics Overall

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.967	.967	36

Table 67. Item-Total Statistics Overall

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Question 1	119.21	590.649	.556	.966
Question 2	119.38	586.720	.643	.966
Question 3	119.26	584.064	.644	.966
Question 4	119.28	581.857	.756	.965
Question 5	119.45	584.166	.693	.965
Question 6	119.72	578.117	.761	.965
Question 7	119.79	581.562	.668	.966
Question 8	119.28	586.117	.682	.965
Question 9	119.53	580.080	.681	.966
Question 10	119.85	584.086	.698	.965
Question 11	119.98	580.326	.711	.965
Question 12	119.70	583.735	.704	.965
Question 13	119.72	584.813	.734	.965
Question 14	119.74	585.629	.687	.965
Question 15	119.28	587.378	.705	.965
Question 16	119.26	588.759	.660	.966
Question 17	119.53	578.515	.778	.965
Question 18	119.55	589.861	.544	.966
Question 19	119.28	596.944	.443	.967
Question 20	119.21	591.519	.623	.966
Question 21	119.28	590.074	.681	.966
Question 22	119.53	583.994	.765	.965

Question 23	120.09	587.862	.600	.966
Question 24	119.72	598.248	.479	.966
Question 25	119.40	592.637	.534	.966
Question 26	120.04	585.129	.652	.966
Question 27	119.51	583.429	.654	.966
Question 28	119.87	583.201	.722	.965
Question 29	119.77	587.574	.622	.966
Question 30	119.81	596.419	.557	.966
Question 31	119.72	590.248	.601	.966
Question 32	119.66	583.751	.657	.966
Question 33	119.55	584.948	.693	.965
Question 34	119.47	591.646	.686	.966
Question 35	119.40	586.290	.734	.965
Question 36	119.43	589.250	.665	.966

APPENDIX I

Frequency Tables for Stakeholder Needs and Requirements Analysis

Table 68. Frequency table for StReq_1

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	7	14.9	14.9	14.9
	Neutral	5	10.6	10.6	25.5
	Agree	35	74.5	74.5	100.0
	Total	47	100.0	100.0	

Table 69. Frequency table for StReq_2

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	8	17.0	17.0	17.0
	Neutral	8	17.0	17.0	34.0
	Agree	31	66.0	66.0	100.0
	Total	47	100.0	100.0	

Table 70. Frequency table for StReq_3

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	8	17.0	17.0	17.0
	Neutral	4	8.5	8.5	25.5
	Agree	35	74.5	74.5	100.0
	Total	47	100.0	100.0	

Table 71. Frequency table for StReq_4

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	7	14.9	14.9	14.9
	Neutral	6	12.8	12.8	27.7
	Agree	34	72.3	72.3	100.0
	Total	47	100.0	100.0	

Table 72. Frequency table for StReq_5

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	8	17.0	17.0	17.0
	Neutral	11	23.4	23.4	40.4
	Agree	28	59.6	59.6	100.0
	Total	47	100.0	100.0	

Table 73. Frequency table for StReq_6

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	14	29.8	29.8	29.8
	Neutral	8	17.0	17.0	46.8
	Agree	25	53.2	53.2	100.0
	Total	47	100.0	100.0	

Table 74. Frequency table for StReq_7

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	15	31.9	31.9	31.9
	Neutral	8	17.0	17.0	48.9
	Agree	24	51.1	51.1	100.0
	Total	47	100.0	100.0	

APPENDIX J

Frequency Tables for System Requirements Analysis

Table 75. Frequency table for SyReq_1

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	6	12.8	12.8	12.8
	Neutral	8	17.0	17.0	29.8
	Agree	33	70.2	70.2	100.0
	Total	47	100.0	100.0	

Table 76. Frequency table for SyReq_2

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	9	19.1	19.1	19.1
	Neutral	7	14.9	14.9	34.0
	Agree	31	66.0	66.0	100.0
	Total	47	100.0	100.0	

Table 77. Frequency table for SyReq_3

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	14	29.8	29.8	29.8
	Neutral	9	19.1	19.1	48.9
	Agree	24	51.1	51.1	100.0
	Total	47	100.0	100.0	

Table 78. Frequency table for SyReq_4

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	17	36.2	36.2	36.2
	Neutral	10	21.3	21.3	57.4
	Agree	20	42.6	42.6	100.0
	Total	47	100.0	100.0	

Table 79. Frequency table for SyReq_5

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	13	27.7	27.7	27.7
	Neutral	6	12.8	12.8	40.4
	Agree	28	59.6	59.6	100.0
	Total	47	100.0	100.0	

Table 80. Frequency table for SyReq_6

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	13	27.7	27.7	27.7
	Neutral	10	21.3	21.3	48.9
	Agree	24	51.1	51.1	100.0
	Total	47	100.0	100.0	

Table 81. Frequency table for SyReq_7

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	11	23.4	23.4	23.4
	Neutral	13	27.7	27.7	51.1
	Agree	23	48.9	48.9	100.0
	Total	47	100.0	100.0	

APPENDIX K

Frequency Tables for System Architecture

Table 82. Frequency table for SyArc_1

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	5	10.6	10.6	10.6
	Neutral	8	17.0	17.0	27.7
	Agree	34	72.3	72.3	100.0
	Total	47	100.0	100.0	

Table 83. Frequency table for SyArc_2

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	5	10.6	10.6	10.6
	Neutral	8	17.0	17.0	27.7
	Agree	34	72.3	72.3	100.0
	Total	47	100.0	100.0	

Table 84. Frequency table for SyArc_3

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	11	23.4	23.4	23.4
	Neutral	8	17.0	17.0	40.4
	Agree	28	59.6	59.6	100.0
	Total	47	100.0	100.0	

Table 85. Frequency table for SyArc_4

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	9	19.1	19.1	19.1
	Neutral	10	21.3	21.3	40.4
	Agree	28	59.6	59.6	100.0
	Total	47	100.0	100.0	

Table 86. Frequency table for SyArc_5

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	7	14.9	14.9	14.9
	Neutral	6	12.8	12.8	27.7
	Agree	34	72.3	72.3	100.0
	Total	47	100.0	100.0	

APPENDIX L

Frequency Tables for System Design and Analysis

Table 87. Frequency table for Sy_Des_Anl_1

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	4	8.5	8.5	8.5
	Neutral	8	17.0	17.0	25.5
	Agree	35	74.5	74.5	100.0
	Total	47	100.0	100.0	

Table 88. Frequency table for Sy_Des_Anl_2

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	3	6.4	6.4	6.4
	Neutral	12	25.5	25.5	31.9
	Agree	32	68.1	68.1	100.0
	Total	47	100.0	100.0	

Table 89. Frequency table for Sy_Des_Anl_3

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	9	19.1	19.1	19.1
	Neutral	11	23.4	23.4	42.6
	Agree	27	57.4	57.4	100.0
	Total	47	100.0	100.0	

APPENDIX M

Frequency Tables for Assessment, Selection and Implementation

Table 90. Frequency table for Sy_Ass_Sel_Imp_1

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	17	36.2	36.2	36.2
	Neutral	12	25.5	25.5	61.7
	Agree	18	38.3	38.3	100.0
	Total	47	100.0	100.0	

Table 91. Frequency table for Sy_Ass_Sel_Imp_2

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	10	21.3	21.3	21.3
	Neutral	13	27.7	27.7	48.9
	Agree	24	51.1	51.1	100.0
	Total	47	100.0	100.0	

Table 92. Frequency table for Sy_Ass_Sel_Imp_3

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	7	14.9	14.9	14.9
	Neutral	8	17.0	17.0	31.9
	Agree	32	68.1	68.1	100.0
	Total	47	100.0	100.0	

APPENDIX N

Frequency Tables for System Integration

Table 93. Frequency table for SyInt_1

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	18	38.3	38.3	38.3
	Neutral	9	19.1	19.1	57.4
	Agree	20	42.6	42.6	100.0
	Total	47	100.0	100.0	

Table 94. Frequency table for SyInt_2

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	12	25.5	25.5	25.5
	Neutral	3	6.4	6.4	31.9
	Agree	32	68.1	68.1	100.0
	Total	47	100.0	100.0	

Table 95. Frequency table for SyInt_3

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	15	31.9	31.9	31.9
	Neutral	10	21.3	21.3	53.2
	Agree	22	46.8	46.8	100.0
	Total	47	100.0	100.0	

Table 96. Frequency table for SyInt_4

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	13	27.7	27.7	27.7
	Neutral	13	27.7	27.7	55.3
	Agree	21	44.7	44.7	100.0
	Total	47	100.0	100.0	

Table 97. Frequency table for SyInt_5

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	11	23.4	23.4	23.4
	Neutral	16	34.0	34.0	57.4
	Agree	20	42.6	42.6	100.0
	Total	47	100.0	100.0	

Table 98. Frequency table for SyInt_6

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	10	21.3	21.3	21.3
	Neutral	14	29.8	29.8	51.1
	Agree	23	48.9	48.9	100.0
	Total	47	100.0	100.0	

APPENDIX O

Frequency Tables for System Verification and Validation

Table 99. Frequency table for SyVV1

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	13	27.7	27.7	27.7
	Neutral	7	14.9	14.9	42.6
	Agree	27	57.4	57.4	100.0
	Total	47	100.0	100.0	

Table 100. Frequency table for SyVV2

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	10	21.3	21.3	21.3
	Neutral	9	19.1	19.1	40.4
	Agree	28	59.6	59.6	100.0
	Total	47	100.0	100.0	

Table 101. Frequency table for SyVV3

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	7	14.9	14.9	14.9
	Neutral	9	19.1	19.1	34.0
	Agree	31	66.0	66.0	100.0
	Total	47	100.0	100.0	

Table 102. Frequency table for SyVV4

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	7	14.9	14.9	14.9
	Neutral	7	14.9	14.9	29.8
	Agree	33	70.2	70.2	100.0
	Total	47	100.0	100.0	

Table 103. Frequency table for SyVV5

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	7	14.9	14.9	14.9
	Neutral	8	17.0	17.0	31.9
	Agree	32	68.1	68.1	100.0
	Tota	47	100.0	100.0	

APPENDIX P

Fisher's Exact Test Tests for Objective 2

1. System Needs and Requirements Analysis

Table 104. Competency Area* StReq_1 Crosstab

			StReq_1			
			Disagree	Neutral	Agree	Total
Department Category	Technology Application Group	Count	7	5	25	37
		Expected Count	5.5	3.9	27.6	37.0
		% within Competency Area	18.9%	13.5%	67.6%	100.0%
	Integrative Systems Group	Count	0	0	6	6
		Expected Count	.9	.6	4.5	6.0
		% within Competency Area	0.0%	0.0%	100.0%	100.0%
	Technology for Special Operations	Count	0	0	4	4
		Expected Count	.6	.4	3.0	4.0
		% within Competency Area	0.0%	0.0%	100.0%	100.0%
Total		Count	7	5	35	47
		Expected Count	7.0	5.0	35.0	47.0
		% within Competency Area	14.9%	10.6%	74.5%	100.0%

Table 105. Chi-Square Tests Competency Area* StReq_1 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	4.355[a]	4	.360	.316		
Likelihood Ratio	6.775	4	.148	.164		
Fisher's Exact Test	2.329			.629		
Linear-by-Linear Association	3.264[b]	1	.071	.078	.035	.035
N of Valid Cases	47					

a. 7 cells (77.8%) have expected count less than 5. The minimum expected count is .43.

b. The standardized statistic is 1.807.

Table 106. Symmetric Measures Competency Area* StReq_1 Crosstab

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.304	.360	.316
	Cramer's V	.215	.360	.316
N of Valid Cases		47		

Table 107. Competency Area* StReq_2 Crosstab

			StReq_2			Total
			Disagree	Neutral	Agree	
Department Category	Technology Application Group	Count	8	8	21	37
		Expected Count	6.3	6.3	24.4	37.0
		% within Competency Area	21.6%	21.6%	56.8%	100.0%
	Integrative Systems Group	Count	0	0	6	6
		Expected Count	1.0	1.0	4.0	6.0
		% within Competency Area	0.0%	0.0%	100.0%	100.0%
	Technology for Special Operations	Count	0	0	4	4
		Expected Count	.7	.7	2.6	4.0
		% within Competency Area	0.0%	0.0%	100.0%	100.0%
Total		Count	8	8	31	47
		Expected Count	8.0	8.0	31.0	47.0
		% within Competency Area	17.0%	17.0%	66.0%	100.0%

Table 108. Chi-Square Tests Competency Area* StReq_2 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	6.556[a]	4	.161	.152		
Likelihood Ratio	9.669	4	.046	.045		
Fisher's Exact Test	4.206			.323		
Linear-by-Linear Association	4.752[b]	1	.029	.026	.009	.009
N of Valid Cases	47					

a. 6 cells (66.7%) have expected count less than 5. The minimum expected count is .68.

b. The standardized statistic is 2.180.

Table 109. Symmetric Measures Competency Area* StReq_2 Crosstab

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.373	.161	.152
	Cramer's V	.264	.161	.152
N of Valid Cases		47		

Table 110. Competency Area* StReq_3 Crosstab

			StReq_3			
			Disagree	Neutral	Agree	Total
Department Category	Technology Application Group	Count	7	4	26	37
		Expected Count	6.3	3.1	27.6	37.0
		% within Competency Area	18.9%	10.8%	70.3%	100.0%
	Integrative Systems Group	Count	1	0	5	6
		Expected Count	1.0	.5	4.5	6.0
		% within Competency Area	16.7%	0.0%	83.3%	100.0%
	Technology for Special Operations	Count	0	0	4	4
		Expected Count	.7	.3	3.0	4.0
		% within Competency Area	0.0%	0.0%	100.0%	100.0%
Total		Count	8	4	35	47
		Expected Count	8.0	4.0	35.0	47.0
		% within Competency Area	17.0%	8.5%	74.5%	100.0%

Table 111. Chi-Square Tests Competency Area* StReq_3 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	2.342[a]	4	.673	.796		
Likelihood Ratio	3.818	4	.431	.606		
Fisher's Exact Test	1.282			.932		
Linear-by-Linear Association	1.470[b]	1	.225	.316	.165	.096
N of Valid Cases	47					

a. 7 cells (77.8%) have expected count less than 5. The minimum expected count is .34.

b. The standardized statistic is 1.212.

Table 112. Symmetric Measures Competency Area* StReq_3 Crosstab

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.223	.673	.796
	Cramer's V	.158	.673	.796
N of Valid Cases		47		

Table 113. Competency Area* StReq_4 Crosstab

			StReq_4			Total
			Disagree	Neutral	Agree	
Department Category	Technology Application Group	Count	7	6	24	37
		Expected Count	5.5	4.7	26.8	37.0
		% within Competency Area	18.9%	16.2%	64.9%	100.0%
	Integrative Systems Group	Count	0	0	6	6
		Expected Count	.9	.8	4.3	6.0
		% within Competency Area	0.0%	0.0%	100.0%	100.0%
	Technology for Special Operations	Count	0	0	4	4
		Expected Count	.6	.5	2.9	4.0
		% within Competency Area	0.0%	0.0%	100.0%	100.0%
Total		Count	7	6	34	47
		Expected Count	7.0	6.0	34.0	47.0
		% within Competency Area	14.9%	12.8%	72.3%	100.0%

Table 114. Chi-Square Tests Competency Area* StReq_4 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	4.857[a]	4	.302	.277		
Likelihood Ratio	7.460	4	.113	.131		
Fisher's Exact Test	2.696			.591		
Linear-by-Linear Association	3.592[b]	1	.058	.075	.025	.025
N of Valid Cases	47					

a. 7 cells (77.8%) have expected count less than 5. The minimum expected count is .51.

b. The standardized statistic is 1.895.

Table 115. Symmetric Measures Competency Area* StReq_4 Crosstab

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.321	.302	.277
	Cramer's V	.227	.302	.277
N of Valid Cases		47		

Table 116. Competency Area* StReq_5 Crosstab

			StReq_5			Total
			Disagree	Neutral	Agree	
Department Category	Technology Application Group	Count	8	11	18	37
		Expected Count	6.3	8.7	22.0	37.0
		% within Competency Area	21.6%	29.7%	48.6%	100.0%
	Integrative Systems Group	Count	0	0	6	6
		Expected Count	1.0	1.4	3.6	6.0
		% within Competency Area	0.0%	0.0%	100.0%	100.0%
	Technology for Special Operations	Count	0	0	4	4
		Expected Count	.7	.9	2.4	4.0
		% within Competency Area	0.0%	0.0%	100.0%	100.0%
Total		Count	8	11	28	47
		Expected Count	8.0	11.0	28.0	47.0
		% within Competency Area	17.0%	23.4%	59.6%	100.0%

Table 117. Chi-Square Tests Competency Area* StReq_5 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	8.620[a]	4	.071	.059		
Likelihood Ratio	12.156	4	.016	.016		
Fisher's Exact Test	6.208			.109		
Linear-by-Linear Association	6.071[b]	1	.014	.009	.003	.003
N of Valid Cases	47					

a. 6 cells (66.7%) have expected count less than 5. The minimum expected count is .68.

b. The standardized statistic is 2.464.

Table 118. Symmetric Measures Competency Area* StReq_5 Crosstab

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.428	.071	.059
	Cramer's V	.303	.071	.059
N of Valid Cases		47		

Table 119. Competency Area* StReq_6 Crosstab

			StReq_6			Total
			Disagree	Neutral	Agree	
Department Category	Technology Application Group	Count	12	5	20	37
		Expected Count	11.0	6.3	19.7	37.0
		% within Competency Area	32.4%	13.5%	54.1%	100.0%
	Integrative Systems Group	Count	1	3	2	6
		Expected Count	1.8	1.0	3.2	6.0
		% within Competency Area	16.7%	50.0%	33.3%	100.0%
	Technology for Special Operations	Count	1	0	3	4
		Expected Count	1.2	.7	2.1	4.0
		% within Competency Area	25.0%	0.0%	75.0%	100.0%
Total		Count	14	8	25	47
		Expected Count	14.0	8.0	25.0	47.0
		% within Competency Area	29.8%	17.0%	53.2%	100.0%

Table 120. Chi-Square Tests Competency Area* StReq_6 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	6.054[a]	4	.195	.197		
Likelihood Ratio	5.523	4	.238	.351		
Fisher's Exact Test	4.602			.266		
Linear-by-Linear Association	.210[b]	1	.646	.695	.381	.092
N of Valid Cases	47					

a. 6 cells (66.7%) have expected count less than 5. The minimum expected count is .68.

b. The standardized statistic is .459.

Table 121. Symmetric Measures Competency Area* StReq_6 Crosstab

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.359	.195	.197
	Cramer's V	.254	.195	.197
N of Valid Cases		47		

Table 122. Competency Area* StReq_7 Crosstab

			StReq_7			Total
			Disagree	Neutral	Agree	
Department Category	Technology Application Group	Count	12	8	17	37
		Expected Count	11.8	6.3	18.9	37.0
		% within Competency Area	32.4%	21.6%	45.9%	100.0%
	Integrative Systems Group	Count	2	0	4	6
		Expected Count	1.9	1.0	3.1	6.0
		% within Competency Area	33.3%	0.0%	66.7%	100.0%
	Technology for Special Operations	Count	1	0	3	4
		Expected Count	1.3	.7	2.0	4.0
		% within Competency Area	25.0%	0.0%	75.0%	100.0%
Total		Count	15	8	24	47
		Expected Count	15.0	8.0	24.0	47.0
		% within Competency Area	31.9%	17.0%	51.1%	100.0%

Table 123. Chi-Square Tests Competency Area* StReq_7 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	3.154[a]	4	.532	.564		
Likelihood Ratio	4.748	4	.314	.471		
Fisher's Exact Test	2.313			.766		
Linear-by-Linear Association	.762[b]	1	.383	.442	.239	.079
N of Valid Cases	47					

a. 6 cells (66.7%) have expected count less than 5. The minimum expected count is .68.

b. The standardized statistic is .873.

Table 124. Symmetric Measures Competency Area* StReq_7 Crosstab

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.259	.532	.564
	Cramer's V	.183	.532	.564
N of Valid Cases		47		

2. System Requirements Analysis

Table 125. Competency Area* SyReq_1 Crosstab

			SyReq_1			
			Disagree	Neutral	Agree	Total
Department Category	Technology Application Group	Count	6	8	23	37
		Expected Count	4.7	6.3	26.0	37.0
		% within Competency Area	16.2%	21.6%	62.2%	100.0%
	Integrative Systems Group	Count	0	0	6	6
		Expected Count	.8	1.0	4.2	6.0
		% within Competency Area	0.0%	0.0%	100.0%	100.0%
	Technology for Special Operations	Count	0	0	4	4
		Expected Count	.5	.7	2.8	4.0
		% within Competency Area	0.0%	0.0%	100.0%	100.0%
Total		Count	6	8	33	47
		Expected Count	6.0	8.0	33.0	47.0
		% within Competency Area	12.8%	17.0%	70.2%	100.0%

Table 126. Chi-Square Tests Competency Area* SyReq_1 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	5.389[a]	4	.250	.244		
Likelihood Ratio	8.169	4	.086	.077		
Fisher's Exact Test	3.185			.473		
Linear-by-Linear Association	3.898[b]	1	.048	.061	.018	.018
N of Valid Cases	47					

a. 7 cells (77.8%) have expected count less than 5. The minimum expected count is .51.

b. The standardized statistic is 1.974.

Table 127. Competency Area* SyReq_1 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.339	.250	.244
	Cramer's V	.239	.250	.244
N of Valid Cases		47		

Table 128. Competency Area* SyReq_2 Crosstab

			SyReq_2			Total
			Disagree	Neutral	Agree	
Department Category	Technology Application Group	Count	9	7	21	37
		Expected Count	7.1	5.5	24.4	37.0
		% within Competency Area	24.3%	18.9%	56.8%	100.0%
	Integrative Systems Group	Count	0	0	6	6
		Expected Count	1.1	.9	4.0	6.0
		% within Competency Area	0.0%	0.0%	100.0%	100.0%
	Technology for Special Operations	Count	0	0	4	4
		Expected Count	.8	.6	2.6	4.0
		% within Competency Area	0.0%	0.0%	100.0%	100.0%
Total		Count	9	7	31	47
		Expected Count	9.0	7.0	31.0	47.0
		% within Competency Area	19.1%	14.9%	66.0%	100.0%

Table 129. Chi-Square Tests Competency Area* SyReq_2 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	6.556[a]	4	.161	.132		
Likelihood Ratio	9.669	4	.046	.048		
Fisher's Exact Test	4.238			.315		
Linear-by-Linear Association	4.817[b]	1	.028	.033	.009	.009
N of Valid Cases	47					

a. 6 cells (66.7%) have expected count less than 5. The minimum expected count is .60.

b. The standardized statistic is 2.195.

Table 130. Competency Area* SyReq_2 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.373	.161	.132
	Cramer's V	.264	.161	.132
N of Valid Cases		47		

Table 131. Competency Area* SyReq_3 Crosstab

			SyReq_3			Total
			Disagree	Neutral	Agree	
Department Category	Technology Application Group	Count	13	8	16	37
		Expected Count	11.0	7.1	18.9	37.0
		% within Competency Area	35.1%	21.6%	43.2%	100.0%
	Integrative Systems Group	Count	1	1	4	6
		Expected Count	1.8	1.1	3.1	6.0
		% within Competency Area	16.7%	16.7%	66.7%	100.0%
	Technology for Special Operations	Count	0	0	4	4
		Expected Count	1.2	.8	2.0	4.0
		% within Competency Area	0.0%	0.0%	100.0%	100.0%
Total		Count	14	9	24	47
		Expected Count	14.0	9.0	24.0	47.0
		% within Competency Area	29.8%	19.1%	51.1%	100.0%

Table 132. Chi-Square Tests Competency Area* SyReq_3 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	5.402[a]	4	.248	.229		
Likelihood Ratio	6.988	4	.137	.201		
Fisher's Exact Test	4.087			.362		
Linear-by-Linear Association	4.627[b]	1	.031	.029	.016	.010
N of Valid Cases	47					

a. 6 cells (66.7%) have expected count less than 5. The minimum expected count is .77.

b. The standardized statistic is 2.151.

Table 133. Competency Area* SyReq_3 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.339	.248	.229
	Cramer's V	.240	.248	.229
N of Valid Cases		47		

Table 134. Competency Area* SyReq_4 Crosstab

			SyReq_4			Total
			Disagree	Neutral	Agree	
Department Category	Technology Application Group	Count	14	8	15	37
		Expected Count	13.4	7.9	15.7	37.0
		% within Competency Area	37.8%	21.6%	40.5%	100.0%
	Integrative Systems Group	Count	2	2	2	6
		Expected Count	2.2	1.3	2.6	6.0
		% within Competency Area	33.3%	33.3%	33.3%	100.0%
	Technology for Special Operations	Count	1	0	3	4
		Expected Count	1.4	.9	1.7	4.0
		% within Competency Area	25.0%	0.0%	75.0%	100.0%
Total		Count	17	10	20	47
		Expected Count	17.0	10.0	20.0	47.0
		% within Competency Area	36.2%	21.3%	42.6%	100.0%

Table 135. Chi-Square Tests Competency Area* SyReq_4 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	2.588[a]	4	.629	.691		
Likelihood Ratio	3.220	4	.522	.694		
Fisher's Exact Test	2.281			.765		
Linear-by-Linear Association	.676[b]	1	.411	.439	.251	.078
N of Valid Cases	47					

a. 6 cells (66.7%) have expected count less than 5. The minimum expected count is .85.

b. The standardized statistic is .822.

Table 136. Competency Area* SyReq_4 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.235	.629	.691
	Cramer's V	.166	.629	.691
N of Valid Cases		47		

Table 137. Competency Area* SyReq_5 Crosstab

			SyReq_5			Total
			Disagree	Neutral	Agree	
Department Category	Technology Application Group	Count	12	6	19	37
		Expected Count	10.2	4.7	22.0	37.0
		% within Competency Area	32.4%	16.2%	51.4%	100.0%
	Integrative Systems Group	Count	1	0	5	6
		Expected Count	1.7	.8	3.6	6.0
		% within Competency Area	16.7%	0.0%	83.3%	100.0%
	Technology for Special Operations	Count	0	0	4	4
		Expected Count	1.1	.5	2.4	4.0
		% within Competency Area	0.0%	0.0%	100.0%	100.0%
Total		Count	13	6	28	47
		Expected Count	13.0	6.0	28.0	47.0
		% within Competency Area	27.7%	12.8%	59.6%	100.0%

Table 138. Chi-Square Tests Competency Area* SyReq_5 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	5.381[a]	4	.250	.252		
Likelihood Ratio	7.534	4	.110	.150		
Fisher's Exact Test	3.625			.391		
Linear-by-Linear Association	4.042[b]	1	.044	.044	.024	.017
N of Valid Cases	47					

a. 7 cells (77.8%) have expected count less than 5. The minimum expected count is .51.

b. The standardized statistic is 2.010.

Table 139. Competency Area* SyReq_5 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.338	.250	.252
	Cramer's V	.239	.250	.252
N of Valid Cases		47		

Table 140. Competency Area* SyReq_6 Crosstab

			SyReq_6			Total
			Disagree	Neutral	Agree	
Department Category	Technology Application Group	Count	10	8	19	37
		Expected Count	10.2	7.9	18.9	37.0
		% within Competency Area	27.0%	21.6%	51.4%	100.0%
	Integrative Systems Group	Count	2	2	2	6
		Expected Count	1.7	1.3	3.1	6.0
		% within Competency Area	33.3%	33.3%	33.3%	100.0%
	Technology for Special Operations	Count	1	0	3	4
		Expected Count	1.1	.9	2.0	4.0
		% within Competency Area	25.0%	0.0%	75.0%	100.0%
Total		Count	13	10	24	47
		Expected Count	13.0	10.0	24.0	47.0
		% within Competency Area	27.7%	21.3%	51.1%	100.0%

Table 141. Chi-Square Tests Competency Area* SyReq_6 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	2.167[a]	4	.705	.758		
Likelihood Ratio	2.948	4	.566	.742		
Fisher's Exact Test	2.168			.782		
Linear-by-Linear Association	.039[b]	1	.843	.896	.486	.107
N of Valid Cases	47					

a. 6 cells (66.7%) have expected count less than 5. The minimum expected count is .85.

b. The standardized statistic is .198.

Table 142. Competency Area* SyReq_6 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.215	.705	.758
	Cramer's V	.152	.705	.758
N of Valid Cases		47		

Table 143. Competency Area* SyReq_7 Crosstab

			SyReq_7			Total
			Disagree	Neutral	Agree	
Department Category	Technology Application Group	Count	10	12	15	37
		Expected Count	8.7	10.2	18.1	37.0
		% within Competency Area	27.0%	32.4%	40.5%	100.0%
	Integrative Systems Group	Count	1	1	4	6
		Expected Count	1.4	1.7	2.9	6.0
		% within Competency Area	16.7%	16.7%	66.7%	100.0%
	Technology for Special Operations	Count	0	0	4	4
		Expected Count	.9	1.1	2.0	4.0
		% within Competency Area	0.0%	0.0%	100.0%	100.0%
Total		Count	11	13	23	47
		Expected Count	11.0	13.0	23.0	47.0
		% within Competency Area	23.4%	27.7%	48.9%	100.0%

Table 144. Chi-Square Tests Competency Area* SyReq_7 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	5.983[a]	4	.200	.188		
Likelihood Ratio	7.551	4	.109	.176		
Fisher's Exact Test	4.476			.293		
Linear-by-Linear Association	4.598[b]	1	.032	.039	.016	.011
N of Valid Cases	47					

a. 6 cells (66.7%) have expected count less than 5. The minimum expected count is .94.

b. The standardized statistic is 2.144.

Table 145. Competency Area* SyReq_7 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.357	.200	.188
	Cramer's V	.252	.200	.188
N of Valid Cases		47		

System Architecture

Table 146. Competency Area* SyArc_1 Crosstab

			SyArc_1			
			Disagree	Neutral	Agree	Total
Department Category	Technology Application Group	Count	4	8	25	37
		Expected Count	3.9	6.3	26.8	37.0
		% within Competency Area	10.8%	21.6%	67.6%	100.0%
	Integrative Systems Group	Count	1	0	5	6
		Expected Count	.6	1.0	4.3	6.0
		% within Competency Area	16.7%	0.0%	83.3%	100.0%
	Technology for Special Operations	Count	0	0	4	4
		Expected Count	.4	.7	2.9	4.0
		% within Competency Area	0.0%	0.0%	100.0%	100.0%
Total		Count	5	8	34	47
		Expected Count	5.0	8.0	34.0	47.0
		% within Competency Area	10.6%	17.0%	72.3%	100.0%

Table 147. Chi-Square Tests Competency Area* SyArc_1 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	3.433[a]	4	.488	.475		
Likelihood Ratio	5.446	4	.244	.293		
Fisher's Exact Test	2.429			.664		
Linear-by-Linear Association	1.381[b]	1	.240	.311	.169	.096
N of Valid Cases	47					

a. 7 cells (77.8%) have expected count less than 5. The minimum expected count is .43.

b. The standardized statistic is 1.175.

Table 148. Competency Area* SyReq_1 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.270	.488	.475
	Cramer's V	.191	.488	.475
N of Valid Cases		47		

Table 149. Competency Area* SyArc_2 Crosstab

			SyArc_2			Total
			Disagree	Neutral	Agree	
Department Category	Technology Application Group	Count	5	8	24	37
		Expected Count	3.9	6.3	26.8	37.0
		% within Competency Area	13.5%	21.6%	64.9%	100.0%
	Integrative Systems Group	Count	0	0	6	6
		Expected Count	.6	1.0	4.3	6.0
		% within Competency Area	0.0%	0.0%	100.0%	100.0%
	Technology for Special Operations	Count	0	0	4	4
		Expected Count	.4	.7	2.9	4.0
		% within Competency Area	0.0%	0.0%	100.0%	100.0%
Total		Count	5	8	34	47
		Expected Count	5.0	8.0	34.0	47.0
		% within Competency Area	10.6%	17.0%	72.3%	100.0%

Table 150. Chi-Square Tests Competency Area* SyArc_2 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	4.857[a]	4	.302	.270		
Likelihood Ratio	7.460	4	.113	.090		
Fisher's Exact Test	2.793			.548		
Linear-by-Linear Association	3.514[b]	1	.061	.072	.025	.025
N of Valid Cases	47					

a. 7 cells (77.8%) have expected count less than 5. The minimum expected count is .43.

b. The standardized statistic is 1.875.

Table 151. Competency Area* SyArch_2 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.321	.302	.270
	Cramer's V	.227	.302	.270
N of Valid Cases		47		

Table 152. Competency Area* SyArc_3 Crosstab

			SyArc_3			
			Disagree	Neutral	Agree	Total
Department Category	Technology Application Group	Count	10	6	21	37
		Expected Count	8.7	6.3	22.0	37.0
		% within Competency Area	27.0%	16.2%	56.8%	100.0%
	Integrative Systems Group	Count	1	2	3	6
		Expected Count	1.4	1.0	3.6	6.0
		% within Competency Area	16.7%	33.3%	50.0%	100.0%
	Technology for Special Operations	Count	0	0	4	4
		Expected Count	.9	.7	2.4	4.0
		% within Competency Area	0.0%	0.0%	100.0%	100.0%
Total		Count	11	8	28	47
		Expected Count	11.0	8.0	28.0	47.0
		% within Competency Area	23.4%	17.0%	59.6%	100.0%

Table 153. Chi-Square Tests Competency Area* SyArc_3 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	4.132[a]	4	.388	.401		
Likelihood Ratio	5.364	4	.252	.389		
Fisher's Exact Test	3.142			.543		
Linear-by-Linear Association	1.914[b]	1	.167	.215	.108	.052
N of Valid Cases	47					

a. 6 cells (66.7%) have expected count less than 5. The minimum expected count is .68.

b. The standardized statistic is 1.383.

Table 154. Competency Area* SyArc_3 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.296	.388	.401
	Cramer's V	.210	.388	.401
N of Valid Cases		47		

Table 155. Competency Area* SyArc_4 Crosstab

			SyArc_4			Total
			Disagree	Neutral	Agree	
Department Category	Technology Application Group	Count	7	9	21	37
		Expected Count	7.1	7.9	22.0	37.0
		% within Competency Area	18.9%	24.3%	56.8%	100.0%
	Integrative Systems Group	Count	1	1	4	6
		Expected Count	1.1	1.3	3.6	6.0
		% within Competency Area	16.7%	16.7%	66.7%	100.0%
	Technology for Special Operations	Count	1	0	3	4
		Expected Count	.8	.9	2.4	4.0
		% within Competency Area	25.0%	0.0%	75.0%	100.0%
Total		Count	9	10	28	47
		Expected Count	9.0	10.0	28.0	47.0
		% within Competency Area	19.1%	21.3%	59.6%	100.0%

Table 156. Chi-Square Tests Competency Area* SyArc_4 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	1.424[a]	4	.840	.892		
Likelihood Ratio	2.254	4	.689	.892		
Fisher's Exact Test	1.399			.935		
Linear-by-Linear Association	.158[b]	1	.691	.775	.419	.110
N of Valid Cases	47					

a. 6 cells (66.7%) have expected count less than 5. The minimum expected count is .77.

b. The standardized statistic is .398.

Table 157. Competency Area* SyArc_4 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.174	.840	.892
	Cramer's V	.123	.840	.892
N of Valid Cases		47		

Table 158. Competency Area* SyArc_5 Crosstab

			SyArc_5			Total
			Disagree	Neutral	Agree	
Department Category	Technology Application Group	Count	4	5	28	37
		Expected Count	5.5	4.7	26.8	37.0
		% within Competency Area	10.8%	13.5%	75.7%	100.0%
	Integrative Systems Group	Count	3	0	3	6
		Expected Count	.9	.8	4.3	6.0
		% within Competency Area	50.0%	0.0%	50.0%	100.0%
	Technology for Special Operations	Count	0	1	3	4
		Expected Count	.6	.5	2.9	4.0
		% within Competency Area	0.0%	25.0%	75.0%	100.0%
Total		Count	7	6	34	47
		Expected Count	7.0	6.0	34.0	47.0
		% within Competency Area	14.9%	12.8%	72.3%	100.0%

Table 159. Chi-Square Tests Competency Area* SyArc_5 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	7.701[a]	4	.103	.102		
Likelihood Ratio	7.141	4	.129	.139		
Fisher's Exact Test	5.864			.134		
Linear-by-Linear Association	.422[b]	1	.516	.531	.304	.100
N of Valid Cases	47					

a. 7 cells (77.8%) have expected count less than 5. The minimum expected count is .51.

b. The standardized statistic is -.650.

Table 160. Competency Area* SyArc_5 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.405	.103	.102
	Cramer's V	.286	.103	.102
N of Valid Cases		47		

3. **System Design and Analysis**

Table 161. Competency Area* Sy_Des_Anl_1 Crosstab

			Sy_Des_Anl_1			Total
			Disagree	Neutral	Agree	
Department Category	Technology Application Group	Count	3	8	26	37
		Expected Count	3.1	6.3	27.6	37.0
		% within Competency Area	8.1%	21.6%	70.3%	100.0%
	Integrative Systems Group	Count	1	0	5	6
		Expected Count	.5	1.0	4.5	6.0
		% within Competency Area	16.7%	0.0%	83.3%	100.0%
	Technology for Special Operations	Count	0	0	4	4
		Expected Count	.3	.7	3.0	4.0
		% within Competency Area	0.0%	0.0%	100.0%	100.0%
Total		Count	4	8	35	47
		Expected Count	4.0	8.0	35.0	47.0
		% within Competency Area	8.5%	17.0%	74.5%	100.0%

Table 162. Chi-Square Tests Competency Area* Sy_Des_Anl_1 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	3.480[a]	4	.481	.460		
Likelihood Ratio	5.347	4	.253	.312		
Fisher's Exact Test	2.669			.534		
Linear-by-Linear Association	1.064[b]	1	.302	.378	.220	.119
N of Valid Cases	47					

a. 7 cells (77.8%) have expected count less than 5. The minimum expected count is .34.

b. The standardized statistic is 1.031.

Table 163. Competency Area* Sy_Des_Anl_1 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.272	.481	.460
	Cramer's V	.192	.481	.460
N of Valid Cases		47		

Table 164. Competency Area* Sy_Des_Anl_2 Crosstab

			Sy_Des_Anl_2			Total
			Disagree	Neutral	Agree	
Department Category	Technology Application Group	Count	2	11	24	37
		Expected Count	2.4	9.4	25.2	37.0
		% within Competency Area	5.4%	29.7%	64.9%	100.0%
	Integrative Systems Group	Count	1	1	4	6
		Expected Count	.4	1.5	4.1	6.0
		% within Competency Area	16.7%	16.7%	66.7%	100.0%
	Technology for Special Operations	Count	0	0	4	4
		Expected Count	.3	1.0	2.7	4.0
		% within Competency Area	0.0%	0.0%	100.0%	100.0%
Total		Count	3	12	32	47
		Expected Count	3.0	12.0	32.0	47.0
		% within Competency Area	6.4%	25.5%	68.1%	100.0%

Table 165. Chi-Square Tests Competency Area* Sy_Des_Anl_2 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	3.423[a]	4	.490	.452		
Likelihood Ratio	4.332	4	.363	.449		
Fisher's Exact Test	3.202			.483		
Linear-by-Linear Association	.841[b]	1	.359	.453	.252	.120
N of Valid Cases	47					

a. 7 cells (77.8%) have expected count less than 5. The minimum expected count is .26.

b. The standardized statistic is .917.

Table 166. Competency Area* Sy_Des_Anl_2 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.270	.490	.452
	Cramer's V	.191	.490	.452
N of Valid Cases		47		

Table 167. Competency Area* Sy_Des_Anl_3 Crosstab

			Sy_Des_Anl_3			Total
			Disagree	Neutral	Agree	
Department Category	Technology Application Group	Count	8	10	19	37
		Expected Count	7.1	8.7	21.3	37.0
		% within Competency Area	21.6%	27.0%	51.4%	100.0%
	Integrative Systems Group	Count	1	0	5	6
		Expected Count	1.1	1.4	3.4	6.0
		% within Competency Area	16.7%	0.0%	83.3%	100.0%
	Technology for Special Operations	Count	0	1	3	4
		Expected Count	.8	.9	2.3	4.0
		% within Competency Area	0.0%	25.0%	75.0%	100.0%
Total		Count	9	11	27	47
		Expected Count	9.0	11.0	27.0	47.0
		% within Competency Area	19.1%	23.4%	57.4%	100.0%

Table 168. Chi-Square Tests Competency Area* Sy_Des_Anl_3 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	3.673[a]	4	.452	.505		
Likelihood Ratio	5.733	4	.220	.361		
Fisher's Exact Test	3.052			.586		
Linear-by-Linear Association	1.907[b]	1	.167	.189	.108	.053
N of Valid Cases	47					

a. 6 cells (66.7%) have expected count less than 5. The minimum expected count is .77.

b. The standardized statistic is 1.381.

Table 169. Competency Area* Sy_Des_Anl_3 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.280	.452	.505
	Cramer's V	.198	.452	.505
N of Valid Cases		47		

4. System Assessment, Selection and Implementation

Table 170. Competency Area* Sy_Ass_Sel_Imp_1 Crosstab

			Sy_Ass_Sel_Imp_1			
			Disagree	Neutral	Agree	Total
Department Category	Technology Application Group	Count	13	11	13	37
		Expected Count	13.4	9.4	14.2	37.0
		% within Competency Area	35.1%	29.7%	35.1%	100.0%
	Integrative Systems Group	Count	3	0	3	6
		Expected Count	2.2	1.5	2.3	6.0
		% within Competency Area	50.0%	0.0%	50.0%	100.0%
	Technology for Special Operations	Count	1	1	2	4
		Expected Count	1.4	1.0	1.5	4.0
		% within Competency Area	25.0%	25.0%	50.0%	100.0%
Total		Count	17	12	18	47
		Expected Count	17.0	12.0	18.0	47.0
		% within Competency Area	36.2%	25.5%	38.3%	100.0%

Table 171. Chi-Square Tests Competency Area* Sy_Ass_Sel_Imp_1 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	2.708[a]	4	.608	.704		
Likelihood Ratio	4.181	4	.382	.584		
Fisher's Exact Test	2.875			.629		
Linear-by-Linear Association	.214[b]	1	.644	.692	.376	.096
N of Valid Cases	47					

a. 6 cells (66.7%) have expected count less than 5. The minimum expected count is 1.02.

b. The standardized statistic is .462.

Table 172. Competency Area* Sy_Ass_Sel_Imp_1 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.240	.608	.704
	Cramer's V	.170	.608	.704
N of Valid Cases		47		

Table 173. Competency Area* Sy_Ass_Sel_Imp_2 Crosstab

			Sy_Ass_Sel_Imp_2			
			Disagree	Neutral	Agree	Total
Department Category	Technology Application Group	Count	7	11	19	37
		Expected Count	7.9	10.2	18.9	37.0
		% within Competency Area	18.9%	29.7%	51.4%	100.0%
	Integrative Systems Group	Count	3	0	3	6
		Expected Count	1.3	1.7	3.1	6.0
		% within Competency Area	50.0%	0.0%	50.0%	100.0%
	Technology for Special Operations	Count	0	2	2	4
		Expected Count	.9	1.1	2.0	4.0
		% within Competency Area	0.0%	50.0%	50.0%	100.0%
Total		Count	10	13	24	47
		Expected Count	10.0	13.0	24.0	47.0
		% within Competency Area	21.3%	27.7%	51.1%	100.0%

Table 174. Chi-Square Tests Competency Area* Sy_Ass_Sel_Imp_2 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	5.716[a]	4	.221	.203		
Likelihood Ratio	7.441	4	.114	.170		
Fisher's Exact Test	5.002			.215		
Linear-by-Linear Association	.003[b]	1	.960	1.000	.526	.113
N of Valid Cases	47					

a. 6 cells (66.7%) have expected count less than 5. The minimum expected count is .85.

b. The standardized statistic is -.050.

Table 175. Competency Area* Sy_Ass_Sel_Imp_2 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.349	.221	.203
	Cramer's V	.247	.221	.203
N of Valid Cases		47		

Table 176. Competency Area* Sy_Ass_Sel_Imp_3 Crosstab

			Sy_Ass_Sel_Imp_3			
			Disagree	Neutral	Agree	Total
Department Category	Technology Application Group	Count	5	5	27	37
		Expected Count	5.5	6.3	25.2	37.0
		% within Competency Area	13.5%	13.5%	73.0%	100.0%
	Integrative Systems Group	Count	2	3	1	6
		Expected Count	.9	1.0	4.1	6.0
		% within Competency Area	33.3%	50.0%	16.7%	100.0%
	Technology for Special Operations	Count	0	0	4	4
		Expected Count	.6	.7	2.7	4.0
		% within Competency Area	0.0%	0.0%	100.0%	100.0%
Total		Count	7	8	32	47
		Expected Count	7.0	8.0	32.0	47.0
		% within Competency Area	14.9%	17.0%	68.1%	100.0%

Table 177. Chi-Square Tests Competency Area* Sy_Ass_Sel_Imp_3 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	9.853[a]	4	.043	.046		
Likelihood Ratio	10.412	4	.034	.028		
Fisher's Exact Test	8.535			.037		
Linear-by-Linear Association	.020[b]	1	.887	1.000	.481	.113
N of Valid Cases	47					

a. 6 cells (66.7%) have expected count less than 5. The minimum expected count is .60.

b. The standardized statistic is -.142.

Table 178. Competency Area* Sy_Ass_Sel_Imp_3 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.458	.043	.046
	Cramer's V	.324	.043	.046
N of Valid Cases		47		

5. System Integration

Table 179. Competency Area* SyInt_1 Crosstab

			SyInt_1			
			Disagree	Neutral	Agree	Total
Department Category	Technology Application Group	Count	14	8	15	37
		Expected Count	14.2	7.1	15.7	37.0
		% within Competency Area	37.8%	21.6%	40.5%	100.0%
	Integrative Systems Group	Count	3	1	2	6
		Expected Count	2.3	1.1	2.6	6.0
		% within Competency Area	50.0%	16.7%	33.3%	100.0%
	Technology for Special Operations	Count	1	0	3	4
		Expected Count	1.5	.8	1.7	4.0
		% within Competency Area	25.0%	0.0%	75.0%	100.0%
Total		Count	18	9	20	47
		Expected Count	18.0	9.0	20.0	47.0
		% within Competency Area	38.3%	19.1%	42.6%	100.0%

Table 180. Chi-Square Tests Competency Area* SyInt_1 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	2.449[a]	4	.654	.714		
Likelihood Ratio	3.044	4	.551	.729		
Fisher's Exact Test	2.012			.830		
Linear-by-Linear Association	.393[b]	1	.531	.610	.314	.083
N of Valid Cases	47					

a. 6 cells (66.7%) have expected count less than 5. The minimum expected count is .77.

b. The standardized statistic is .627.

Table 181. Competency Area* SyInt_1 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.228	.654	.714
	Cramer's V	.161	.654	.714
N of Valid Cases		47		

Table 182. Competency Area* SyInt_2 Crosstab

			SyInt_2			Total
			Disagree	Neutral	Agree	
Department Category	Technology Application Group	Count	10	3	24	37
		Expected Count	9.4	2.4	25.2	37.0
		% within Competency Area	27.0%	8.1%	64.9%	100.0%
	Integrative Systems Group	Count	2	0	4	6
		Expected Count	1.5	.4	4.1	6.0
		% within Competency Area	33.3%	0.0%	66.7%	100.0%
	Technology for Special Operations	Count	0	0	4	4
		Expected Count	1.0	.3	2.7	4.0
		% within Competency Area	0.0%	0.0%	100.0%	100.0%
Total		Count	12	3	32	47
		Expected Count	12.0	3.0	32.0	47.0
		% within Competency Area	25.5%	6.4%	68.1%	100.0%

Table 183. Chi-Square Tests Competency Area* SyInt_2 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	2.664[a]	4	.616	.701		
Likelihood Ratio	4.221	4	.377	.537		
Fisher's Exact Test	1.989			.857		
Linear-by-Linear Association	1.188[b]	1	.276	.305	.193	.095
N of Valid Cases	47					

a. 7 cells (77.8%) have expected count less than 5. The minimum expected count is .26.

b. The standardized statistic is 1.090.

Table 184. Competency Area* SyInt_2 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.238	.616	.701
	Cramer's V	.168	.616	.701
N of Valid Cases		47		

Table 185. Competency Area* SyInt_3 Crosstab

			SyInt_3			Total
			Disagree	Neutral	Agree	
Department Category	Technology Application Group	Count	12	9	16	37
		Expected Count	11.8	7.9	17.3	37.0
		% within Competency Area	32.4%	24.3%	43.2%	100.0%
	Integrative Systems Group	Count	2	1	3	6
		Expected Count	1.9	1.3	2.8	6.0
		% within Competency Area	33.3%	16.7%	50.0%	100.0%
	Technology for Special Operations	Count	1	0	3	4
		Expected Count	1.3	.9	1.9	4.0
		% within Competency Area	25.0%	0.0%	75.0%	100.0%
Total		Count	15	10	22	47
		Expected Count	15.0	10.0	22.0	47.0
		% within Competency Area	31.9%	21.3%	46.8%	100.0%

Table 186. Chi-Square Tests Competency Area* SyInt_3 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	1.932[a]	4	.748	.813		
Likelihood Ratio	2.682	4	.612	.788		
Fisher's Exact Test	1.623			.871		
Linear-by-Linear Association	.610[b]	1	.435	.512	.266	.080
N of Valid Cases	47					

a. 6 cells (66.7%) have expected count less than 5. The minimum expected count is .85.

b. The standardized statistic is .781.

Table 187. Competency Area* SyInt_3 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.203	.748	.813
	Cramer's V	.143	.748	.813
N of Valid Cases		47		

Table 188. Competency Area* SyInt_4 Crosstab

			SyInt_4			Total
			Disagree	Neutral	Agree	
Department Category	Technology Application Group	Count	10	11	16	37
		Expected Count	10.2	10.2	16.5	37.0
		% within Competency Area	27.0%	29.7%	43.2%	100.0%
	Integrative Systems Group	Count	2	2	2	6
		Expected Count	1.7	1.7	2.7	6.0
		% within Competency Area	33.3%	33.3%	33.3%	100.0%
	Technology for Special Operations	Count	1	0	3	4
		Expected Count	1.1	1.1	1.8	4.0
		% within Competency Area	25.0%	0.0%	75.0%	100.0%
Total		Count	13	13	21	47
		Expected Count	13.0	13.0	21.0	47.0
		% within Competency Area	27.7%	27.7%	44.7%	100.0%

Table 189. Chi-Square Tests Competency Area* SyInt_4 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	2.332[a]	4	.675	.764		
Likelihood Ratio	3.305	4	.508	.713		
Fisher's Exact Test	2.283			.789		
Linear-by-Linear Association	.207[b]	1	.649	.683	.385	.101
N of Valid Cases	47					

a. 6 cells (66.7%) have expected count less than 5. The minimum expected count is 1.11.

b. The standardized statistic is .455.

Table 190. Competency Area* SyInt_4 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.223	.675	.764
	Cramer's V	.158	.675	.764
N of Valid Cases		47		

Table 191. Competency Area* SyInt_5 Crosstab

			SyInt_5			Total
			Disagree	Neutral	Agree	
Department Category	Technology Application Group	Count	7	15	15	37
		Expected Count	8.7	12.6	15.7	37.0
		% within Competency Area	18.9%	40.5%	40.5%	100.0%
	Integrative Systems Group	Count	3	1	2	6
		Expected Count	1.4	2.0	2.6	6.0
		% within Competency Area	50.0%	16.7%	33.3%	100.0%
	Technology for Special Operations	Count	1	0	3	4
		Expected Count	.9	1.4	1.7	4.0
		% within Competency Area	25.0%	0.0%	75.0%	100.0%
Total		Count	11	16	20	47
		Expected Count	11.0	16.0	20.0	47.0
		% within Competency Area	23.4%	34.0%	42.6%	100.0%

Table 192. Chi-Square Tests Competency Area* SyInt_5 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	5.633[a]	4	.228	.217		
Likelihood Ratio	6.490	4	.165	.269		
Fisher's Exact Test	5.150			.220		
Linear-by-Linear Association	.009[b]	1	.925	1.000	.528	.115
N of Valid Cases	47					

a. 6 cells (66.7%) have expected count less than 5. The minimum expected count is .94.

b. The standardized statistic is .095.

Table 193. Competency Area* SyInt_5 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.346	.228	.217
	Cramer's V	.245	.228	.217
N of Valid Cases		47		

Table 194. Competency Area* SyInt_6 Crosstab

			SyInt_6			
			Disagree	Neutral	Agree	Total
Department Category	Technology Application Group	Count	7	13	17	37
		Expected Count	7.9	11.0	18.1	37.0
		% within Competency Area	18.9%	35.1%	45.9%	100.0%
	Integrative Systems Group	Count	3	1	2	6
		Expected Count	1.3	1.8	2.9	6.0
		% within Competency Area	50.0%	16.7%	33.3%	100.0%
	Technology for Special Operations	Count	0	0	4	4
		Expected Count	.9	1.2	2.0	4.0
		% within Competency Area	0.0%	0.0%	100.0%	100.0%
Total		Count	10	14	23	47
		Expected Count	10.0	14.0	23.0	47.0
		% within Competency Area	21.3%	29.8%	48.9%	100.0%

Table 195. Chi-Square Tests Competency Area* SyInt_6 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	7.665[a]	4	.105	.094		
Likelihood Ratio	8.652	4	.070	.105		
Fisher's Exact Test	5.833			.150		
Linear-by-Linear Association	.858[b]	1	.354	.388	.226	.082
N of Valid Cases	47					

a. 6 cells (66.7%) have expected count less than 5. The minimum expected count is .85.

b. The standardized statistic is .926.

Table 196. Competency Area* SyInt_6 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.404	.105	.094
	Cramer's V	.286	.105	.094
N of Valid Cases		47		

6. System Verification and Validation

Table 197. Competency Area* SyVV_1 Crosstab

			SyVV_1			Total
			Disagree	Neutral	Agree	
Department Category	Technology Application Group	Count	11	7	19	37
		Expected Count	10.2	5.5	21.3	37.0
		% within Competency Area	29.7%	18.9%	51.4%	100.0%
	Integrative Systems Group	Count	2	0	4	6
		Expected Count	1.7	.9	3.4	6.0
		% within Competency Area	33.3%	0.0%	66.7%	100.0%
	Technology for Special Operations	Count	0	0	4	4
		Expected Count	1.1	.6	2.3	4.0
		% within Competency Area	0.0%	0.0%	100.0%	100.0%
Total		Count	13	7	27	47
		Expected Count	13.0	7.0	27.0	47.0
		% within Competency Area	27.7%	14.9%	57.4%	100.0%

Table 198. Chi-Square Tests Competency Area* SyVV_1 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	4.714[a]	4	.318	.327		
Likelihood Ratio	7.046	4	.133	.200		
Fisher's Exact Test	3.251			.502		
Linear-by-Linear Association	2.447[b]	1	.118	.146	.075	.038
N of Valid Cases	47					

a. 6 cells (66.7%) have expected count less than 5. The minimum expected count is .60.

b. The standardized statistic is 1.564.

Table 199. Competency Area* SyVV_1 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.317	.318	.327
	Cramer's V	.224	.318	.327
N of Valid Cases		47		

Table 200. Competency Area* SyVV_2 Crosstab

			SyVV_2			Total
			Disagree	Neutral	Agree	
Department Category	Technology Application Group	Count	8	8	21	37
		Expected Count	7.9	7.1	22.0	37.0
		% within Competency Area	21.6%	21.6%	56.8%	100.0%
	Integrative Systems Group	Count	2	1	3	6
		Expected Count	1.3	1.1	3.6	6.0
		% within Competency Area	33.3%	16.7%	50.0%	100.0%
	Technology for Special Operations	Count	0	0	4	4
		Expected Count	.9	.8	2.4	4.0
		% within Competency Area	0.0%	0.0%	100.0%	100.0%
Total		Count	10	9	28	47
		Expected Count	10.0	9.0	28.0	47.0
		% within Competency Area	21.3%	19.1%	59.6%	100.0%

Table 201. Chi-Square Tests Competency Area* SyVV_2 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	3.405[a]	4	.492	.529		
Likelihood Ratio	4.776	4	.311	.528		
Fisher's Exact Test	2.550			.693		
Linear-by-Linear Association	1.098[b]	1	.295	.327	.189	.071
N of Valid Cases	47					

a. 6 cells (66.7%) have expected count less than 5. The minimum expected count is .77.

b. The standardized statistic is 1.048.

Table 202. Competency Area* SyVV_2 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.269	.492	.529
	Cramer's V	.190	.492	.529
N of Valid Cases		47		

Table 203. Competency Area* SyVV_3 Crosstab

			SyVV_3			Total
			Disagree	Neutral	Agree	
Department Category	Technology Application Group	Count	5	8	24	37
		Expected Count	5.5	7.1	24.4	37.0
		% within Competency Area	13.5%	21.6%	64.9%	100.0%
	Integrative Systems Group	Count	2	1	3	6
		Expected Count	.9	1.1	4.0	6.0
		% within Competency Area	33.3%	16.7%	50.0%	100.0%
	Technology for Special Operations	Count	0	0	4	4
		Expected Count	.6	.8	2.6	4.0
		% within Competency Area	0.0%	0.0%	100.0%	100.0%
Total		Count	7	9	31	47
		Expected Count	7.0	9.0	31.0	47.0
		% within Competency Area	14.9%	19.1%	66.0%	100.0%

Table 204. Chi-Square Tests Competency Area* SyVV_3 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	3.857[a]	4	.426	.468		
Likelihood Ratio	4.781	4	.311	.461		
Fisher's Exact Test	2.988			.483		
Linear-by-Linear Association	.343[b]	1	.558	.646	.355	.110
N of Valid Cases	47					

a. 6 cells (66.7%) have expected count less than 5. The minimum expected count is .60.

b. The standardized statistic is .586.

Table 205. Competency Area* SyVV_3 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.286	.426	.468
	Cramer's V	.203	.426	.468
N of Valid Cases		47		

Table 206. Competency Area* SyVV_4 Crosstab

			SyVV_4			Total
			Disagree	Neutral	Agree	
Department Category	Technology Application Group	Count	6	6	25	37
		Expected Count	5.5	5.5	26.0	37.0
		% within Competency Area	16.2%	16.2%	67.6%	100.0%
	Integrative Systems Group	Count	1	1	4	6
		Expected Count	.9	.9	4.2	6.0
		% within Competency Area	16.7%	16.7%	66.7%	100.0%
	Technology for Special Operations	Count	0	0	4	4
		Expected Count	.6	.6	2.8	4.0
		% within Competency Area	0.0%	0.0%	100.0%	100.0%
Total		Count	7	7	33	47
		Expected Count	7.0	7.0	33.0	47.0
		% within Competency Area	14.9%	14.9%	70.2%	100.0%

Table 207. Chi-Square Tests Competency Area* SyVV_4 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	1.857[a]	4	.762	.892		
Likelihood Ratio	2.986	4	.560	.788		
Fisher's Exact Test	1.352			1.000		
Linear-by-Linear Association	1.067[b]	1	.302	.356	.199	.079
N of Valid Cases	47					

a. 6 cells (66.7%) have expected count less than 5. The minimum expected count is .60.

b. The standardized statistic is 1.033.

Table 208. Competency Area* SyVV_4 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.199	.762	.892
	Cramer's V	.141	.762	.892
N of Valid Cases		47		

Table 209. Competency Area* SyVV_5 Crosstab

			SyVV_5			Total
			Disagree	Neutral	Agree	
Department Category	Technology Application Group	Count	6	6	25	37
		Expected Count	5.5	6.3	25.2	37.0
		% within Competency Area	16.2%	16.2%	67.6%	100.0%
	Integrative Systems Group	Count	1	2	3	6
		Expected Count	.9	1.0	4.1	6.0
		% within Competency Area	16.7%	33.3%	50.0%	100.0%
	Technology for Special Operations	Count	0	0	4	4
		Expected Count	.6	.7	2.7	4.0
		% within Competency Area	0.0%	0.0%	100.0%	100.0%
Total		Count	7	8	32	47
		Expected Count	7.0	8.0	32.0	47.0
		% within Competency Area	14.9%	17.0%	68.1%	100.0%

Table 210. Chi-Square Tests Competency Area* SyVV_5 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	3.173[a]	4	.529	.560		
Likelihood Ratio	4.194	4	.380	.562		
Fisher's Exact Test	2.594			.644		
Linear-by-Linear Association	.654[b]	1	.419	.458	.279	.108
N of Valid Cases	47					

a. 6 cells (66.7%) have expected count less than 5. The minimum expected count is .60.

b. The standardized statistic is .809.

Table 211. Competency Area* SyVV_5 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.260	.529	.560
	Cramer's V	.184	.529	.560
N of Valid Cases		47		

APPENDIX Q

Fisher's Exact Test Tests for Objective 3

1. Stakeholder Needs and Requirements Analysis

Table 212. Job Category * StReq_1 Crosstab

			StReq_1			
			Disagree	Neutral	Agree	Total
Job Category	Discipline Tech/Eng/Res/KA	Count	4	4	14	22
		Expected Count	3.3	2.3	16.4	22.0
		% within Job Category	18.2%	18.2%	63.6%	100.0%
	Systems Engineer	Count	1	0	11	12
		Expected Count	1.8	1.3	8.9	12.0
		% within Job Category	8.3%	0.0%	91.7%	100.0%
	Manager	Count	2	1	10	13
		Expected Count	1.9	1.4	9.7	13.0
		% within Job Category	15.4%	7.7%	76.9%	100.0%
Total		Count	7	5	35	47
		Expected Count	7.0	5.0	35.0	47.0
		% within Job Category	14.9%	10.6%	74.5%	100.0%

Table 213. Chi-Square Tests Job Category * SyReq_1 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	3.902[a]	4	.419	.449		
Likelihood Ratio	5.022	4	.285	.427		
Fisher's Exact Test	3.328			.578		
Linear-by-Linear Association	.617[b]	1	.432	.490	.258	.071
N of Valid Cases	47					

a. 6 cells (66.7%) have expected count less than 5. The minimum expected count is 1.28.

b. The standardized statistic is .785.

Table 214. Job Category * StReq_1 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.288	.419	.449
	Cramer's V	.204	.419	.449
N of Valid Cases		47		

Table 215. Job Category * StReq_2 Crosstab

			StReq_2			Total
			Disagree	Neutral	Agree	
Job Category	Discipline Tech/Eng/Res/KA	Count	6	6	10	22
		Expected Count	3.7	3.7	14.5	22.0
		% within Job Category	27.3%	27.3%	45.5%	100.0%
	Systems Engineer	Count	1	0	11	12
		Expected Count	2.0	2.0	7.9	12.0
		% within Job Category	8.3%	0.0%	91.7%	100.0%
	Manager	Count	1	2	10	13
		Expected Count	2.2	2.2	8.6	13.0
		% within Job Category	7.7%	15.4%	76.9%	100.0%
Total		Count	8	8	31	47
		Expected Count	8.0	8.0	31.0	47.0
		% within Job Category	17.0%	17.0%	66.0%	100.0%

Table 216. Chi-Square Tests Competency Area* StReq_2 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	8.818[a]	4	.066	.060		
Likelihood Ratio	10.764	4	.029	.049		
Fisher's Exact Test	8.089			.063		
Linear-by-Linear Association	4.406[b]	1	.036	.043	.021	.010
N of Valid Cases	47					

a. 6 cells (66.7%) have expected count less than 5. The minimum expected count is 2.04.

b. The standardized statistic is 2.099.

Table 217. Job Category * StReq_2 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.433	.066	.060
	Cramer's V	.306	.066	.060
N of Valid Cases		47		

Table 218. Job Category * StReq_3 Crosstab

			StReq_3			Total
			Disagree	Neutral	Agree	
Job Category	Discipline Tech/Eng/Res/KA	Count	4	4	14	22
		Expected Count	3.7	1.9	16.4	22.0
		% within Job Category	18.2%	18.2%	63.6%	100.0%
	Systems Engineer	Count	2	0	10	12
		Expected Count	2.0	1.0	8.9	12.0
		% within Job Category	16.7%	0.0%	83.3%	100.0%
	Manager	Count	2	0	11	13
		Expected Count	2.2	1.1	9.7	13.0
		% within Job Category	15.4%	0.0%	84.6%	100.0%
Total		Count	8	4	35	47
		Expected Count	8.0	4.0	35.0	47.0
		% within Job Category	17.0%	8.5%	74.5%	100.0%

Table 219. Chi-Square Tests Job Category * StReq_3 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	5.237[a]	4	.264	.277		
Likelihood Ratio	6.771	4	.149	.241		
Fisher's Exact Test	3.953			.414		
Linear-by-Linear Association	.875[b]	1	.350	.378	.211	.062
N of Valid Cases	47					

a. 6 cells (66.7%) have expected count less than 5. The minimum expected count is 1.02.

b. The standardized statistic is .935.

Table 220. Job Category * StReq_3 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.334	.264	.277
	Cramer's V	.236	.264	.277
N of Valid Cases		47		

Table 221. Job Category * StReq_4 Crosstab

			StReq_4			Total
			Disagree	Neutral	Agree	
Job Category	Discipline Tech/Eng/Res/KA	Count	4	5	13	22
		Expected Count	3.3	2.8	15.9	22.0
		% within Job Category	18.2%	22.7%	59.1%	100.0%
	Systems Engineer	Count	1	1	10	12
		Expected Count	1.8	1.5	8.7	12.0
		% within Job Category	8.3%	8.3%	83.3%	100.0%
	Manager	Count	2	0	11	13
		Expected Count	1.9	1.7	9.4	13.0
		% within Job Category	15.4%	0.0%	84.6%	100.0%
Total		Count	7	6	34	47
		Expected Count	7.0	6.0	34.0	47.0
		% within Job Category	14.9%	12.8%	72.3%	100.0%

Table 222. Chi-Square Tests Job Category * StReq_4 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	5.068[a]	4	.280	.303		
Likelihood Ratio	6.497	4	.165	.270		
Fisher's Exact Test	4.489			.342		
Linear-by-Linear Association	1.450[b]	1	.229	.250	.140	.047
N of Valid Cases	47					

a. 6 cells (66.7%) have expected count less than 5. The minimum expected count is 1.53.

b. The standardized statistic is 1.204.

Table 223. Job Category * StReq_3 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.328	.280	.303
	Cramer's V	.232	.280	.303
N of Valid Cases		47		

Table 224. Job Category * StReq_5 Crosstab

			StReq_5			Total
			Disagree	Neutral	Agree	
Job Category	Discipline Tech/Eng/Res/KA	Count	6	6	10	22
		Expected Count	3.7	5.1	13.1	22.0
		% within Job Category	27.3%	27.3%	45.5%	100.0%
	Systems Engineer	Count	0	4	8	12
		Expected Count	2.0	2.8	7.1	12.0
		% within Job Category	0.0%	33.3%	66.7%	100.0%
	Manager	Count	2	1	10	13
		Expected Count	2.2	3.0	7.7	13.0
		% within Job Category	15.4%	7.7%	76.9%	100.0%
Total		Count	8	11	28	47
		Expected Count	8.0	11.0	28.0	47.0
		% within Job Category	17.0%	23.4%	59.6%	100.0%

Table 225. Chi-Square Tests Job Category * StReq_5 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	6.933[a]	4	.139	.147		
Likelihood Ratio	9.193	4	.056	.095		
Fisher's Exact Test	6.826			.131		
Linear-by-Linear Association	3.083[b]	1	.079	.092	.048	.020
N of Valid Cases	47					

a. 5 cells (55.6%) have expected count less than 5. The minimum expected count is 2.04.

b. The standardized statistic is 1.756.

Table 226. Job Category * StReq_5 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.384	.139	.147
	Cramer's V	.272	.139	.147
N of Valid Cases		47		

Table 227. Job Category * StReq_6 Crosstab

			StReq_6			Total
			Disagree	Neutral	Agree	
Job Category	Discipline Tech/Eng/Res/KA	Count	10	3	9	22
		Expected Count	6.6	3.7	11.7	22.0
		% within Job Category	45.5%	13.6%	40.9%	100.0%
	Systems Engineer	Count	1	4	7	12
		Expected Count	3.6	2.0	6.4	12.0
		% within Job Category	8.3%	33.3%	58.3%	100.0%
	Manager	Count	3	1	9	13
		Expected Count	3.9	2.2	6.9	13.0
		% within Job Category	23.1%	7.7%	69.2%	100.0%
Total		Count	14	8	25	47
		Expected Count	14.0	8.0	25.0	47.0
		% within Job Category	29.8%	17.0%	53.2%	100.0%

Table 228. Chi-Square Tests Job Category * StReq_6 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	7.865[a]	4	.097	.099		
Likelihood Ratio	8.141	4	.087	.121		
Fisher's Exact Test	7.268			.107		
Linear-by-Linear Association	3.147[b]	1	.076	.080	.046	.016
N of Valid Cases	47					

a. 5 cells (55.6%) have expected count less than 5. The minimum expected count is 2.04.

b. The standardized statistic is 1.774.

Table 229. Job Category * StReq_6 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.409	.097	.099
	Cramer's V	.289	.097	.099
N of Valid Cases		47		

Table 230. Job Category * StReq_7 Crosstab

			StReq_7			Total
			Disagree	Neutral	Agree	
Job Category	Discipline Tech/Eng/Res/KA	Count	9	6	7	22
		Expected Count	7.0	3.7	11.2	22.0
		% within Job Category	40.9%	27.3%	31.8%	100.0%
	Systems Engineer	Count	2	1	9	12
		Expected Count	3.8	2.0	6.1	12.0
		% within Job Category	16.7%	8.3%	75.0%	100.0%
	Manager	Count	4	1	8	13
		Expected Count	4.1	2.2	6.6	13.0
		% within Job Category	30.8%	7.7%	61.5%	100.0%
Total		Count	15	8	24	47
		Expected Count	15.0	8.0	24.0	47.0
		% within Job Category	31.9%	17.0%	51.1%	100.0%

Table 231. Chi-Square Tests Job Category * StReq_7 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	7.214[a]	4	.125	.129		
Likelihood Ratio	7.500	4	.112	.154		
Fisher's Exact Test	6.612			.146		
Linear-by-Linear Association	2.212[b]	1	.137	.150	.082	.026
N of Valid Cases	47					

a. 5 cells (55.6%) have expected count less than 5. The minimum expected count is 2.04.

b. The standardized statistic is 1.487.

Table 232. Job Category * StReq_7 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.392	.125	.129
	Cramer's V	.277	.125	.129
N of Valid Cases		47		

Table 233. Job Category * SyReq_1 Crosstab

			SyReq_1			Total
			Disagree	Neutral	Agree	
Job Category	Discipline Tech/Eng/Res/KA	Count	3	6	13	22
		Expected Count	2.8	3.7	15.4	22.0
		% within Job Category	13.6%	27.3%	59.1%	100.0%
	Systems Engineer	Count	2	0	10	12
		Expected Count	1.5	2.0	8.4	12.0
		% within Job Category	16.7%	0.0%	83.3%	100.0%
	Manager	Count	1	2	10	13
		Expected Count	1.7	2.2	9.1	13.0
		% within Job Category	7.7%	15.4%	76.9%	100.0%
Total		Count	6	8	33	47
		Expected Count	6.0	8.0	33.0	47.0
		% within Job Category	12.8%	17.0%	70.2%	100.0%

2. System Requirements Analysis

Table 234. Chi-Square Tests Job Category * SyReq_1 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	4.605[a]	4	.330	.345		
Likelihood Ratio	6.470	4	.167	.254		
Fisher's Exact Test	4.577			.331		
Linear-by-Linear Association	1.023[b]	1	.312	.340	.190	.060
N of Valid Cases	47					

a. 6 cells (66.7%) have expected count less than 5. The minimum expected count is 1.53.

b. The standardized statistic is 1.012.

Table 235. Job Category * SyReq_1 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.313	.330	.345
	Cramer's V	.221	.330	.345
N of Valid Cases		47		

Table 236. Job Category * SyReq_2 Crosstab

			SyReq_2			
			Disagree	Neutral	Agree	Total
Job Category	Discipline Tech/Eng/Res/KA	Count	6	4	12	22
		Expected Count	4.2	3.3	14.5	22.0
		% within Job Category	27.3%	18.2%	54.5%	100.0%
	Systems Engineer	Count	1	1	10	12
		Expected Count	2.3	1.8	7.9	12.0
		% within Job Category	8.3%	8.3%	83.3%	100.0%
	Manager	Count	2	2	9	13
		Expected Count	2.5	1.9	8.6	13.0
		% within Job Category	15.4%	15.4%	69.2%	100.0%
Total		Count	9	7	31	47
		Expected Count	9.0	7.0	31.0	47.0
		% within Job Category	19.1%	14.9%	66.0%	100.0%

Table 237. Chi-Square Tests Job Category * SyReq_2 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	3.101[a]	4	.541	.559		
Likelihood Ratio	3.258	4	.516	.567		
Fisher's Exact Test	2.834			.623		
Linear-by-Linear Association	1.265[b]	1	.261	.286	.157	.047
N of Valid Cases	47					

a. 6 cells (66.7%) have expected count less than 5. The minimum expected count is 1.79.

b. The standardized statistic is 1.125.

Table 238. Job Category * SyReq_2 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.257	.541	.559
	Cramer's V	.182	.541	.559
N of Valid Cases		47		

Table 239. Job Category * SyReq_3 Crosstab

			SyReq_3			Total
			Disagree	Neutral	Agree	
Job Category	Discipline Tech/Eng/Res/KA	Count	8	6	8	22
		Expected Count	6.6	4.2	11.2	22.0
		% within Job Category	36.4%	27.3%	36.4%	100.0%
	Systems Engineer	Count	1	0	11	12
		Expected Count	3.6	2.3	6.1	12.0
		% within Job Category	8.3%	0.0%	91.7%	100.0%
	Manager	Count	5	3	5	13
		Expected Count	3.9	2.5	6.6	13.0
		% within Job Category	38.5%	23.1%	38.5%	100.0%
Total		Count	14	9	24	47
		Expected Count	14.0	9.0	24.0	47.0
		% within Job Category	29.8%	19.1%	51.1%	100.0%

Table 240. Chi-Square Tests Job Category * SyReq_3 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	10.872[a]	4	.028	.026		
Likelihood Ratio	13.169	4	.010	.018		
Fisher's Exact Test	10.483			.025		
Linear-by-Linear Association	.141[b]	1	.707	.770	.393	.073
N of Valid Cases	47					

a. 5 cells (55.6%) have expected count less than 5. The minimum expected count is 2.30.

b. The standardized statistic is .376.

Table 241. Job Category * SyReq_3 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.481	.028	.026
	Cramer's V	.340	.028	.026
N of Valid Cases		47		

Table 242. Job Category * SyReq_4 Crosstab

			SyReq_4			Total
			Disagree	Neutral	Agree	
Job Category	Discipline Tech/Eng/Res/KA	Count	9	4	9	22
		Expected Count	8.0	4.7	9.4	22.0
		% within Job Category	40.9%	18.2%	40.9%	100.0%
	Systems Engineer	Count	3	3	6	12
		Expected Count	4.3	2.6	5.1	12.0
		% within Job Category	25.0%	25.0%	50.0%	100.0%
	Manager	Count	5	3	5	13
		Expected Count	4.7	2.8	5.5	13.0
		% within Job Category	38.5%	23.1%	38.5%	100.0%
Total		Count	17	10	20	47
		Expected Count	17.0	10.0	20.0	47.0
		% within Job Category	36.2%	21.3%	42.6%	100.0%

Table 243. Chi-Square Tests Job Category * SyReq_4 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	.988[a]	4	.912	.929		
Likelihood Ratio	1.027	4	.906	.911		
Fisher's Exact Test	1.221			.911		
Linear-by-Linear Association	.012[b]	1	.911	.924	.495	.076
N of Valid Cases	47					

a. 5 cells (55.6%) have expected count less than 5. The minimum expected count is 2.55.

b. The standardized statistic is .111.

Table 244. Job Category * SyReq_4 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.145	.912	.929
	Cramer's V	.103	.912	.929
N of Valid Cases		47		

Table 245. Job Category * SyReq_5 Crosstab

			SyReq_5			Total
			Disagree	Neutral	Agree	
Job Category	Discipline Tech/Eng/Res/KA	Count	8	5	9	22
		Expected Count	6.1	2.8	13.1	22.0
		% within Job Category	36.4%	22.7%	40.9%	100.0%
	Systems Engineer	Count	1	0	11	12
		Expected Count	3.3	1.5	7.1	12.0
		% within Job Category	8.3%	0.0%	91.7%	100.0%
	Manager	Count	4	1	8	13
		Expected Count	3.6	1.7	7.7	13.0
		% within Job Category	30.8%	7.7%	61.5%	100.0%
Total		Count	13	6	28	47
		Expected Count	13.0	6.0	28.0	47.0
		% within Job Category	27.7%	12.8%	59.6%	100.0%

Table 246. Chi-Square Tests Job Category * SyReq_5 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	9.142[a]	4	.058	.052		
Likelihood Ratio	10.819	4	.029	.050		
Fisher's Exact Test	8.290			.060		
Linear-by-Linear Association	1.316[b]	1	.251	.285	.148	.041
N of Valid Cases	47					

a. 5 cells (55.6%) have expected count less than 5. The minimum expected count is 1.53.

b. The standardized statistic is 1.147.

Table 247. Job Category * SyReq_5 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.441	.058	.052
	Cramer's V	.312	.058	.052
N of Valid Cases		47		

Table 248. Job Category * SyReq_6 Crosstab

			SyReq_6			Total
			Disagree	Neutral	Agree	
Job Category	Discipline Tech/Eng/Res/KA	Count	7	4	11	22
		Expected Count	6.1	4.7	11.2	22.0
		% within Job Category	31.8%	18.2%	50.0%	100.0%
	Systems Engineer	Count	3	4	5	12
		Expected Count	3.3	2.6	6.1	12.0
		% within Job Category	25.0%	33.3%	41.7%	100.0%
	Manager	Count	3	2	8	13
		Expected Count	3.6	2.8	6.6	13.0
		% within Job Category	23.1%	15.4%	61.5%	100.0%
Total		Count	13	10	24	47
		Expected Count	13.0	10.0	24.0	47.0
		% within Job Category	27.7%	21.3%	51.1%	100.0%

Table 249. Chi-Square Tests Job Category * SyReq_6 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	1.890[a]	4	.756	.778		
Likelihood Ratio	1.793	4	.774	.809		
Fisher's Exact Test	1.883			.804		
Linear-by-Linear Association	.387[b]	1	.534	.552	.303	.066
N of Valid Cases	47					

a. 5 cells (55.6%) have expected count less than 5. The minimum expected count is 2.55.

b. The standardized statistic is .622.

Table 250. Job Category * SyReq_6 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.201	.756	.778
	Cramer's V	.142	.756	.778
N of Valid Cases		47		

Table 251. Job Category * SyReq_7 Crosstab

			SyReq_7			Total
			Disagree	Neutral	Agree	
Job Category	Discipline Tech/Eng/Res/KA	Count	6	6	10	22
		Expected Count	5.1	6.1	10.8	22.0
		% within Job Category	27.3%	27.3%	45.5%	100.0%
	Systems Engineer	Count	1	4	7	12
		Expected Count	2.8	3.3	5.9	12.0
		% within Job Category	8.3%	33.3%	58.3%	100.0%
	Manager	Count	4	3	6	13
		Expected Count	3.0	3.6	6.4	13.0
		% within Job Category	30.8%	23.1%	46.2%	100.0%
Total		Count	11	13	23	47
		Expected Count	11.0	13.0	23.0	47.0
		% within Job Category	23.4%	27.7%	48.9%	100.0%

Table 252. Job Category * SyReq_7 Symmetric Measures

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	2.138[a]	4	.710	.727		
Likelihood Ratio	2.477	4	.649	.676		
Fisher's Exact Test	2.264			.716		
Linear-by-Linear Association	.004[b]	1	.950	1.000	.519	.083
N of Valid Cases	47					

a. 4 cells (44.4%) have expected count less than 5. The minimum expected count is 2.81.

b. The standardized statistic is .063.

Table 253. Chi-Square Tests Job Category * SyReq_7 Crosstab

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.213	.710	.727
	Cramer's V	.151	.710	.727
N of Valid Cases		47		

3. System Architecture

Table 254. Job Category * SyArc_1 Crosstab

			SyArc_1			
			Disagree	Neutral	Agree	Total
Job Category	Discipline Tech/Eng/Res/KA	Count	2	5	15	22
		Expected Count	2.3	3.7	15.9	22.0
		% within Job Category	9.1%	22.7%	68.2%	100.0%
	Systems Engineer	Count	0	2	10	12
		Expected Count	1.3	2.0	8.7	12.0
		% within Job Category	0.0%	16.7%	83.3%	100.0%
	Manager	Count	3	1	9	13
		Expected Count	1.4	2.2	9.4	13.0
		% within Job Category	23.1%	7.7%	69.2%	100.0%
Total		Count	5	8	34	47
		Expected Count	5.0	8.0	34.0	47.0
		% within Job Category	10.6%	17.0%	72.3%	100.0%

Table 255. Chi-Square Tests Job Category * SyArc_1 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	4.574[a]	4	.334	.345		
Likelihood Ratio	5.498	4	.240	.359		
Fisher's Exact Test	3.918			.415		
Linear-by-Linear Association	.137[b]	1	.711	.802	.401	.092
N of Valid Cases	47					

a. 6 cells (66.7%) have expected count less than 5. The minimum expected count is 1.28.

b. The standardized statistic is -.370.

Table 256. Job Category * SyArc_1 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.312	.334	.345
	Cramer's V	.221	.334	.345
N of Valid Cases		47		

Table 257. Job Category * SyArc_2 Crosstab

			SyArc_2			Total
			Disagree	Neutral	Agree	
Job Category	Discipline Tech/Eng/Res/KA	Count	2	5	15	22
		Expected Count	2.3	3.7	15.9	22.0
		% within Job Category	9.1%	22.7%	68.2%	100.0%
	Systems Engineer	Count	0	2	10	12
		Expected Count	1.3	2.0	8.7	12.0
		% within Job Category	0.0%	16.7%	83.3%	100.0%
	Manager	Count	3	1	9	13
		Expected Count	1.4	2.2	9.4	13.0
		% within Job Category	23.1%	7.7%	69.2%	100.0%
Total		Count	5	8	34	47
		Expected Count	5.0	8.0	34.0	47.0
		% within Job Category	10.6%	17.0%	72.3%	100.0%

Table 258. Chi-Square Tests Job Category * SyArc_2 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	4.574[a]	4	.334	.345		
Likelihood Ratio	5.498	4	.240	.359		
Fisher's Exact Test	3.918			.415		
Linear-by-Linear Association	.137[b]	1	.711	.802	.401	.092
N of Valid Cases	47					

a. 6 cells (66.7%) have expected count less than 5. The minimum expected count is 1.28.

b. The standardized statistic is -.370.

Table 259. Job Category * SyArc_2 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.312	.334	.345
	Cramer's V	.221	.334	.345
N of Valid Cases		47		

Table 260. Job Category * SyArc_3 Crosstab

			SyArc_3			Total
			Disagree	Neutral	Agree	
Job Category	Discipline Tech/Eng/Res/KA	Count	6	5	11	22
		Expected Count	5.1	3.7	13.1	22.0
		% within Job Category	27.3%	22.7%	50.0%	100.0%
	Systems Engineer	Count	2	1	9	12
		Expected Count	2.8	2.0	7.1	12.0
		% within Job Category	16.7%	8.3%	75.0%	100.0%
	Manager	Count	3	2	8	13
		Expected Count	3.0	2.2	7.7	13.0
		% within Job Category	23.1%	15.4%	61.5%	100.0%
Total		Count	11	8	28	47
		Expected Count	11.0	8.0	28.0	47.0
		% within Job Category	23.4%	17.0%	59.6%	100.0%

Table 261. Chi-Square Tests Job Category * SyArc_3 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	2.174[a]	4	.704	.708		
Likelihood Ratio	2.260	4	.688	.714		
Fisher's Exact Test	2.047			.753		
Linear-by-Linear Association	.446[b]	1	.504	.543	.289	.066
N of Valid Cases	47					

a. 5 cells (55.6%) have expected count less than 5. The minimum expected count is 2.04.

b. The standardized statistic is .668.

Table 262. Job Category * SyArc_3 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.215	.704	.708
	Cramer's V	.152	.704	.708
N of Valid Cases		47		

Table 263. Job Category * SyArc_4 Crosstab

			SyArc_4			Total
			Disagree	Neutral	Agree	
Job Category	Discipline Tech/Eng/Res/KA	Count	5	6	11	22
		Expected Count	4.2	4.7	13.1	22.0
		% within Job Category	22.7%	27.3%	50.0%	100.0%
	Systems Engineer	Count	0	3	9	12
		Expected Count	2.3	2.6	7.1	12.0
		% within Job Category	0.0%	25.0%	75.0%	100.0%
	Manager	Count	4	1	8	13
		Expected Count	2.5	2.8	7.7	13.0
		% within Job Category	30.8%	7.7%	61.5%	100.0%
Total		Count	9	10	28	47
		Expected Count	9.0	10.0	28.0	47.0
		% within Job Category	19.1%	21.3%	59.6%	100.0%

Table 264. Chi-Square Tests Job Category * SyArc_4 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	5.765[a]	4	.217	.226		
Likelihood Ratio	8.229	4	.084	.137		
Fisher's Exact Test	5.987			.198		
Linear-by-Linear Association	.127[b]	1	.722	.748	.406	.081
N of Valid Cases	47					

a. 6 cells (66.7%) have expected count less than 5. The minimum expected count is 2.30.

b. The standardized statistic is .356.

Table 265. Job Category * SyArc_4 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.350	.217	.226
	Cramer's V	.248	.217	.226
N of Valid Cases		47		

Table 266. Job Category * SyArc_5 Crosstab

			SyArc_5			Total
			Disagree	Neutral	Agree	
Job Category	Discipline Tech/Eng/Res/KA	Count	2	4	16	22
		Expected Count	3.3	2.8	15.9	22.0
		% within Job Category	9.1%	18.2%	72.7%	100.0%
	Systems Engineer	Count	2	1	9	12
		Expected Count	1.8	1.5	8.7	12.0
		% within Job Category	16.7%	8.3%	75.0%	100.0%
	Manager	Count	3	1	9	13
		Expected Count	1.9	1.7	9.4	13.0
		% within Job Category	23.1%	7.7%	69.2%	100.0%
Total		Count	7	6	34	47
		Expected Count	7.0	6.0	34.0	47.0
		% within Job Category	14.9%	12.8%	72.3%	100.0%

Table 267. Chi-Square Tests Job Category * SyArc_5 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	2.089[a]	4	.719	.771		
Likelihood Ratio	2.095	4	.718	.771		
Fisher's Exact Test	2.117			.752		
Linear-by-Linear Association	.434[b]	1	.510	.566	.293	.073
N of Valid Cases	47					

a. 6 cells (66.7%) have expected count less than 5. The minimum expected count is 1.53.

b. The standardized statistic is -.659.

Table 268. Job Category * SyArc_5 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.211	.719	.771
	Cramer's V	.149	.719	.771
N of Valid Cases		47		

4. System Design and Analysis

Table 269. Job Category * Sy_Des_Anl_1 Crosstab

			Sy_Des_Anl_1			Total
			Disagree	Neutral	Agree	
Job Category	Discipline Tech/Eng/Res/KA	Count	0	7	15	22
		Expected Count	1.9	3.7	16.4	22.0
		% within Job Category	0.0%	31.8%	68.2%	100.0%
	Systems Engineer	Count	1	0	11	12
		Expected Count	1.0	2.0	8.9	12.0
		% within Job Category	8.3%	0.0%	91.7%	100.0%
	Manager	Count	3	1	9	13
		Expected Count	1.1	2.2	9.7	13.0
		% within Job Category	23.1%	7.7%	69.2%	100.0%
Total		Count	4	8	35	47
		Expected Count	4.0	8.0	35.0	47.0
		% within Job Category	8.5%	17.0%	74.5%	100.0%

Table 270. Chi-Square Tests Job Category * Sy_Des_Anl_1 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	11.292[a]	4	.023	.020		
Likelihood Ratio	13.725	4	.008	.012		
Fisher's Exact Test	9.913			.017		
Linear-by-Linear Association	.699[b]	1	.403	.421	.243	.075
N of Valid Cases	47					

a. 6 cells (66.7%) have expected count less than 5. The minimum expected count is 1.02.

b. The standardized statistic is -.836.

Table 271. Job Category * Sy_Des_Anl_1 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.490	.023	.020
	Cramer's V	.347	.023	.020
N of Valid Cases		47		

Table 272. Job Category * Sy_Des_Anl_2 Crosstab

			Sy_Des_Anl_2			Total
			Disagree	Neutral	Agree	
Job Category	Discipline Tech/Eng/Res/KA	Count	1	7	14	22
		Expected Count	1.4	5.6	15.0	22.0
		% within Job Category	4.5%	31.8%	63.6%	100.0%
	Systems Engineer	Count	0	2	10	12
		Expected Count	.8	3.1	8.2	12.0
		% within Job Category	0.0%	16.7%	83.3%	100.0%
	Manager	Count	2	3	8	13
		Expected Count	.8	3.3	8.9	13.0
		% within Job Category	15.4%	23.1%	61.5%	100.0%
Total		Count	3	12	32	47
		Expected Count	3.0	12.0	32.0	47.0
		% within Job Category	6.4%	25.5%	68.1%	100.0%

Table 273. Chi-Square Tests Job Category * Sy_Des_Anl_2 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	3.829[a]	4	.430	.495		
Likelihood Ratio	4.141	4	.387	.524		
Fisher's Exact Test	3.187			.541		
Linear-by-Linear Association	.169[b]	1	.681	.780	.391	.101
N of Valid Cases	47					

a. 5 cells (55.6%) have expected count less than 5. The minimum expected count is .77.

b. The standardized statistic is -.411.

Table 274. Job Category * Sy_Des_Anl_2 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.285	.430	.495
	Cramer's V	.202	.430	.495
N of Valid Cases		47		

Table 275. Job Category * Sy_Des_Anl_3 Crosstab

			Sy_Des_Anl_3			Total
			Disagree	Neutral	Agree	
Job Category	Discipline Tech/Eng/Res/KA	Count	5	8	9	22
		Expected Count	4.2	5.1	12.6	22.0
		% within Job Category	22.7%	36.4%	40.9%	100.0%
	Systems Engineer	Count	1	1	10	12
		Expected Count	2.3	2.8	6.9	12.0
		% within Job Category	8.3%	8.3%	83.3%	100.0%
	Manager	Count	3	2	8	13
		Expected Count	2.5	3.0	7.5	13.0
		% within Job Category	23.1%	15.4%	61.5%	100.0%
Total		Count	9	11	27	47
		Expected Count	9.0	11.0	27.0	47.0
		% within Job Category	19.1%	23.4%	57.4%	100.0%

Table 276. Chi-Square Tests Job Category * Sy_Des_Anl_3 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	6.570[a]	4	.160	.164		
Likelihood Ratio	6.905	4	.141	.195		
Fisher's Exact Test	6.023			.197		
Linear-by-Linear Association	.939[b]	1	.333	.387	.197	.056
N of Valid Cases	47					

a. 5 cells (55.6%) have expected count less than 5. The minimum expected count is 2.30.

b. The standardized statistic is .969.

Table 277. Job Category * Sy_Des_Anl_3 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.374	.160	.164
	Cramer's V	.264	.160	.164
N of Valid Cases		47		

5. System Assessment, Selection and Implementation

Table 278. Job Category * Sy_Ass_Sel_Imp_1 Crosstab

			Sy_Ass_Sel_Imp_1			
			Disagree	Neutral	Agree	Total
Job Category	Discipline Tech/Eng/Res/KA	Count	9	8	5	22
		Expected Count	8.0	5.6	8.4	22.0
		% within Job Category	40.9%	36.4%	22.7%	100.0%
	Systems Engineer	Count	4	2	6	12
		Expected Count	4.3	3.1	4.6	12.0
		% within Job Category	33.3%	16.7%	50.0%	100.0%
	Manager	Count	4	2	7	13
		Expected Count	4.7	3.3	5.0	13.0
		% within Job Category	30.8%	15.4%	53.8%	100.0%
Total		Count	17	12	18	47
		Expected Count	17.0	12.0	18.0	47.0
		% within Job Category	36.2%	25.5%	38.3%	100.0%

Table 279. Chi-Square Tests Job Category * Sy_Ass_Sel_Imp_1 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	4.815[a]	4	.307	.318		
Likelihood Ratio	4.946	4	.293	.320		
Fisher's Exact Test	4.641			.319		
Linear-by-Linear Association	2.044[b]	1	.153	.166	.092	.029
N of Valid Cases	47					

a. 6 cells (66.7%) have expected count less than 5. The minimum expected count is 3.06.

b. The standardized statistic is 1.430.

Table 280. Job Category * Sy_Ass_Sel_Imp_1 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.320	.307	.318
	Cramer's V	.226	.307	.318
N of Valid Cases		47		

Table 281. Job Category * Sy_Ass_Sel_2 Crosstab

			Sy_Ass_Sel_Imp_2			Total
			Disagree	Neutral	Agree	
Job Category	Discipline Tech/Eng/Res/KA	Count	4	9	9	22
		Expected Count	4.7	6.1	11.2	22.0
		% within Job Category	18.2%	40.9%	40.9%	100.0%
	Systems Engineer	Count	2	1	9	12
		Expected Count	2.6	3.3	6.1	12.0
		% within Job Category	16.7%	8.3%	75.0%	100.0%
	Manager	Count	4	3	6	13
		Expected Count	2.8	3.6	6.6	13.0
		% within Job Category	30.8%	23.1%	46.2%	100.0%
Total		Count	10	13	24	47
		Expected Count	10.0	13.0	24.0	47.0
		% within Job Category	21.3%	27.7%	51.1%	100.0%

Table 282. Chi-Square Tests Job Category * Sy_Ass_Sel_Imp_2 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	5.737[a]	4	.220	.224		
Likelihood Ratio	5.991	4	.200	.237		
Fisher's Exact Test	5.430			.241		
Linear-by-Linear Association	.005[b]	1	.945	1.000	.513	.085
N of Valid Cases	47					

a. 5 cells (55.6%) have expected count less than 5. The minimum expected count is 2.55.

b. The standardized statistic is -.069.

Table 283. Job Category * Sy_Ass_Sel_Imp_2 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.349	.220	.224
	Cramer's V	.247	.220	.224
N of Valid Cases		47		

Table 284. Job Category * Sy_Ass_Sel_3 Crosstab

			Sy_Ass_Sel_Imp_3			Total
			Disagree	Neutral	Agree	
Job Category	Discipline Tech/Eng/Res/KA	Count	3	3	16	22
		Expected Count	3.3	3.7	15.0	22.0
		% within Job Category	13.6%	13.6%	72.7%	100.0%
	Systems Engineer	Count	0	3	9	12
		Expected Count	1.8	2.0	8.2	12.0
		% within Job Category	0.0%	25.0%	75.0%	100.0%
	Manager	Count	4	2	7	13
		Expected Count	1.9	2.2	8.9	13.0
		% within Job Category	30.8%	15.4%	53.8%	100.0%
Total		Count	7	8	32	47
		Expected Count	7.0	8.0	32.0	47.0
		% within Job Category	14.9%	17.0%	68.1%	100.0%

Table 285. Chi-Square Tests Job Category * Sy_Ass_Sel_Imp_3 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	5.169[a]	4	.270	.282		
Likelihood Ratio	6.414	4	.170	.279		
Fisher's Exact Test	4.885			.316		
Linear-by-Linear Association	1.461[b]	1	.227	.250	.140	.044
N of Valid Cases	47					

a. 6 cells (66.7%) have expected count less than 5. The minimum expected count is 1.79.

b. The standardized statistic is -1.209.

Table 286. Job Category * Sy_Ass_Sel_Imp_3 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.332	.270	.282
	Cramer's V	.234	.270	.282
N of Valid Cases		47		

6. System Integration

Table 287. Job Category * SyInt_1 Crosstab

			SyInt_1			Total
			Disagree	Neutral	Agree	
Job Category	Discipline Tech/Eng/Res/KA	Count	9	6	7	22
		Expected Count	8.4	4.2	9.4	22.0
		% within Job Category	40.9%	27.3%	31.8%	100.0%
	Systems Engineer	Count	4	2	6	12
		Expected Count	4.6	2.3	5.1	12.0
		% within Job Category	33.3%	16.7%	50.0%	100.0%
	Manager	Count	5	1	7	13
		Expected Count	5.0	2.5	5.5	13.0
		% within Job Category	38.5%	7.7%	53.8%	100.0%
Total		Count	18	9	20	47
		Expected Count	18.0	9.0	20.0	47.0
		% within Job Category	38.3%	19.1%	42.6%	100.0%

Table 288. Chi-Square Tests Job Category * SyInt_1 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	2.946[a]	4	.567	.600		
Likelihood Ratio	3.144	4	.534	.565		
Fisher's Exact Test	2.858			.618		
Linear-by-Linear Association	.700[b]	1	.403	.448	.231	.054
N of Valid Cases	47					

a. 5 cells (55.6%) have expected count less than 5. The minimum expected count is 2.30.

b. The standardized statistic is .837.

Table 289. Job Category * SyInt_1 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.250	.567	.600
	Cramer's V	.177	.567	.600
N of Valid Cases		47		

Table 290. Job Category * SyInt_2 Crosstab

			SyInt_2			Total
			Disagree	Neutral	Agree	
Job Category	Discipline Tech/Eng/Res/KA	Count	5	2	15	22
		Expected Count	5.6	1.4	15.0	22.0
		% within Job Category	22.7%	9.1%	68.2%	100.0%
	Systems Engineer	Count	4	1	7	12
		Expected Count	3.1	.8	8.2	12.0
		% within Job Category	33.3%	8.3%	58.3%	100.0%
	Manager	Count	3	0	10	13
		Expected Count	3.3	.8	8.9	13.0
		% within Job Category	23.1%	0.0%	76.9%	100.0%
Total		Count	12	3	32	47
		Expected Count	12.0	3.0	32.0	47.0
		% within Job Category	25.5%	6.4%	68.1%	100.0%

Table 291. Chi-Square Tests Job Category * SyInt_2 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	1.855[a]	4	.762	.797		
Likelihood Ratio	2.630	4	.622	.793		
Fisher's Exact Test	1.938			.819		
Linear-by-Linear Association	.027[b]	1	.870	.915	.474	.070
N of Valid Cases	47					

a. 5 cells (55.6%) have expected count less than 5. The minimum expected count is .77.

b. The standardized statistic is .164.

Table 292. Job Category * SyInt_2 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.199	.762	.797
	Cramer's V	.140	.762	.797
N of Valid Cases		47		

Table 293. Job Category * SyInt_3 Crosstab

			SyInt_3			Total
			Disagree	Neutral	Agree	
Job Category	Discipline Tech/Eng/Res/KA	Count	7	6	9	22
		Expected Count	7.0	4.7	10.3	22.0
		% within Job Category	31.8%	27.3%	40.9%	100.0%
	Systems Engineer	Count	4	2	6	12
		Expected Count	3.8	2.6	5.6	12.0
		% within Job Category	33.3%	16.7%	50.0%	100.0%
	Manager	Count	4	2	7	13
		Expected Count	4.1	2.8	6.1	13.0
		% within Job Category	30.8%	15.4%	53.8%	100.0%
Total		Count	15	10	22	47
		Expected Count	15.0	10.0	22.0	47.0
		% within Job Category	31.9%	21.3%	46.8%	100.0%

Table 294. Chi-Square Tests Job Category * SyInt_3 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	1.044[a]	4	.903	.910		
Likelihood Ratio	1.046	4	.903	.904		
Fisher's Exact Test	1.105			.935		
Linear-by-Linear Association	.211[b]	1	.646	.697	.361	.070
N of Valid Cases	47					

a. 5 cells (55.6%) have expected count less than 5. The minimum expected count is 2.55.

b. The standardized statistic is .459.

Table 295. Job Category * SyInt_3 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.149	.903	.910
	Cramer's V	.105	.903	.910
N of Valid Cases		47		

Table 296. Job Category * SyInt_4 Crosstab

			SyInt_4			Total
			Disagree	Neutral	Agree	
Job Category	Discipline Tech/Eng/Res/KA	Count	5	6	11	22
		Expected Count	6.1	6.1	9.8	22.0
		% within Job Category	22.7%	27.3%	50.0%	100.0%
	Systems Engineer	Count	3	4	5	12
		Expected Count	3.3	3.3	5.4	12.0
		% within Job Category	25.0%	33.3%	41.7%	100.0%
	Manager	Count	5	3	5	13
		Expected Count	3.6	3.6	5.8	13.0
		% within Job Category	38.5%	23.1%	38.5%	100.0%
Total		Count	13	13	21	47
		Expected Count	13.0	13.0	21.0	47.0
		% within Job Category	27.7%	27.7%	44.7%	100.0%

Table 297. Chi-Square Tests Job Category * SyInt_4 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	1.288[a]	4	.863	.872		
Likelihood Ratio	1.240	4	.871	.882		
Fisher's Exact Test	1.421			.882		
Linear-by-Linear Association	.846[b]	1	.358	.413	.208	.054
N of Valid Cases	47					

a. 4 cells (44.4%) have expected count less than 5. The minimum expected count is 3.32.

b. The standardized statistic is -.920.

Table 298. Job Category * SyInt_4 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.166	.863	.872
	Cramer's V	.117	.863	.872
N of Valid Cases		47		

Table 299. Job Category * SyInt_5 Crosstab

			SyInt_5			Total
			Disagree	Neutral	Agree	
Job Category	Discipline Tech/Eng/Res/KA	Count	4	10	8	22
		Expected Count	5.1	7.5	9.4	22.0
		% within Job Category	18.2%	45.5%	36.4%	100.0%
	Systems Engineer	Count	3	4	5	12
		Expected Count	2.8	4.1	5.1	12.0
		% within Job Category	25.0%	33.3%	41.7%	100.0%
	Manager	Count	4	2	7	13
		Expected Count	3.0	4.4	5.5	13.0
		% within Job Category	30.8%	15.4%	53.8%	100.0%
Total		Count	11	16	20	47
		Expected Count	11.0	16.0	20.0	47.0
		% within Job Category	23.4%	34.0%	42.6%	100.0%

Table 300. Chi-Square Tests Job Category * SyInt_5 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	3.333[a]	4	.504	.521		
Likelihood Ratio	3.571	4	.467	.491		
Fisher's Exact Test	3.482			.489		
Linear-by-Linear Association	.025[b]	1	.875	.914	.482	.085
N of Valid Cases	47					

a. 4 cells (44.4%) have expected count less than 5. The minimum expected count is 2.81.

b. The standardized statistic is .157.

Table 301. Job Category * SyInt_5 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.266	.504	.521
	Cramer's V	.188	.504	.521
N of Valid Cases		47		

Table 302. Job Category * SyInt_6 Crosstab

			SyInt_6			Total
			Disagree	Neutral	Agree	
Job Category	Discipline Tech/Eng/Res/KA	Count	3	9	10	22
		Expected Count	4.7	6.6	10.8	22.0
		% within Job Category	13.6%	40.9%	45.5%	100.0%
	Systems Engineer	Count	3	3	6	12
		Expected Count	2.6	3.6	5.9	12.0
		% within Job Category	25.0%	25.0%	50.0%	100.0%
	Manager	Count	4	2	7	13
		Expected Count	2.8	3.9	6.4	13.0
		% within Job Category	30.8%	15.4%	53.8%	100.0%
Total		Count	10	14	23	47
		Expected Count	10.0	14.0	23.0	47.0
		% within Job Category	21.3%	29.8%	48.9%	100.0%

Table 303. Chi-Square Tests Job Category * SyInt_6 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	3.265[a]	4	.515	.544		
Likelihood Ratio	3.387	4	.495	.549		
Fisher's Exact Test	3.308			.529		
Linear-by-Linear Association	.107[b]	1	.743	.748	.412	.081
N of Valid Cases	47					

a. 5 cells (55.6%) have expected count less than 5. The minimum expected count is 2.55.

b. The standardized statistic is -.328.

Table 304. Job Category * SyInt_6 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.264	.515	.544
	Cramer's V	.186	.515	.544
N of Valid Cases		47		

7. System Verification and Validation

Table 305. Job Category * SyVV_1 Crosstab

			SyVV_1			Total
			Disagree	Neutral	Agree	
Job Category	Discipline Tech/Eng/Res/KA	Count	6	3	13	22
		Expected Count	6.1	3.3	12.6	22.0
		% within Job Category	27.3%	13.6%	59.1%	100.0%
	Systems Engineer	Count	2	2	8	12
		Expected Count	3.3	1.8	6.9	12.0
		% within Job Category	16.7%	16.7%	66.7%	100.0%
	Manager	Count	5	2	6	13
		Expected Count	3.6	1.9	7.5	13.0
		% within Job Category	38.5%	15.4%	46.2%	100.0%
Total		Count	13	7	27	47
		Expected Count	13.0	7.0	27.0	47.0
		% within Job Category	27.7%	14.9%	57.4%	100.0%

Table 306. Chi-Square Tests Job Category * SyVV_1 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	1.601[a]	4	.809	.833		
Likelihood Ratio	1.641	4	.801	.816		
Fisher's Exact Test	1.817			.833		
Linear-by-Linear Association	.425[b]	1	.514	.559	.290	.063
N of Valid Cases	47					

a. 5 cells (55.6%) have expected count less than 5. The minimum expected count is 1.79.

b. The standardized statistic is -.652.

Table 307. Job Category * SyVV_1 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.185	.809	.833
	Cramer's V	.131	.809	.833
N of Valid Cases		47		

Table 308. Job Category * SyVV_2 Crosstab

			SyVV_2			Total
			Disagree	Neutral	Agree	
Job Category	Discipline Tech/Eng/Res/KA	Count	5	4	13	22
		Expected Count	4.7	4.2	13.1	22.0
		% within Job Category	22.7%	18.2%	59.1%	100.0%
	Systems Engineer	Count	1	2	9	12
		Expected Count	2.6	2.3	7.1	12.0
		% within Job Category	8.3%	16.7%	75.0%	100.0%
	Manager	Count	4	3	6	13
		Expected Count	2.8	2.5	7.7	13.0
		% within Job Category	30.8%	23.1%	46.2%	100.0%
Total		Count	10	9	28	47
		Expected Count	10.0	9.0	28.0	47.0
		% within Job Category	21.3%	19.1%	59.6%	100.0%

Table 309. Chi-Square Tests Job Category * SyVV_2 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	2.544[a]	4	.637	.666		
Likelihood Ratio	2.756	4	.600	.648		
Fisher's Exact Test	2.620			.661		
Linear-by-Linear Association	.290[b]	1	.590	.603	.332	.072
N of Valid Cases	47					

a. 6 cells (66.7%) have expected count less than 5. The minimum expected count is 2.30.

b. The standardized statistic is -.538.

Table 310. Job Category * SyVV_2 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.233	.637	.666
	Cramer's V	.165	.637	.666
N of Valid Cases		47		

Table 311. Job Category * SyVV_3 Crosstab

			SyVV_3			Total
			Disagree	Neutral	Agree	
Job Category	Discipline Tech/Eng/Res/KA	Count	2	6	14	22
		Expected Count	3.3	4.2	14.5	22.0
		% within Job Category	9.1%	27.3%	63.6%	100.0%
	Systems Engineer	Count	1	2	9	12
		Expected Count	1.8	2.3	7.9	12.0
		% within Job Category	8.3%	16.7%	75.0%	100.0%
	Manager	Count	4	1	8	13
		Expected Count	1.9	2.5	8.6	13.0
		% within Job Category	30.8%	7.7%	61.5%	100.0%
Total		Count	7	9	31	47
		Expected Count	7.0	9.0	31.0	47.0
		% within Job Category	14.9%	19.1%	66.0%	100.0%

Table 312. Chi-Square Tests Job Category * SyVV_3 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	4.937[a]	4	.294	.317		
Likelihood Ratio	4.733	4	.316	.414		
Fisher's Exact Test	4.242			.394		
Linear-by-Linear Association	.622[b]	1	.430	.492	.251	.066
N of Valid Cases	47					

a. 6 cells (66.7%) have expected count less than 5. The minimum expected count is 1.79.

b. The standardized statistic is -.789.

Table 313. Job Category * SyVV_3 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.324	.294	.317
	Cramer's V	.229	.294	.317
N of Valid Cases		47		

Table 314. Job Category * SyVV_4 Crosstab

			SyVV_4			Total
			Disagree	Neutral	Agree	
Job Category	Discipline Tech/Eng/Res/KA	Count	4	3	15	22
		Expected Count	3.3	3.3	15.4	22.0
		% within Job Category	18.2%	13.6%	68.2%	100.0%
	Systems Engineer	Count	0	3	9	12
		Expected Count	1.8	1.8	8.4	12.0
		% within Job Category	0.0%	25.0%	75.0%	100.0%
	Manager	Count	3	1	9	13
		Expected Count	1.9	1.9	9.1	13.0
		% within Job Category	23.1%	7.7%	69.2%	100.0%
Total		Count	7	7	33	47
		Expected Count	7.0	7.0	33.0	47.0
		% within Job Category	14.9%	14.9%	70.2%	100.0%

Table 315. Chi-Square Tests Job Category * SyVV_4 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	3.884[a]	4	.422	.463		
Likelihood Ratio	5.534	4	.237	.374		
Fisher's Exact Test	3.878			.471		
Linear-by-Linear Association	.000[b]	1	.996	1.000	.539	.091
N of Valid Cases	47					

a. 6 cells (66.7%) have expected count less than 5. The minimum expected count is 1.79.

b. The standardized statistic is -.005.

Table 316. Job Category * SyVV_4 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.287	.422	.463
	Cramer's V	.203	.422	.463
N of Valid Cases		47		

Table 317. Job Category * SyVV_5 Crosstab

			SyVV_5			Total
			Disagree	Neutral	Agree	
Job Category	Discipline Tech/Eng/Res/KA	Count	4	3	15	22
		Expected Count	3.3	3.7	15.0	22.0
		% within Job Category	18.2%	13.6%	68.2%	100.0%
	Systems Engineer	Count	0	3	9	12
		Expected Count	1.8	2.0	8.2	12.0
		% within Job Category	0.0%	25.0%	75.0%	100.0%
	Manager	Count	3	2	8	13
		Expected Count	1.9	2.2	8.9	13.0
		% within Job Category	23.1%	15.4%	61.5%	100.0%
Total		Count	7	8	32	47
		Expected Count	7.0	8.0	32.0	47.0
		% within Job Category	14.9%	17.0%	68.1%	100.0%

Table 318. Chi-Square Tests Job Category * SyVV_5 Crosstab

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	3.315[a]	4	.507	.547		
Likelihood Ratio	4.961	4	.291	.402		
Fisher's Exact Test	3.499			.509		
Linear-by-Linear Association	.079[b]	1	.779	.819	.431	.087
N of Valid Cases	47					

a. 6 cells (66.7%) have expected count less than 5. The minimum expected count is 1.79.

b. The standardized statistic is -.281.

Table 319. Job Category * SyVV_5 Symmetric Measures

		Value	Approximate Significance	Exact Significance
Nominal by Nominal	Phi	.266	.507	.547
	Cramer's V	.188	.507	.547
N of Valid Cases		47		