University of Southern Queensland
Faculty of Health, Engineering & Sciences

Applying Systems Engineering Approaches to the Management of Electrical Engineering Projects

A dissertation submitted by
Darius Nooriafshar

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Abstract

Electrical engineering projects are becoming increasingly complex due to the advances in technology. Traditional project management practices and approaches may not be the best method. Research has indicated that a large portion of electrical engineering projects are not completed successfully. Therefore, adopting new processes and methods in order to attempt to improve project success rates is worth investigating. Generally, projects have been viewed with a static approach. Modern electrical engineering projects, however, are complex dynamic systems and should be viewed and managed in a holistic way. A project can be viewed as a closed loop system with external and internal factors that can impact the outcome. Hence, this research project explores the application of systems engineering approaches to the management of electrical engineering projects. An initial investigation of the relevant literature revealed that there was a knowledge gap in applying systems engineering to the management of electrical engineering projects. The identified gap led to the development of the in-depth interview instrument. Five senior key domain experts were selected for in-depth interviewing with the purpose of acquiring experiential knowledge. From this extracted knowledge and literature review, a systems engineering model for electrical engineering project management was developed. The model was built on existing project management methodologies and was refined for electrical engineering based projects. The model was tested on a hypothetical electrical engineering project and verified by obtaining feedback from the domain experts. The outcome from the testing and verification suggested that the model has the potential to help improve the project management process in the electrical engineering industry. Project management is an ever growing, changing and challenging industry. Hence, the results from this research study help to contribute to the knowledge base of project management in the electrical engineering environment.

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Darius Nooriafshar

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List of Abbreviations

INCOSE	International Council On Systems Engineering
PM	Project Manager
PMBOK	Project Management Body Of Knowledge
PMI	Project Management Institute
PRINCE2	Projects In A Controlled Environment
SE	Systems Engineering

Chapter 1

Introduction

This chapter will provide a background on project management and electrical engineering projects. It will introduce the idea of adopting a systems engineering approach to project management and briefly discuss the importance of improving current project processes being utilised in electrical engineering projects. The main purpose of this research study will be presented by discussing the aims and objectives, research motivation, justification and scope. Finally, the organisation of the following chapters of the dissertation will be mentioned.

1.1 Background

As technology continues to improve and advance, the number of electrical engineering projects being carried out will continue to increase. For example, large nationwide telecommunications network projects have become extremely common. The number of electrical engineering projects is growing rapidly as the industry moves to a more automated and digital platform. Hence, project management improvement techniques is an area that is extremely important and worth investigating. Millions of dollars worth of equipment and technology are involved in electrical engineering projects. Therefore, improving the success rate of these projects will be extremely beneficial to all stakeholders involved.

Perhaps a traditional approach to managing a project would be to focus on the individual aspects such as cost, time and quality. These three aspects are often referred to as the iron triangle or triple constraint triangle. As suggested by Caccamese and Bragantini (2012), it is common for a project manager to have to balance these three constraints in a trade-off manner. For example, if a project needs to be completed in a shorter timeframe, one option could be to employ more manpower and labour. Therefore, the cost of the project would increase, however, the schedule/timeline would decrease. Another scenario might be that the quality of a project would suffer if shortcuts were taken in order to reduce the schedule. The balancing of these constraints is an approach generally adopted by project managers with a background in business. Electrical engineers, however, have a different way of thinking and

approaching problems. It could be suggested that business graduate project managers lack the engineering skills and systems knowledge required to solve complex problems. Hence, this unique way of thinking about things with an engineering mind could be greatly utilised in project management. The ability to break a larger problem or system down into smaller sub systems is the basis of systems engineering. This approach could be applied to large engineering projects in the electrical industry. The project could be viewed as a number of smaller interrelated parts of a larger system. Farnell, Saddington and Lacey (2019), suggest that while each sub system may have a particular function, it will also have an impact on the entire system. This is applicable in electrical engineering projects as individual tasks should not be viewed in isolation. In other words, discrete components of a project should not be looked at in isolation. They are interrelated parts of a larger, more complex system and a holistic approach needs to be adopted. Systems engineering brings together a number of sub systems from different disciplines and interconnects them. Applying this approach to electrical engineering project management, would allow the project to essentially be viewed and treated as a system. The project could then be broken down into smaller more manageable systems. Hence, projects may be considered as systems and processes made up of many interrelated components. They are not one large process immune to changes or disturbances introduced in different sub systems. Therefore, the three main hypotheses that this research project will test are:

- There is a strong connection and overlap between systems engineering and project management. Systems engineering and project management appear to complement one another.
- Electrical engineering projects are dynamic in nature and should be treated as systems.
- Management of electrical engineering projects adopting a systems engineering approach could be more suitable than traditional project management methods.

1.2 Aims and Objectives

The purpose of this research is to identify and determine if it is possible to apply systems engineering approaches to electrical engineering project management.

The main objectives are:

1. Perform a critical review of the relevant literature regarding project management in engineering, systems engineering approaches and previous electrical engineering projects.
2. Identify the domain experts based on a number of criteria (position, relevant qualifications and experience).
3. Develop the in-depth interview instrument based on the knowledge gap identified in the literature review.
4. Conduct the in-depth interviews with the identified senior domain experts.
5. Analyse the information obtained manually by theme with a view to generate domain knowledge.
6. Use the domain knowledge to develop an initial model for the systems engineering approach to electrical engineering projects.
7. Have the model verified by the domain experts to obtain feedback in order to refine and improve the model.

1.3 Research Motivation

Initial investigations into the management of electrical engineering projects suggested that there appeared to be a lack of adoption of systems engineering approaches. Hence, the purpose of this present study is to investigate the possibility of adopting a systems engineering approach to the management of electrical engineering projects. Applying systems engineering approaches to electrical engineering projects could potentially have many benefits. For example, it could help to reduce the cost of a project, possibly increase the ability to finish a project on time and contribute to the overall knowledge base of electrical engineering project management.

1.4 Justification

The goal and purpose of this present research is to help to contribute to the improvement of project management processes in electrical engineering projects. This research focuses specifically on electrical engineering projects, however, the findings and model presented could possibly be applied to project management within the other engineering disciplines. This may help to improve the timely completion, cost and success rate of all future engineering projects performed. Findings from this research could potentially be used by practicing electrical engineers in future projects. The successful completion of this current research could have the ability to help improve project management success rates within the electrical engineering industry.

1.5 Scope

The scope of the project is limited to a small number of in-depth interviews with senior domain experts. A number of key electrical engineers and project managers were identified and interviewed. The individual interviews were focused on electrical engineering projects only. Hence, the scope of this project did not consider project management practices performed in the other engineering disciplines . It is assumed, however, that all branches of the engineering profession follow similar project management processes. Therefore, the

results obtained and any recommendations suggested at the completion of this project are relevant to all engineering disciplines.

1.6 Structure of Dissertation

The structure of this dissertation is as follows:

Chapter 2 Literature Review

This chapter discusses and evaluates the relevant literature regarding project management, systems engineering approaches and electrical engineering projects.

Chapter 3 Methodology

This chapter outlines and discusses the key steps taken in developing the methodology. It discusses the identification and selection of the domain experts, the development of the in-depth interview instrument and the analysis of the obtained data. Finally, the development of the proposed systems engineering model for electrical engineering projects is discussed.

Chapter 4 Results, Analysis and Discussion

The key results from the in-depth interviews are discussed and analysed. The proposed systems engineering model for electrical engineering projects is presented, verified and tested.

Chapter 5 Conclusion

This chapter concludes the dissertation by summarising the main outcomes and findings. Finally, a number of recommendations and future work are suggested.

Chapter 2

Literature Review

2.1 Introduction

This chapter reviews and examines the current literature and previously conducted research in the area of electrical engineering project management and systems engineering approaches. It will specifically consider project management in an engineering context, current project management models and methodologies, project success factors and electrical engineering projects. Finally it will discuss the application of systems engineering approaches to project management in an electrical engineering environment.

2.2 Project Management in Engineering

Ramazani and Jergeas (2015), suggest that projects play an important role in modern industries and enterprises. This is especially true in the electrical engineering industry. Many electrical engineering projects can be worth millions of dollars and can have a major impact on the majority of the society. Hence, project management is an extremely important and sometimes overlooked aspect of engineering. A recent study performed by Project Management Institute (2013), estimated that there would be 15.7 million new project management jobs created between the years 2010 and 2020. It could be predicted that the majority of these positions will likely be filled by professional engineers or individuals with a background in engineering. Hence, the ability and skill to successfully manage a project is crucial to all electrical engineers.

Project Management Institute (2008), states that a project is a unique and temporary non-routine operation. Burke (2010) agrees, stating that a project must have finite duration. As projects are a temporary endeavour with a defined start and finish, they can be difficult to

manage effectively. This requires project managers to have a unique set of skills, tools and techniques in order to successfully manage and complete projects. The work conducted by Bordley, Keisler and Logan (2019), added to this by discussing the issue of changing project deadlines. A project manager must be able to adapt and make necessary adjustments throughout a project. This is especially true in electrical engineering projects. As stated by Alias et al. (2012), 'Project managers are unique because they manage temporary, non-repetitive activities and frequently act independently of the formal organisation'. One of the main research findings from their work was that best practice processes and models are required in order to successfully manage projects. The work conducted by Devore, McCollum and Ledbetter (1982) suggested that, 'modern industry has become extremely complex and as technology has increased in our society it has provided a more complex industrial environment'. This is especially true within the modern electrical engineering industry. Therefore, it could be suggested that a combination of existing project management models and systems engineering approaches may be a suitable best practice method for electrical engineering projects.

There has been quite a lot of research performed in the area of project management training for engineers, most notably the work performed by Ramazani and Jergeas (2015). Their research focused on the training and education of project managers in an engineering context. It was identified that a gap exists between the education provided and the actual requirements of project managers working in the industry. One of the key findings of their research was, 'successful project management is a complex process involving the alignment of multiple factors'. Therefore, there is no single skill that can be taught in education institutes to produce good project managers. It is a combination of many skills and disciplines. Engineers are highly technical individuals and sometimes lack the so called soft skills of leadership and communication that are critical in project management. As stated by Guerrero, Palma and La Rosa (2014), 'the soft skills or professional skills are what make the real difference between a professional and another'. Their research confirmed that the modern engineer is required to have both hard skills and soft skills. Furthermore, it was concluded that an engineer must have the right balance of technical skills and knowledge and also professional skills in order to be successful. Rogers, (2002) agrees stating that, 'project engineers must possess other key attributes, such as engineering expertise, systems knowledge, and the ability to read technical drawings and specifications'. Hence, when developing or selecting an appropriate model to use for the management of engineering projects, the soft skills should not be neglected. As a

systems engineering approach essentially zooms out and attempts to look at the overall problem or project, it may be a suitable model.

2.3 Project Management Methodologies and Models

There are many project management models and methodologies that are currently being implemented by engineering companies. The common theme, however, with all of the different models is that they provide a framework for how the project will be established and managed. This allows the project manager to follow a set procedure and sequence of steps. Matos and Lopes (2013), found that project management methodologies are an indispensable tool which help to measure and control project progress. Hence, the most important aspect is to select a project management methodology that will meet all of the requirements of a particular project. The work performed by Sánchez, Gaya and Peréz (2013), suggests that following good practice and a globally accepted project process common to all industry groups will increase the chance of a successful project completion. Garel (2013) agrees, stating that project management theories are a collection of best practices. Interestingly, a study performed by Rivera and Kashiwagi (2016), found that traditional project management models are major contributors to the delivery of poor services and outcomes. The outcome of their research determined that existing project management models based on management, direction and control are not sufficient. They suggest that the models should be changed to leadership-based structures. Typically, project managers with a background in business focus on the iron triangle or triple constraints of time, scope and quality (figure 1). A large emphasis is placed on these three aspects and sometimes other equally important components may be overlooked. Hence, a systems engineering approach may help to prevent this from occurring.

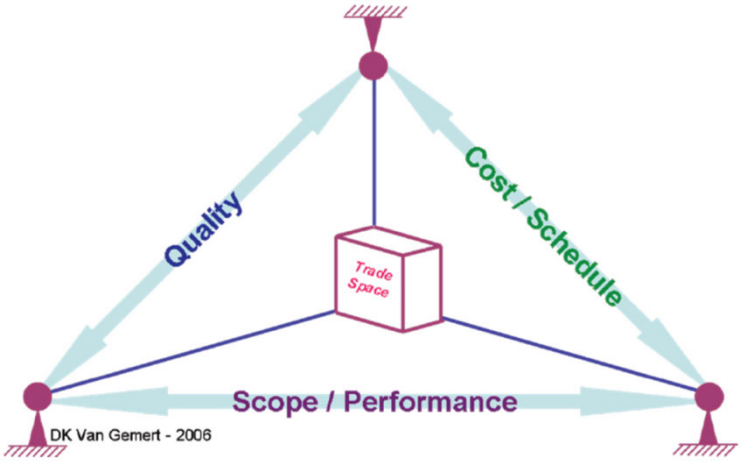

Figure 1: Trade space triple constraint or iron triangle used in traditional project management practices (reproduced from Van Germet, 2013).

There appears to be a number of different opinions on which project management model is the most suitable. This is confirmed in a study performed by Franková, Drahošová and Balco (2016). They found that the view on standard project management models is divided amongst practitioners and experts. Some individuals argue that the standard project management methodologies are applicable to all projects. The other group suggest that each project management methodology should be adapted and modified to suit an individual project. For example, an electrical engineering project may have some unique features that a typical business based project does not include. Hence, the ability to adopt an individualised or more specific project management model would be beneficial.

Two of the more popular models currently being implemented in the electrical engineering industry are the Project Management Body of Knowledge (Project Management Institute, 2017), known as PMBOK and Projects In Controlled Environments, Turley (2017), commonly referred to as PRINCE2. The basic structure and features of these models will be briefly discussed.

2.3.1 PMBOK

The PMBOK (2017), was created by the Project Management Institute in order to ensure that there was a standard knowledge and procedure for project management. It is a method that breaks the project down into a number of defined stages or processes (figure 2). The five individual processes are:

1. Initiating
2. Planning
3. Executing
4. Monitoring and Controlling
5. Closing

PMBOK also defines the following ten knowledge areas relevant to project management practice:

1. Integration
2. Scope
3. Time
4. Cost
5. Quality
6. Procurement
7. Human Resources
8. Communications
9. Risk Management
10. Stakeholder Management

Figure 2: PMBOK processes (reproduced from Sánchez, 2013).

2.3.2 PRINCE2

The PRINCE2 method has eight distinct processes (figure 3). These processes are as follows:

1. Starting Up
2. Directing
3. Initiating
4. Planning
5. Controlling a Stage
6. Managing Product Delivery
7. Directing
8. Closing

Figure 3: PRINCE2 phases (reproduced from Sánchez, 2013).

The PMBOK methodology can be viewed more as a standard. Whereas, the PRINCE2 can be considered a method. In other words, PMBOK is a descriptive approach focusing on the broader aspects of tools, techniques and good practices. It provides an in-depth discussion and description of best practice methodologies, rather than focusing on a step by step process. PMBOK is more broad and can be tailored to specifically meet the requirements of each individual project and should be used as a guide. PRINCE2, however, is prescriptive with a focus on compliance and control (Sheffield and Lemetayer, 2010). It provides more of a guideline and rules to follow when managing a project. There is some overlap with the two methodologies as shown in figure 4. Hence, it is evident that the most important thing is to select a model suitable to the particular project. Another model which is quite common in electrical engineering project management, particularly software based projects is agile. This methodology is neither descriptive or prescriptive. It is regarded as having an appreciative/value driven characteristic. It is an iterative and incremental approach to delivering the project objectives (Sliger, 2011).

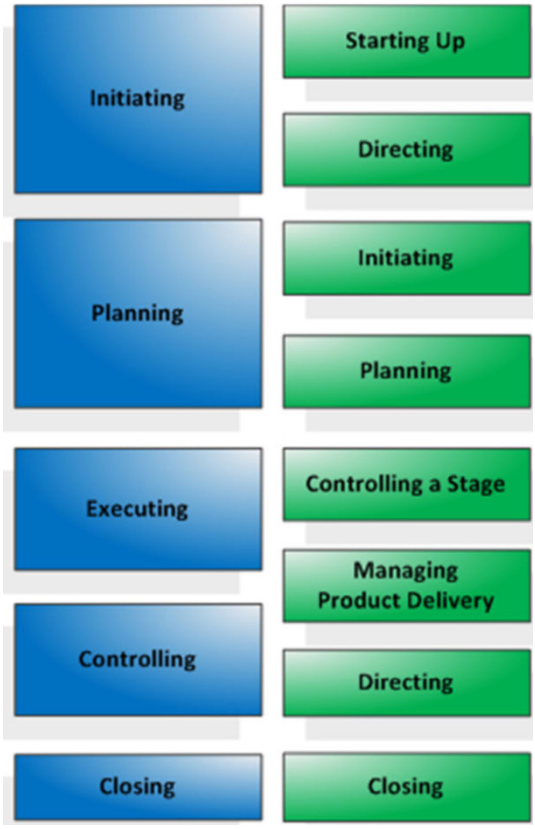

Figure 4: PMBOK and PRINCE2 comparison (reproduced from Matos, 2013).

2.4 Project Success Factors

As discussed by Ackara, Kazaz and Ulubeyli (2017) in a study focusing on project quality, 'the primary goal of project management is to finish a project within its scope'. This statement may seem obvious and simple, however, in reality it can be very difficult to achieve. There are numerous factors and variables that determine the success of a project. The study and research performed by Radujković and Sjekavica (2017), suggests that 'project management success can be evaluated through the criteria of time, cost, quality, scope, resource and activity'. Although success is difficult to define, the majority of the research and literature agrees that there are many variables that contribute. A project is not a static process but rather a dynamic system with many inputs and unknowns. Due to their system like behaviour, many projects are not completed successfully or on time.

Rivera and Kashiwagi (2016), found that approximately 60% of construction and information technology projects are, 'over budget, over schedule and have low customer satisfaction'. It is believed that project managers may be overwhelmed by the many different project management methods and processes available. The researchers suggested that many project managers find it difficult to choose an appropriate approach to use. This is a contributing factor to the unsuccessful completion of many projects. The work conducted by Locatelli, Mancini and Romano (2014) agrees with these findings stating that, 'projects delivered in complex environments are often late and over budget'. The study by Gepp et al. (2014), further builds on this idea confirming that the majority of engineering projects are in danger of failure due to the complex environments that they are carried out in. This is especially true in large government projects as the nature of these projects are extremely complex (Componation et al., 2015). As suggested by Patanakul et al. (2016), 'government projects involve many stakeholders and can significantly contribute to national wealth and growth'. Their research also found that most large scale government projects underperform in terms of expected outcomes. The main focus of their work was to determine what factors impact the performance of large government projects. Many large electrical engineering projects (electrical power generation and distribution, telecommunications networks) are government based projects. Therefore, it is crucial that improvement techniques and processes are adopted in order to improve project success.

2.5 Project Management In An Electrical Engineering Environment

Electrical engineering projects carried out within Australia are of extreme value and importance. For example, reliable and secure communications have become part of everyday life for most individuals. It is expected that one can access the internet or make a phone call. Businesses and industries rely on the infrastructure to be operating correctly and working at all times. Hence, it is crucial that these telecommunications projects are executed in the most efficient and effective manner as possible. Another modern day luxury that individuals have become used to is a reliable power generation and distribution network. It is almost expected that when one turns on a light switch in their house that the light will turn on. Very rarely, would individuals consider the complexity of these electrical engineering projects and the on going life cycle support required. Hence, projects involving the design, installation and maintenance of electrical power generation and distribution systems are of a high importance. There is no room for a delay in equipment purchasing or an extended project schedule. This makes electrical engineering projects unique and the management of them must be adjusted accordingly.

Electrical engineering projects are not only unique in their nature but they also present unique challenges that are not very common in many other industries. For example, not only are electrical engineering projects generally very technically complex and challenging, there are also many other factors to consider. Some of these include:

- Relevant standards and practices
- Community engagement
- Health and safety compliance

Some of the more common standards that will be applicable to electrical engineering projects are (Electrical Safety Office, 2019):

- AS/NZS 3000:2018 Electrical Installations (The Wiring Rules)
- AS/NZS 3012:2010 Electrical Installations – Construction and demolition sites
- AS/NZS 3017:2007 Electrical Installations – Verification guidelines
- AS/NZS 3760:2010 In-service safety inspection and testing of electrical equipment

- AS/NZS 4836:2011 Safe working on low-voltage electrical installations and equipment

These standards cover the technical rules and regulations for electrical projects, however, they do not provide a framework for the non-technical aspects of an electrical project. For example, if a new power station was to be built, community engagement would be a major aspect of the project process. Not only would the project engineers need to focus on the technical aspects, but also the social and environmental aspects regarding the surrounding communities. Hence, a systems or holistic approach is necessary in order to successfully manage and complete electrical engineering projects. The research carried out by Love, Zhou and Matthews (2019), found that the ability to successfully monitor, control and complete projects could potentially be improved by adopting a Systems Information Modelling (SIM) approach. As stated by Love, Zhou and Matthews (2019), 'a SIM approach has the ability to model complex connected systems, such as electrical, control, power and communications'. Spagnuolo et al. (2018), conducted research in applying systems engineering approaches to the design of a fusion power plant. They found that systems engineering is a powerful interdisciplinary approach that can be used to manage and develop complex systems. Zheng et al. (2017), were able to successfully integrate and map systems engineering measurements to project management performance indicators. The researchers implemented a case study approach which used a high tech company that manufactures electrical and mechanical components. A significant outcome was that processes and performance can be enhanced by integrating and combining systems engineering and project management. A systems engineering approach allows the project requirements to be analysed and monitored in a way that traditional project management methods do not. By incorporating many technical, engineering and managerial disciplines, systems engineering provides a holistic and robust method to manage projects. Hence, it appears that systems engineering approaches could be applicable to electrical engineering project management.

2.6 Systems Engineering

Gausemeier, Gaukstern and Tschirner (2013) define Systems Engineering as, ‘a holistic and interdisciplinary approach to enable the realisation of successful systems. It integrates systems thinking, discipline specific engineering approaches (methods, tools, and procedure models), human sciences, and management aspects’. Systems engineering brings together a number of different technical and management disciplines and interconnects them (figure 5). The International Council On Systems Engineering (INCOSE, 2018), states that a system is a construct or collection of different elements that together produce results not obtainable by the elements alone. Systems engineering is a planned and structured approach to solving a problem. Hence, it would be a highly applicable method to manage complex electrical engineering projects. There are a number of systems engineering standards and practices which INCOSE closely monitors and updates regularly. The purpose of the standards is to harmonise and integrate all systems engineering practices worldwide in order to develop a best practice approach. As stated by INCOSE, the fundamental seven step process approach to solving an engineering problem is as follows:

1. State the Problem
2. Investigate Alternatives
3. Model the System
4. Integrate
5. Launch the System
6. Assess Performance
7. Re-evaluate

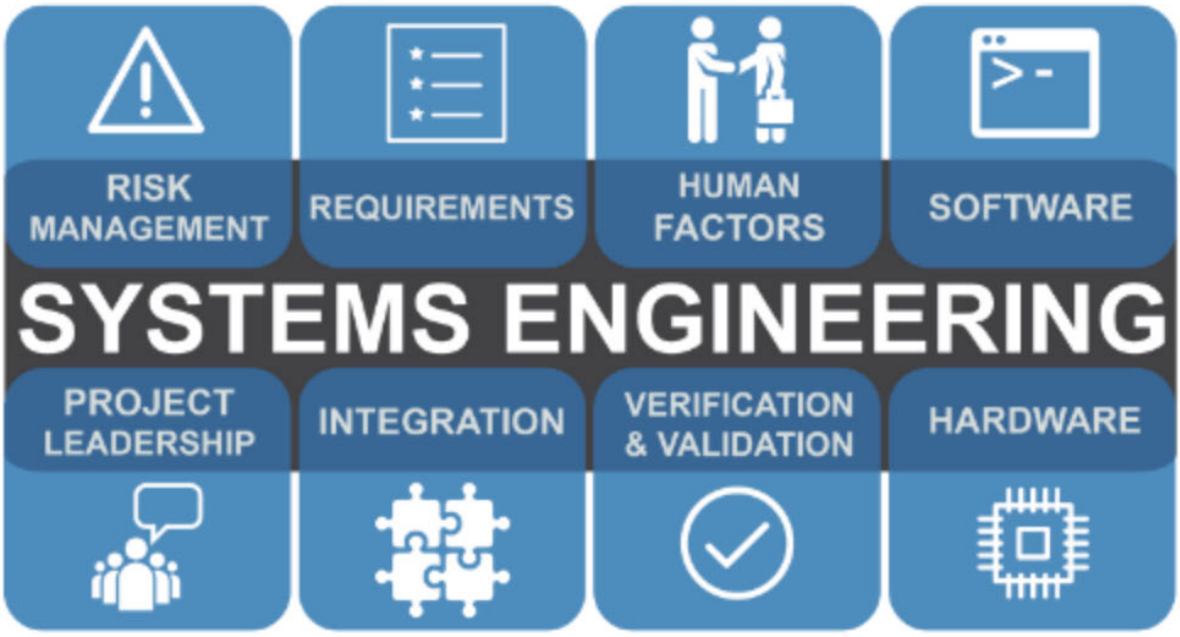

Figure 5: Representation of the different disciplines and components that encompass systems engineering.

2.7 Projects As A System

An emerging method being applied to project management is systems engineering. Sankaran, Haslett and Sheffield (2010), suggest that systems engineering has a close relationship with project management. Systems engineering approaches and project management have been used to manage large research and development projects, particularly by Defence for many years. Applying systems engineering and systems thinking allows the project or process to be viewed in a holistic way. As stated by Cristóbal (2017), 'systems thinking concentrates on the whole process and adopts a holistic view'. Locatelli, Mancini and Romano (2014), further add to this by suggesting that, 'systems thinking takes into account the environment and its interactions in which the project is accomplished'. Cleland (1977), suggests 'the systems approach as a disciplined way of viewing the world, and the solution of problems and the exploitation of opportunities in that world'. The findings from these previous studies agree that applying systems approaches and methods in general to engineering projects could potentially increase the success rate.

Systems engineering essentially brings together a number of different engineering based disciplines. Much like systems thinking, systems engineering is a method that adopts a whole picture view or holistic approach. As stated by Locatelli, Mancini and Romano (2014), 'systems engineering was developed after the Second World War for governing the development of military and aerospace projects'. Hence, systems engineering approaches are highly applicable to electrical engineering projects. One of the major outcomes of their research was that the adoption of systems engineering has the ability to transform the governance of a project from the typical project management style approach to a more holistic system. It was further identified that this systems management approach could improve the success rate of projects. Gepp et al. (2014) agree with one of their major findings being that 'holistic considerations are important for the success of engineering projects'.

The outcome from the work of Wilberg et al. (2015), has identified that projects are becoming increasingly complex. More specifically, engineering projects are exposed to many internal and external dynamic influences that can have a major impact on the final output. Cristóbal (2017), suggests that, 'traditional project management methods that use a static approach may not be adequate'. Hence, the identification and application of systems

engineering processes to project management may help to contribute to the successful outcome of future electrical engineering projects as the complexity increases.

A study conducted by Van Gemert (2013), found that there is a connection and overlap between systems engineering and project management. It could be suggested that the two complement each other. The work performed by Sharon and Dori (2012) also found that there is a link between systems engineering and project management. Langley, Robitaille and Thomas (2011) suggest that project management and systems engineering share common objectives. They suggest that a new mindset needs to be adopted. Instead of project managers and system engineers viewing the project problem separately, they need to work together as their skill sets complement one another. The results of a survey conducted by PMI and INCOSE (2013) agrees, suggesting that there appears to be a cultural barrier between practitioners of systems engineering and of project management. A consequence of having a separate view and division often leads to projects taking longer to complete and costing more. A holistic, team view needs to be adopted as the previous research has indicated that there is a connection and overlap between systems engineering and project management. Essentially, a team view needs to be adopted in order to produce better outcomes (figure 6). Lachhab et al. (2017), performed research in integrating systems engineering processes and project management processes. A major finding from their work was that system engineering and project management could be integrated with the possible benefit of improving the overall success rate of a project.

Figure 6: Integrating Systems Engineering and Project Management with a team view (reproduced from Langley et al., 2011).

Acheson, Dagli and Kilicay-Ergin (2013), found that Model Based Systems Engineering (MSBE) is becoming an increasingly popular approach to system development. This approach could be adopted in the project management of electrical engineering projects. MSBE allows communication and verification across all levels of system development. It is essential that communication and verification is performed at all stages of an electrical project as they essentially operate as a complex system. Hence, MSBE could be applicable to the management of electrical engineering projects.

The work carried out by Locatelli, Mancini and Romano (2014), has shown that there is a connection between applying systems engineering processes and the success rate of projects but further work and research is required. A significant amount of research has been performed in the area of improving project management. The main focus of these previous research studies has been on improving quality and efficiency. A limited number of studies have been performed focusing on the relationship between systems engineering and project success rates. Applying these methods to electrical engineering projects, however, has not been investigated in great detail. Hence, the focus of this research project is to explore this possibility.

2.8 Conclusion

As the literature indicated, project management has been extensively used in electrical engineering projects. There has been significant research and work conducted in improving project best practice models, efficiency and quality. Adopting systems engineering approaches, however, has not received a great deal of attention. Hence, this research aims to address the gap and contribute to the overall knowledge base. It will focus on investigating the application of systems engineering approaches to electrical engineering projects. The use of systems engineering approaches in large electrical engineering projects could be extremely beneficial. Therefore, the following chapters of this dissertation present the method followed to identify and develop a suitable proposed systems engineering approach to electrical engineering projects.

Chapter 3

Methodology

3.1 Introduction

This chapter discusses the methodology that was adopted in order to identify the domain experts, develop the in-depth interview instrument, analyse the information obtained from the domain experts and finally develop and refine the proposed systems engineering model. It will also discuss the potential consequential impacts of the research and the strategies implemented in order to reduce any associated risks.

3.2 Methodology Overview

Generally, in any research project one needs to consider an investigation focusing on the breadth or an in-depth study focusing on a more narrow sample. For example, the former approach could entail survey-based questionnaires targeting a large sample allowing statistical analysis of the obtained data. The latter approach adopts an in-depth and focused study based on detailed interviews with a small number of domain experts. For the purpose of this research an in-depth approach was adopted. The objective was to obtain qualitative data and reliable information. Hence, a number of key personnel from within the engineering industry, specifically electrical engineers were identified and interviewed. As suggested by Marshall (1996), key informant interviews target a selection of experts in order to obtain quality information in a relatively short period of time. This method is the most suitable for this research project.

The key steps involved with the methodology for this research project were the following:

1. Identify the domain experts based on a number of criteria (position, relevant qualifications and experience).
2. Develop the in-depth interview instrument based on the knowledge gap identified in the literature review.
3. Conduct the in-depth interviews with the identified senior domain experts.
4. Use the domain knowledge to develop an initial model for the systems engineering approach to electrical engineering projects.
5. Have the model verified by the domain experts to obtain feedback in order to refine and improve the model.

The simplification of each step of the project process allowed a schedule to be developed and followed (see appendix F). This schedule was broken down further into a semester 1 and semester 2 timeline. It was necessary to do this in order to ensure that the research project progressed adequately with clear milestones identified and defined.

3.3 Selection Of Domain Experts

The first step required was to obtain a human ethics approval from USQ (see appendix E). Once this milestone was achieved the process for interview participation selection could commence. Each interview participant was required to meet a number of key criteria in order to be deemed suitable. These standards were set to ensure that only participants with extensive knowledge and relevant experience were interviewed. This would allow the results obtained to be reliable and valid. Hence, only senior domain experts were identified and selected. There was a total of five domain experts interviewed. This allowed for the interviews to be in-depth. The selection criteria for the domain expert interview participants included the following:

- Hold a Bachelor of Engineering (minimum education level)
- No less than 10 years professional engineering and project management experience
- Currently working in a senior role
- Of sound mental health and cognitive ability
- A current resident of Australia and legally working

The potential interview participants were selected from a range of industry professionals known to the student researcher. Hence, the selection was purposively and not merely random. There was no financial or any other form of material incentive offered to the participants. The in-depth interviews were entirely voluntarily and participation was not mandatory. If an identified participant did not wish to be involved in the interviews, their decision did not negatively impact their relationship with the student researcher or USQ.

3.4 Development of the In-depth Interview Instrument

The findings from the critical literature review conducted in chapter 2 led to the identification of a knowledge gap. It became evident that there was a lack of systems engineering approaches being applied to electrical engineering projects. Hence, five key domain experts were identified for in-depth interviewing. A suitable in-depth interview instrument was designed and developed. The development process involved analysing the findings from the literature review. Hence, the interview question came from reviewing the literature (appendix G). Common themes began to emerge with the majority of the literature agreeing that systems engineering approaches has the ability and potential to improve project management in electrical projects. Previous research studies in this field were examined in order to help identify and develop a suitable interview instrument. The advantages and disadvantages of the different methods were compared before selecting the final approach. In order to limit and reduce the impact on the interview participants, it was necessary to limit the number of questions to a reasonable amount. A total of 15 questions was deemed suitable. This would allow the participants approximately 2 minutes to answer each of the questions (total of 30 minutes).

The purpose of the interview instrument was to determine if the domain experts agreed with the literature findings and to ascertain input and suggestions from their experiential knowledge. The questions addressed specific aspects unique to electrical engineering projects. A number of the questions were to determine the participants understanding of project management and systems engineering in general. This was necessary in order to gauge each domain experts perception and understanding of the general topic. After the general questions the purpose of the interview instrument was to obtain specific information from the domain experts related to systems engineering and project management. These questions included questions about current project management models, electrical standards and systems engineering processes. Refer to appendix D for a complete copy of the interview instrument.

A Strength/Weaknesses and Opportunities/Threats (SWOT) analysis of the interview instrument was performed in order to determine its suitability (table 1). After careful consideration the interview instrument was deemed suitable for this research project.

Table 1: SWOT analysis of in-depth interview instrument

Strength	**Weakness**
Simple and straightforward questions.	Small sample of participants. Possibly the information gathered will be quite broad.
Opportunity	**Threat**
Data collected is qualitative which will allow experiential knowledge to be extracted.	Not compulsory to participate in the interview. Therefore, could result in low number of participants.

3.5 In-depth Interviews

Based on the knowledge gap identified in the literature, the in-depth interviews with the domain experts were conducted with the purpose of knowledge acquisition. Initial interviews were independent. In other words the experts were not aware of the other's responses. The domain experts were provided with a participant information sheet (appendix B) and required to sign a participant consent form (appendix C). The purpose of the interviews was to attempt to find out if there was a general consensus among the experts. The extracted knowledge was used in conjunction with the gaps identified in the literature to develop and propose an initial model. The in-depth interviews were semi-structured in order to ensure there was consistency between the independent interviews. The student researcher conducted the interviews and transcribed the participants responses to ensure accuracy of information. Performing the in-

depth interviews with a selection of the industry experts helped to build a model that could be analysed. The information obtained from the participants contributed towards identifying a relationship and trend with applying systems approaches to electrical engineering projects. Analysis of the obtained information was performed manually by theme. These themes were common and consistent among the responses from the domain experts.

3.6 Model Development

Following the completion and analysis of the in-depth interviews results, a suitable model was devised. This model attempted to build on and improve existing models previously discussed in the literature review and attempted to make them more applicable to electrical engineering projects. The reviewed project management and systems engineering models are extremely well developed and tested. Hence, the model developed in this research will only be building and expanding the existing proven models. This refined model could have the ability to enable the experts and practitioners in the field to address the weaknesses identified in the current project management processes and models.

3.7 Model Testing

Follow up individual interviews were conducted with three of the domain experts to discuss the results. The domain experts were asked a series of questions in order to verify and validate the results obtained from the in-depth interviews and proposed systems model (appendix H). The model was presented to each of the domain experts for their input and feedback. The purpose was to determine if any adjustments needed to be made before potentially testing the model on a real-world electrical engineering project. The model was then tested on a hypothetical electrical engineering project in order to illustrate the key features.

3.8 Research Considerations

When conducting research of any form, one must consider the potential consequences and identify all risks. The following section will discuss the potential risks and consequences of this research project.

3.8.1 Interview Participants

As the research project involved interviewing human participants, appropriate human ethical clearances were required. A human ethical application was submitted to the USQ human ethics committee for review and approval. As stated in the National Statement on Ethical Conduct in Human Research, 2018 special care and consideration must be applied when working with the following:

- Women who are pregnant and the human fetus
- Children and young people
- People in dependent or unequal relationships
- People highly dependent on medical care who may be unable to give consent
- People with a cognitive impairment, an intellectual disability, or a mental illness
- People who may be involved in illegal activities
- Aboriginal and Torres Strait Islander peoples
- People in other countries

As the potential interview participants for this research project did not meet any of the above criteria, no special consideration needed to be applied. The standard USQ human research ethics application and clearance was adequate.

3.8.2 Risk Assessment

This research project work was deemed relatively low risk. There was no laboratory work or physical prototype building. Hence, the risks and hazards associated with physical activities was negligible. There were, however, site visits to the interview participants workplaces. Appropriate behaviour and risk reduction was implemented when on these sites. All health and safety rules were followed when on site. The rules and procedures presented in any inductions were followed and adhered to at all times.

As there are limited personal risks, a generic risk assessment matrix has been used in order to determine the associated risk with regards to the project work. The risk assessment matrix used to evaluate the associated risk level was borrowed from the report titled 'Australian Defence Force Risk Management Framework: A Comparative Study' published by the ADF. This risk assessment matrix is shown in table 2. The potential project risks and the measurements put in place to lower these risks are highlighted in table 3.

Table 2: Risk Analysis Matrix. Source: (Australian Defence Force 2005)

Likelihood	**Consequences**				
	Insignificant 1	Minor 2	Moderate 3	Major 4	Catastrophic 5
A (almost certain)	High	High	Extreme	Extreme	Extreme
B (likely)	Medium	High	High	Extreme	Extreme
C (moderate)	Low	Medium	High	Extreme	Extreme
D (unlikely)	Low	Low	Medium	High	Extreme
E (rare)	Low	Low	Medium	High	High

Table 3: Potential risks and reduction plan

Phase	Hazard	Risk Level	Reduction measurement
1c	Unable to obtain ethics approval	Low	Apply for approval as soon as possible to allow adequate time for complications.
1d	Unable to obtain interview participants	Low	Organise and arrange interview times well in advance – contact all necessary personnel and maintain regular contact. Arrange necessary escorts, paperwork etc if required to attend participants workplace.
All	Loss of collected data and work due to computer fault	High	Regularly save all work to back up hard drive and cloud service. Keep files well organised and updated. Do not have only one copy of work.
All	Unforeseeable personal event or circumstance	Medium	Allow adequate time for all stages of project. Build in buffer time for each phase of project to allow for things to go wrong and take longer than planned.

3.9 Conclusion

This chapter has discussed the methodology that was adopted for this research project. The first step was to identify five suitable domain experts for in-depth interviews. Once the domain experts were selected a suitable in-depth interview instrument was devised. Following the development of the interview instrument the interviews were conducted. The results obtained were analysed manually by theme and used in conjunction with the reviewed literature to produce an appropriate proposed model. The model was then verified and validated by conducting further interviews with three domain experts. A hypothetical electrical engineering project was devised in order to test the model. Necessary modifications and adjustments were made following the feedback from the experts. The potential impact and consequences of the research project have also been discussed with a focus on human ethics and risk assessment.

Chapter 4

Results, Analysis and Discussion

4.1 Introduction

This chapter presents the results that were obtained from the in-depth interviews with the domain experts. An analysis and discussion of the results leading to the development of the proposed model is included. Finally, the testing and verification of the systems engineering model for electrical engineering projects will be discussed.

4.2 In-depth Interview Responses

The in-depth interviews were conducted with five senior domain experts with the purpose of extracting experiential knowledge. The results obtained from the in-depth interviews were deemed suitable for analysis manually by theme. The domain experts were asked 15 questions regarding their experience and expertise in the areas of electrical engineering, project management and systems engineering.

The initial questions focused on general project management and systems engineering concepts. The purpose of these questions was to determine the domain experts understanding of project management and its importance in electrical engineering. The latter questions were more targeted at specific systems engineering and project management processes based on their individual experiences. There appeared to be a general consensus among the experts with the majority agreeing that project management is an essential part of electrical engineering. This is compatible with the literature reviewed particularly, Project Management Institute (2008) and Burke (2010). The domain experts agree that project management is essentially the skill of managing the specification, budget, scope and requirements of a project. It is a systematic process with clearly defined roles and objectives and is an extremely important aspect of electrical engineering.

The majority of the experts commented that undergraduate electrical engineering degrees focus on more of the technical theory and very little on project management. This may lead to a lack of soft skills such as effective communication, management and leadership. This outcome agrees with the work conducted by Ramazani and Jergas (2015). It is quite common for an electrical engineer to study a post graduate degree in project management or a similar area to develop and improve these inadequacies. The majority of the domain experts interviewed had completed post graduate courses in project management. Hence, this outcome is compatible with the reviewed literature.

The domain experts were asked which project management methodology they currently follow and adopt. As expected and consistent with the work conducted by Matos and Lopes (2013), the main methodologies being utilised are PMBOK and PRINCE2. Depending on the project, however, some of the experts mentioned that they may adopt an Agile approach. Particularly, in large software based projects. One of the domain experts suggested that PRINCE2 is very applicable to electrical engineering projects as they are generally very complex. This observation is compatible with the reviewed literature.

In order to determine if a project was successfully completed, it is first necessary to define how project success is measured. Hence, the experts were asked how they define and measure project success. It is interesting to note that their answers essentially referred to the traditional iron triangle (time, cost and scope) as a success indicator. This is consistent with the literature, particularly the work conducted by Sanchez, Gaya and Perez (2013). It is noted that project success is relevant to each individual project and the project objectives must be clearly defined. Regardless of the project, however, there is a general consensus that a project is successful if it is delivered on time, on budget and meets the requirements that the customer defined. The domain experts commented on what has contributed to the successful completion of past projects that they have been involved with. Their responses were in line with the work performed by Ackara, Kazaz and Ulubeuli (2017). Clearly defining the requirements of the project and constantly reviewing them throughout the project was a consistent response. Essentially, knowing and understanding what the project is trying to achieve is one of the key contributors to a successful outcome. Projects can often fail due to unclear requirements and poor communication. Hence, it is important that the soft skills of management, communication and leadership are not neglected. These responses are consistent with the work conducted by Raudujkovic and Sjekavica (2017). From their

experience, the experts tend to agree that most electrical projects fail due to running over schedule. An interesting point made was that the schedule and budget are closely connected. For example, if a project runs over schedule, generally it will also go over budget as the project manager would need to spend more money in order to complete the project. Hence, when an electrical project runs over schedule, the cost will inevitably rise too. The work performed by Rivera and Kashiwaga (2016) and Patankakul et al. (2016), also found that the schedule and budget are the main contributing factors to project failure.

The interpretation of systems engineering approaches among the experts was consistent. Responses such as, systems thinking and holistic management were common. All responses were similar to the definition provided by INCOSE (2018). Also, the common themes in their answers revolved around the same themes as mentioned in the work conducted by Cristobal (2017). The domain experts appear to agree that a systems engineering approach to the management of electrical engineering projects is highly applicable. They believe that systems engineering and project management complement each other as mentioned in the work performed by Van Gemert (2013). An interesting point noted by one of the domain experts was that they believed that systems engineering is the only approach appropriate to the management of complex electrical engineering projects. Another notable statement by one of the domain experts is that they believed that electrical engineering projects drove and helped to develop systems engineering. This observation agrees with the work conducted by Locatelli, Mancini and Romano (2014).

The majority of the domain experts mentioned that due to the rapid advances in technology it is common for electrical technology to advance and become obsolete before a project has been completed. A piece of technology or software intended for use at the beginning stages of a project may become irrelevant before the completion of the project. Hence, as suggested by the literature and confirmed by the domain experts, electrical projects are becoming increasingly complex. In order to combat this inherent trait of electrical projects, it is necessary to continuously monitor and review previously completed stages. The approach of treating the project as a closed loop system allows this constant monitoring and adjusting to occur when necessary, essentially adopting a systems engineering approach. As electrical engineering projects are dynamic and complex in nature, they require a more holistic approach. The majority of the domain experts responded with similar answers to the in-depth interview questions and their response agreed with the reviewed literature.

Hence, after analysing the results manually, the following common themes are evident:

- Project management is crucial in electrical engineering and a formal education will help to develop the necessary skills applicable to electrical engineering projects.
- Clear requirements and effective communication are the foundation of a successful project.
- Most electrical projects fail due to running over schedule. This is closely linked to the budget as a longer schedule will inherently cost more money.
- Systems engineering would be a suitable project management model for electrical engineering projects as it allows the project manager to adopt a holistic view. The project engineer must have an understanding of the entire project and not be distracted by small engineering design details.
- Systems engineering and project management are closely related and complement one another. This relationship can be used to effectively manage technically challenging, dynamic electrical engineering projects.

The following section will present a sample of the key responses provided by the domain experts. These responses were transcribed by the student researcher at the time of the interviews.

4.2.1 Response to Question One

What is your interpretation of project management and why do you believe it plays an important role in electrical engineering projects?

- *Project management is the skill of managing the specification, schedule and the budget to deliver the outcome the customer requires.*
- *Project management is the mechanism by which the engineering plan is turned from a technical pipe-dream into a logical break down of activities, personalities, skills and resources to achieve the required outcome.*
- *To ensure and enable delivery of an agreed requirement/capability/scope, schedule and cost. The requirement or scope can be defined from various roles or environments including electrical engineering programs.*

- *Project management is valuable to any engineering project as most engineering projects align with the definition of a project in that they are time bound, discrete, and very often not repeatable. Project management is a management framework that guides the development and satisfaction of the customers' requirements.*
- *Project management is vital in any electrical engineering activity. It enables a manager to set goals and systematically step by step achieve these goals. It allows for the objectives to be determined, constraints to be defined and strategies towards the goals to be established.*

4.2.2 Response to Question Two - Based on your professional experience, how do you think that formal training in project management could help electrical engineers?

- *Electrical engineers love tinkering and building things but sometimes lack personal skills such as communications (talking to other engineers, accountants, managing large contracts)*
- *Providing a structured form of training would enhance an engineer's ability to design/maintain/improve electrical systems.*
- *Often, engineers as project managers get too involved in the detailed engineering instead of retaining oversight of the whole project, which engineering is but one element. Adequate formal training will assist pragmatic engineers in becoming better project managers as they would hopefully retain a holistic view for the project and what is required.*
- *An electrical engineer with formal training in project management will be equipped with most of the necessary skills to approach various projects. Electrical engineering projects due to the dynamic nature, may have many interrelated activities which lend themselves perfectly to systematic approaches of project management.*

4.2.3 Response to Question Three - How do you measure project success?

- *A project is successful if the engineer delivers the solution that the customer asked for and at the end of testing the customer agrees that what they have received is what they asked for. Basically the specification is met, it is delivered on time and on budget.*
- *End use acceptance of the delivered article/capability. Not much use being under budget and ahead of time if the validation shows you've missed the mark on what was required. (also not much use being late and over budget).*
- *Meeting the full set of requirements/scope of the program on schedule and within allocated cost.*
- *Project success is relevant to each project and must be defined as part of the project charter. Traditionally, project success has been defined as meeting the constraints of time, cost and scope ('iron triangle'). Failure to achieve one implies that the project was a failure.*
- *Project success can be measured by the successful outcomes. These outcomes include staying within the budget constraints, delivering the expected quantities with the expected quality in a timely manner.*

4.2.4 Response to Question Four - Based on your experience of successful projects please indicate what has, mainly, contributed to their success?

- *A clear and written specification, what do you really want, unambiguous engineering language, specification is a big stake of paper, constantly reviewing specification, know exactly what you want and write it down as clearly as possible. A clear specification and a contract gives the customer a written agreement.*
- *Someone who can manage the resources to deliver the project in the timeframe the customer expected, otherwise you run the risk of people going bust. Delivering something on time is extremely important*
- *Knowledge of what the task actually required, and engagement of the correct stakeholder groups. Early ground work and correct identification and elicitation of the requirements saves a lot of time and useless design features being incorporated into the end product.*
- *Identifying a good robust set of project controls (communication, management strategy, and independent assurance measures).*

- *The experience has shown that in order to produce the desired outcome (time, cost, quality), the PM needs to have a vision of the final product/service and by adopting relevant managerial activities (financial, quality, leadership, HR) move in the direction of the set goals.*

4.2.5 Response to Question Five - Could you please explain your interpretation of systems engineering approaches?

- *Systems engineering uses systems thinking principles to design and manage complex systems.*
- *Defining the problem space and developing solutions based on a risk management approach which is governed holistically by a system of systems concept where subsystems will be suboptimal to optimise the performance of the entire system.*
- *Cradle to grave engineering design approach, what you need, how to get it/build it, how to use it, feed it, fix it and finally get rid of it when you're done.*
- *Systems engineering approaches has its foundations based on the idea of a system. A system has the main components of input, process and output. An activity such as a project also comes under the definition of a system because it includes input, process and outputs. Systems engineering is basically taking a holistic approach and considering all aspects.*

4.2.6 Response to Question Six - If you are currently using a project management model, could you please explain the process? If you are not adopting a model please explain why?

- *PRINCE2 process based breakdown of activities and PMBOK.*
- *Based on PRINCE2 – strategy and concepts, risk mitigation and requirement setting, acquisition, sustainment and disposal. For smaller non-complex activities, an Agile project management model is used ie Kamban or scrum.*
- *Waterfall or spiral upgrade would be the most common. As software driven architecture is becoming more common, I see more influence of the spiral upgrade by the capability managers and project officers.*

- *Currently we are employing various tools and techniques which include the use of WBS, network diagrams and Gantt charts. We also utilise industry standard software such as MS project. Basically following the PMBOK standard.*

4.2.7 Response to Question Seven - Based on your experience and the use of current project management models, how do you think the models could become more applicable to electrical engineering projects?

- *Increased integration and technology creep will potentially increase the earned value of using a more applicable project management model.*
- *Using the PRINCE2 model would be applicable to electrical engineering projects as these projects are inherently highly complex and at times, developmental in nature and they require a level of integration. However it does not automatically call out the technical needs of the customer.*
- *Various project models would be applicable subject to the organisation frame work in is it small, large, multidisciplinary or multi- organisational. I believe that iterative/incremental project management would be best suited to where a large degree of uncertainty exists or an exploratory approach is being adopted. To adopt a concept from Scrum, "Failing fast" to learn what doesn't work fast.*
- *More traditional forms of project management i.e. waterfall, spiral upgrade are possibly more suited to the development of new hardware. Mostly as it requires baselining to assist with software development to leverage the enhance capability of the new hardware*
- *They are definitely very suitable to the EE projects. EE projects contain numerous interrelated and in some cases complex activities. Scheduling these activities (in many cases concurrently) in order to achieve the desired goal would certainly benefit from the use of systematic models. In other words, systematically approaching the project will benefit the outcomes.*

4.2.8 Response to Question Eight - Do you agree that electrical engineering projects are a dynamic process? Please provide an explanation for your answer.

- *It is dynamic because the customer specification can change, or the system may change around it. If a customer changes their mind the specification will need to be managed accordingly.*
- *Anything with long lead times and technology are dynamic processes. The rate of advance of technology is such that the final electrical design of a project is potentially not even scoped when steel is first cut.*
- *Electrical engineering projects are dynamic in process. They are influenced by many sub systems and relationships with sub systems and elements which can affect the output. There are complexities and technical risk which need to be considered in the flow of decision making throughout the process.*
- *I would see a large proportion of electrical engineering projects as dynamic based on my involvement in aviation. Particular in the phases of analysis, design and development.*
- *There could be numerous unexpected events such as issues with suppliers, an increase cost of spare parts, reduction in the quality of parts. Therefore, by the nature of EE projects is definitely dynamic.*

4.2.9 Response to Question Nine - What electrical engineering standards and regulations do you currently follow?

- *AS/NZS 3000 wiring rules.*
- *AS2067:2016 Substations and high voltage installations exceeding kV a.c.*
- *ISO 9001:2015*
- *AS2124 General conditions of contract.*
- *DO-178 and MIL-Stds.*

4.2.10 Response to Question Ten - Based on your professional experience, how do you think a systems engineering approach could improve project success rates?

- *Systems engineering takes a much slower and more careful/systematic approach to managing the project. Break the project down into smaller stages and review. Formal design review, look how it interacts with the entire system - Testing and validation. Systems engineering allows mistakes to be found before significant money is wasted.*
- *It's the only approach I use, as an ex-tradesman and operator it's not much use building something that isn't repairable or practical.*
- *Using a systems engineering approach would improve development quality, cost and schedule compliance and is especially important early in the project life cycle.*
- *To me, combining systems engineering in project management at the project level increase the risk of the project satisfying the customers true need. It moves project management from a quasi-art form to more of a social science framework.*
- *Systems thinking will encourage all involved in the project to approach relevant activities in a systematic matter. Hence, success rate will be improved.*

4.2.11 Response to Question Eleven - What are some practical recommendations for the implementation of a systems engineering approach to project management?

- *A practical recommendation would be application of a systems model for a project. Hence, a project can be defined as a systems model in which input includes the necessary resources, process is the conversion of resources into the desired outcome. The conversion process can be defined as the typical management cycle.*
- *Systems engineering as a project management tool would provide a proven, disciplined approach to creating and delivering successful systems by managing complexity, technical risk and the flow of decision making.*
- *Become skilled in both SE and PM. If possible, employ qualified organisations to assist from concept to project start up as a minimum. This would help to support the development of the combination of systems engineering and project management to suit the organisation and project.*
- *By looking at the core or basis of SE we can analyse the concept of systems. In other words, resources are input, within the system a process takes place (plan, organise,*

control, improve) until an desired outcome is reached. Resource = input, to this end, incorporating systems engineering into project management is an improvement as it integrates the discrete project outcomes into the overarching system for which the product of the project is to be integrated. The focus then shifts from optimising the project to optimising the product with respect to the physical/logical interfaces external to the project.

4.2.12 Response to Question Twelve - The literature has suggested that most projects fail due to running over schedule or budget. In your experience, which one of these factors contributes more significantly to the failure?

- *Budget. Although timeliness is extremely important in many cases higher costs have a negative impact on the projects sponsor. Unexpectedly higher costs have a negative impact on the overall project.*
- *A schedule over run contributes more to the failure of the project as it means that critical capability is not being delivered.*
- *Both. The schedule causes financial pain of a critical nature. Running over schedule usually adds cost which means you blow the project. The schedule drives the budget. If you are not on time you are wasting money.*
- *Project managers that have no idea what they are producing and therefore have loose control over the engineering/development/production cause schedule over runs and kill the budget correcting their problems.*

4.2.13 Response to Question Thirteen - Do you believe that project management and systems engineering complement each other? Please provide an explanation of your answer.

- *These concepts complement each other because they force the engineer to break the project down into smaller more manageable tasks that can be performed by a lot of people at once. Both project management skills and systems engineering skills allows you to break a big project into manageable steps that can allow the cost and schedule to be monitored before cost or problems occur.*
- *Yes, they do complement each other. If we take a good look at a project we would realise that it can be modelled as a system. In other words, there are resources which enter the system, a process takes place and a desired outcome is generated. Hence, there is definitely a compatibility between these two functions.*

- *Yes, project managers need a technical back bone inserted and engineers need to be pulled out of the playground and into reality a bit too.*
- *Yes, systems engineering provides a comprehensive, iterative and recursive problem solving process, applied sequentially top-down by integrated interdisciplinary teams. It emphasises continuous review during all stages of the life cycle and is supported by the monitoring performance, recording of baselines, technical risk and decisions. Tradition project management models provide a structured approach to capture timelines and decisions on requirements, costs and performance.*

4.2.14 Response to Question Fourteen - Do you believe that electrical engineering projects are becoming increasingly complex? Please explain your response.

- *They are complex in that technology can move faster than the project scope or the delivery. The systems in which they work are becoming more and more complex.*
- *Yes, technology integration and dependency on electronics/avionics/electrical systems to overcome inherent design compromises is increasing.*
- *Yes. As the world ventures further into the digital environment electrical systems require a high level of interoperability with other systems. The relationship between systems has increased the overall system environment. Therefore meaning that changes to the system environment requires the smaller systems to be adaptive to change.*
- *Not only has the electrical engineering become more complex, it now requires much more integration with a wide suite of engineering specialities.*
- *Yes, definitely. This complexity is due to the exponential growth of computing power and introduction of emerging technologies, products, tools and techniques. (Moore's law). Electrical engineering projects rely on computing technology in many cases and are becoming more complex.*

4.2.15 Response to Question Fifteen - Please explain based on your professional experience how systems engineering approaches could be applicable to electrical engineering projects?

- *A project can be modelled as a system. Hence, systems engineering, which is based on the concept of a system is certainly applicable to electrical engineering projects.*
- *I think electrical engineering drove systems engineering. Systems engineering makes the electrical engineer conscious of the impact of his designs upon other aspects of the project.*
- *Systems engineering 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 for Operations, Manufacturing, Cost & Schedule, Performance, Training & Support, Test 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 the customer. From its definition, systems engineering is certainly applicable to electrical engineering projects as a project management tool.*

4.3 Summary of In-depth Interviews

The in-depth interviews were conducted independently, however, the domain experts responses were quite similar and consistent with the literature. The in-depth interviews have been successful in extracting the experiential knowledge from the experts. The domain experts interviewed, appear to agree with the current literature. Hence, it was possible to develop a conceptual proposed model.

4.4 Proposed Model

Following the literature review and in-depth interviews with the domain experts it was possible to develop a conceptual model (figure 7). It is based on the existing project management models and systems engineering approaches. The existing project management models are generic and applicable to both industrial and commercial based projects. Hence, the purpose was to develop a more discipline specific and electrical engineering based project management model by adopting a systems engineering approach. The common themes from the in-depth interviews were identified and used to help develop the model. An important aspect that the domain experts agreed on was the need to support a project or engineering asset throughout its entire lifecycle. Another recurring theme was the need for requirements analysis and the constant review and modification of them. Essentially, the domain experts agreed that requirements management was an extremely important aspect in electrical engineering project management.

The best management practices applied within the traditional project management models (PMBOK and PRINCE2), include planning, scheduling, controlling, executing and closing. Essentially, these key features of good project management practice allows the control of the iron triangle components (time, cost and quality). Systems engineering focuses on a holistic approach by considering aspects such as risk management, requirements, human factors, software and hardware. Hence, an improved management approach can be developed by integrating the key features of each of these models. Therefore, by using the existing models identified in the literature review and after analysing the results obtained in the in-depth interviews the following model is proposed:

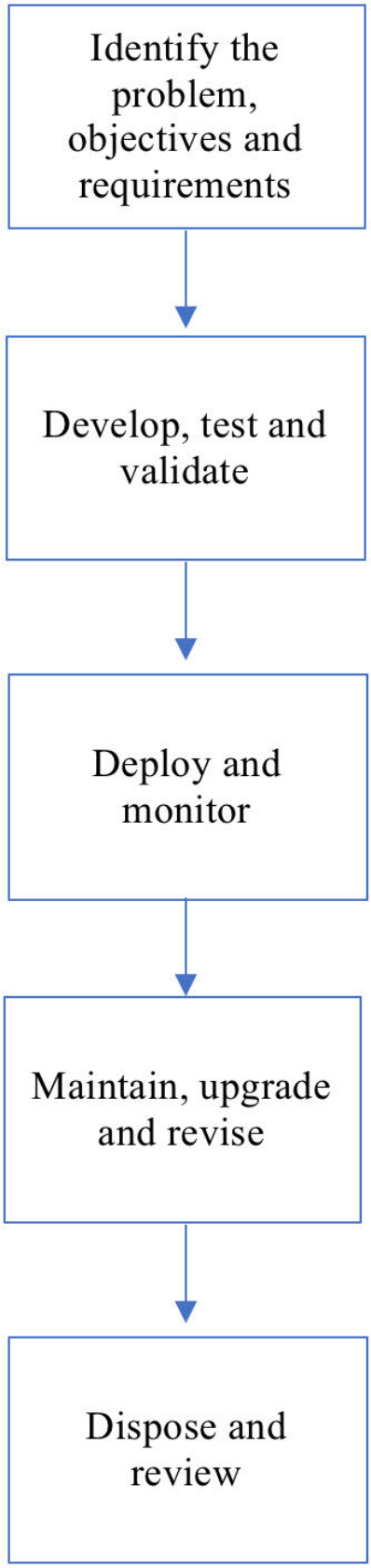

Figure 7: Proposed model for systems engineering approach to project management.

4.4.1 Identify the Problem, Objectives and Requirements

The first step is concerned with clearly identifying what the project is trying to achieve. This will involve careful engagement with the customer and other relevant stakeholders. All requirements will need to be explicitly defined in order for the project to achieve them. The importance of developing a well-written, clear and unambiguous contract cannot be overlooked. This was a key area that the domain experts emphasised as crucial for a projects success. This step can be compared to the PMBOK process of initiating and the PRINCE2 processes of starting up and directing. By incorporating the systems engineering aspect of requirements analysis and the traditional project management methods of starting up and directing, an enhanced method can be adopted. During this stage the cost and budget of the project would be developed. This will allow the monitoring of expenses throughout the rest of the project.

4.4.2 Develop, Test and Validate

The development of an electrical product or process should include various test and validation stages. Essentially, during this stage the design would firstly be developed and built. A suitable testing phase would then occur. If the tests revealed a defect or fault then it would go back to the development step. This process can repeat until the final testing and validation is acceptable. This process is similar to the PMBOK process of planning. The difference is that in electrical engineering projects there is a requirement for constant testing and validation. The processes of initiating and planning in the PRINCE2 method are similar and if following this method then this stage would involve the initial development and testing of the system or design. The previous stage and this stage allow the quality control of the project. This is one of the iron triangle triple constraints within the traditional project management methods.

4.4.3 Deploy and Monitor

This stage is crucial as the engineering asset or system will be handed over to the customer and it must be fully operational. It must be what the customer initially agreed on as developed in the first stage. All of the requirements must be met and objectives achieved that were defined at the start of the project. During the initial deployment stage it would be necessary to monitor the product or system. This would allow for any issues to be identified as soon as possible. If a major problem was discovered, it may be necessary to go back to the previous stage. PMBOK's process of executing and PRINCE2's processes of controlling a stage could be comparable to this stage. The key aspect of quality is considered in this stage also. Continuously monitoring and reviewing the project performance allows the objective of ensuring quality to be met.

4.4.4 Maintain, Upgrade and Revise

Throughout the life of a product or service, it is necessary to constantly monitor it. This will involve general maintenance, repairs and upgrades. The PRINCE2 method includes processes called managing product delivery and directing. This is similar to the maintain, upgrade and revise stage suggested in this model. Similarly, PMBOK includes a controlling stage. Hence, during the initial stages of a project design it is necessary to ensure that the final product will be maintainable. This is sometimes an overlooked aspect in traditional project management. Hence, a systems approach would help to deliver a serviceable product.

4.4.5 Dispose and Review

Disposal of an engineering asset, system or project is becoming an increasingly important aspect. Due to the large increase in landfill from electronics combined with the throw away society attitude, disposing correctly of an outdated project is growing in importance. An important part of electrical engineering project management is adopting the whole life cycle approach. This includes considering how and when the engineering assets or systems will be disposed of. It is necessary that this step is discussed and developed early in the project cycle. The final step of reviewing a completed project helps to identify what worked and what did

not. This is an element that the domain experts agree on. The reflection and reviewing helps to improve the outcome of future projects. Both PMBOK and PRINCE2 have a process dedicated to closing a project. Hence, it is evident that this sometimes overlooked aspect of project management is beneficial and care needs to be taken to include it.

4.5 Proposed Model Summary

The key is to constantly review and revise at each stage during a project. In a sense, each stage is a closed loop system connected to the previous stage. This constant reviewing allows for any problems or issue to be identified at an early stage. Another extremely important aspect is to communicate effectively during all stages of the project. As indicated in the literature and verified by the in-depth interviews, engineers sometimes lack the ability to communicate effectively. Hence, the development and focus on these soft skills will greatly benefit electrical engineers.

4.6 Model Testing, Verification and Validation

The proposed model was presented to the domain experts in order to obtain feedback. Following the feedback a hypothetical electrical engineering project was devised in order to test the proposed model. The purpose was to illustrate the key features of the newly proposed model.

4.6.1 Domain Expert Feedback

Three domain experts from the initial interviews were selected to test and verify the suitability of the proposed model. This verification was performed by presenting the model and obtaining feedback. The experts provided their opinions and recommendations on the model. The following are the key comments provided:

- *The model is adequate, however, there may need to be more information provided for each stage to be utilised to the full extent. It is a good systems approach to project management.*

- *The systems model is a suitable starting point and could be further built on and refined. It provides a good structure for the management of electrical engineering projects.*
- *This model has the potential to help redevelop the thinking and processes regarding electrical engineering project management.*

Following the feedback from the three domain experts a SWOT analysis was performed on the model (table 4). The purpose of the SWOT analysis was to determine the suitability of the proposed model before testing it on a hypothetical electrical engineering project.

Table 4: SWOT analysis of the proposed model

Strength	**Weakness**
Simple and straightforward, built on already existing approaches.	Limited detail of each stage.
Opportunity	**Threat**
Can be applied to a variety of electrical engineering projects regardless of size.	May be too broad and not specific enough.

4.6.2 Testing of the Proposed Model on a Hypothetical Electrical Engineering Project

In order to appreciate and realise the full potential of the proposed model a hypothetical electrical engineering project was developed for testing purposes. The project aimed to measure and evaluate the usefulness of the proposed model. The design and installation of a radio communications network was selected as the project. This project was selected as it incorporates many aspects of systems engineering. For example, a number of different disciplines and different tradespeople will be required in this project. The erection of communications towers requires concrete for the foundation, a rigging team to build the tower and radio technicians to install the antennas and cables. Hence, it is evident that many sub systems and sub disciplines are required. The base sites will also require electrical power. Therefore, an electrician or electrical engineer will be required to design and install the necessary equipment to provide power. Although this is an electrical engineering project, the electrical aspect almost appears as a sub system. This is in essence, systems engineering. Incorporating and integrating a number of sub systems to realise the goal of a larger system. In this example the main system is the radio communications network. The following section steps through the process of applying the proposed model to the project.

Stage 1: Identify the problem, objectives and requirements

The problem is that a two way radio communications network needs to be designed and installed. Stating the basic problem in simple and straightforward language allows the purpose of the project to be understood by all stakeholders involved. The objective of the project is to install and commission a two way radio communications network. The customer has defined and agreed on the following requirements:

- Reliable two way radio network
- Full network coverage
- GPS tracking enabled in radios

As mentioned, it is also necessary at this early stage in the project to consider the disposal process of this system. The hardware installed (coaxial cable, power cable, antennas,

mounting brackets etc.) could be reused in future projects. Used hardware may be an option for a future customer that is concerned with their budget. The base site radio repeaters, mobile transceivers and portable radios will be able to be redeployed in future projects. The advances in technology have allowed the simple application of reprogramming new frequencies into the radio communications equipment a quick process.

Stage 2: Develop, test and validate

In this stage the radio network would be designed. This would include the radio repeater base sites, the network backbone and the vehicle mobile radios. An initial step would be to conduct site surveys. This would allow a model to be developed of the potential network coverage areas. From this survey the correct frequency band would also be determined. The radios would need to be programmed by the radio technicians and installed into the vehicles by installers or auto electricians. A rigging team would be required to install the base site towers and radio technicians would install the antennas. It would be necessary to deploy a small section of the network for testing and validation purposes. A number of vehicles would conduct coverage testing and overall system performance. This testing would be conducted before the programming and installation of the entire system. Hence, any issues identified would be able to be rectified at an early stage. If an issue was identified it may be necessary to return to the previous stage and redefine the requirements.

Stage 3: Deploy and monitor

During this stage the system is deployed and will become active. It will essentially be handed over to the customer. Hence, all of the agreed requirements defined in stage one will need to be met. The process of monitoring will ensure that the quality of these requirements is maintained. Sometimes in traditional project management practices, the project may be considered complete at this stage. The system has been designed, deployed and handed over to the customer. A systems engineering approach, however, considers the entire life cycle of the project/system. Hence, the following steps are a key feature of systems engineering approaches.

Stage 4: Maintain, upgrade and revise

The system has been designed in such a way that it is maintainable and upgradable. The software can be updated in the radio equipment by connecting remotely and programming the changes. This stage is potentially the longest stage and can be referred to as the working life of the system. During this period a number of software updates and modifications may be required. Some of these may be customer requirements (eg. enabling new features not specified at the start of the project) and some of them may be necessary to keep the system in optimal operation.

Stage 5: Dispose and review

This stage was initially considered at the beginning of the project. Due to its importance, however, it will be briefly discussed again. The equipment has been deemed suitable to be reused in future projects. Any of the cabling or components that cannot be reused could potentially be recycled. For example, the copper out of the cables could be removed to be melted down and recycled. A number of the mounting brackets and hardware (metal pipes, clamps, nuts and bolts) could be repurposed. Hence, the notion of reuse, recycle and repurpose has been considered. The final process of the project is to review. Perhaps in this project an issue was identified regarding the location of some of the radio equipment in the vehicle. The reviewing stage allows this problem to be prevented in future projects.

After reviewing the testing of the proposed model on a hypothetical electrical engineering project it was identified that the model may need refinement. One of the problems identified was the feedback/connection between stage one and stage two. It may be necessary to repeatedly go between these two initial stages. Hence, the refined model in figure 8 is suggested.

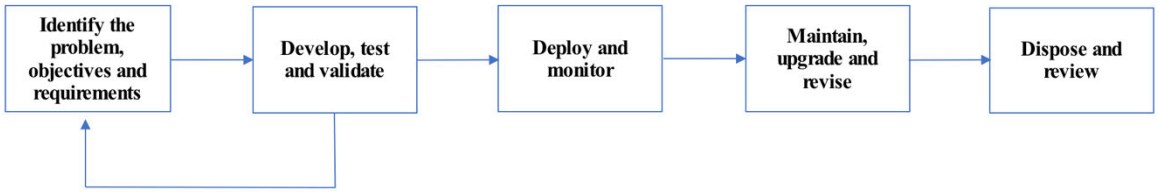

Figure 8: Refined proposed model for systems engineering approach to project management including a feedback path between the initial stages.

This refined model incorporates a closed feedback approach between the first two stages. Essentially, treating a project as a closed loop system allows a systems engineering and holistic approach to be adopted. Hence, this refined model allows the project to be considered and viewed as a system. This allows the integration of the key features of traditional project management and systems engineering approaches. Ultimately this approach will lead to a more successful project.

4.7 Conclusion

This chapter has presented and discussed the results obtained from the in-depth interviews. The results were analysed manually by theme and led to the development of the proposed model. The model has five distinct steps and was tested and verified by presenting it to the domain experts and applying it to a hypothetical project. The feedback obtained will help to make future improvements and enhancements of the model. A SWOT analysis was performed on the model and it was deemed as a suitable conceptual model for a systems engineering approach to the management of electrical engineering projects.

Chapter 5

Conclusion

5.1 Introduction

This chapter provides a summary of the research conducted and the major findings. A number of recommendations are suggested based on the outcome of this research project. Finally, possible future work and research is mentioned in the area of electrical engineering project management.

5.2 Research Summary

A thorough review of the relevant literature regarding electrical engineering, project management and systems engineering identified a knowledge gap. This identified gap led to the development of an in-depth interview instrument. Five key senior domain experts were identified based on education, experience and professional qualifications. The experts had a diverse range of skills and experience in the fields of engineering and project management. The interviews were conducted with the purpose of acquiring experiential knowledge. Following the in-depth interviews, the data and results were analysed manually by theme. A comparison between the literature and domain expert responses showed a connection. Both the literature and the domain experts agreed that systems engineering is applicable to the management of electrical engineering projects. This led to the development of the proposed model. As the existing traditional project management models are extremely reliable and well-established, the model proposed in this research built on them. The purpose was to make a model more applicable to electrical engineering projects. Systems engineering approaches was the chosen method adopted as this process allows a top-down overall control of a project. This is crucial, as electrical engineering projects are generally technically complex and dynamic.

Overall, the main finding from this research is that applying systems engineering approaches to the management of electrical engineering projects has the potential to improve the success and outcomes. This finding, already well-established in the current literature was extended by applying the methods and approaches specifically to electrical engineering projects. A systems engineering project management model tailored to electrical projects was developed. The literature suggested that a systems based approach could have the potential to improve project success and the independent in-depth interviews with the domain experts verified this.

Based on the results and outcome of this research study there appears to be sufficient evidence to accept the following hypotheses:

- There is a strong connection and overlap between systems engineering and project management. Systems engineering and project management appear to complement one another.
- Electrical engineering projects are dynamic in nature and should be treated as systems.
- Management of electrical engineering projects adopting a systems engineering approach could be more suitable than traditional project management methods.

5.3 Recommendations

The following recommendations are made:

- A combination of traditional project management methodologies and systems engineering approaches may be the best method to manage electrical engineering projects.
- Viewing an electrical engineering project as a dynamic complex system rather than static, will allow for a better management process.
- Do not view any component or process in isolation. Everything is interconnected and will impact the final project outcome.

5.4 Limitations and Further Work

Project management is an extremely important aspect in electrical engineering. As technology continues to advance and evolve the ability to successfully manage and deliver projects will be crucial. Hence, further work and research in this area would be worthwhile. Although this current research has been successful a number of limitations were identified. Firstly, due to time and resource constraints it was not possible to test the model thoroughly on a real-world electrical engineering project. Secondly, the small sample size of domain experts interviewed may have provided responses that were biased due to their opinions. The purpose of the in-depth interviews was to extract knowledge, however, a larger sample size may have been beneficial. Finally, it would have been ideal to validate the model with domain experts that were not part of the original interviews. This would allow for the independence of the initial data gathered to be maintained. Therefore, the following recommendations for future work are suggested:

- Test the model on a real-world electrical engineering project.
- Further refine the model by obtaining feedback from different domain experts. (Delphi study).
- Investigate the application of emerging technologies and their use in electrical engineering project management practices.

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Appendix A – Project Specification

ENG4111/4112 Research Project

Project Specification

For: Darius Nooriafshar

Title: Applying Systems Engineering Approaches to The Management of Electrical Engineering Projects

Major: Electrical and Electronic Engineering

Supervisors: Associate Professor Tony Ahfock
Associate Professor David Thorpe

Enrolment: ENG4111 – ONC S1, 2019
ENG4112 – ONC S2, 2019

Project Aim: To investigate how systems engineering approaches could be applied to the management of electrical engineering projects. Once identified, a model will be developed in order to assist in improving future project outcomes and success.

Programme: Version 1.1, 4th March 2019

1. Perform a review of the relevant literature regarding project management in engineering, systems engineering approaches and electrical engineering projects.
2. Identify the domain experts based on a number of criteria (position, relevant qualifications and experience –education level of BEng, no less than 10 years professional engineering and project management experience and currently working in a senior role).
3. Develop the in-depth interview instrument based on the knowledge gap identified in the literature review.
4. Conduct the in-depth interviews with the identified senior domain experts.
5. Analyse the information obtained with a view to generate domain knowledge.
6. Use the domain knowledge to develop an initial model for the systems engineering approach to electrical engineering projects.
7. Have the model verified by the domain experts to obtain feedback in order to refine and improve the model.
8. Write and submit the dissertation in the required format.

If time and resources permit:

9. Test the model by applying it to a hypothetical electrical engineering project based on the suggestions made by the domain experts.
10. Make further modifications and improvements to the model based on the hypothetical project test results.

Appendix B – Participant Information Sheet

Participant Information for USQ Research Project Interview

Project Details

Title of Project:	**Applying Systems Engineering Approaches To The Management Of Electrical Engineering Projects**
Human Research Ethics Approval Number:	H19REA068

Research Team Contact Details

Principal Investigator Details

Mr Darius Nooriafshar
Email: w0100130@umail.usq.edu.au
Mobile: +61 427 174 568

Supervisor Details

Associate Professor Tony Ahfock
Email: Tony.Ahfock@usq.edu.au
Telephone: +61 7 4631 2507

Description

This project is being undertaken as part of an Honours Project.

The purpose of this project is to investigate how systems engineering approaches could be applied to the management of electrical engineering projects. Once identified, a model will be developed in order to assist in improving future project outcomes and success.

The research team requests your assistance in order to obtain experiential knowledge for the purpose of verifying the current literature available. Your industry experience will help to identity and develop a systems engineering model that can be applied to electrical engineering projects.

Participation

Your participation will involve participation in 2 interviews that will take approximately a total of 45 minutes of your time (initial interview 30 minutes, follow up interview 15 minutes).

The interview will take place at a time and venue that is convenient to you.

OR

The interview will be undertaken by teleconference at a date and time that is convenient to you.

Questions will include, Do you think systems engineering and project management complement each other? Do you currently use a systems engineering approach to project management? What standards do you follow?

Your participation in this project is entirely voluntary. If you do not wish to take part, you are not obliged to. If you decide to take part and later change your mind, you are free to withdraw from the project at any stage. You may also request that any data collected about you be withdrawn and confidentially destroyed. If you do wish to withdraw from this project or withdraw data collected about you, please contact the Research Team (contact details at the top of this form).

Your decision whether you take part, do not take part, or to take part and then withdraw, will in no way impact your current or future relationship with the University of Southern Queensland.

Expected Benefits

It is expected that this project will not directly benefit you. However, it may benefit the future outcome of the management of electrical engineering projects. The research aims to contribute to the knowledge of systems engineering and project management processes in the electrical engineering industry.

Risks

In participating in the interview,

There are no anticipated risks beyond normal day-to-day living. However, in order to reduce the impact and disruption to your normal day, the interviews will be scheduled at a time and location most suitable to you.

Privacy and Confidentiality

All comments and responses will be treated confidentially unless required by law.

Participant's data will be made available for future research purposes (whether for similar projects only or for full unspecified use).The data will be stored and shared in an non-identifiable form. (*in accordance with 2.5.2 of the "Australian Code for the Responsible Conduct of Research", research data should be made available for use by other researchers unless this is prevented by ethical, privacy or confidentiality matters).*

Participants can contact the research team if they wish to receive a summary of the research results.

Any data collected as a part of this project will be stored securely as per University of Southern Queensland's Research Data Management policy.

Consent to Participate

We would like to ask you to sign a written consent form (enclosed) to confirm your agreement to participate in this project. Please return your signed consent form to a member of the Research Team prior to participating in your interview.

Questions or Further Information about the Project

Please refer to the Research Team Contact Details at the top of the form to have any questions answered or to request further information about this project.

Concerns or Complaints Regarding the Conduct of the Project

If you have any concerns or complaints about the ethical conduct of the project, you may contact the University of Southern Queensland Manager of Research Integrity and Ethics on +61 7 4631 1839 or email researchintegrity@usq.edu.au. The Manager of Research Integrity and Ethics is not connected with the research project and can facilitate a resolution to your concern in an unbiased manner.

Thank you for taking the time to help with this research project. Please keep this sheet for your information.

Appendix C – Participant Consent Form

University of Southern Queensland

Consent Form for USQ Research Project Interview

Project Details

Title of Project:	**Apply Systems Engineering Approaches To The Management Of Electrical Engineering Projects**
Human Research Ethics Approval Number:	H19REA068

Research Team Contact Details

Principal Investigator Details

Mr Darius Nooriafshar
Email: w0100130@umail.usq.edu.au
Mobile: +61 426 174 568

Supervisor Details

Associate Professor Tony Ahfock
Email: Tony.Ahfock@usq.edu.au
Telephone: +61 7 4631 2507

Statement of Consent

By signing below, you are indicating that you:

- Have read and understood the information document regarding this project. ☐Yes / ☐No
- Have had any questions answered to your satisfaction. ☐Yes / ☐No
- Understand that if you have any additional questions you can contact the research team. ☐Yes / ☐No
- Are over 18 years of age. ☐Yes / ☐No
- Understand that any data collected may be used in future research activities ☐Yes / ☐No
- Agree to participate in the project. ☐Yes / ☐No

Participant Name	
Participant Signature	
Date	

Please return this sheet to a Research Team member prior to undertaking the interview.

Appendix D – Interview Instrument

Interview Instrument for USQ Research Project H19REA06

Applying Systems Engineering Approaches To The Management Of Electrical Engineering Projects

1. **What is your interpretation of project management and why do you believe it plays an important role in electrical engineering projects?**

2. **Based on your professional experience, how do you think that formal training in project management could help electrical engineers?**

3. **How do you measure project success?**

4. **Based on your experience of successful projects please indicate what has, mainly, contributed to their success?**

5. **Could you please explain your interpretation of systems engineering approaches?**

6. **If you are currently using a project management model, could you please explain the process? If you are not adopting a model please explain why?**

7. **Based on your experience and the use of current project management models, how do you think the models could become more applicable to electrical engineering projects?**

8. **Do you agree that electrical engineering projects are a dynamic process? Please provide an explanation for your answer.**

9. **What electrical engineering standards and regulations do you currently follow?**

10. **Based on your professional experience, how do you think a systems engineering approach could improve project success rates?**

11. **What are some practical recommendations for the implementation of a systems engineering approach to project management?**

12. **The literature has suggested that most projects fail due to running over schedule or budget. In your experience, which one of these factors contributes more significantly to the failure?**

13. **Do you believe that project management and systems engineering complement each other? Please provide an explanation of your answer.**

14. **Do you believe that electrical engineering projects are becoming increasingly complex? Please explain your response.**

15. **Please explain based on your professional experience how systems engineering approaches could be applicable to electrical engineering projects?**

Research Team Contact Details

Principal Investigator Details

Mr Darius Nooriafshar
Email: w0100130@umail.usq.edu.au
Mobile: +61 427 174 568

Supervisor Details

Associate Professor Tony Ahfock
Email: Tony.Ahfock@usq.edu.au
Telephone: +61 7 4631 2507

Appendix E – Human Research Ethics Approval

[RIMS] USQ HRE Application - H19REA068 - Expedited review outcome -Approved

Dear Darius

I am pleased to confirm your Human Research Ethics (HRE) application has now been reviewed by the University's Expedited Review process. As your research proposal has been deemed to meet the requirements of the National Statement on Ethical Conduct in Human Research (2007), ethical approval is granted as follows:

USQ HREC ID: H19REA068
Project title: Applying Systems Engineering Approaches To The Management Of Electrical Engineering Projects
Approval date: 26/04/2019
Expiry date: 31/12/2019
USQ HREC status: Approved

The standard conditions of this approval are:

a) responsibly conduct the project strictly in accordance with the proposal submitted and granted ethics approval, including any amendments made to the proposal;.

(b) advise the University (email:ResearchIntegrity@usq.edu.au) immediately of any complaint pertaining to the conduct of the research or any other issues in relation to the project which may warrant review of the ethical approval of the project;

(c) promptly report any adverse events or unexpected outcomes to the University (email: ResearchIntegrity@usq.edu.au) and take prompt action to deal with any unexpected risks;

(d) make submission for any amendments to the project and obtain approval prior to implementing such changes;

(e) provide a progress 'milestone report' when requested and at least for every year of approval.

(f) provide a final 'milestone report' when the project is complete;

(g) promptly advise the University if the project has been discontinued, using a final 'milestone report'.

The additional conditionals of approval for this project are:

(a) Nil.

Please note that failure to comply with the conditions of this approval or requirements of the Australian Code for the Responsible Conduct of Research, 2018, and the National Statement on Ethical Conduct in Human Research, 2007 may result in withdrawal of approval for the project. Congratulations on your ethical approval! Wishing you all the best for success!

If you have any questions or concerns, please don't hesitate to make contact with an Ethics Officer.

Kind regards

Human Research Ethics

University of Southern Queensland
Toowoomba Queensland 4350 Australia
Phone: (07) 4631 2690
Email: human.ethics@usq.edu.au

Appendix F – Project Schedule and Timeline

Phase 1	**Project Setup**
1a	Submit project proposal form.
1b	Conduct initial literature review.
1c	Organise and obtain ethics approval from USQ ethics committee.
1d	Identify and contact interview participants.
1e	Submit project specification report.
Phase 2	**Data Collection**
2a	Continue literature review.
2b	Develop interview instrument.
2c	Confirm location of interviews.
2d	Conduct interviews.
2e	Submit project progress report.
Phase 3	**Data Analysis**
3a	Analyse data from in-depth interviews.
3b	Build a model based on information obtained.
3c	Confirm model with domain experts.
3d	Apply model to hypothetical electrical engineering project.
Phase 4	**Dissertation Write Up**
4a	Write up and submit partial draft dissertation.
4b	Attend ENG4903 (PP2) and present findings.
4c	Review supervisor feedback and make any adjustments required to dissertation.
4d	Write up and submit final dissertation for marking.

Phases of project.

Activity	Week																			
	Semester 1															Exams/recess				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Phase 1																				
1a																				
1b																				
1c																				
1d																				
1e																				
Phase 2																				
2a																				
2b																				
2c																				
2d																				
2e																				

ENG4111 semester 1 schedule.

Activity	Week													
	Semester 2													
	21	22	23	24	25	26	27	28	29	30	31	32	33	34
Phase 3														
3a														
3b														
3c														
3d														
Phase 4														
4a														
4b														
4c														
4d														

ENG4112 semester 2 schedule.

Appendix G – Questions and Literature Connection

Question	Literature
What is your interpretation of project management and why do you believe it plays an important role in electrical engineering projects?	Project Management Institute (2008), Burke (2010)
Based on your professional experience, how do you think that formal training in project management could help electrical engineers?	Ramazani and Jergeas (2015), Guerrero, Palma and La Rosa (2014), Rogers (2002)
How do you measure project success?	Sanchez, Gaya and Perez (2013)
Based on your experience of successful projects please indicate what has, mainly, contributed to their success?	Ackara, Kazaz and Ulubeyli (2017), Radujkovic and Sjekavica (2017)
Could you please explain your interpretation of systems engineering approaches?	Gausemeier, Gaukstern and Tschirner (2013), INCOSE (2018), Cristobal (2017)
If you are currently using a project management model, could you please explain the process? If you are not adopting a model please explain why?	Matos and Lopes (2013), Garel (2013), Project Management Institute (2017), Turley (2017), Sheffield and Lemetayer (2010), sliger (2011)
Based on you experience and the use of current project management models, how do you think the models could become more applicable to electrical engineering projects?	Alias et al. (2012), Cleland (1977), Lachhab et al. (2017)
Do you agree that electrical engineering projects are a dynamic process? Please provide an explanation for your answer.	Bordley, Keisler and Logan (2019), Cristobal (2017)
What electrical engineering standards and regulations do you currently follow?	AS/NZS 3000, 3012, 3017, 3760 and 4836.
Based on your professional experience, how do you think a systems engineering approach could improve project success rates?	Love, Zhou and Matthews (2019), Zheng et al. (2017), Gepp et al. (2014)
What are some practical recommendations for the implementation of a systems engineering approach to project management?	Spagnuolo et al. (2018), Sharon and Dori (2012), Acheson, Dagli and Kilicay-Ergon (2013)
The literature has suggested that most projects fail due to running over schedule or budget. In your experience, which one of these factors contributes more significantly to the failure?	Rivera and Kashiwagi (2016), Patankakul et al. (2016),
Do you believe that project management and systems engineering complement each other? Please provide an explanation of your answer.	Sankaran, Haslett and Sheffield (2010), Van Gemert (2013), Langley, Robitaille and Thomas (2011)
Do you believe that electrical engineering projects are becoming increasingly complex? Please explain your response.	Devore, McCollum and Ledbetter (1982), Gepp et al. (2014), Locatelli, Mancini and Romano (2014), Wilberg et al. (2015),
Please explain based on your professional experience how systems engineering approaches could be applicable to electrical engineering projects?	Frankova, Drahosova and Balco (2016)

Appendix H – Post Model Development Verification Questions

University of Southern Queensland

Post Model Development Verification Questions for USQ Research Project H19REA06

Applying Systems Engineering Approaches To The Management Of Electrical Engineering Projects

1. **Based on your professional experience, do you think that this model could be applicable to the management of electrical engineering projects?**

2. **Could you please provide some suggestions on how to improve the model?**

3. **Results from the in-depth interviews suggested that a systems engineering approach is suitable for the management of electrical engineering projects. Do you agree with this outcome?**

Research Team Contact Details

Principal Investigator Details

Mr Darius Nooriafshar
Email: w0100130@umail.usq.edu.au
Mobile: +61 427 174 568

Supervisor Details

Associate Professor Tony Ahfock
Email: Tony.Ahfock@usq.edu.au
Telephone: +61 7 4631 2507